ELECTRONICS

INSTALLATION

AND

MAINTENANCE BOOK

GENERAL

MAINTENANCE

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LIST OF EFFECTIVE PAGES

Dates of issue for original and changed pages are:

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TOTAL NUMBER OF PAGES IN THIS PUBLICATION IS 172 CONSISTING OF THE FOLLOWING:

Page No.	● Change No.	Page No.	'Change No.
Title	0	3-I–3-32.	0
A	0	4-1–4-19.	0
i.	0	4-20 Blank	0
ii Blank.	0	5-I–5-22.	0
iii – xi	0	6-1–6-15.	0
xii81ank.	0	6-16Blank.	0
I-I-I-2.	0	7-I–7-39.	0
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INSTRUCTION SHEET

1. The enclosed material constitutes a complete revision to the General Maintenance Chapter of the Electronics Installation and Maintenance Book.

2. Remove all existing pages of Sections 1 through 6 and the Front Matter of the General Maintenance Handbook, NAVSHIPS 0967-000-0160 and replace with this package, NAVSEA SE000-00-EIM-160 dated January 1981.

3. Check each page of this package against the List of Effective Pages to be sure that all new pages are included. Missing pages should be reported to this office by using the Comment Sheets provided as the last pages of the handbook.

RECORD OF CHANGES

CHANGE NO.	DATE	TITLE OR BRIEF DESCR I PT 10N	ENTERED BY

NOTES

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NOTES

(1) The number listed in this column indicates that this handbook issue incorporates information from EIB issues up to and including the one shown.

(2) This change reserved for Tab Separator Package.

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PREFACE

POLICY AND PURPOSE

The Electronics Installation and Maintenance Book (EIMB) was established as the medium for collecting, publishing, and distributing, in one convenient source document, those subordinate maintenance and repair policies, installation practices, and overall electronic equipment and material-handling procedures required to implement the major policies set forth in Chapter 400 of the Naval Ships' Technical Manual. All data contained within the EIMB derive their authority from Chapter 400 of the Naval Ships' Technical Manual, as established in accordance with Article 1201, U. S. Navy Regulations.

Since its inception the EIMB haa been expanded to include selected information of general interest to electronic installation and maintenance personnel. These items are such as would generally be contained in texthooks, periodicals, or technical papers, and form (along with the information cited above) a comprehensive reference document. In application, the EIMB is to be used for information and guidance by all military and civilian personnel involved in the installation, maintenance, and repair of electronic equipment under cognizance, or technical control, of the Naval Sea Systems Command (NAVSEA). The information, instructions, and procedures, in the EIMB supplement instructions and data supplied in equipment technical manuals and other approved maintenance publications.

INFORMATION SOURCES

Periodic revisions are made to provide the best current data in the EIMB and keep abreast of new developments. In doing this, many source documents are researched to obtain pertinent information. Some of these sources include the Electronics Information Bulletin (EIB), the NAVSEA Journal, electronics and other textbooks, industry magazines and periodicals, and various military installation and maintenance-related publications.

ORGANIZATION

The EIMB is organized into a series of handbooks to afford maximum flexibility and ease in handling. The handbooks are stocked and issued as separate items so that individual handbooks may be obtained as needed.

The handbooks fall within two categories: general information handbooks, and equipment-oriented handbooka. The general information handbooks contain data which are of interest to all personnel involved in installation and maintenance, regardless of their equipment specialty. The titles of the various general information handbooks give an overall idea of their data content; the GeneraI Handbook includes more complete descriptions of each handbook.

The equipment handbooks are devoted to information about particular classes of equipment. They include general test procedures, adjustments, general servicing information, and field change identification data.

All handbooks of the series are listed below with their NAVSEA numbers.

HANDBOOK TITLE	NAVSEA NUMBER
EIMB General Information Handbooks	
General	SEOOO-OO-EIM-1OO
. Installation Standards	SEOOO-OO-EIM-11O
Electronic Circuits	SE000-00-EIM-120
Test Methods& Practices	SEOOO-OO-EIM-130
Reference Data	SEOOO-OO-EIM-140
EMI Reduction	SEOOO-OO-EIM-150
General Maintenance	SEOOO-OO-EIM-160
EIMB Equipment-Oriented Handbooks	
Communications	SEOOO-OO-EIM-O1O
Radar	SEOOO-OO-EIM-020
Sonar	SEOOO-OO-EIM-030
Test Equipment	SEOOO-OO-EIM-040
Countermeasures	SEOOO-OO-EIM-060

DISTRIBUTION

Initial Set: An "AF" Restriction Code has been assigned to NAVSEA SEOOO-OO-EIM-OOO control the over-requisitioning of the EIMB Series. Fleet and shore activities requiring an initial set of the EIMB Series (13 handbooks with all changes and heavy-duty bindera) should submit their requisition (DD Form 1348 with written justification) through their Supply Officer or area, for issue approval to:

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PREFACE

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SUGGESTIONS/CORRECTIONS

NAVSEA recognizes that users of the EIMB will have occasion to offer corrections or suggestions. To encourage more active participation, a pre-addressed comment sheet is provided in the back of each handbook change. Complete information should be given when preparing suggestions. Suggesters are encourages to include their names and addresses so that clarifying correspondence can be initiated when necessary. Such correspondence will be by letter directly to the individual concerned.

If a comment sheet is not available, or if correspondence is lengthy, corrections or suggestions should be directed to the following:

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SECTION 1

INTRODUCTION

1-1 PURPOSE

The purpose of the General Maintenance Handbook, NAVSHIPS SEOOO-OO-EIM-160, is to provide Naval personnel with an informative and comprehensive maintenance reference. This handbook contains general maintenance data that pertains to all electronic equipments and it can be used to supplement information contained in equipment technical manuals. The satisfactory performance of modem electronic equipment depends to a great extent upon the maintenance procedures employed by the electronics technician. It further depends upon the skillful application of these procedures by the technician. Continued satisfactory performance is dependent upon the work done by the men who inspect, repair, and maintain electronic equipment. The objectives of the General Maintenance Handbook are to aid in the maintenance effort by:

1. Preparing and assembling, in one handbook, the approved procedures and concepts to be employed in the maintenance of all electronic equipment.

2. Standardizing these procedures and concepts which, when used, will provide uniform and satisfactory electronic maintenance.

3. Indoctrinating all personnel engaged in maintenance with the importance of good workmanship.

4. Making all personnel involved in electronic maintenance aware of the importance of good maintenance techniques.

5. Preventing personnel injury and equipment damage by emphasizing safety precautions and by prohibiting unsafe maintenance practices.

1-2 SCOPE

Information for the General Maintenance Handbook has been collected from other EIMB handbooks, the EIB, the NAVSHIPS Technical News, and many other pertinent sources, both military and commercial. The General Maintenance Handbook will be useful as a convenient reference book for three general categories of maintenance personnel:

1-2.1 EXPERIENCED TECHNICIAN

The experienced technician has no great difficulty in coping with maintenance problems because of previous experience and well developed maintenance skills. This person will use the handbook as reference or review material. He will increase his knowledge of electronics maintenance as new concepts and procedures are added to this text.

1-2.2 TECHNICIAN OUT-OF-SCHOOL

This category of technician is representative of the individual who has completed Navy training courses, but has limited experience with the fleet. His experience will probably be limited to equipments covered in training courses and to equipments he has encountered in his brief tour of duty with the fleet. Consequently, this handbook will prove extremely valuable to him, especially as new equipments are confronted. The maintenance concepts in this handbook will help familiarize him with the new techniques involved in maintaining modern equipments.

1-2.3 TRAINEE

The trainee willl find the information contained in the handbook to be useful as a reference while in training. Later, he will find that it serves as a source of review as well as reference. As a training aid, the individdurd sections might be recommended for suggested reading. Information contained in this handbook is of lasting interest to all Naval personnel engaged in the maintenance of electronic equipment.

1-3 ORGANIZATION

Information in the General Maintenance Handbook, NAVSEA SEOOO-OO-EIM-160, is presented in seven sections:

Section 1- INTRODUCTION

This section explains the purpose, scope, and organization of the General Maintenance , Handbook. It also describes the relationship of this handbook to other handbooks of the EIMB series.

Section 2- MAINTENANCE CONCEPTS

This section presents the basic concepts to the technician. These concepts are the foundation of good electronic maintenance. Preventive maintenance programs (POMSEE and PMS) are explained and the procedures required for carrying out these programs are covered. Responsibilities of the operator and technician in carrying out the preventive maintenance program are defined. Troubleshooting and failure analysis are discussed. Types and classes of alterations, field changes, and the procedures to follow after accomplishment of each are also covered in detail in this section.

Section 3- ROUTINE MAINTENANCE AND MAINTENANCE AIDS

This section reviews routine maintenance procedures such as cleaning; inspection; lubrication; use of maintenance aids, such as soldering tools and special hand tools; and soldering and splicing techniques. Emphasis is placed on the importance of these procedures in hopes of making the technician more aware of their value. The importance of safety, not only to prevent injury to the technician, but to prolong the life of electronic equipment as well, are also required. References are made to publications that cover personnel safety and equipment operation and maintenance safety procedures.

Section 4- SOLDERING TECHNIQUES

Because of the complexity of today's modem electronic systems and the lack of documentation on the subject, an attempt has been made to acquaint the technician with some of the system test equipment that has been, and is being, designed to test these modem systems. When these new means of testing are not available, the technician is told how to use the resources at his disposal to cope with system maintenance problems.

Section 5- MINIATURE REPAIR

This section gives a practicaJ approach to the problem of maintaining equipments. Maintenance information such as testing, troubleshooting, repair of subassemblies, modular components, and printed circuit boards is included in this section.

Section 6- MICROMINIATURE REPAIR

This section is broken into a number of subsections, each of which deals with one type of component and its associated maintenance peculiarities. Information such as special tests, removal and replacement, and inspection is presented in detail for each of the major components discussed in this section.

Section 7- DIGITAL TROUBLESHOOTING TECHNIQUES

This section provides practical techniques of digital troubleshooting with logic clips, logic probes, logic pulsers, current tracers, logic comparators and logic analyzers. State Flow analysis techniques are also covered in this section.

SECTION 2

MAINTENANCE CONCEPTS

2-1 INTRODUCTION

In general, the concept of maintenance is that of work done to correct, prevent, or reduce failure and damage to equipment. Maintenance of Navy electronic equipment is divided into two main categories: preventive maintenance, and corrective maintenance. Preventive (routine) maintenance consists of checks to determine if equipment is functioning properly, visual inspections for damage, and lubrication. Corrective maintenance is the isolation of trouble, the replacement of defective components, and the realignment and readjustment of equipment to restore it to a satisfactory operating level. See figure 2-1.

2-2 PREVENTIVE MAINTENANCE PROGRAMS

An electronics preventive maintenance program consists of a schedule of inspections, tests, and routine maintenance procedures and a system of

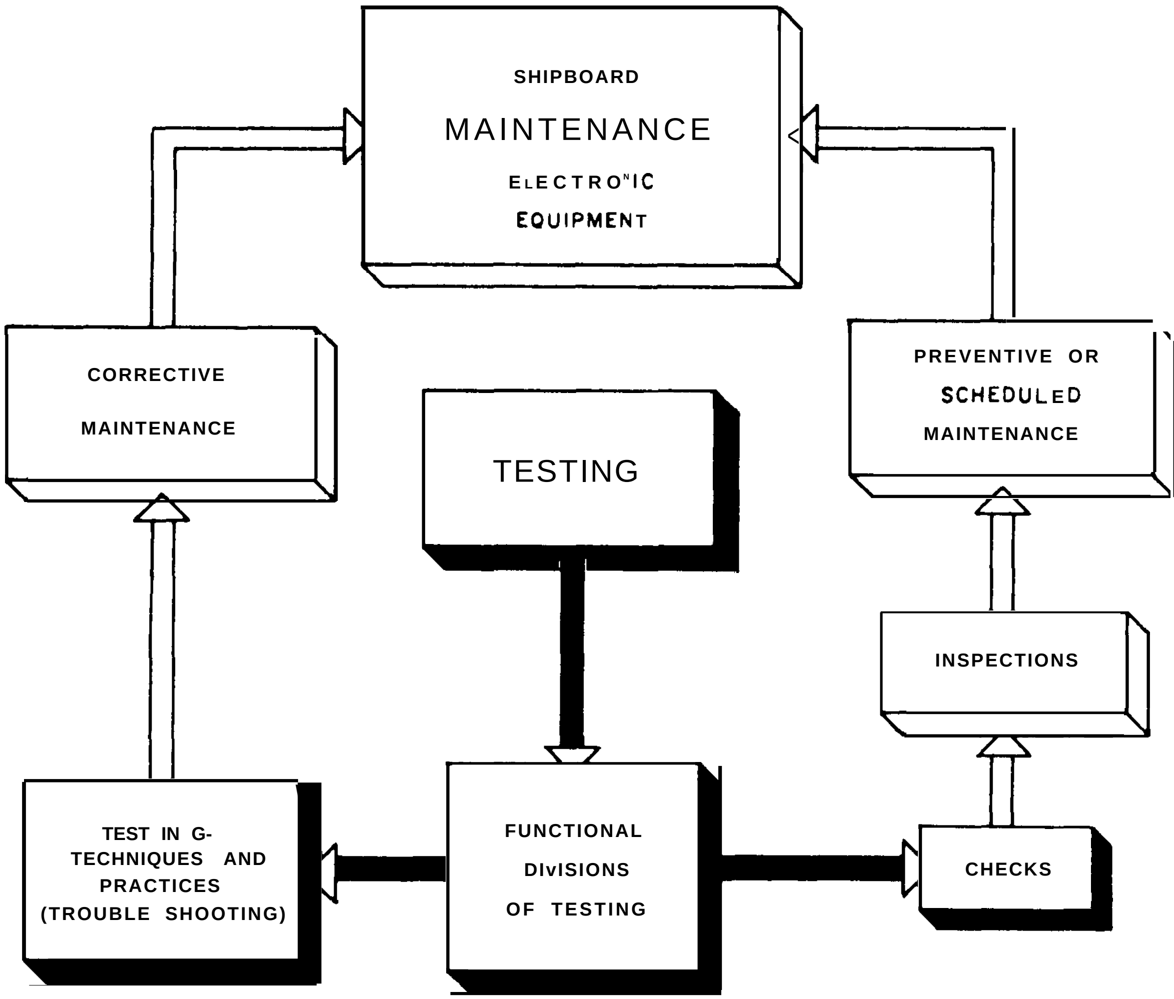


Figure 2-1. Electronic Maintenance, Functional Diagram

checkoff lists to ensure that the schedule is carried out. The administration of such a program aboard ship requires that the preventive maintenance needs of every equipment be recognized, planned for, accomplished, and recorded. The Planned Maintenance Subsystem (PMS) has been developed to accomplish these tasks. The Performance Operation and Maintenance Systems for Electronic Equipment (POMSEE) is still current for selected equipments; however, it is currently implemented only on a case basis. These programs do not provide a means for technicians to report maintenance problems. Such a system employing automatic data processing was then developed. This system, the Maintenance Data System (MDS), complements the PMS to form the basic Maintenance and Material Management (3-M) System. Each of these current maintenance programs (POMSEE, PMS, and 3-M) are discussed subsequently.

2-2.1 POMSEE PROGRAM

The POMSEE program is designed to help operational and maintenance personnel determine and maintain proper performance of electronic equipment. It is implemented on a case basis by acquisition managers. The fundamental elements of POMSEE are the Reference Standards Tests, Reference Standards Summary Sheets, and Performance Standards Sheets. The Reference Standards Tests and Reference Standards Summary Sheets comprise the Reference Standards Book. The scheduled tests, however, are superseded when the PMS is implemented. The requirements for establishing the Reference Standard Tests for electronic equipment after installation, and for using these test procedures as a basis for equipment check-out after overhaul or restoration, remain in effect. A preliminary copy of the Reference Standards Book is normally packed with each new electronic equipment. Upon its receipt, maintenance personnel should immediately perform the tests listed in the Reference Standards Tests and forward the results recorded on the Reference Standard Summary Sheets to NAVSEA for review. Finrd copies or changes are then published after NAVSEA evaluates the Reference Standards Summary Sheets. POMSEE is a test document for equipment check-out after its installation or re-installation aboard ship, and after steps have been taken to ensure that the equipment is properly installed and operating satisfactorily. It does not eliminate the necessity for making adjustments, alignments, checks, or other installation procedures described in the technical manual which are necessary to obtain satisfactory operation. Before establishing the reference standards, the equipment must be completely checked out by qualified technical personnel to ensure optimum equipment operation. The qualified technical personnel should have received training in operation and maintenance of the equipment and have sufficient skill to tune, align, and peak the equipment until it is performing as near design characteristics as possible. While there is no objection in having the installing activity perform operational tests in the shop prior to installation, NAVSEA requires that the POMSEE measurements be conducted on board ship, operating off ship's power. Shop tests will not disclose the effects of poor installation, wiring errors, noise pickup, instability in ship's power generating source, self-generated and receiving interference, or the rough handling effects in transportation from shop to ship.

2-2.1.1 Reference Standards Tests

The Reference Standards Tests consist of a series of measurements made initially when the equipment is operating at peak performance. These measurements, containing upper and lower limits, provide maintenance personnel with standards against which subsequent measurements may be compared. The tests are scheduled on a routine basis such as daily, weekly, and monthly. Daily tests are designed so that they can be performed in less than 10 minutes on a single-unit set. These tests are usually performed by the operator on watch and they consist mainly of a performance check using the equipment modes and features, and built-in test equipment. Weekly tests are designed to monitor an equipment function where there is a definite likelihood that the interpretation of test results will reveal potential trouble. Monthly and quarterly tests consist of measurements that cannot normally be performed when the ship is underway. Examples typical of this test are: sonar beam pattern tests, sonar transducer maintenance, and cleaning and lubricating antennas. In some instances, unscheduled tests are provided. These tests are not designed to detect impending failure but are performed upon completion of repair for check out.

2-2.1.2 Reference Standards Summary Sheets

The Reference Standards Summary Sheets basically provide spaces for recording measurements and the initials of the person performing the tests. The tests used are those in the Reference Standards Tests. Two identical Reference Standards Summary Sheets precede the front matter of a newly issued Reference Standards Book. After the sheets are filled in, one is retained in the book and the second is submitted to NAVSEA for evaluation.

2-2.1.3 Performance Standards Sheets

The Performance Standards Sheets list the operational characteristics of an equipment or system. The characteristics given include such parameters as meter readings, sensitivity values, output power, standing wave ratios, and all other measurable parameters that indicate the operational condition of the equipment. Performance Standards Sheets are used by maintenance personnel to determine the overall operation of an equipment by comparing its data with the test results recorded in the Reference Standards Book. This sheet is usually the first page in a newly issued Reference Standards Book. As part of the POMSEE program, this sheet should be removed from the Reference Standards Book and placed in a binder titled, "Electronic Equipment Performance Standard Sheets," NAVSEA 93000.

2-2.2 MAINTENANCE AND MATERIAL MANAGEMENT SYSTEM

The Maintenance and Material Management (3-M) System is an integrated management system which, when fully implemented and properly used, provides for orderly scheduling and accomplishment of maintenance and for reporting and disseminating significant maintenance related information. It is composed of two principle subsystems: the Planned Maintenance System (PMS), and the Maintenance Data System (MDS). Together, PMS and MDS form the nucleus of a shipboard maintenance program which can contribute significantly toward achieving improved fleet readiness with reduced expenditure of resources.

2-2.2.1 Planned Maintenance System

The Planned Maintenance System (PMS) pertains to the planning, scheduling, and management of resources (men, material, and time) to perform those actions which contribute to the uninterrupted functioning of equipment within its design characteristics. It defines uniform maintenance standards, based on engineering experience, and prescribes simplified procedures and management techniques for the accomplishment of maintenance. The increasing complexity and quantity of equipment required for the operation of the modern Navy has necessitated the continuous updating of maintenance procedures and the refinement of maintenance management organization at all levels. These improved procedures are necessary for the assurance of equipment readiness, the key to operational readiness. For this reason it is of utmost importance that **all** maintenance personnel be familiar with the proper use of the PMS documents and schedules for implementing and accomplishing planned maintenance. OPNAVINST 4790,4 describes the detailed operation of PMS. The following paragraphs summarize shipboard operation.

2-2.2.1.1 Maintenance Index Page

The Maintenance Index Page (MIP), OPNAV Form 4700-3, is the basic reference document in the PMS. See Figure 2-2. It catalogues the maintenance requirements, skill levels considered qualified to perform the maintenance requirements, reference documents, and other reference data for all equipments listed in the Master manuaf. Each MIP contains a list for one set of Maintenance Requirement Cards. Specifically, the information listed is as follows:

1. The system, sub-system, or component, by noun name, AN Nomenclature, Mark, Mod, etc.
2. Reference Publications pertaining to the specific system, sub-system or component.
3. The date of preparation of the MIP (month and year).
4. The System Command MRC Control Number to control library issue and identify specific MRCS as applicable to a certain MIP.
5. A brief description of each maintenance requirement.
6. The periodicity code of each maintenance requirement listed on the MIP.
7. The recommended skill level/s considered qualified to perform the maintenance requirements.
8. The average time required for each skill level listed to perform the maintenance requirements as listed. (This does not include "make ready" and "put away" time.)
9. Any related maintenance actions to be scheduled for simultaneous accomplishment.
10. Notations included as Management Aids when such information is available and needed for selective scheduling of a specific requirement. MIPs are a ready reference to be used in conjunction with the planning and scheduling of PMS. Each MIP indexes one complete set of MFtCs which are applicable to a component or system.
11. A letter and a number indicating the Maintenance Group and the equipment concerned,

ITEM, SUBSYSTEM, OR COMPONENT	REFERENCE PUBLICATIONS	DATE
Input Output Data Display Group AN/UYA-5(XN-1)(V)	NAVSHIPS 0967-306-4010 0967-306-4020	Nov 1970

SYSCOMMRC CONTROL NO	MAINTENANCE REQUIREMENT	PERIODICITY CODE	SKILL	MAN HOURS	RELATED MAINTENANCE
864376	Check output voltage of Power Supplies	W	ET3	.5	None
864377	Check memory drive current	M	ET3	.5	None

MAINTENANCE INDEX PAGE
OPNAV 4700-3 (REV)

Figure 2-2. Sample Maintenance Index Page for example, F-1, (F) indicates the Fireroom maintenance group and the (1) indicates Boilers.

2-2.2.1.2 Maintenance **Requirement Card**

The Maintenance Requirement Card (MRC), OPNAV Form 4700-1, is a 5 x 8-inch card which defines a specific preventive maintenance task in terms of step-by-step procedures. See Figure 2-3. It provides maintenance personnel with detailed guidance for performance of each specific PMS requirement. The MRC contains the following information and instructions:

1. The identification of the System, Subsystem, or Component involved in the maintenance action.

2. The MRC Code assigned to the card. This code is in two parts. The first part is the Equipment Code adapted from the first portion of the number identifying the MIP for that card set in the Departmental and Work Center PMS Manuals. The second part identifies the periodicity for the maintenance action, using a letter code for repetitive time element as follows:

D - Daily
W - Weekly
M - Monthly
Q - Quarterly
S - Semi-annual
A - Annual
C - Overhaul Cycle
R - Situation Requirement (100 hr., prefiring, prior to getting underway, etc.)

The periodicity code also includes a number for specific identity when more than one MRC of the same penodicity exists in the same MRC set. When two or more MRCS in the same set are prepared for the same periodicity, but for separate, distinct job requirements, the cards will be numbered consecutively e.g., "D-1", "D-2", or "M-l", "M-2", etc.

3. When a single maintenance requirement has need for more than one penodicity they will be numbered as "Q-lR", "M-lR", "M-2 R", etc.; the "R," in the case meaning "related," indicates a situation that is defined in an accompanying note. Related maintenance requirements are maintenance actions described on other MRCS within the same set which are most efficiently accomplished when they are done prior to, in conjunction with, or after a task described on the basic MRC. For example, if the equipment is opened for a maintenance action, that MRC may list and identify other MRCS which also require equipment opening and, therefore, can most logically and appropriately be accomplished at this same time. The intent of related maintenance is to take advantage of work effort and to avoid repetitious maintenance steps. If no related maintenance exists, the word "Non" will appear in this block.

4. Maintenance Requirement Description is a brief description of the PMS action to be performed.

5. Rate is the recommended skill level, identified by rate or Navy Enlisted Classification Code (NEC), designated to perform the described maintenance action. This information is provided as a management aid for workload assignment.

6. The average manhours required to accomplish the PMS task by each rate. The total manhours and total elapsed time are also listed. These times are expressed to the nearest tenth of an hour. "Make ready" and "put away" times are not included.

7. Safety Precautions direct attention to potential hazards to personnel or equipment while performing maintenance tasks. "Observe Standard Safety Precautions" is required in this block on every MRC. These are two specific categories of additional precautionary conditions. They are:

WARNING

Operating procedures, practices, etc., which may result in personnel injury or loss of life if not correctly followed.

CAUTION

Operating procedures, practices, etc., which if not strictly observed, may result in damage to the equipment.

WARNINGS and CAUTIONS are repeated immediately before the appropriate procedural step.

8. Safety of Ship. An MRC that has been identified on the MIP as a Safety of Ship Item will have "SAFETY OF SHIP" stamped in large outline letters across the face of the MRC and in such a

YSTEM nput Output Data Display iroup AN/UYA-5 (XN-1)(V)	COMPONEN Memory	IRC CODE E17 M-1
UBSYSTEM	RELATED MAINTENANCE None	RATES ET3 / IA, M/H 0.5
AINTENANCE REQUIREMENT DESCRIPTION Check memory drive current		TOTAL M/H 0.5 ELAPSED TIME 0.5
AFETY PRECAUTIONS		
Oscilloscope Tuning Tool Current Probe for oscilloscope		

1. Check Memory Drive Current

   a. Place ON-LINE/OFF-LINE switch on maintenance panel to the off-line position.

   b. Set data toggles on maintenance panel to the 1 position.

   c. Connect current prohe in turn to the following points:

   (1) J17-10
   (2) J17-20
   (3) J18-10
   (4) J18-20
   (5) J19-10
   (6) J19-20

   Oscilloscope should indicate O. 5V ±0. IV

PAGE OF

86 4376 M

ICATION DATE 5 Nov 1970

MAINTENANCE REQUIREMENT CARD (MRC)
OPNAV 4700-1(C) (REV. 11/68)

Figure 2-3. Sample Maintenance Requirement Card manner to avoid interference with other printing on the MRC. If Safety of Ship Items is included on an associated Equipment Guide List, the MRC has both "SAFETY OF SHIP" and "EQUIPMENT GUIDE LIST" stamped on the face of card. Every effort has been made to indicate hazards in the safety precautions block and at appropriate steps in the procedures block; however, common sense, through safety indoctrination and training of personnel maintaining and operating shipboard equipments, is still required.

9. A list of specific tools, parts and materials required to properly perform the maintenance action is given.

10. Detailed step-by-step procedures to be followed to accomplish maintenance actions are given. In some instances, cards will contain blanks which must be completed by ship's personnel in order to supply the data (e.g., limiting speeds, tolerances, and pressures) necessary for the proper execution of the work specified. These data readings will vary from ship-to-ship.

11. The System Command MRC Control Number in the lower right side is a Library Identification Code. This number must be referenced along with MRC codes in all correspondence pertaining to specific MRCS.

12. A space is also provided for recording the location of a specific equipment aboard individual installation, or for alerting maintenance personnel to the existence of EGLs.

13. In most cases, the contents of the MRC is unclassified even though it may be applicable to classified equipment. In cases where classification of an individual MRC is required due to content, the following entry is found in the "Procedure" block: "Maintenance Procedure with this requirement is CLASSIFIED. MRC is stowed in ________" (Ship will fill in the blank.) The completed MRC is printed on pink stock with the classification printed at top and bottom of each printed side and shall be handled in accordance with OPNAVINST 5510-1 series (Security Manual for Classification Information).

14. The date on the card is the month and year when the MRC was prepared.

15. The MRC cards are to be used as follows:

a. A complete working group of MRCS are to be located, in the holder provided, in the work center area.

b. Maintenance personnel are to remove the assigned MRCS from the Work Center card container, obtain the required tools, parts, and materials listed on MRC, and perform the maintenance action as stated on MRC, observing all safety precautions.

c. When compIeted, maintenance personnel should then correct and/or report any deficiencies discovered during the performance of the maintenance action. Report the completion of the maintenance action to the Work center Supervisor, who will update the Weekly Schedule.

d. The MRCS should then be returned to the container after the job has been completed.

2-2.2.1,3 Equipment Guide List

The Equipment Guide List (EGL) is a 5- x 8- inch card that accompanies specific MRCS to list identical-type equipment to which preventive maintenance task is to be performed. Identical-type equipments, such as radar repeaters, power supplies, etc., are listed to show their quantity and location. For example, a particular ship may have eight AN/SPA-4A Radar Repeaters, and each repeater requires the accomplishment of the same preventive maintenance task. The EGL is actually an extension of the Cycle and Weekly Schedules. When EGLs are required, a Guide List Index (GLI) is also prepared listing each EGL along with its controlling MRC. The index is included at the end of the List of Effective Pages in the PMS Manual.

2-2.2.1.4 Cycle Schedule

The Cycle Schedule (OPNAV Form 4700-4), shown in figure 2-4, is a visurd display of the planned maintenance requirements that are to be performed by shipboard personnel between major overhauls of the ship. "Between overhauls" is defined as "the time between a departure after overhaul and through the completion of the next major overhaul." Most PMS requirements listed on the Cycle Schedule are within the capability of the ship's force. Occasions may arise where special test equipment, special tools, or outside assistance will be required in order to accomplish the required maintenance. The Cycle Schedule contains the name and hull number of ship involved, the work center concerned, the effective date of the schedule, the listings of the MIPs and their related systems, subsystems and components for which the PMS requirements are to be scheduled. It also contains the schedules of the Semiannual, Annual, Cycle, and Situation Requirements. Cycle requirements axe divided into "Quarters after Overhaul" for listing the Quarterly requirements, and Monthly requirements which have been scheduled in each quarter. Care and attention must be devoted to the preparation of the Cycle Schedule as it has a direct influence on the subsequent effectiveness of the long range PMS scheduling by maintenance personnel. The procedure for filling out the Cycle Schedule is as follows:

1. Type in the ship's name and hull number in the upper left block and enter the date of preparation in the upper right corner. When a new cycle schedule is prepared, the old schedule must be **filed** with its applicable quarterly schedule.

2. Type in the Maintenance Group Block, i.e., Radio ETs, Radar ET. Indicate sheet number (e.g., 1 of 3, 2 of 3, 3 of 3) when more than one schedule is required.

3. Starting with the first MIP in the Work Center Manual, list the Equipment Code in the first column titled "Equip Page" (that is, E-I,F-l, EL-4, A-l). When more than one of the same equipment is located in the same Work Center, each must be entered as a separate line item. For example, two power supplies are located in the same space; PS-1 will be entered twice, on separate lines.

4. From the MIP in the column titled "Component," list the noun name or AN nomenclature of each component. If more than one of the same type equipment is located in the same Work Center, each will be identified separately using the standard shipboard numbering system (i.e., Radio #l, Radio #2, ECM ##1, ECM #2, and including equipment serial numbers). When a large number of similar equipments such as radar, power supplies, radar repeaters, etc., are to, be maintained in accordance with the same MRC, it is advantageous to use the Equipment Guide List method of accountability. The last line of the Cycle Schedule should be left blank so that space will be available on the matching Quarterly Schedule for the entry of ship's operational schedule, including space to make corrections without completely removing the previous operational schedule.

5. From the MIP, list each Maintenance Requirement for Monthly (M), Quarterly (Q), and Situation Requirement (R) in the column headed "Each Quarter." Situation Requirement requirements are listed here only as a reminder and will not be scheduled on a calendar basis. Daily (D) and Weekly (W) requirements are scheduled only on the weekly Schedule and are not listed on the Cycle Schedule. Calendar requirement which may be modified by a situation, such as A-2R, will appear in appropriate "Quarter After Overhaul" column. Pay particular attention to the "Related Maintenance" column of the MIP. If any Semi-annual (S), Annual (A) or Cycle (C) requirements are related, they shall be scheduled in the same "Quarter After Overhaul" column.

6. From the MIP, list each Semi-annual (S) maintenance requirement in one of the four columns titled "Quarter After Overhaul," then list the same requirement to occur six months later. For example, an S-1 requirement scheduled to occur in the 1,5 and 9 quarters shall also be scheduled to occur in the 3, 7 and 11 quarters. Requirements in these four columns should be staggered to ensure an even distribution of workload.

7. From the MIP, list each Annual (A) maintenance requirement in one of the four columns titled "Quarter After Overhaul."

8. From the MIP, list each Cycle (C) maintenance requirement, reviewing each to determine if a specific quarter after overhaul is indicated on the MIP. Ensure that all Cycle requirement have an appropriate quarter after overhaul indicated in parenthesis after each entry on the cycle schedule. As an example, C-1 (6) is a Cycle maintenance requirement scheduled to be accomplished in the 6th quarter after overhaul.

9. Cycle Schedules for ships with overhaul cycles extending beyond 12 quarters will be prepared for the entire overhaul cycle indicating 13, 14, etc., as necessary. Sbips with overhaul cycles less than 12 quarters will schedule "Cycle Requirements" within the specified overhaul time frame. Ships encountering delays in entering overhaul shall extend their cycle scheduled by the addition of appropriate quarter numbers in the "Quarter After Overhaul" block. (Ensure cycle requirements required prior to entering overhaul are reviewed and rescheduled as necessary.)

10. The completed "Cycle Schedule" **shall** be signed by the Department Head over the words "Scheduled As Indicated."

2-2.2.1.5 Quarterly Schedule

The Quarterly Schedule (OPNAV form 4700-5), shown in Figure 2-5, is a visual display of the ship's tentative operational employment schedule in conjunction with the PMS requirements to be performed during a three-montb period. This schedule is a directive issued by the Department Head and as such may be changed only by him or his authority. It is updated weekly and provides a ready shipboard reference to the current status of PMS for each Work Center. The schedule provides space for entering "Work Centers, Year, Quarter After Overhaul," and the current months covered. Space must be reserved

EQUIP PAGE	USS Worcester CL 144 MAINTENANCE GROUP; Computer ET COMPONENT	Daniel Buckley — QUARTER AFTER OVERHAUL 1 5 9	2 6 10	3 7 11	4 8 12	11/70 EACH QUARTER
E 1	AN/UYA5(XN-1)('	A1				Ml Q1
E 2	AN/UYA6(XN-1)(		A1			M1 Q1
E 3	RP-161/UYK			A1		Ml Q1
E 4	RO-367(XN-1)/U				A1	M1 Q1

CYCLE SCHEDULE OPNAV FORM 4700-4 (3-68) S/N-0107-766-400 C. 2521!

☆ U. S. GOVERNMENT PRINTING OFFICE : 1968 —346-886/A-110

Figure 2-4. Sample Cycle Schedule

MAINTENANCE GROUP Computer Room	YEAR 1971	QUARTER AFTER OVERHAUL 2 Daniel Buckley
MONTH Jan	MONTH Feb	MONTH Mar

EMPLOYMENT SCHEDULE

4 Jan	11	18	25	1 Feb	8	15	22	1 Mar	8	15	22	29
MI, Q1				Ml				Ml				
Al, M1, Q1				M1				Ml				
MI, Q1				Ml				Ml				
Ml Q1				Ml				M1				
UPK	UPK	ASW	ASW	ASW	UPK	UPK	UPK	UPK	UPK	UPK	UPK	UPK

QUARTERLY MAINTENANCE SCHEDULE OPNAV FORM 4700-5 (4-64) C-40997

Figure 2-5. Sample Quarterly Maintenance Schedule on the schedule for entering tentative ship's employment schedule. Thirteen columns, one for each week in the quarter, are available to enable scheduling of maintenance requirements on a weekly basis throughout the quarter. The procedure for filling out the Quarterly Schedule is given below.

1. Enter the name of Work Center concerned in the space provided on the schedule.

2. Enter the corresponding sheet number from cycle being scheduled (1 of 2, 2 of 2).

3. Enter the cafendar months of the quarter to be scheduled, in accordance with one of the quarterly groupings shown below. Groupings other than those shown are not acceptable.

JAN	APR	JUL	OCT
FEB	MAY	AUG	NOV
MAR	JUN	SEP	DEC

4. Enter the number of the "Quarter After Overhaul" in the space provided. For example: a ship completing major **overhaul** during August 1969 will list the months of July, August and September for the first Quarter after overhaul schedule. The second Quarter of the overhaul would then list the months of October, November, and December. While in overhaul, ships must continue PMS whenever possible. Ships departing major overhaul late in the **quarter** are not expected to complete all planned maintenance scheduled during that quarter, but should accomplish a proportionate share based on the time remaining in the quarter. When departure occurs within the last two weeks of the quarter, ships will complete that quarter to the maximum extent possible utilizing the current quarterly schedule. The first quarter after overhaul in this case will then begin with the next quarter.

5. Identify a date for the starting of each week. The main body of the Quarterly Schedule is divided into thirteen columns; each column represents a week. Each column is further divided into seven days by the use of check marks across the top of the columns. Write directly over the first check space of each week to identify the date of each Monday.

6. From the ship's operational employment schedule enter the following information:

a. Across the top of the columns lightly shade in the days that the ship expects to be underway.

b. Across the bottom line of the current Quarterly Schedule, write in the type of employment, corresponding to the dates indicated across the top columns. (Upkeep, ASW, ISE, TAV, etc.)

7. Place the new Quarterly Schedule next to the Cycle **Schedule.**

8 From the Cycle Schedule, select the "Quarter After Overhaul" column corresponding to the current quarter. Penodicity codes listed in this column and the column titled "Each Quarter" will be transcribed to the current quarterly schedule. The other columns on the cycle Schedule will not affect the current quarter.

9. Refer to the MIPs for a brief description of the maintenance actions scheduled on the cycle schedule in order to determine if the action should be performed in port or at sea. Schedule the requirement on the Quarterly Schedule in the week most appropriate for accomplishment. Schedule afl related maintenance together.

10. From tbe Cycle Schedule column titled "Each Quarter" schedule **all** monthly and quarterly requirements into appropriate weeks of the Quarterly Schedule. Next, from the "Quarter After Overhaul" column, schedule **all** annual and semi-annual requirements. The ultimate goal in scheduling the Quarterly PMS requirements is to ensure the completion of all necessary maintenance actions while maintaining a balanced workfoad within the framework of the ship's operating schedule. When there are changes in the ship's operating schedule, maintenance requirements may require rescheduling to fit the new operating schedule.

11. Schedule afl cycle requirements for which the number in parentheses matches the quarter after overhaul being scheduled.

12. The completed Quarterly Schedule **shall** be signed by the Department Head in the "Quarter After Overhaul" block. Fill in all header information for the next quarter on another Quarterly Schedule form and place it beside the current schedule in the holder. This provides continuity for scheduling and planning on a long-range basis. This Quarterly Schedule serves as a directive for Work Center Supervisors for scheduling weekly maintenance. At the end of each work week, the Work Center Supervisor will cross-out (X) all maintenance requirements on the Quarterly Schedule that have been completed and will circle (0) afl requirements that were not accomplished. The Department Head is responsible for the rescheduling of all circled requirements, if they remain within the same penodicity (i.e., a monthly can only be rescheduled in the same month, a quarterly can only be rescheduled within the same quarter, etc.). Any requirement which cannot be accomplished during the

current quarter, in addition to being circled, shall be identified on the back of the quarterly schedule with the reason it was not accomplished. Other unaccomplished requirements shall be rescheduled for accomplishment in the next quarter. The completed Quarterly Schedule is removed from the holder after the close of each quarter and retained as a Planned Maintenance record. This record may be discarded by quarters, when the same number quarter after the next major overhaul has been completed, thereby providing a complete cycle of history. Maintenance requirements shall not be rescheduled on the subsequent Quarterly Schedule until the ship's employment schedule is known or until the last week of the current quarter, whichever comes first.

2-2.2.1.6 Weekly Schedule

The Weekly Schedule (OPNAV Form 4700/6), shown in Figure 2-6, is a visual display of planned maintenance scheduled for accomplishment in a given Work Center during that week. The Weekly Schedule is posted in each Work Center and is used by the Work Center Supervisor to assign and monitor the accomplishment of the required PMS tasks by the Work Center personnel. It contains the name of the Work Center concerned, a listing of the systems, subsystems, and components assigned to the maintenance group of the Work Center, and the respective equipment codes. It lists the maintenance requirement to be performed in a specific week, the names of the personnel assigned to individual maintenance actions, and the outstanding repairs, PMS checks (Monthly and above), and known Situation Requirements due in the next four weeks. The procedure for filling out the Weekly Schedule is as follows:

1. Type in the following information from the current Cycle Schedule.

a. Work Center identification, e.g., Radio # 1 and corresponding cycle schedule sheet number (e.g., 1 of 2, 2 of 2).

b. System, subsystem or component and MIP number, line for line to match the cycle schedule.

2. From the MIPs enter the recurring weekly and daily requirements. Weekly requirements should be entered on Monday to provide ease of rescheduling. Daily requirements must appear each day.

3. Place clear plastic over the weekly schedule.

4. From the current Quarterly Sched- the Work Center Supervisor transposes all PMS requirements and the date for the current week to the Weekly Schedule. Exercise care to ensure a balanced workload, appropriate consideration of the week's operating schedule, and that all related maintenance actions are scheduled together. Review MIPs/MRCs and determine related maintenance requirements.

5. Using information from the Quarterly Schedule, fill in the "Outstanding Repairs Due" column (right column) with known corrective maintenance and all Monthly (and above) PMS requirement due in the next four weeks. This should include all PMS Situation Requirements which may be accomplished during that four-week period.

6. Assign maintenance personnel, by name, to specific maintenance tasks. Maintenance personnel will then obtain their PMS assignments from the Weekly Schedule, obtain the required MRC cards, tools or material, and perform the maintenance action. They must report all completed maintenance action to the Work Center Supervisor. The Work Center Supervisor will then cross off all completed requirements when reported and will circle the uncompleted requirement for rescheduling as the work load and ship's operations permit. At the end of each week, the Work Center Supervisor should bring the Quarterly Schedule up to date by comparing it to the weekly schedule, crossing out completed requirements and circling requirements not completed. The Weekly Schedule is then erased and the next week's schedule prepared.

2-2.2.1.7 Maintenance Control Board

The Maintenance Control Board is a prefabricated aluminum holder that contains a Cycle Schedule, a current Quarterly Schedule, and a subsequent quarterly maintenance schedule for each maintenance group. As its name implies, the Maintenance Control Board presents a readily available summary of the current and planned status of shipwide preventive maintenance for all interested personnel.

2-2.2.2 Maintenance Data Collection System

The Maintenance Data Collection System (MDCS) provides a means for recording the expenditure of resources (men, material and time) associated with certain categories of maintenance actions. Maintenance personnel are provided a means to record, at the source, designated information pertaining to accomplishment of preventive or corrective maintenance actions. It also provides a system for processing significant maintenance and logistic information, and disseminates the results in the form of technical information for maintainability /reliability studies of operational equipment, and in the form of management information for improving workload planning and control. It incorporates the use of coded data elements for data standardization

Daniel Buckley

GROUP Computer Room WORK SCHEOULE FOR WEEK OF 4 Jan 1971 1 1/70

COMPONENT	MAINTENANCE RESPONSIBILITY	PAGE	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT/SUN	OUTSTANDING "C" ,(RS AND P.M. CHECKS DUE IN NEXT. WEEK,
AN/UYA 5(XN-1)(V	Hanrahan	El	DIW1	DIQ1	D1	D1	D1	D1	
AN/UYA 6(XN-1)(V	Urban	E2	WIM1	Q1	Al				
RP-161/UYK	Franck	E3	W1Q1						
RO-367(XN-1)/UY	: Nuzzo	E4	DIW1	D1Q1	D1	D1	D1	D1	

WEEKLY WORK SCHEOULE OPNAV FORM 4700/6 (9-65) S," O* 07-766-6600 A-20932

★ U.*. GOVERNMENT PRINTING OFFICE, 1969-346-894/ A-349

Figure 2-6. Sample Weekly Work Schedule

and facilitating automatic data processing. Failure and corrective action information recorded on the maintenance action documents and the material usage information recorded on associated supply system issue documents, is retrievable through this system for use in engineering analysis and developing maintenance actions (deferred actions) and indicating the principal reason for the delays. This information is also retrievable for use in maintenance problem and logistic support analysis and for developing a Current Ships Maintenance Project (CSMP) file which will assist in improving the planning and coordination of the ship's workload. For those maintenance actions which have been deferred because of a requirement for technical skills or special equipment not available on board ship, the MDCS makes provisions for documenting a work request to an appropriate repair activity. Follow-UP reporting by these repair activities, upon completion of requested repair assistance, contributes significantly to the detail and depth maintenance information available for retrieval and subsequent use through MDS. The reports and forms used in MDS are employed in the following subsections.

2-2.2.2.1 PMS Feedback Report

The PMS Feedback Report (OPNAV Form 4700-7), shown in Figure 2-7, provides a direct line of communication, via the TYCOM, between the maintenance man and the Naval Material Command. The PMS Feedback is utilized to submit recommended modifications and revisions to PMS documentation and to request certain additional or replacement software and hardware. In addition, it is used to suggest changes to technical manuafs and to report or inquire about other matters in connection with PMS. Instruction for completing and submitting reports are printed on the back of the last copy of this five-part form.

2-2.2.2.2 Maintenance Data Form

The Maintenance Data Form (OPNAV Form 4790/2 K), shown in Figure 2-8, is a multipurpose form used to report the completion or deferral of a maintenance action or to request needed assistance. The data element that must be completed to report any one of the categories of maintenance information are grouped together in separate, clearly labeled sections on the form, to simplify data recording and to facilitate Automatic Data Processing (ADP). In addition to the standard data elements which are used for recording all reportable maintenance actions, this form provides special shaded sections for recording other necessary data elements for maintenance actions associated with specially identified systems or equipments, or reports completed under certain unique circumstances. This form supersedes OPNAV Forms 4700-2J, 4700 -2 B,4700-2C, and 4700-2D.

2-2.2.2.3 Supplemental Report Form

The Supplemental Report Form (OPNAV Form 4790/2L), shown in Figure 2-9, is an MDS feedback report used to inquire about,or comment on, any subject related to maintenance accomplishment or maintenance action reporting. In this application, this report may be used individually or in con. juction with OPNAV Form 4790/2K. This form has been approved by CNO as the reporting form for limited duration data collection programs. This form permits collecting more detailed maintenance information than is available through routine MDS reporting. Section I of this form is filled in the same way as on associated form 4790/2K if it is being used as a continuation sheet. Otherwise, only block 1, date and serial number, is required. Section II is filled in with the voluntary information being reported. It should contain comments, sketches, technical data, etc. When required for mandatory submission, this section will be filled in as directed by appropriate authority. Section III is for signature use as indicated or as directed for special report use. Section IV is reserved for special reporting programs only and shall be filled in according to instructions. Section V is for addressing; use as indicated unless otherwise directed for special reporting.

2-2.2.2.4 Work Supplement Card

The Work Supplement Card (OPNAV Form 4790/2 F), shown in Figure 2-10, is a prepunched pre-printed card supplied to the Lead Work Center and each assist work center included in the initial planning phase of the Work Request. This card is used primarily by repair work centers to report the daily progress (action taken, manhours expended, date) on a work request. This card may also be used to record remaining hours, report work delay/status and to request additional work supplement cards. The assist work center will use the same card to estimate their portion of the job. Information from these cards is used for Workload Planning and Control (WLP&C) reports.

1. Daily Progress. The Work Supplemental Cards are used to document all manhours expended on each job in progress within the work center. The senior man actively engaged in the maintenance action is responsible for documenting the daily progress.

INSTRUCTIONS ON BACK OF GREEN PAGE

ROM: USS Worcester

SERIAL #: C-69

DATE 15 Nov 1970

O: NAVY MAINTENANCE
MANAGEMENT FIELD OFFICE
Box 604 Hampton Roads Branch
Norfolk, Virginia 23511

1A:

SUBJECT: PLANNED MAINTENANCE SYSTEM FEEDBACK REPORT

YSTEM	COMPONENT
AN/UYA 5 (XN-1)(V)	Memory
UB-SYSTEM	M. R. NUMBER E-17 M I
	CONTROL "864376

'DISCREPANCY:

- [ ] M. R. Description
- [ ] Equipment Change
- [ ] Typographical
- [ ] Safety Precautions
- Missing Maintenance Index Page (MIP)
- [x] Technical Publications
- [ ] Tools, Etc.
- [ ] Technical
- [ ] Miscellaneous
- [ ] Missing Maintenance Requirement Card (MRC)
- [ ] Procedure

Logic Diagrams in 0967-306-4020 are in error. Gate number 6D5A has output pin shown as 14. This pin should be 13.

Daniel Buckley

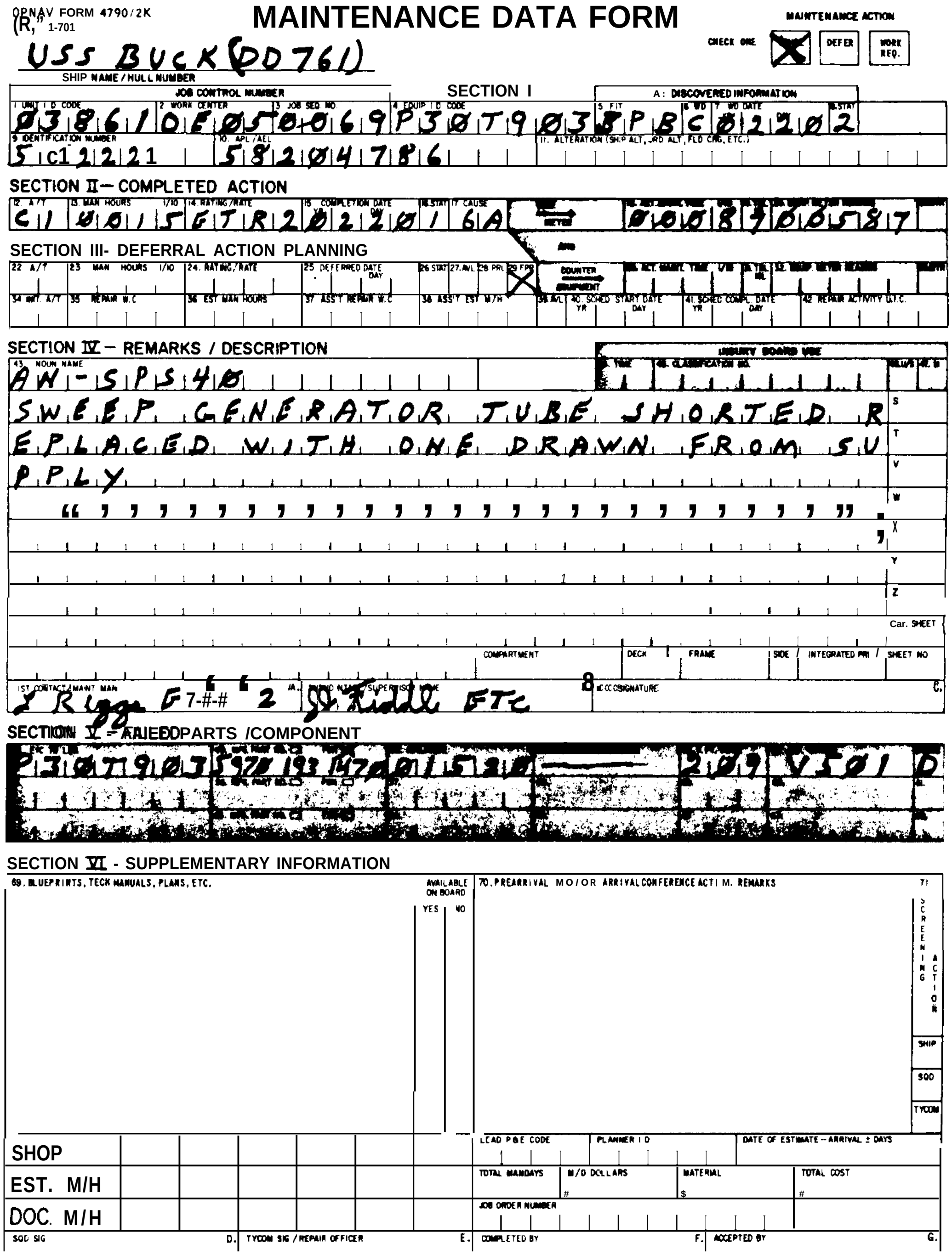
SIGNATURE

THIS COPY FOR:

'NAV FORM 4700/7 (Rev.8-66)

ADDRESSEE 1

Figure 2-7. Sample PMS Feedback Form



OPNAV FORM 4790/2K (R, 1-701

MAINTENANCE DATA FORM

MAINTENANCE ACTION — CHECK ONE: [X] DEFER WORK REQ.

USS BUCK (DD 761)

SHIP NAME/HULL NUMBER

SECTION I

JOB CONTROL NUMBER: 1 UNIT I D CODE 03861 | 2 WORK CENTER 0E05 | 3 JOB SEQ NO. 0069

4 EQUIP I D CODE P30T903 | 5 FIT 8 | 6 WD P | 7 WD DATE BC 02102 | 8 STAT 2

A: DISCOVERED INFORMATION

9 IDENTIFICATION NUMBER 5 C1 2 2 2 1 | 10 APL/AEL 582047816 | 11. ALTERATION (SHIP ALT, ORD ALT, FLD CHG, ETC.)

SECTION II — COMPLETED ACTION

12 A/T C | 13 MAN HOURS 1/10 0015 | 14 RATING/RATE ETR2 | 15 COMPLETION DATE 2021 | 16 STAT 0 | 17 CAUSE 1 6A | METER 00087 | 0005817

SECTION III - DEFERRAL ACTION PLANNING

22 A/T | 23 MAN HOURS 1/10 | 24 RATING/RATE | 25 DEFERRED DATE DAY | 26 STAT | 27 AVL | 28 PRI | 29 FPR | COUNTER EQUIPMENT

34 ... A/T | 35 REPAIR W.C | 36 EST MAN HOURS | 37 ASS'T REPAIR W.C | 38 ASS'T EST M/H | 39 AVL | 40. SCHED START DATE YR DAY | 41. SCHED COMPL DATE YR DAY | 42 REPAIR ACTIVITY U.I.C.

SECTION IV — REMARKS / DESCRIPTION

43. NOUN NAME AN-SPS40

INQUIRY BOARD USE

SWEEP GENERATOR TUBE SHORTED R
EPLACED WITH ONE DRAWN FROM SU
PPLY

COMPARTMENT | DECK | FRAME | SIDE | INTEGRATED PRI | SHEET NO

1ST CONTACT/MAINT MAN J Riggs E7-#-# 2 | SUPERVISOR J. Kidd ETC | 8 ... SIGNATURE C.

SECTION V - RAIED PARTS /COMPONENT

P30T903 5978 193 1470 01 5 210 209 V501 D

SECTION VI - SUPPLEMENTARY INFORMATION

69. BLUEPRINTS, TECH MANUALS, PLANS, ETC. | AVAILABLE ON BOARD YES NO | 70. PREARRIVAL MO/OR ARRIVAL CONFERENCE ACT M. REMARKS | 71 SCREENING ACTION | SHIP | SQD | TYCOM

SHOP | EST. M/H | DOC. M/H

LEAD P&E CODE | PLANNER I D | DATE OF ESTIMATE — ARRIVAL ± DAYS

TOTAL MANDAYS | M/D DOLLARS | MATERIAL $ | TOTAL COST $

JOB ORDER NUMBER

SQD SIG D. | TYCOM SIG / REPAIR OFFICER E. | COMPLETED BY F. | ACCEPTED BY G.

Figure 2-8. Sample Maintenance Data Form

2. Remaining Hours. Whenever the remaining hours, as listed on the WLP & C reports, do not accurately reflect the scope of the job for this work center, this figure can be revised by entering the hours remaing for the job in block D of this form. The work center supervisor must concur with the new entry.

3. Work Delay. Work delays or work stoppage affecting satisfactory progress on the job is reported by using the Work Supplement Card. The Lead Work Center or the Assist Work Center may use the Work Delay/Stoppage Codes, found on the reverse side of the card, in block G. There can be only one Work Delay/Stoppage Code effective at any one time for any specific work center. The latest delay code that is submitted will be reflected on WPL & C reports. The delay code 00 will be used to show the delay status from that work center WPL & C reports. The Work Center Supervisor must. concur with assignment and removal of delay codes.

4. Replenishment. Request for replenishment of the supply of Work Supplement cards can be accomplished by submitting a card for that specific purpose or in conjunction with the daily progress report by entering the number of cards desired (1 to 9) in block H.

5. Assigning an Assist Work Center. When additional repair work centers are required to complete the requested work, the Lead Repair Work Center will provide to Assist Repair Work Center two or more pre-punched/pre-printed Work Supplement Cards One is to establish the Assist Repair Work Center Job Planning Record, and the others are for reporting progress prior to receiving additional cards from Data Services. The Lead Repair Work Center will make the entries indicated on each card. The Lead Repair Work Center will provide sufficient description in the remarks section of the card to enable the Assist Work Center to scope the job.

6. Multiple Units. Multiple Unit work requests on items such as binoculars, printing, photographing, plaques, sound-powered phones, clocks, etc., are permitted by using the words "various" or "miscell" in block 9 of the work request submitted on a 4790/2K form. Block 9 of the pre-punched 4790/2F card will always be blank when associated with this type work request. These multiple items will always be documented as a single maintenance action unless rejection of individually serialized items is involved. When individually serialized items are rejected, the Rejection Action Taken Code must be on a one-for-one basis for each item. For non-serialized items or whenever rejection is not involved, the Action Taken Code that best describes the overall effort will be recorded. Assist Work Centers will not reject individual units of a multiple unit work request, Multiple unit work requests on maintenance history significant items are not permitted.

7. Completion. Completion of a work request can be reported using the 4790/2F and entering the code''3O" in block G. Assist Work Centers may also report completion of their portion of a job by using code "30" in block G on the 4790/2F. When code "30" is received by Lead Work Center, sheet 1 of the 4790/2K must be completed for the job to be closed out.

2-2.2.2.5 Failed Parts/Components Card

The Failed Parts/Component Card (OPNAV Form 4790-2M), shown in Figure 2-11, is used to document a failed part or component only when block 29 on the OPNAV 4790/2K (Work Request) indicates this requirement with an entry. One pre-printed 4790-2M card is provided the Lead Work Center for this purpose. It is the Lead Work Center's responsibility to document failed parts/components including those discovered by Assist Work Centers. A maximum of three failed parts/components will be reported. When there are more than three, the Lead Work Center will determine and report the three most insignificant failures in the order of their importance.

2-2.2.2.6 Single Line Item Requisition Document

This document (DD Form 1348), shown in Figure 2-12, is used for internal issue of material aboard ships that have automated (mechanical) supply records with Automatic Data Processing (APD) equipment. The procedure for filling out this document is as follows:

1. Enter the Job Control Number (JCN) in blocks L, M, and N. The JCN is made up from the Unit Identification Code (UIC), Work Center (WC), and the Job Sequence Number (JSN) contained in blocks 1, 2, and 3 of OPNAV Form 4790/2K pertaining to the maintenance action for which the item is requested. Care must be exercised to ensure that the same JCN is used on all supply documents relating to the same maintenance action.

2. Enter the National Stock Number (NSN) in blocks 4, 5 and 6 for the item requested.

OPNAV FORM 4790/2L
(REV. 1-70)
S/ N-0 107-770-3053

SUPPLEMENTAL REPORT FORM

CONTINUATION 2K 2L

USS BUCK (DD761)
SHIP NAME/HULL NUMBER

OEØ5-3
SERIAL NUMBER (OPTIONAL USE)

JOB CONTROL NUMBER — SECTION I

1. UNIT I.D. CODE	2. W		YR	DAY
Ø3861	ØEØ	M91619	Ø	223

SECTION II - REMARKS/DESCRIPTION
COMMENTS, REQUESTS, SKETCHES, ETC. – VOLUNTARY OR AS DIRECTED:

AN/SPS-4Ø SWEEP GENERATOR TUBE REPLACED.
BELIEVE VIBRATION AND SHOCK TO THIS TUBE COULD BE
REDUCED BY INSTALLING GUARD AROUND IT.

SECTION III - SIGNATURE

MAINTAINER REPORTING:	RANK/RATE	SUPERVISOR:	RANK/RATE
J Riggs	ETR2	J Tiddle	ETC

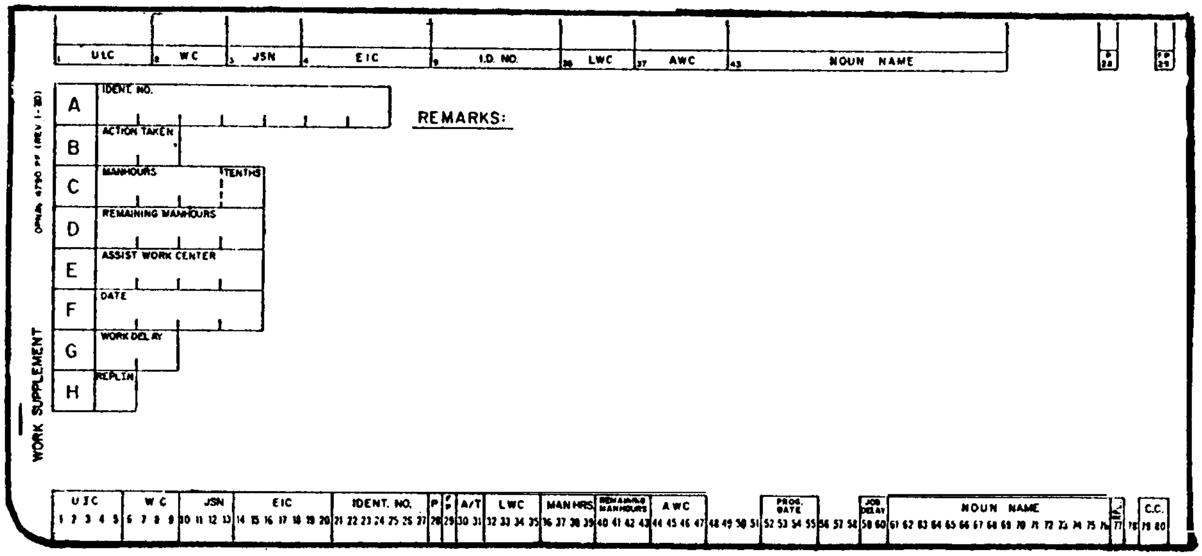
SECTION IV . SUPPLEMENTARY INFORMATION (FOR USE ONLY WHEN DIRECTED BY REQUIRING ACTIVITY)

SECTION V - MAILING ADDRESS (FILL IN ACCORDING TO "DIRECTIONS OR AS MODIFIED BY REQUIRING ACTIVITY)

TO,	VIA,
NMMFO(E)	CCDL (COM G&&(LANT)
CODE Ø411E BOX SECTION 6Ø4	US ATLANTIC FLEET
HAMPTON ROADS BRANCH	NEWPORT. R.I.
NORFOLK VA. 23511	

ADDRESSEE

Figure 2-9. Sample Supplemental Report Form


UIC | WC | JSN | EIC | I.D. NO. | LWC | AWC | NOUN NAME

WORK SUPPLEMENT OPNAV 4790 2F (REV 1-80)

A IDENT. NO.

B ACTION TAKEN

C MANHOURS TENTHS

D REMAINING MANHOURS

E ASSIST WORK CENTER

F DATE

G WORK DELAY

H REPLIN

REMARKS:

UIC | WC | JSN | EIC | IDENT. NO. | P | A/T | LWC | MAN HRS. | REMAINING MANHOURS | AWC | PROG. DATE | JOB DELAY | NOUN NAME | C.C.

OPNAV Form 4790/2F Work Supplement Card (Front)

CODE — WORK NOT STARTED

11. Not Delivered to Work Center . . . . "NOT DELIVERED"
12. Insufficient Information . . . . "INSUFF INFO"
13. Awaiting Parts/Material . . . . "WAITG PARTS/MATL"
14. Lack of Manpower . . . . "LACK MANPOWER"
15. Work Center Equipment Unavailable . . . . "WC EQUIP UNAVAIL"

WORK STARTED BUT STOPPED

21. Priorty Changed . . . . "STP-PRIORITY CHANGE"
22. Insufficient Information . . . . "STP-INSUFF INFO"
23. Awaiting Parts/Material . . . . "STP-WAITG PARTS/MATL"
24. Awaiting Assist Work Center . . . . "STP-WAITG ASSIST WC"
25. Work Center Equipment Unavailable . . . . "STP-WC EQUIP UNAVAIL"

STATUS CODES

30. Completed–Not Signed Off . . . . "COMPL-NOT SIGNED OFF"
40. Re-Work Required . . . . "RE-WORK REQUIRED"
50-59. Special Purpose . . . . "SPECIAL STATUS"

OPNAV Form 4790/2F Work Supplement Card (Reverse) Work Delay and Status Codes

Figure 2-10. Sample Work Supplement Card

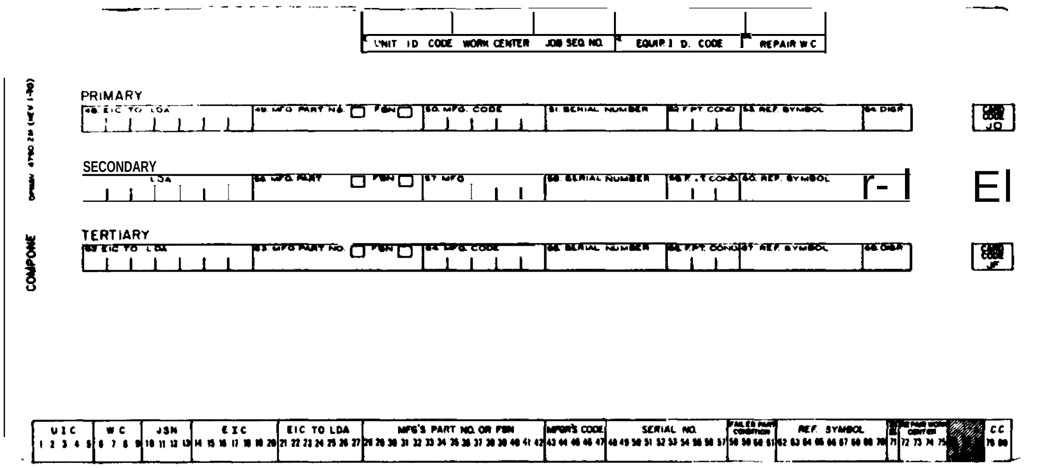


Figure 2-11. 8ample Failed Parts/Components Card

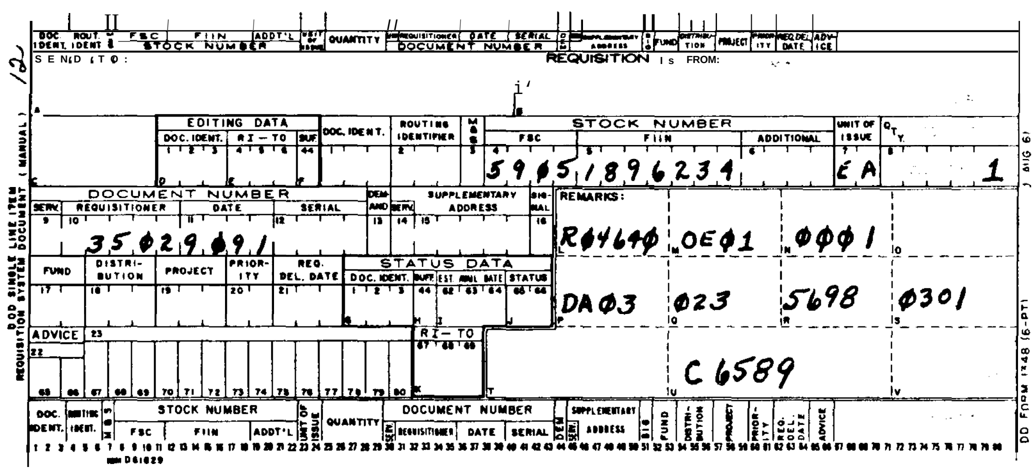


Figure 2-12. Sample DD Form 1348

The FSN is generally found in the Coordinated Shipboard Allowance List (COSAL) within the Allowance Parts List/Allowance Equipage List (APL/AEL) for the equipment/component being worked on. When only the part number is known, the NSN may be obtained from the Master Cross Reference List (MCRL). When an item is identified only by the Manufacturer's Part Number for which no NSN has been assigned, the part number preceded by the Federal Supply Code of Manufacturers (FSCM) will be entered. When a requested item cannot be identified by an FSN or a Manufacturer's Part Number, the Noun Name and a brief description of the item will be provided in blocks 4, 5, and 6.

3. Enter the quantity of the item required in block 8. Provide the actual quantity required, consistent with the standard unit of issue, to complete the maintenance action.

4. Enter the Document Number in blocks 10 and 11. The document number contains two data elements. In block 10, enter the department/division serial number. In block 11 enter the Julian date of the day that the request for the item was placed with the Supply Department.

5. Enter the urgency code in block 20. This code shall be a realistic code assigned by personnel designated by the Department Head.

6. When the item requested is Not In Stock (NIS) or Not Carried (NC) and it is imperative that the item be on board by a certain date in order to complete the maintenance action to meet ship's operations, enter the Required Delivery Date (RDD) in block 21. This date shall be a realistic date and assigned by personnel designated by the Department Head.

7. Enter the Equipment Identification Code (EIC) in blocks P and Q. The EIC code is obtained from the EIC Manual and should be the Lowest Designated Assembly (LDA) listed in the EIC Manual for the item requested. The EIC used here may not necessarily be identical to the EIC used on the 4790/2K.

8. Enter the APL and AEL code in blocks R and S. These codes are taken from the ship's COSAL. Exercise care to ensure that the APL/AEL is for the equipment/component actually being worked on. This entry may not necessarily be identical to the APL/AEL entry on the 4790/2K. In a case where the APL/AEL does not exist on board, enter "Not Listed."

9. Enter the Reference Circuit Symbol for the part or item in block U. This reference/circuit symbol may be found on schematics, circuit diagrams, and technical manuals. Further documentation of the DD Fonu 1348 will be accomplished by the Supply Department. After appropriate action has been taken by supply, the maintenance technician will receive a copy of the DD Form 1348 with the material requested. In cases where the material is not available on board, the WC will be provided with a copy marked NIS or NC as appropriate for the WCs status information.

2-2.2.2.7 Single Line Item Consumption/ Management Document

This document (NAVSUP Form 1250), shown in Figure 2-13, is used to request and issue material internally aboard ships that do not have automated (mechanized) supply records. A copy of this form is used to report all maintenance related material issues. The procedure for tilling out this document is as follows:

1. Enter the material request date in block A. This entry will be the Julian date of the day that the request for the item is placed with the Supply Department.

2. Enter the Department Number in block B. This number is the next sequential number for each transaction of the department issuing the request.

3. Check the word "Issue" in block C to ensure proper reporting of the item used.

4. When the item requested is Not In Stock (NIS) or Not Carried (NC) and it is imperative that the item be on board by a certain date in order to complete the maintenance action to meet ships operations, enter the Required Delivery Date (RDD) in block I. This date shall be a realistic date and assigned by personnel designated by the Department Head.

5. Enter the Urgency code in block J. This code shall be a realistic code assigned by personnel designated by the Department Head.

6. Enter the National Stock Number (NSN) in blocks 3, 4, and 5 for the item requested. The NSN is generally found in the Coordinated Shipboard Allowance List (COSAL) within the Allowance Parts List/Allowance Equipage List (APL/AEL) for the equipment/component being worked on. When only the part number is known, the NSN may be obtained from the Master Cross Reference List (MCRL). When an item is identified only by the Manufacturer's Part Number for which no NSN has been assigned, the part number preceded by the Federal Supply Code of Manufacturers (FSCM) will be entered. When a requested item cannot be identified by a FSN or a Manufacturer's Part Number, the Noun Name and a brief description of the item will be provided in blocks 3,4, and 5.

7. Enter the Reference Circuit Symbol or Noun Name for the part or item in block 6. The reference symbol may be found on schematics, circuit diagrams, and technical manuals.

8. Enter the **quantity** of the item required in block 8. Provide the actual quantity required, consistent with the standard unit of issue, to complete the maintenance action.

9. Enter the Job Control Number (JCN) in blocks 10, 11, and 12. The JCN is made up from the Unit Identification Code **(UIC),** Work Center (WC), and the Job Sequence Number **(JSN)** contained in blocks 1, 2, and 3 of OPNAV Form 4790/2K pertaining to the maintenance action for which the item is requested. Care must he exercised to ensure that the same JCN is used on all supply documents relating to the same maintenance action.

10. Enter the Equipment Identification Code (EIC) in block 13. The EIC code is obtained from the EIC Manual and should be the Lowest Designated Assembly **(LDA)** listed in the EIC Manual for the item requested. The EIC used here may not necessarily be identical to the EIC used on the 4790/2K. **In** a case where the APL/AEL does not exist on board, enter "Not Listed. "

11. The Approval Signature will he placed in block U. This block requires the signature of the Department Head or personnel designated by him.

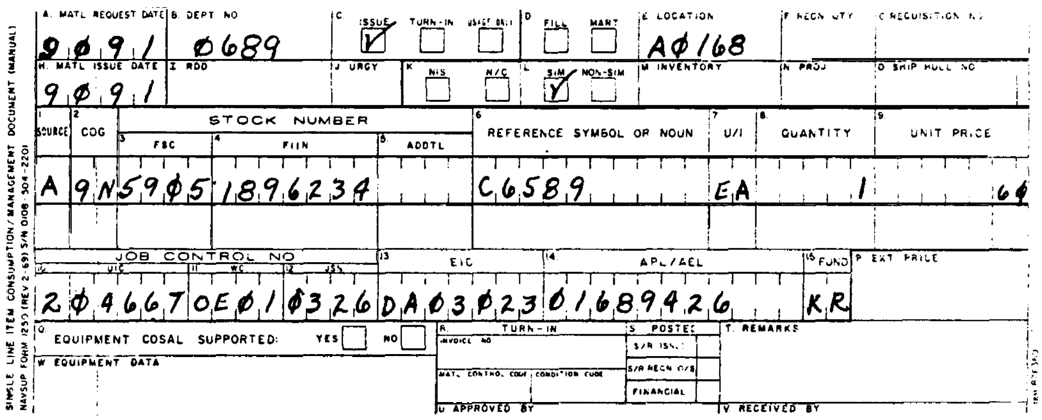
12. When the item is issued by supply personnel, the maintenance technician receiving the item will sign his name in block V as proof of delivery for the Supply Department. Further documentation of the NAVSUP Form 1250 will be accomplished by supply personnel. After appropriate action has been taken by supply, the requesting maintenance technician will receive the yellow copy with the material. In cases where the material is not available on board, the maintenance technician will receive the yellow copy marked NIS or NC as appropriate.

2-3 OPERATIONAL MAINTENANCE

Operational maintenance consists of inspections, cleaning, servicing, preservation, lubrication, adjustment, and minor parts replacement not requiring a high degree of technical skill or knowledge.

2-3.1 OPERATOR RESPONSIBILITIES

Very often, a competent equipment operator can see or sense a malfunction in an equipment which he can correct without the aid of a technician. He is qualified to make some adjustments and changes to an equipment, provided they do not require a high degree of technical skill. Further, he may be required to perform the following duties:


SINGLE LINE ITEM CONSUMPTION/MANAGEMENT DOCUMENT (MANUAL)
NAVSUP FORM 1250 (REV 2-69) S/N 0108-504-2201

A. MATL REQUEST DATE: 9ø91
B. DEPT NO: ø689
C. ISSUE [✓] TURN-IN [ ] USAGE ONLY [ ]
D. FILL [ ] MART [ ]
E. LOCATION: Aø168
F. RECN QTY
G. REQUISITION NO
H. MATL ISSUE DATE: 9ø91
I. RDD
J. URGY
K. NIS [ ] N/C [ ]
L. SIM [✓] NON-SIM [ ]
M. INVENTORY
N. PROJ
O. SHIP HULL NO

1 SOURCE	2 COG	3 FSC (STOCK NUMBER)	4 FIIN	5 ADDTL	6 REFERENCE SYMBOL OR NOUN	7 U/I	8 QUANTITY	9 UNIT PRICE
A	9N	59ø5	1896234		C6589	EA	1	6ø

10 UIC (JOB CONTROL NO)	11 WC	12 JSN	13 EIC	14 APL/AEL	15 FUND	P EXT PRICE
2ø4667	OEø1	ø326	DAø3ø23	ø1689426	KR	

Q. EQUIPMENT COSAL SUPPORTED: YES [ ] NO [ ]
R. TURN-IN: INVOICE NO; MATL CONTROL CODE; CONDITION CODE
S. POSTED: S/R ISSUE; S/R RECN O/S; FINANCIAL
T. REMARKS
U. APPROVED BY
V. RECEIVED BY
W. EQUIPMENT DATA

Figure 2-13. Sample NAVSUP Form 1250

1. Carry out routine maintenance such as lubrication and cleaning.

2. Maintain an adequate, up-to-date, and accessible list of replacement parts.

3. Log all the work performed on an equipment, including all significant measurements that are taken.

2-3.2 TECHNICIAN RESPONSIBILITIES

A technician performs the tests, adjustments, and repairs that are beyond the ability of the operator. A technician must do maintenance work that involves internal alignment, disassembly, and critical adjustment. He must perform tests and follow procedures as required by PMS and the technical manual.

2-4 TROUBLESHOOTING FOR CORRECTIVE MAINTENANCE

Corrective maintenance is the correction of equipment troubles, whether this be the repair of an equipment after a complete breakdown or the tuning and adjustment of an equipment necessary to restore it to an operating condition. Before corrective maintenance can be performed, operators and technicians must know that the trouble exists. Sounds like an erroneous statement? Numerous instances have occurred where obviously malfunctioning equipments were operating for hours, days, and even months without the symptom of the malfunction being recognized by either the operator or technician. Of course, no corrective actions were taken.

2-4.1 SYMPTOM RECOGNITION

Symptom recognition is the first step in troubleshooting, and is based on a complete knowledge and understanding of equipment operation and operational characteristics. In many cases, this is the responsibility of an operator even though he has no technical background. For an operator to recognize a symptom of malfunction, he must be thoroughly familiar with proper equipment operating techniques, and know the function of each mode and feature, even of those rarely used. Symptom recognition may be difficult under electronic countermeasures attack, but consider the probable consequences if corrective action was not taken, or the symptom was not reported to a technician. In many cases, a mode change or the adjustment of an operator's control is all that is needed. Not all equipments produce symptoms that are easily recognized. This type of equipment trouble may then be discovered while performing preventive maintenance under a planned maintenance program, such as PMS. It is important that the "not so apparent" as well as the apparent troubles be recognized. Operators who are not technically qualified technicians on the equipment they operate are still responsible for reporting a malfunction or a symptom to the electronics technician.

2-4.2 SYMPTOM ELABORATION

After an equipment trouble has been recognized, all the available aids designed into the equipment should be used to further elaborate on the symptom. Use of front panel controls and otber built-in indicating and testing aids should provide better identification of the symptom. The equipment operation section of technical manuals may serve as a guide.

2-4.3 LISTING PROBABLE FAULTY FUNCTIONS

The next step in troubeshooting is to formulate a number of logical choices as to the basic cause of the symptom, or what function is at fault. The logical choices should be mental decisions based on knowledge of equipment operation, a full identification of the symptom, and information contained in technical manuals. The overall functional description with associated block diagrams of technical manuals can help the electronics technician formulate logical choices.

24.4 LOCALIZING THE FAULTY FUNCTION

Localizing the faulty function is normally accomplished by using the diagrams in technical manuals. For the greatest efficiency in localizing the trouble, the logical choices should be tested by following the signal flow of a function through the diagrams in an order that will require the least time. If one test does not prove that a particular function is at fault, the next choice should be tested, and so on, until the faulty function or basic cause of the symptom is located.

2-4.5 LOCALIZING TROUBLE TO THE CIRCUIT

Once the faulty function is determined, it may be necessary to make additional choices as to which circuit, or group of circuits, is at fault. Again, the diagrams supported with these parameters are used, along with schematics and other test location information that may be helpful in bracketing the faulty circuit. If the trouble is not immediately apparent, test methods are then necessary to further isolate the fault. The most common test methods are waveform analysis, voltage checks, resistance checks, tube testing, and semiconductor testing. Briefly, they are explained in the following subsections.

2-4.5.1 Waveform Analysis

Waveform analyses are made by observing voltage and current variations with respect to time. The cathode-ray synchroscope is a device that accurately displays the voltage variations with respect to a time-base that is synchronized internally by its own circuits or externally by other synchronous signals. Numerous types of synchroscopes (commonly called oscilloscopes) are available, the required one being supplied with each equipment. The synchroscope required for particular types of tests is determined by characteristics such as the bandwidth of the input frequency, the input impedance, the sensitivity, the sweep rate (time base), and the methods of sweep control (synchronization).

2-4.5.2 Voltage Checks

Voltage measurements, when compared with available voltage charts, provide a valuable aid in locating the trouble. However, the sensitivity of some test voltmeters differs from that of the voltmeter used to make the charts. In such cases, there will be a discrepancy in voltage readings, and they must then be evaluated before the true circuit conditions can be determined. A voltmeter of low sensitivity may disturb a circuit or even render it inoperative.

2-4.5.3 Resistance Checks

Resistance changes are often the cause of a malfunction and degraded performance. The change in a resistance can then be detected by measuring the dc resistance with an ohmmeter between a given point and a reference (usually ground). Point-to-point resistance charts are provided in the technical manuals. Extreme caution should be used when making resistance checks in transistor circuits as the transistor may be damaged by ohmmeter battery voltage.

2-4.5.4 Tube Testing

Electron tubes are more prone to failure than are any other electronic component. It is unwise, however, to attempt to make a general tube check in an equipment containing a large number of tubes. Before tube testing is attempted, the area of trouble should be localized as much as possible to avoid excessive tube testa. Only the tubes in a circuit judged to be faulty should be tested along with tubes associated with the faulty circuit. When replacing a tube, equipment control settings should be noted before insertion of a new tube. A new tube should always be tested for gas or for shorts before insertion. If, with the new tube, the equipment performs abnormally and changing the control setting does not correct the trouble, the original tube should be reinserted, provided that it did not prove defective on a reliable checker. Tubes should not be swapped at random, as the interelectrode capacitance of a tube is a factor in a tuned circuit, and indiscriminate swapping may detune certain circuits. Also, sockets and tube prongs are bound to be damaged from excessive swapping.

2-4.5.5 semiconductor Testing

Transistor, unlike vacuum tubes, are very rugged in that they can tolerate vibration and a rather large degree of shock, and under normal operating conditions will provide for a long period of dependable operation. However, transistors are subject to failure when subjected to excessive temperature and minor overloads. To determine the condition of semiconductors, various test methods are available. In many cases it is possible to substitute a transistor of known good quality for a questionable one, and thus determine the condition of a suspected transistor. This method of test is highly accurate and sometimes expeditious for plug-in types. However, indiscriminate substitution of semiconductors in critical circuits is to be avoided. When transistors are soldered into equipment, this substitution becomes impracticrd; it is generally desirable to test these transistors in their circuits. Since certain fundamental characteristics are an indication of the condition of semiconductors, test equipment is available for testing these characteristics with the semiconductors both in and out of their circuits.

2-4.6 FAILURE ANALYSIS

After the faulty component, misalignment, etc., has been located, but prior to performing corrective action, the procedures followed up to this point should be reviewed to determine exactly why the fault affected the equipment in the manner it did. This review is usually necessary to make certain that the fault discovered is actually the cause of the malfunction, and not just the result of the malfunction.

2-5 ALTERATIONS

An alteration is any change in hull, machinery, fittings, or equipment which involves changes in design, materials, number, location, or relationship of the component parts of an assembly, regardless of whether undertaken separately or together with repairs. Changes in allowances of installed equipment are alterations and should be so handled. The word "approve" in connection with an alteration indicates the Command's action on the proposed change. Command approval is promulgated in letters of technical instruction or SHIPALTS. Approval alone, however, does not constitute authority to proceed with the work. The word "authorize" is used to signify the Command's permission to proceed and the granting of funds for a particular ship during a particular availability. Alterations which affect the military characteristics of a ship may be approved only by the Chief of Naval Operations, who also establishes their relative priority for accomplishment. Alterations other than those affecting military characteristics are approved by the cognizant commands without reference to CNO. In general, alterations of this type concern matters of safety, efficiency, and economy of operation or upkeep (recorded in the Operational Improvement Plan), and health and comfort of personnel (recorded in the Habitability Improvement Plan). The command concerned is responsible for determining whether military characteristics are involved. Alterations to vessels which are made necessary by changes in armament or by changes in equipment furnished by other commands are under the cognizance of the Naval Sea Systems Command.

2-5.1 SHIPALTS

Approved alterations to ships under the cognizance of NAVSEA are known as SHIPALTS. Each quarter, these are listed according to priorities (A, mandatory; B, essential; and C, desirable), compiled as type priority lists, and forwarded to cognizant Type Commanders for information. Type Commanders are requested to review outstanding approved alterations annually and initiate action to cancel those no longer considered essential. Priority lists are also forwarded to the cognizant naval shipyards for guidance in advance planning; for proceeding with design, procurement, and installation work; and for resolving conflicting demands upon personnel and facilities. In order to facilitate record keeping in the case of multiple building programs, alterations ordered in ships under construction, which are also approved as SHIPALTS for ships already delivered, are indicated by including the ships under construction in the applicable SHIPALT. This facilitates the orderly accomplishment of these alterations after delivery in case they are not completed during the construction period. Items omitted from master lists are assigned appropriate priorities at the time work is authorized for applicable ships, or upon request. NAVSEA reviews outstanding SHIPALTS for an individual ship in advance of its scheduled overhaul period and issues, not later than 180 days before such overhaul, a list of the alterations authorized for accomplishment during the overhaul. The list is based upon available funds and equipment. The order of priority follows, as far as practicable, that of the type priority lists. The Type Commander and the commander of the overhauling naval shipyard are requested to comment upon this list. Upon receipt of their recommendations, NAVSEA modifies, as considered desirable, the original list of authorized alterations. SHIPALTS are issued on NAVSHIPS Form 4720/4 (formerly NAVSHIPS 99). Upon completion of an alteration, Section IV of the record must be returned to NAVSEA with an endorsement reporting its completion and a statement to the effect that the ship plans and technical manuals have been corrected to record the changes made.

2-5.2 OR DALTS

Ordnance Alterations (ORDALTS) provide the standard means by which naval activities are furnished plans, instructions, and material for accomplishment of alterations or modifications to naval ordnance material in service or in store. An ORDALT instruction states the specific conditions of applicability of the ORDALT and the method by which the ORDALT is accomplished. An ORDALT set provides the material necessary for the accomplishment of the ORDALT. Whenever possible, ORDALTS will be prepared in such a fasbion that they are unclassified, and can be accomplished by forces afloat without the assistance of contractor field engineer except as follows:

1. ORDALTS either too complex or too time consuming to be accomplished by forces afloat will. be prepared, whenever possible, so that they are unclassified and can be accomplished by shipyard personnel during ship availability.

2. In certain situations, contractor personnel (field engineers and/or installation teams) may be assigned to provide technical assistance or to accomplish the ORDALT.

2-6 FIELD CHANGES

Electronic Field Changes provide operational, reliability, and maintainability improvements to existing electronic equipment. In addition, assistance is provided in the areas of installation, identification, and logistic support. These improvementa, which overcome deficiencies in design and material, are accomplished after manufacture and delivery to the Navy. Prompt accomplishment of all applicable field changes is mandatory to the extent stated in the instructions that accompany the field changes.

2-6.1 CLASSES OF FIELD CHANGES

There are three class designations (A, B, and C) for field changes, one of which is assigned to each field change kit. They provide an abbreviated method of indicating the funding and installation responsibility. A Class A field change requires no installation funding. These field changes are approved for accomplishment (installation) by forces afloat or station personnel on ship- or shore-installed equipment without further reference to the cognizant management command, under conditions stated in the field change instructions. A Class B field change requires Fleet installation funding (not applicable to shore-installed equipment except at training activities). Changes to shipboard equipment are approved for accomplishment by naval shipyards or repair facilities without further reference to NAVSEA, under conditions stated in the field change instructions, when authorized by Type Commanders. Changes to equipment at training activities are approved for accomplishment and funded by the appropriate systems Command. The issuance of field changes which require Fleet funding for accomplishment is discontinued. Except for class B field changes presently under procurement in the supply system, or in Fleet installation planning stage, this type of field change will no longer be issued. A Class C field change normally requires industrial assistance for installation, and requires the appropriate Systems Command installation funding. This class of field change includes, but is not limited to, changes of an operational improvement nature which are to be authorized and accomplished by SHIPALT in the Modernization Plan. Changes to equipment at training activities are approved for accomplishment and funded by the appropriate Systems Command.

2-6.2 TYPES OF FIELD CHANGES

A Type I field change consista of the publications material (field change bulletins and publication corrections) and all parts, materials, and special tools required to accomplish the change to one equipment and to revise existing equipment nameplates, publications, and charta. A Type H field change consists only of publications material required to accomplish the change to the equipment and to revise existing equipment publications and charts. The publications material may be promulgated in the form of the bulletins and correction material, or by means of a published article. Type II changes may require the parts be requisitioned from stock. A Type III field change consists of the publications material (field change bulletins and publication corrections) and only a portion of the parts, materials, and special tools required to accomplish the change to one equipment and to revise existing nameplates, publications and charts. A Type IV field change consists of only publications material required to accomplish the field change to the equipment and to revise existing equipment publications and charts. The Type IV field change information will be in the form of a publication package, but may be promulgated in advance by means of a published article such as in the Electronic Information Bulletin (EIB). Type IV field changes do not require the use of parts, materials, or special tools.

2-6.3 RECORDING AND REPORTING ACCOMPLISHMENT OF FIELD CHANGES

The recording and reporting of field changes shall be in accordance with the instructions in the Field Change Bulletin.

SECTION 3

ROUTINE MAINTENANCE AND MAINTENANCE AIDS

3-1 SAFETY PRECAUTIONS

Before attempting any repair or maintenance work on electronic equipment, the equipment must be disconnected from the power supply and the main switch properly tagged so that it cannot be inadvertently energized. If there is any doubt as to whether the supply circuits have been deenergized, they should be checked with a voltmeter or voltage tester. Make certain that the power supply filter capacitors are shorted and grounded using an approved grounding probe. Check the wiring diagram also to determine if there are any other capacitors that should be discharged by connecting their terminals to each other and to ground by means of a shorting probe. An exception to the rule for deenergizing the equipment may be made when it is necessary to observe operation. In this case, observe the safety precautions necessary to prevent shock or arcs which might start fires, ignite explosive vapors, or be injurious to the health of personnel. Refer to articles contained in EIMB General Handbook, NAVSEA SEOOO-OO-EIM-1OO, Section 3, for general electronic safety precautions.

3-2 ROUTINE MAINTENANCE

Routine maintenance is the application of special procedures of inspection, cleaning, and lubrication of an equipment or system on a scheduled basis in order to keep an equipment or system at the most reliable and efficient operating level at all times.

3-2.1 CLEANING AND INSPECTION

A regular schedule of cleaning and inspection will go far toward ensuring trouble-free operation and the detection of incipient faults before they develop into a major source of difficulty. Cleaning procedures are given in most electronic equipment technical manuals and reference standards books. Where definite times for cleaning and inspection are not specified in the instructions given in the applicable technical manuals for the equipment, each ship should set up a schedule or periodic cleaning and inspection at intervals sufficiently short to keep the equipment ready for service. In setting up such a schedule, the following points should be considered:

1. All electronic equipment must be cleaned to assure good performance; such cleaning is not for appearance only.

2. Steel wool or emery in any form shall not be used on or near electronic equipment.

3. Sandpaper and files should not be used except as a result of competent advice.

4. A vacuum cleaner with a nonmetallic nozzle and adequate dust receiver should be used whenever practicable.

5. Solventa are to be used only when absolutely necessary and then only after proper safety precautions have been taken.

6. When cleaning, care must be exercised to avoid damaging components.

Dirt and foreign matter, if allowed to collect on heat-dissipating components, act as thermal insulators which prevent internally created heat from dissipating into the air. When this occurs, the electronic components thus affected operate at abnormally high temperatures. This condition shortens the life of the component and thus precipitates a breakdown of the electronic equipment itself. Periodic cleaning of the interior of radio transmitted or other equipments employing high voltage is particularly important. Potentials in excess of 3000 volts are often present in these equipment, and dust on insulators or other high-voltage components forms a convenient path for arc-overs and consequent damage. In addition, a mixture of dust and lubricant forms an abrasive which can cause considerable damage to moving parts.

3-2.1.1 Ultrasonic Cleaning

Ultrasonic cleaning is rapidly becoming an accepted method of cleaning various shipboard electrical and electronic hardware. Properly applied and intelligently used, ultrasonics will do a more thorough cleaning job than any other method presently known. For cleaning jobs, the utility of this tool is limited only by the size or weight of the part and ingenuity of the person using it. As with any new tool, attention must be given to understanding the tool—how it works and how to make it work effectively. Basically, two things are required for any efficient and satisfactory cleaning operation: the cleaning solution, and the method. Cleaning solutions are either water-based solutions or solvents. The method is how the solution is applied: hand scrubbing, soaking, spray washing, or ultrasonic cleaning. Ultrasonic cleaning utilizes both chemical and physical action. The proper solutions are selected first to loosen the chemically bonded material. Ultrasonic cavitation of the solution then loosens the mechanically bonded material (dirt). Cavitation is a phenomenon in which vacuum bubbles are rapidly generated and violently collapsed in a solution. As these bubbles collapse, they exert a scrubbing force against the surface of the part placed in the solution. Detergenta play a large part in ultrasonic cleaning. Addition of a detergent to water decreases the amount of energy dissipated in cavitation. Addition of a wetting agent also accelerates degassing of the solution. Some of the initial energy is consumed in degassing air from the solution before maximum cavitation is achieved. The air bubbles formed during degassing act as an energy sink which reduces the energy generated by the ultrasonic transducer. Detergenta are of three basic types: alkaline, acidic, and solvent. Alkaline detergents generally consist of such alkalies as caustic phosphates, silicates, carbonates and surface active agenta. Cleaning solutions on board submarines must be limited to alkaline solutions to avoid atmospheric contamination. A satisfactory cleaning job can generally be done with alkaline detergenta. Acids and solvents may be used in shipyard and repair ship ultrasonic cleaners if the material used for the cleaning tank, drain valves, and piping is stainless steel or monel. Generally, the solution that is best for cleaning the part by conventionrd methods (soaking, flushing, and rinsing) is also best when using ultrasonics. To do a good cavitating job, cleaning solutions must meet the following conditions:

1. Their density must be about that of water or a little higher.
2. They must have a relatively low vapor pressure at the working temperature of the bath.
3. They must remain thin-bodied and nonviscous at operating temperature.

These three characteristics-density, volatility, viscosity—are important from the standpoint of cavitation. Sonic energy levels are down to approximately one-sixth capacity in chlorinated solvents and one-tenth capacity in fluorinated solvents as compared to water-based solutions. In addition, the following conditions also affect cleaning:

4. Length of time in the ultrasonic cleaner (usually 15 minutes maximum).
5. Temperature of solution.
6. Height of solution (depth of immersion).
7. Type of rinse (pressurized spray is preferred type).
8. Cleanliness of solution.
9. Types of cleaning fixtures used (baskets, subtanks, wire hangers, etc.).
10. Position of part (area to be cleaned should be completely submerged in solution).
11. Line voltage fluctuations.
12. State of cleaning solution (new or used).

For components saturated with oil, presoaking in a hot detergent solution in a separate tank is highly recommended. This method removes excess surface dirt and oils, thus lengthening the life of the ultrasonic cleaning solution and recirculation system filter. When a cleaning job requires a stronger cleaning solution than is normally used, or a solution that is not compatible with materials used in the ultrasonic cleaner, a small subtank or container should be employed. The subtank material should be compatible with the cleaning solution. The subtank containing the solution should be suspended in the cleaning solution in the ultrasonic tank so that the bottom of the subtank is at least several inches away from the bottom of the ultrasonic cleaning tank. (The top of the subtank must remain above the weaker cleaning solution in which it is partially submerged.) Glass beakers with cracks should not be used as a subtank because the ultrasonic action will break the cracked container. The loss in cleaning efficiency with a subtank is negligible if the wall thickness of the subtank is equivalent to the wall thickness of the ultrasonic tank. Due to the smaller amount of cleaning solution required, this method is less hazardous to operating personnel, and dumping the dirty solution is less of a problem. Highly caustic cleaning solutions should not be kept in the ultrasonic cleaner beyond the time required for a particular cleaning job. After dumping the cleaning solution, the drain system of the ultrasonic cleaner should be flushed with fresh water. Copper drain pipe and brass drain valves will be eroded by any standing caustic cleaning solution. For the same reason, aluminum parts or components should not be cleaned in highly caustic solutions. The amount of air trapped in the cleaning solution affecta the intensity of cavitation and cleaning ability. Some of the initial energy will be consumed in degassing air from the solution before maximum cavitation is achieved. Ultrasonic agitation will effectively degas liquids; however, the bubbles formed during degassing act as an energy sink that may rob a transducer of energy. Therefore, a new or stagnant solution must be degassed before full ultrasonic cleaning efficiency is realized. The time normally required for degaasing detergent solutions is approximately 15 minutes; fresh water may require as much as 30 minutes. Ability to recognize the degassed condition for the various cleaning solutions comes with experience. Flushing or rinsing the cleaned part is extremely important in the overall ultrasonic cleaning process. The detergent keeps the particles of contamination suspended in the cleaning solution. When the cleaned part is removed from the ultrasonic tank, it becomes recontaminated by these suspended particles. Therefore, flushing or rinsing of the cleaned part is required to remove these loose particles. Rinsing should be in the direction opposite to the normal fluid flow through the filter. True cleaning is assured only by flushing or rinsing. Ultrasonics alone is not the complete answer to cleaning problems, but it is a useful tool in the overall cleaning system. Since the type and degree of contamination vary even for the same application, no fixed process can be specified for all conditions.

3-2.1.2 Ultrasonic Cleaning of Modular Assemblies

The choice of ultrasonic cleaning equipment should be governed not so much by the transducer type as by the intensity of cavitation needed to perform a given task, and the reliability of the equipment under conditions of rigorous field use. A typical ultrasonic cleaning unit is one in which the frequency of the ultrasonic oscillator is approximately 20,000 Hertz. The amount of energy required by the transduce to reach this threshold of cavitation is naturally dependent on the efficiency of the transducers, as well as the acoustic properties of the liquid, the frequency, the temperature, the presence of standing waves, and other factors. For example, a good rule of thumb in selecting the proper generator is to multiply the capacity of the tank (number of gallons) by a quantity of 50 to 70, to derive the required power in watta. After selection of the ultrasonic cleaner and solution (see Table 3-1) for a particular cleaning task, follow the procedural steps below, in the sequence given.

1. Place the contaminated assembly or parts (in a wire-mesh basket or suspended on a wire hook) into the cleaning emulsion contained in the ultrasonic cleaning tank, and energize the ultrasonic equipment.

NOTE

Only baskets that are specifically designed for ultrasonic cleaning should be used. Such baskets are available from equipment manufacturers. Avoid the use of small mesh, which has the tendency to cut down on the amount of ultrasonics.

2. Leave the immersed assembly or parts in the cleaning solution for approximately 2 to 3 minutes (depending on the amount and type of contamination).

NOTE

Use immersion heaters to heat the solution to a suitable temperature, depending on the type of solution used.

3. Remove the assembly or parts being cleaned from the ultrasonic cleaning tank, and flush with fresh water (preferably warm or hot).

4. Drain the cleaning emulsion from the cleaning tank, and refill the tank with fresh water.

5. Place the assembly or parts (in a wire-mesh basket or suspended on a wire hook) into the tank of fresh water, to remove the remaining cleaning emulsion.

6. Remove the assembly or parts from the fresh water bath, and blow as much water as possible from the cleaned parts with dry, filtered air at no more than 50 lb/in^2 pressure.

7. Spray all surface areas with a water-displacing fluid.

8. After spraying, allow approximately 20 minutes for the water-displacing fluid to penetrate the crevices and combine with the remaining water.

9. Blow the residual mixture of water and water-displacing fluid from the assembly or parts with dry, heated air from a portable electric blower, or place into an air-drying circulating oven.

The electronic equipment can now be reinstalled and operated after drying and check-out of the unita and components. If the equipment cannot be returned to operational condition, it should be sprayed again with the water-displacing fluid, and the drying process repeated.

WARNING

Operating personnel should not immerse their hands in ultrasonic baths over long periods of time, since some burning of skin tissue may result.

Although ultrasonic cleaning is not a cure-all for cleaning electronic assemblies, when

Table 3-1. General Guide for Ultrasonic Cleaning

PRINCIPAL USE	TYPICAL PRODUCTS	CLEANING CHEMICAL	BATH TEMPERATURE & IMMERSION TIME
General cleaning of water contaminants (fingerprints, buffing compounds shop dirt, blood, animal and vegetable oils, inks, milk residues, chemical salts and residues, carbohydrates, radioactive contaminant, food particles, dried soaps).	Surgical instruments and laboratory glassware, flasks, petri dishes, syringes, ampullae, catheters, nursing bottles, eyeglasses and frames, pipettes, test tubes, microscope slides and covers, jewelry and precious stones, technical and optical glassware, dentures, plates, bridges, fossils, archeological specimens, styrene and methacrylate plastics, poly-plastics, hypo needles, plastic contact lenses, ceramics, precision metal products, quartz crystals.	Concentrated water base detergent, containing silicates, phosphates, synthetic detergent, wetting agent.	Room temp. to 93 °C, 15 Sec to 5 min.
Same as above, except to remove tartar, nicotine, hard soap deposits.	Same as above, but is more effective on lab and optical glass, jewelry, dental appliances, eyeglasses, polishing and buffing compounds, surgical instruments.	Ammoniated concentrated water-base detergent containing silicates, phosphates, wetting agents.	Room temp. to 93 °C, 15 Sec to 5 min.
General cleaning of solvent-soluble contaminant (mineral oils, greases, pitch, shop soils, tar, paraffins, waxes, fats, fluxes, alkyd and polyvinyl printing inks, marking compounds, silicone oils and greases, methylmethacrylate and styrene).	Gears, bearings, electrical contacts, micromodule wafers, type faces, data film and tape, filters, semiconductor parts, mechanical devices, glass lenses, optical parts, gyros, electronic components, relays, tuning forks, bellows, electronics, ceramics, polyvinyl and polyethylene plastics, hermetic seals, precision metal products, screw machine products, connectors, technical and optical glass, electric motors, generators, armatures, machined parts, dressing tools and stones, precision stampings and castings, gas and water meters, cameras, microscopes, sight mechanisms, gages, precision measuring instruments, potentiometers, printed circuit boards, wax impressions.	Chlorinated hydrocarbon solvent.	Room temp. to 49 °C, 10 sec.

Table 3-1. General Guide for Ultrasonic Cleaning - Continued

PRINCIPAL USE	TYPICAL PRODUCTS	CLEANING CHEMICAI	BATH TEMPERA-TURE & IMMERSION TIME
General purpose pickling agent, and remover or tai nish, oxide, heat-treat scale, dried blood, milk-stone.	Stained surgical instruments, chrome, cadmium, titanium, copper-base alloy and steel, parts and instruments, alum. inure, prepaint finishing, phospbatizing.	Concentrated water-bas phosphoric acid.	Room temp. to 66 "C, 1 to 10 min.
Removes milkstone, in-vestment plaster, tempo-rary cement, zinc oxide, rust, oxides from cast iron and steel, heat-treat scale and smut from hardened steel.	Precision investment castings, brewery and dairy stainless steel valves and process appa-ratus. Temporary dental splints, gold, acrylic, chrome crowns, inlays. Can be used on copper and alloys, ferrous metals, chrome, molybdenum, tin.	Powdered and inhibited acid.	38 °C to 82 "C, 3 to 30 min.
Removal of corrosion or oxides on ferrous metals, salvaging engine parts (valves, bearings, pumps, etc.). Precleaning of heavy greases, shop dirt, drawing and lubricating oils, prior to solvent cleaning.	Ferrous metals, bearings, mechanical parts, diamonds, orthodontic appliances. Not to be used on aluminum, magnesium or zinc.	Heavy-duty alkaline soda ash, powder.	49"C to 82 "C, 1 to 10 min.
Carbon and lead deposit cleaner, heavy greases anc preservatives, buffing com pounds, drawing and lub-ricating compounds, wax and paraffin, shop dirt.	Aircraft, marine and auto-motive engine parts, spark plugs, valves, pistons, cylin-ders, rings, filters, jet fuel nozzles.	Water-base emulsion.	49"C to 82 'C, 1 to 30 min.
Copper cleaner, brigh-tener and tarnish remover, also to clean shop dirt, chips, grinding and cut-ting coolants, light oils and greases.	Thermostats, relays, switches, jacks, connectors, brass and copper machinings and castings, copper sheet and laminates.	Water-base, moderately alkaline cleaner.	Room temp. to 60 "C, 1 to 5 min.
Rust and heat-treat scale cleaner, oils, greases, buf-fing compounds, drawing lubricants, grinding oils and coolants, cutting oils and coolants, printing and typewriter inks.	Filaments of vacuum tubes, tungsten, steel, drawn wire and rod, heat-treated metal parts.	Powdered alkaline.	38'C to 82 'C, 1 to 15 min.

Table 3-1. General Guide for Ultrasonic Cleaning-Continued

PRINCIPAL USE	TYPICAL PRODUCTS	CLEANING CHEMICAL	BATH TEMPERA-TURE & IMMERSION TIME
Silver cleaner, brightener and tarnish remover.	Thermostats, relays, switches, jacks, connectors, silverware, sterling silver.	Water-base acid cleaner.	Room temp. to 60°C, 1 to 10 min.
All-purpose emulsion-solvent agent for one bath duo-cleaning of water-soluble and solvent-soluble contaminants. Heavy greases, oils, waxes, marking compounds, grinding, drawing, cutting oils, lubricants and coolant in any combination.	Pitch, ink, wax and paint, marking compounds and grinding compounds from glass lenses, carburetors, engine parts.	Light brown organic and chlorinated hydro-carbon solvents.	Room temp. to 82 "C, 30 sec to 5 min.

properly employed for a specific application it is a very fast, efficient, and reliable method of removing contamination. Also, ultrasonic cleaning units provide a degree of cleanliness that could not be obtained previously by other techniques.

3-2.1.3 **Cleaning Solvent Hazards**

The technician who smokes while using a volatile inflammable cleaning solvent is inviting disaster. Unfortunately, many such disasters have occurred. For this reason, the Navy does not permit the use of gasoline, benzine, ether, or like substances for cleaning purposes. Only non-volatile solvents shall be used to clean electrical or electronic equipment. In addition to the potentiaf hazard of accidental fire, many cleaning solvents are capable of damaging the human respiratory system in cases of prolonged inhalation. Inhibited methyl chloroform (1, 1, 1, trichloroethane) should be used where water compounds are not feasible. Methyl chloroform has a threshold of 500 parts per million (ppm) in air, whereas carbon tetrachloride has a threshold of 25 ppm. The threshold is the point above which the concentration in air becomes dangerous. Methyl chloroform is an effective cleaner and about as safe as can be expected when reasonable care is exercised. Care requires plenty of ventilation and observance of fire precautions. Avoid direct inhalation of the vapor. Inhibited methyl chloroform is not safe for use with a gas mask since the vapor displaces oxygen in the air. The following list of "Dos" and "Don'ts" will serve as effective reminders to maintenance technicians who must use cleaning solvents.

1. Use a blower or canvas wind chute to blow air into a compartment in which a cleaning solvent is being used.
2. Open all usable port holes and place air scoops in them.
3. Don't work alone in a poorly ventilated compartment.
4. Place a fire extinguisher nearby and ready for use.
5. Don't use solvents in the presence of any open flame since this may lead to the formation of phosgene gas, which is very poisonous.
6. Don't use carbon tetrachloride as it is a highly toxic compound.
7. Don't apply solvents to warm or hot equipment as this increases the toxicity hazard.
8. Don't directly breathe the vapor of any cleaning solvent for a prolonged period.
9. Use water-based compounds in lieu of other solvents wherever feasible.
10. Wear rubber gloves to prevent coming in direct contact with the solvent.
11. Wear gloves when spraying solvent on permissible surfaces.
12. Hold the nozzle close to the object being sprayed.
13. Don't spray cleaning solvents on electrical windings or insulation.

For additional information on the safety precautions to be observed when using solvents, see NAVSHIPS Technical Manual NAVSEA 59086 -WK-STM-000/CH-670.

3-2.1.4 Cleaning of Air Filters

Some air filters used on naval electronic equipment are designed to be installed with a film of oil on the filter element. Filters of this type provide effective filtration with a minimum reduction of air flow. When this type of filter is used without an oil coating, as is done in many ships, the filter effectiveness is greatly reduced. The major disadvantage of the oiled filter is in cleaning. This drawback may be overcome by washing the filter element in a standard shipboard dishwashing machine (if an air filter cleaning room or area is not provided). No special procedures are necessary, although dirty filters may require two washings. The manhours used in cleaning equipment air filters, and oiling when required, will he more than regained in improved reliability of the equipment. Some of the commercial air filter adhesives (filter oils), to be used when required, authorized by the Navy, are listed in Table 3-2.

Table 3-2. Typical Air Filter Adhesives

ADHESIVES DESIGNATION	SUPPLIER
Airsan 1-S	Air Filter Corporation Milwaukee, Wisconsin
Filterkote "M" or "W"	Air Maze Corporation Cleveland, Ohio
"NCC" Visosine	American Air Filter Company Louisville, Kentucky
WS-4530	Exon Standard Division, Humble Oil & Refining Company New York, New York
Super Filter Coat	Research Products Corporation Madison, Wisconsin
Chevron Filter Coat (applied at 71 "C)	Standard Oil of California San Francisco, California
EAC-2	Trion, Incorporated McKees Rocks, Pennsylvania

WARNING: Adhesives in pressurized (aerosol) spray cans are not approved for use in the Navy due to the possibility of toxicity caused by the decomposition of the released gas.

3-2.1.5 Cleaning of Transistor Heat Sinks

As the complexity of electronic equipment increases, the available space for individual components has all but disappeared. Widespread use of transistors in equipment design results in less space in which heat can he dissipated, thereby causing an ever-increasing environmental temperature in which the transistor must operate. The transistor is completely dependent upon its ability to absorb and dissipate internally generated heat while operating at the increased temperature which it has generated. For this reason, heat-dissipating devices, referred to as heat sinks, are being utilized to increase the heat-dissipating capability of the transistor and to prevent transistor failures due to excessive heat. Transistor heat sinks are designed to utilize the natural methods of conduction, convection, and radiation in order to reduce the transistor case and junction temperatures and thereby increase the overall reliability of the transistor. To obtain maximum transistor life, it is of utmost importance that the transistor temperature be kept within its design tolerance. Therefore, all transistorized equip. ments should be inspected on a routine basis to ensure that heat sinks are free of any accumulation of dust or dirt, that air filters are clean, and that proper air flow is maintained either from natural sources or by forced-air systems.

3-2.2 LUBRICATION

Electronic equipments which utilize moving mechanical parts require periodic lubrication. Failure to lubricate jeopardizes the useful life of the mechanical part and thus precipitates a breakdown of the electronic equipment. It is essential that maintenance personnel be thoroughly familiar with the Lubrication requirements of the equipments for which they are responsible. Proper lubrication of the mechanical components in electronic equipment is emphasized in technical manuals and in reference standards books.

3-2.2.1 Lubrication of Ball Bearings

Improper greasing procedures are a frequent cause of derangements to rotating electrical machinery provided with grease-lubricated ball bearings. The trouble is generally caused by forcing an excessive quantity of grease into the hearing housing, with either one or both of the following results:

1. Grease is forced through the bearing housing seals and onto the windings and, in the case of DC machines, onto the commutators where it causes deterioration of insulation and eventually results in grounds or short circuits.

2. The excessive quantity of pressure of grease in the bearing housing results in churning, increased temperatures, rapid deterioration of the grease, and ultimate destruction of the bearing.

The following instructions apply generally to all equipment except oil-lubricated bearings, synchros, and similar devices where friction must be maintained at an absolute minimum, and equipment for which approved lubrication charts or other specific instructions are furnished by the Navy.

3-2.2.1.1 Greasing

3-2.2 .1.1.1 Grease Cups

Motors and generators provided with bearings that should be lubricated with grease are now normally delivered from the manufacturer with the grease cups removed from the bearing housings and replaced with pipe plugs. The grease cups, however, are delivered with the onboard repair parts or special tools. It is recommended that grease cups be attached to electric motors and generators only when the bearings are being greased. When the grease cup is removed from the bearing housing after a bearing has been greased, the hole which remains should be plugged with a suitable pipe plug. When this procedure is used, the grease cups should remain in the custody of responsible maintenance personnel and can be stored in the workshop or toolroom. This procedure is particularly advantageous when the motors and generators maintained by a particular group of maintenance personnel need only relatively few different sizes of grease cups. This procedure should also be followed for motors and generators which have been supplied with grease cups attached to the machine.

NOTE

Care should be taken to make sure that a grease cup is clean before it is used to add grease to a bearing, and that the pipe plug used to replace the grease cup after greasing is also clean.

A typical grease-lubricated bearing is shown in Figure 3-1.

3-2.2 .1.1.2 Selection of Grease

The grease used for grease-lubricated ball bearings should be selected as follows:

1. Bearings which normally operate at a temperature of 194“F (90 “C) or below should be lubricated with grease in accordance with Military Specification MIL-G-18709.

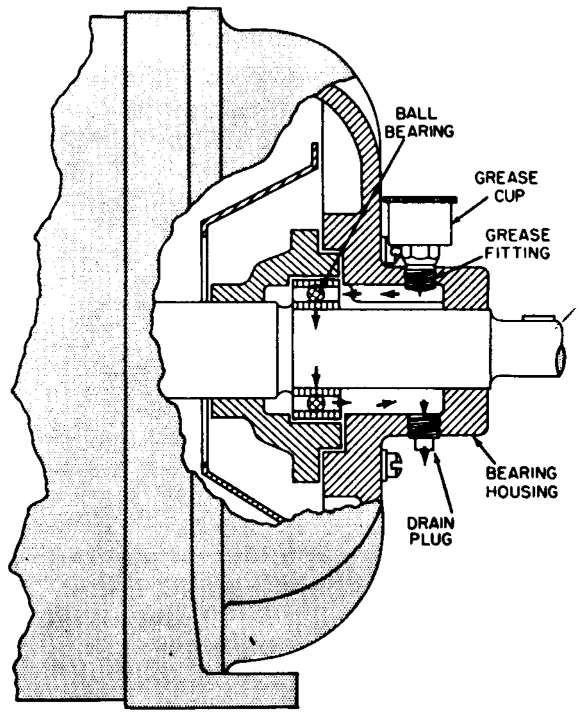


Figure 3-1. Grease-Lubricated Ball Bearings

2. Bearings which normally operate at a temperature above 194‘F (90 “C) should be lubricated with a silicone grease in accordance with Military Specification MIL-L-15719. Machines which require this special grease have a caution plate stating “USE HIGH TEMPERATURE GREASE” which is attached near the grease fitting by the manufacturer.

3-2.2 .1.1.3 Adding Grease

Bearings on new machines are properly lubricated when they leave the factory. The frequency with which grease must be added depends upon the service of the machine and the tightness of the housing seals, and should be determined for each machine by the engineer officer. Ordinarily, the addition of grease will not be necessary more often than once in six months. The use of excessive quantities of grease is to be avoided because it causes bearing failures. When a bearing housing is too full of lubricant, the churning of the grease generates heat which in turn causes deterioration of the grease. Under these conditions the grease separates into oil and minute abrasive particles, becomes increasingly sticky, and tends to seal the bearing against fresh lubricant until the resulting friction, heat, and wear cause failure of the bearing. To avoid the difficulties caused by an excessive amount of grease, add grease only when necessary.

When grease is added, it should be done as follows:

1. Wipe outside of grease fitting and drain plug free of all dirt.

2. Remove bearing drain plug, and make sure the passage is open by probing with a clean screwdriver or similar implement.

3. Remove pipe plug on top of grease pipe. Select proper grease cup and clean it thoroughly. Install bottom portion of grease cup on the grease pipe. Put in the top portion of the grease cup no more grease than will half fill it.

4. Empty and clean out the receptacles of the grease fitting down to the neck, then fill with clean grease.

5. Replace the grease cup and screw it down as far as it will go.

6. Run the machine and let grease run out of drain hole until drainage stops (normally about 30 minutes). Remove grease cup and replace pipe plug.

7. Replace the drain plug.

8. Do not use a grease gun to lubricate bearings unless there are no other means available. If a grease gun must be used, remove the drain plug in the bearing housing while greasing and use extreme care to avoid inserting too much grease or applying more than just enough pressure to get the grease into the housing.

3-2.2 .1.1.4 Renewal of Grease Without Disassembling the Bearing Housing

Removal of grease without at least partial disassembly of the bearing housing is not recommended. In any case, renewal of grease without at least partial disassembly of the bearing housing should not be attempted unless the following conditions apply.

1. The machine is horizontal. In vertical machines, there is no adequate means of protecting the windings against displaced lubricant.

2. A suitable fitting is provided for admitting grease. If a grease-gun fitting is provided, it should be replaced by a grease cup.

3. The drain hole on the bearing housing is accessible. Drain pipes do not permit satisfactory escape of displaced grease, and should be removed when renewing grease.

NOTE

The machine must be capable of being run continuously while renewing grease. If the machine cannot be run continuously during the greasing period without injuring the driven auxiliary or endangering personnel, the bearing housing must be disassembled as described in paragraph 3-2.2 .1.1.5 to renew grease.

If the above conditions apply, the grease may be renewed in assembled bearing housings by the following method:

1. Run the machine sufficiently to warm up the bearings.

2. Wipe any dirt away from the area around the grease fittings.

3. Remove the drain plug and drain pipes from the drain hole in the bearing housing.

4. With a clean wire, screwdriver, or similar implement, clear the drain hole of all hardened grease.

5. Remove the grease cup and clear the grease inlet hole of hardened grease.

6. Fill the grease cup with fresh, clean grease, reinstall the cup and screw it down as far as it will go. Keep the machine running continuously.

7. Repeat steps (4) and (6) above until clean grease begins to emerge from the drain hole.

8. At this point it is important to stop inserting grease and allow the machine to run until no more grease comes out of the drain hole.

9. Clean any drain pipes which have been removed, and reinstall the pipes.

10. Install the drain plug.

NOTE

Be careful to keep grease from reaching the electrical windings. The emergence of a large quantity of grease through the shaft extension end of the housing indicates excessive leakage inside the machine.

3-2.2 .1.1.5 Renewal of Grease with the Bearing Housing Disassembled

The extent of disassembly necessary will depend upon the construction of the bearing. For the usual construction which uses bearings with outer bearing caps, the following method should be employed:

1. Remove the outer bearing cap after thoroughly wiping all exterior surfaces.

2. Remove old grease from all accessible portions of the housing and clean these parts thoroughly. Be careful not to introduce dirt or lint into the bearing housing.

3. Flush out the bearing cap with clean, hot (about 120 “F) kerosene, diesel fuel oil, or dry cleaning fluid (Federrd Specification P-D-680). FoI1ow this by flushing out with a light mineral oil (not heavier than SAE1O, similar to diesel lubricating oil, N.D. Specification 14-0-13 symbol 9110).

4. Where practicable, plug all holes leading into the intenor of the machine and flush out the complete housing with the outer bearing cap removed. Use the solvents and procedures described in the preceding paragraph. This should not be done on equipment where the conditions are such that the cleaning fluids may leak into the windings. In such cases, omit this step.

5. Drain the mineral oil thoroughly; then pack housing half full with fresh, clean grease, and reinstall the outer bearing cap.

3-2.2 .1.1.6 Oil-Lubricated Ball Bearings

Some electric motors and generators may be equipped with oil-lubricated ball bearings. Lubrication charts or special instructions are generally furnished for this type of bearing and should be carefully followed by personnel maintaining the equipment. In the absence of other instructions, the oil level inside the bearing housing should be maintained approximately level with the 1owest point of the bearing inner oil ring. This will provide enough oil to lubricate the bearing for a considerable operating period, but not enough to cause churning or overheating. One common method by which the oil level is maintained in ball bearings is the wick-feed method. In this method, the oil is fed from an oil cup to the inside of the bearing housing through an absorbent wick, which also filters the oil and prevents leakage through the cup in the event that momentary pressure is built up within the housing. A typical wick-fed, oil-lubricated ball bearing is shown in Figure 3-2.

3-2.2.2 Lubrication of Sleeve Bearings

When lubricating sleeve bearings, proceed generally as follows:

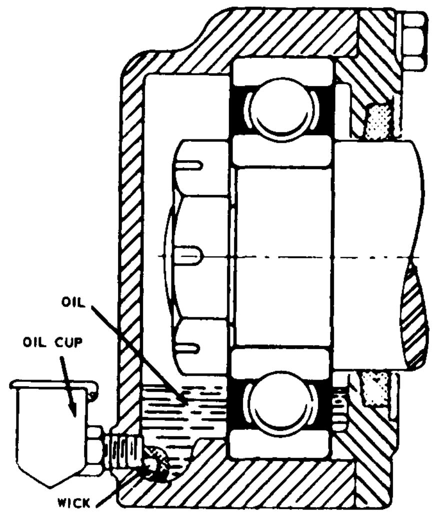


Figure 3-2. Wick-Fed Ball Bearing

1. Take every precaution to keep the oil and bearings clean and free from water or foreign particles.

2. Do not add oil while the machine is running. This affords an opportunity for oil mist or spray to escape from the bearing housing and be blown on the machine windings.

3. Bearings having an overflow gage should be filled until the oil is about one-sixteenth inch from the top of the gage. If the machine is equipped with an oil filler gage, the gage should be tilled to the manufacturer’s oil level mark, or (if no mark is available) the gage should be between two-thirds and three-quarters full at all times. Be sure that the gage glass and piping to the gage are clean or the glass will give false indications of the oil level. If the bearing has neither an overflow gage nor an oil filler gage, fill it to a level such that the oil ring dips into oil to a depth of about haJf the shaft diameter.

4. When the bearing and bearing housing are in good condition, there should be no loss of oil. If the proper oil level cannot be maintained witbout adding oil, it is probable ‘that oil is leaking from the bearing. Be sure the oil sight gage connection to bearing is tight. Much of the oil that leaks out of a bearing is drawn into the machine by the cooling air and sprayed onto the windings where it causes oil-soaked dirt to collect. This condition tends to cause insulation failure. If oil leakage is suspected, carefully clean and chalk the shaft outside the bearing, the outside of the bearing housing, and the parts of the rotor adjacent to the bearing. If the machine is throwing

oil, discoloration of the chalk will so indicate after a short run. (This test is not dependable unless the chalked part is made perfectly clean at the beginning of the test.) If leakage is found, the labyrinth seal in the bearing housing should be corrected to make it effective. Another possible source of leakage is from the vent with which some labyrinths are provided. Make sure that any such vent is not stopped up and that it vents into still air at atmospheric pressure, and also where there is no current of air over the vent that will suck oil out of the bearing housing or oil vapor out of the vent into the machine. Such oil leakage is often due to overfilling the bearing or trying to fill the bearing through the vent.

5. Bearing oil should be renewed semi-annually. Drain the oil off by removing the drain plug, then flush the bearing with clean oil until the drained oil flows clean.

3-2.2.3 Types of Lubricants

The correct choice of a lubricant for electronic equipment is important, especially if the equipment is being operated under adverse conditions. To assist in the selection of the correct lubricant, the following lubrication charts are provided.

Chart 1 (Table 3-3) lists all lubricants specified in MIL-L-17192 (SHIPS) (NAVY), Military specifications of lubricants, and lubrication information for electronic equipment. Many electronics technical manuals and their associated publications refer to many of these lubricants by Military Symbols. These symbols, where applicable, are added to the chart for cross-referencing.

Chart 2 (Table 3-4) provides cross--referencing between the old and new Military Specification designations assigned to lubricants as listed in Federal Supply Catalogues.

Chart 3 (Table 3-5) provides Military Specification designations and Federal Stock Numbers for those lubricants listed in electronics publications by the "Manufacturer's Designation."

Chart 4 (Table 3-6) provides a listing of those lubricants which are used in electronics equipments and are listed in electronics publications but not listed in MIL-L-17192 (SHIPS).

3-2.3 ENVIRONMENTAL EFFECTS ON ELECTRONIC EQUIPMENT

It is beyond the scope of this subsection to present all the problems encountered from environmental conditions, because individual methods of installation and stowage of electronic equipments differ from ship to ship, and from one Naval shore station to another. However, some of the preventive and corrective measures that should be taken under adverse environmental conditions, and the effects on the equipment subjected to these conditions, are described in the following paragraphs.

3-2.3.1 Temperature

The cooling or heating of air spaces surrounding the components of electronic equipment is generally accomplished and controlled by blowers, fans, hot oil and water coolers, etc., either to dissipate the heat generated by the equipment components, or to heat or cool the surrounding ambient air. Regardless of the method employed for the cooling or heating of spaces, if maintenance personnel neglect to keep the screens, filters, fans, ducts, surface area of coolers, and equipment free from foreign matter, the heating or cooling will be greatly affected, which may result in equipment damage or malfunction caused by improper temperature control. Extremely low temperature may cause brittleness in certain types of metals, and loss of flexibility in rubber, insulation, and similar materials. Extremely high temperature may cause deformation and deterioration of terminal boards, seals, insulation, and heat-sensitive devices. Rapid changes of temperature may be especirdly damaging to certain types of electronic components.

3-2.3.2 Humidity

High humidity, the "arch enemy" of electronic equipment, with its resultant damage to equipment components from condensation and fungus growth under conditions of both high salt-laden moist air and high temperature, is normally found in tropical climates. In this case, adequate ventilation of the equipment is of the utmost importance to protect the equipment components from entrapped moisture and extremely high operating temperatures. To overcome any adverse effecta on electronic equipments, maximum and minimum temperature gradients should be controlled by one of the cooling or heating mediums provided. In many cases, critical electronic components are encapsulated, potted, or sealed to protect them from the detrimental effects of moisture and temperature variations. However, sealing the component does not completely eliminate the problem of high-humidity conditions because the seals sometimes must be broken for maintenance or repair work. There is also the possibility that the maintenance technician will not always have the suitable sealing compounds on hand to repair or replace sealed components. Where this condition exists, except in cases of emergency, the repair or replacement of sealed components should not be performed in the field.

Table 3-3. Standard Navy Lubricants

SPECIFICATION; NUMBER AND TITLE	UNIT OF ISSUE	STOCK NUMBER	MILITAR SYMBOL	COMMERCIA DESIGNATION	GENERAL USE
VV-P-236 Petrolatum, Technical	1 lb. can 5 lb. can	9G9150-250-0926 9G9150-250-0933	PET	Amber Petro- latum U.S.P.	For use as a light grade of lubricating grease but not recommended for use as a lubricant in heavily loaded or hot running bearings. It may be used as a constituent in certain types of rust preventive compounds.
VV-I-530 Insulating Oil Electrical	1 qt. can 1 gal. can 5 gal. pail 55 gal. drun	9G9160-685-0912 9G9160-611-2000 9G9160-685-0913 9G9160-685-0914			Dielectric strength 30,000 volts, with exception of 9G9160-082-2428 which is 40,000 volts. Used in oil-immersed transformers, oil switches, and oil circuit breakers.
P-D-680 Dry Cleaning Solvent	5 gal. pail	9G6850-274-5421	SD-2		For general cleaning of air filters, electronic equipment, and other general purpose cleanup.
MIL-G-23827 Grease, Aircraft and Instrument	1 oz. tube 4 oz. tube 8 oz. tube 1 lb. can 5 lb. can 35 lb. pail	9G9150-985-7243 9G9150-985-7244 9G9150-985-7245 9G9150-985-7246 9G9150-985-7247 9G9150-985-7248	GIA		In ball, roller, needle bearings, gears and sliding and rolling surfaces of such equipment as instruments, cameras, electronic gear and aircraft control systems. Particularly suitable for equipment which must operate at both very low and very higb temperatures for short periods. Does not contain extreme pressure or special antiwear additives. It is destructive to paint, naturrd rubber, and neoprene.
MIL-G-81322 Grease, Aircraft	5 lb. can 35 lb. pail	9G9150-OO-190-0893 9G9150-OO-190-0907		Grade I	For lubrication and protection against corrosion of plain ball and roller bearings, and preservation of threads on ammunitions.

Table 3-3. Standard Navy Lubricants - Continued

SPECIFICATION NUMBER AND TITLE	UNIT OF ISSUE	STOCK NUMBER	MILITARY SYMBOL	COMMERCIAL DESIGNATION	GENERAL USE
MIL-L-17331 Lubricating Oil Steam Turbine	5 grd. 55 gal.	9G9150-235-9061 9G9150-235-9062	2190 TEP		In main turbines and gears, auxiliary turbine installation, certain hydraulic equipment general mechanical lubrication, and air compressors.
MIL-G-18709 Grease, Ball and Roller Bearing	8 oz. tube 1 lb. can 5 lb. can 35 lb. pail	9G9150-753-4650 9G9150-526-4205 9G9150-663-9795 9G9150-249-0908	BR	Andok B or Nebula EP-1 Grade III	For ball and roller bearings operating at medium speeds and temperature range 125° F to 200°F.
MIL-L-2105 Lubrication Oil Gear	5 gal. 1 gal. 55 gal. 55 gal.	9G9150-577-5481 9G9150-754-2635 9G9150-577-5843 9G9150-035-5394	GO-75 GO-90 GO-75 GO-90	SAE 75 SAE 90 SAE 75 SAE 90	For lubrication of automotive gear units, heavy duty industrial-type enclosed gear units, steering gears, and fluid-lubricated universal joints of automotive equipment.
MIL-L-6085 Lubricating Oil Instrument	1 1/2 oz. btl. 4 oz. can 1 qt.	9G9150-664-6518 9G9150-257-5449 9G9150-223-4129	OAI		For aircraft instruments, electronic equip- or where a low evaporation oil is required for both high and low temperature application, and where oxidation and corrosion resistance are desirable. Destructive to paint, neoprene and rubber.
MIL-L-6086 Lubricating Oil Gear	1 grd. can 1 pt. can 1 gal. can 5 grd. drum	9G9150-265-9417 9G9150-240-2235 9G9150-223-4130 9G9150-223-4116	Grade L Grade M	-lo w- -20 w-	For use under extremely low temperature, mild extreme pressure-type oil with load carrying additive. General use in aircraft gear mechanisms, exclusive of engines.

Table 3-3. Standard Navy Lubricants - Continued

SPECIFICATION NUMBER AND TITLE	UNIT OF ISSUE	STOCK NUMBER	MILITARY SYMBOL	COMMERCIAL DESIGNATION	GENERAL USE
MIL-L-9000 Lubricating Oil Internal Combustion	5 gal. 55 gal. 5 gal. 55 gal. 5 gal. 55 gal.	9G9150-231-9037 9G9150-231-9030 9G9150-188-9858 9G9150-189-6729 9G9150-181-8229 9G9150-181-8097	9110 9170 9250	SAE 10 SAE 20 SAE 30	For internal-combustion engines operating under normal load and temperature conditions.
MIL-L-17331 & MIL-L-17672 Lubricating Oil General Purpose	1 pt. 5 gal. 5 gal. 55 gal.	9G9150-985-7230 9G9150-985-4137 9G9150-235-9061 9G9150-235-9062	2075 2110 2190	SAE 20W SAE 10 SAE 30	For all applications which require other than special lubricants, and which are subject to normal variation between ambient and operating temperature. Use in lieu of MIL-L-6085 when oil will be in contact with neoprene.

Table 3-4. Old and New Specification Designations

OLD MILITARY SPECIFICATION	NEW MILITARY SPECIFICATION	REFERENCE
14-P-1	VV-P-236	See Table 3-3
14-L-3	MIL-G-18709	See Table 3-3
14-G-1O	MIL-G-16908	See Table 3-3
14-L-11	VV-G-632	See Table 3-6
14-0-12	VV-1-530	See Table 3-3
14-0-13	MIL-L-9000	See Table 3-3
14-0-15	MIL-L-17331	See Table 3-3
14-0-20	MIL-L-6085	See Table 3-3
AN-O-6a	MIL-L-7870	See Table 3-6
KS 7470	MIL-L-17672	See Table 3-6
MIL-S-16067	P-D-680	See Table 3-3
VV-O-401	VV-I-530	See Table 3-3
P-S-661	P-D-680	See Table 3-3
MIL-G-3545	MIL-G-81322	See Table 3-6
MIL-G-3278	MIL-G-23827	See Table 3-3

Table 3-5. Manufacturer's Designations

MANUFACTURER DESIGNATION	MILITARY SPECIFICATION	UNIT OR ISSUE	STOCK NUMBER
Lubri-Plate No. 105	None	2 oz.	9G9150-291-9088
Lubri-Plate No. 110	None	1 lb.	9G9150-223-4003
Molykote "G"	None	1 lb.	9G9150-985-7317
Molykote M-77	None	1 lb.	9G9150-985-7317
Stoddard Solvent	P-D-680		See Table 2-3
140-F	P-D-680		See Table 2-3
MOS, Lube-Powder	MIL-M-7866	10 oz.	
GE 10C	VV-I-530		See Table 2-3
GE SS4005	MIL-S-8660	1 oz.	9G6850-880-7616
Dow-Corning DC-4	MIL-S-8660	1 oz.	9G6850-880-7616
McLube MOS_2-210 (formerly MOS_2-200)	None	As Requested	*
McLube MOS_2-1118	None	As Requested	*
Thermotex ϕϕϕ	None	1 lb.	9G9150-082-2650

* Must be ordered from McGee Chemical Co., Inc., 8000 West Chester Pike, UPper Darby, pa.

Table 3-6. Lubricants Used in Electronics Equipments But Not Listed in MIL-L-17192D (Navy) (Lubrication Information of Electronic Equipment)

SPECIFICATION NUMBER AND TITLE	UNIT OF ISSUE	STOCK NUMBER	MILITARY SYMBOL	COMMERCIAL DESIGNATION	GENERAL USE
51-F-23 Hydraulic Fluid	5 gal. 55 gal.	9G9150-261-8317 9G9150-261-8318			Used in connection with the hydraulic transmission of power. For use with Synthetic Serd.
ASTM D-3699 Kerosene	5 gal.	9G9140-242-6749	K		General uses such as a cleaner for machinery or tools.
MIL-L-7870 Lubrication Oil General Purpose	4 oz. 1 qt. 1 gal.	9G9150-542-1430 9G9150-263-3490 9G9150-273-2397	OGP		Specially designed for use where an oil of low evaporation, possessing rust-protective properties, is desired.
VV-G-632 General Purpose Grease	35 lb. 100 lb.	9G9150-190-0907 9G9150-235-5551	CG-1		Automotive chassis, suitable for lubrication of machinery equipped with pressure grease fitting.
MIL-G-23827 Grease Aircraft	1 lb.	9G9150-985-7246			Used in rolling and sliding surfaces having very low motivating power.

Table 3-6. Lubricants Used in Electronics Equipments But Not Listed in MIL-L-17192D (Navy) (Lubrication Information of Electronic Equipment) - Continued

SPECIFICATION NUMBER AND TITLE	UNIT OF ISSUE	STOCK NUMBER	MILITARY SYMBOL	COMMERCIAL DESIGNATION	GENERAL USE
MIL-G-81322 Grease Aircraft	1 lb.	9G9150-233-4003			Used in antifriction bearings operating at high speeds and high temperatures.
MIL-C-11090 Cleaning Compound	5 gal. 55 gal.	9G6850-224-6665 9G6850-224-6666			Used as a solvent for cleaning grease and oils.
MIL-L-17672 Lubrication Oil General Purpose	1 gal. 55 gal.	9G9150-753-4799 9G9150-582-5480	211 O-H		Used in steam turbines, hydraulic systems, water generators and hydraulic turbine governors.
VV-L-751 Lubrication Oil	35 lb. 35 lb.	9G9150-246-3262 9G9150-246-3267	CW-lA CW-lB		Cold weather. Warm weather. Hot weather. Used for lubricating chain, wire rope, exposed gears.

3-2.3.3 Storage

When electronic equipment and component parts are to be stored, or when they must remain in an inoperative condition for a considerable length of time, additional preventive measures must be taken to prevent detrimental effects from environmental conditions. New or repaired modular assemblies and parts are received in accordance with the applicable packaging specification. When the outer bulky casing (crate or carton with its Kimpak, Reliso-Pak or similar material) is removed, the unit (or units) remains packaged in a water-vaporproof bag. This package should be stored intact until drawn for use as a replacement item by the maintenance technician.

3-2.3.4 Standby Equipment

Equipment that is to remain idle and deenergized for a considerable length of time should have its space heaters (if provided) turned ON to keep the insulation and equipment dry. If space heaters are not provided for the equipment, electric lamp bulbs or a portable electric heater as a temporary measure can be placed within or near the equipment. This is especially important in humid or cold climates. Heaters should cycle/go off when main power is secured.

3-2.3.5 Corrosive Atmosphere

A corrosive atmosphere can cause serious damage to unprotected electronic equipment. For this reason, the maintenance technician should be cognizant of the harmful effects of all corrosive elements. He must be especially aware of the effects produced by salt spray or salt-impregnated air. To prevent corrosive effects, a regular periodic cleaning schedule should be established. This schedule should include dusting and cleaning, lubrication of moving parts, and the application of approved solvents or wetting agents to remove any accumulation of foreign matter, such as soil, dust, dirt, oil film, salt-impregnation, etc. In addition, all access doors and panels should be fastened securely and in place when no maintenance work is being performed on the equipment.

3-2.3.6 Barometric Pressure Effects

Electronic equipment installed in aircraft or submarines is often subjected to severe changes in barometric pressure. To overcome any adverse effects on the equipment, pressurization of individual components by use of pressurized chambers is often employed. These components are hermetically sealed to prevent variations in barometric pressure, and are generally classified as throwaway or nonrepairable items. Therefore, the maintenance technician should not attempt to repair such items.

3-2.3.7 Vibration and Shock

Vibration effects are directly related to the resonant mechanical frequency of the equipment concerned. Vibration caused by loosening of parts, or relative motion between parts, can produce objectionable operating conditions such as noise, intermittent circuit malfunctions, short circuits, component electrical overload or burnout, and equipment failure. Mechanical shock caused by impacts or high acceleration or deceleration can result in extensive damage to, or derangement of, the electrical equipment. In order to maintain and minimize the detrimental effecta from shock or vibration, shock-mounting and anti-vibration devices of various types and sizes are being employed in shipboard installations to isolate the component-s and equipments from their mountings. Each device has its own place in the field of isolation; the selection of isolators depends upon specialized requirements and tolerance to the environmental conditions in which they must operate. Shock-mount and anti-vibration devices are relatively simple in their design and construction and require little maintenance. Conditions of service and age and the condition of the equipment differ from ship-to-ship. Consequently, it is impracticable to provide a rigid schedule of inspections and tests, However, certain general requirements and precautions must be taken and observed to ensure that the mounting clips, shock-mounts, ground straps, and associated hardware are secured and are in place. Precautions must be taken to ensure that paint, oil, solvents, and other types of organic material are not applied to or allowed to come in contact with the resilient surface area of a shock-mount. If allowed to do so, this will result in loss of resiliency, deterioration, and premature failure of the resilient member of the shock-mount.

3-3 MAINTENANCE AIDS

Proper care and maintenance of electronics equipment are dependent in large measure on the quality and condition of the tools with which the electronics technician performs his duties. It is important that the technician know the capabilities of each of his tools and the techniques by which each tool may be used. It is also important that the technician be familiar with methods for the care of his tools. Good workmanship depends not only on the skill of the technician but also on the quality of his tools; good, clean tools aid good, clean work. This section will deal with the tools most likely to be used in electronic maintenance and repair; their various usages will be discussed with regard to safety of personnel and proper maintenance and stowage of the took..

3-3.1 SOLDERING TOOLS

Three groups of soldering tools are used in electronic maintenance. Each group is designed to be used for the particular job at hand, such as heavy duty, light or generaJ duty, and intricate soldering duty on such items as semiconductors, printed circuit boards, and modular assemblies used in electronic equipment.

3-3.1.1 Soldering Irons

Soldering irons are used for heavy duty types of electronic work such as unsoldering heavy connections and tinning surface. There are two types of such irons: a plug tip, and a thermostatically controlled screw-in tip. These irons are shown in Figure 3-3 and the tips used with each type iron are listed in Table 3-7.

Table 3-7. Soldering Iron Tips
(Standard Plug Tip Soldering Iron)

DIAMETER (INCH) A *2 PERCENT	LENGTH EXTENDING FROM SHELL (INCH) B (rein)	HEATING TIME (MINUTES) (max)
1/4	1-1/4	2-1/2
3/8	2	4
1/2	2	4-1/2
5/8	2-1/4	5
7/8	2-1/4	6

3-3.1.2 Pencil Irons

Pencil irons are used for general or light duty work or for intricate work. There are two styles of pencil irons: a plug tip, and a screw-in tip with a self-contained heating element. The pencil irons are shown in Figure 3-3; the tips for each style are given in Table 3-8.

Table 3-8. Pencil Iron Tips
(Type III, Style "A", Pencil Plug Tip Iron)

DIAMETER A ±2 PERCENT	LENGTH EXTENDING FROM SHELL (INCH) B (rein)	SHELL ASSEMBLY DIAMETER (INCH) C (max)	HEATING TIME (MINUTES) (max)
1/8	7/8	3/8	1-1/2
1/4	1-1/4	1/2	2

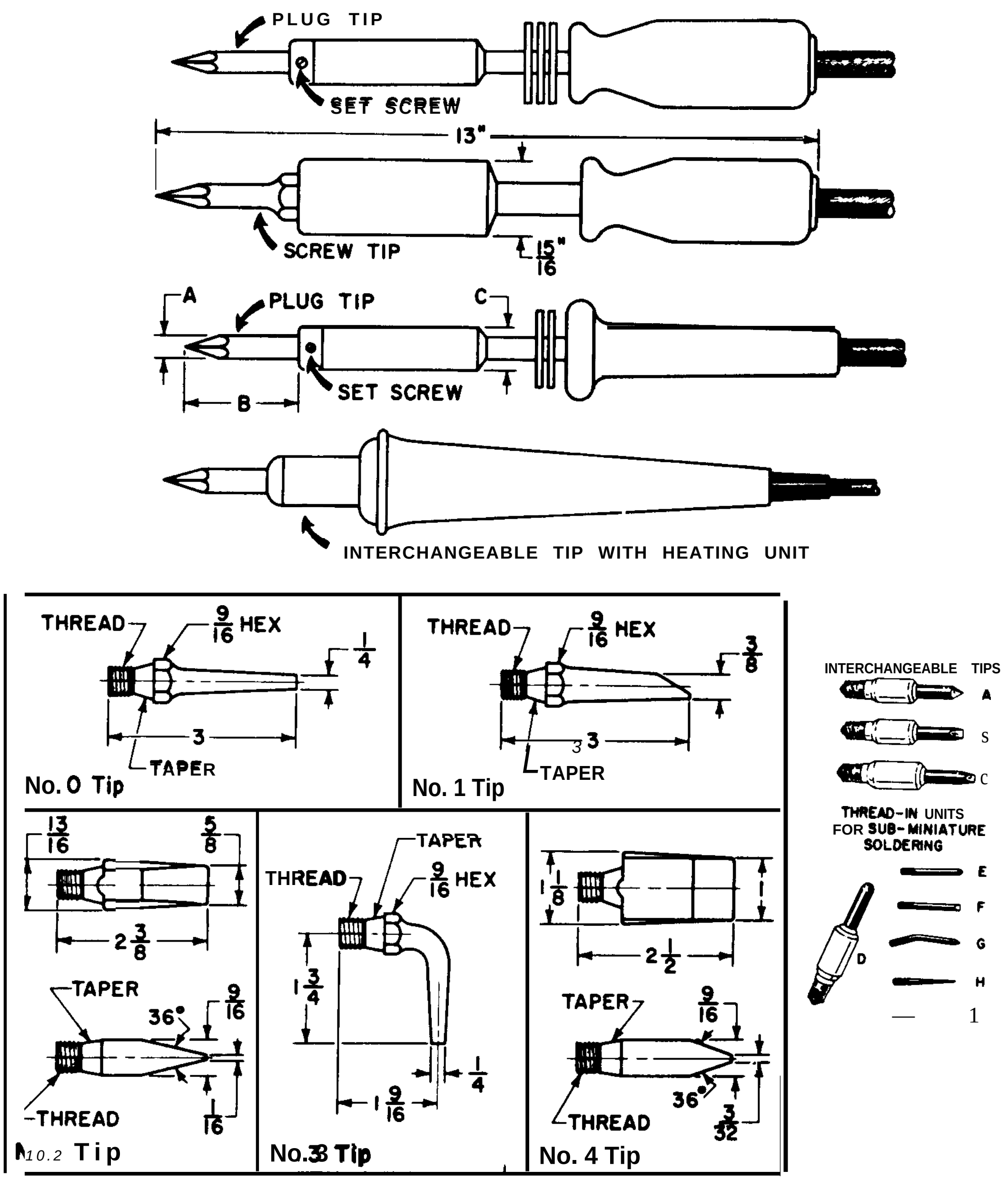


Figure 3-3. Types of Soldering Irons and Tips

3-3.1.3 Soldering Guns

Soldering guns are used for general purpose or light work when virtually instantaneous heat is required for just a short time. There are two types of such guns. Type I utilizes a transformer and a solid copper wire tip; Type II does not have the transformer and uses a straight, solid copper, screw-in tip. The two types of guns are shown in Figure 3-4; the tips for each type gun are listed in Table 3-9.

3-3.2 SPECIAL HAND TOOLS

For successful installation, repair, and maintenance of electronic equipment, the electronics technician must have not only a high degree of mechanical skill and dexterity, but also a thorough knowledge of the proper selection and use of tools. Most faults in electronic maintenance cannot be corrected without the use of tools. The ease and efficiency with which a repair can be made is often a direct function of the tool selected to perform a given task. In the performance of their duties, maintenance personnel should be provided with, or have access to, at least one each of the basic tools listed in the Electronics Tool Allowance List, and should also have access to the special hand took discussed in the following subsections.

3-3.2.1 Punches

Punches (shown in Figure 3-5) often prove useful in electronics work. Punches usually provided in the electronics shop are the center punch, starting punch, pin punch, aligning punch, gasket punch, and various types of chassis punches.

1. The center punch is used to make a punch mark for starting a drill. The point of this punch is carefully ground to an angle of 60 degrees, which is the same as the angle of a standard twist drill. Drills will start more quickly and have less tendency to wander if they are started in a punched hole.

2. The starting punch is used to knock out rivets after the heads have been cut off. It is also used to start driving out straight and tapered pins because it can withstand the heavy hammer blows necessary to break the pin loose and start it moving. This punch is made with a long, gentle taper extending from the tip to the body of the punch.

3. The pin punch is made with a straight shank and is used to follow-up on the job requiring a starting punch. After a pin has been partially driven out with a starting punch, which is limited in use because of its increasing taper, the pin punch with its slim shank is used to finish the job. The pin punch should never be used as a starting punch because a hard blow may cause the slim shank to bend or break. The largest size pin punch that will fit into the hole should always be used. The pin punch should never be struck with a glancing blow as it may break the punch and broken pin punches may be difficult to remove from the hole.

4. The aligning punch is generally from 12 to 16 inches in length and has a long taper. This punch is used for moving or shifting plates or parts so that corresponding holes will line up. It should never be used as a pry bar.

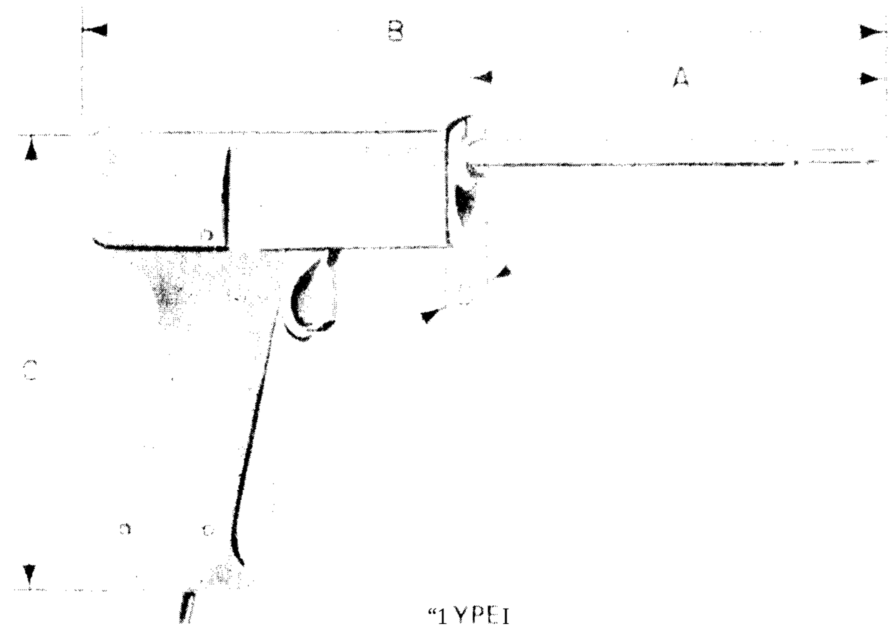
5. The hollow shank gasket punch is used for cutting holes in gaskets and similar materirds. The cutting end is tapered to a sharp cutting edge to make clean, uniform holes. The material to be cut should be placed on a soft background such as lead or hardwood so that the cutting edge will not be damaged.

6. The scratch awl, or metal scribe, is also in this category of tools. It is used to mark soft metals and can serve as an alignment tool. Punches are made of tool steel, tempered and hardened at the point. A punch should never be used to work on extremely hard metals or remove bolts by force because its point will be dulled.

7. The chassis punch provides a quick method of cutting round, round-keyed, square, or "D" shaped holes in steel up to 16-gauge in thickness. These punches are made of tool steel and are operated by screw action to provide clean-cut holes. The round chassis punches are available in sizes ranging from 1/2 to 3 inches in diameter. To use the chassis punch, a hole slightly larger than the punch screw size must be drilled in the material at the center of the hole to be cut. The punch must then be disassembled. The cutter section has two cutting edges located symmetrically for balance and is threaded to receive the bolt (punch screw). The bolt is inserted through the die section and then through the drilled hole in the material. The bolt is then screwed into the cutter until it is "finger tight." A wrench of the proper size to fit the bolt head is then used to turn the bolt clockwise until the cutter has completely cut through the material. After the hole is made, the punch must be disassembled again and the metal. removed from the die. The edge of the hole in the material should be smoothed and deburred with a half-round file.

3-3.2.2 Taps

The tap is a tool employed for cutting threads to receive a machine screw. These threads are cut into the sides of a hole which has been drilled for the root (minor diameter) of the screw. The tap is numbered the same as the screw; i.e., if a No. 5-40 screw is to be used, a No. 5-40 tap is used to cut the threads in the sides of the hole. There are three styles



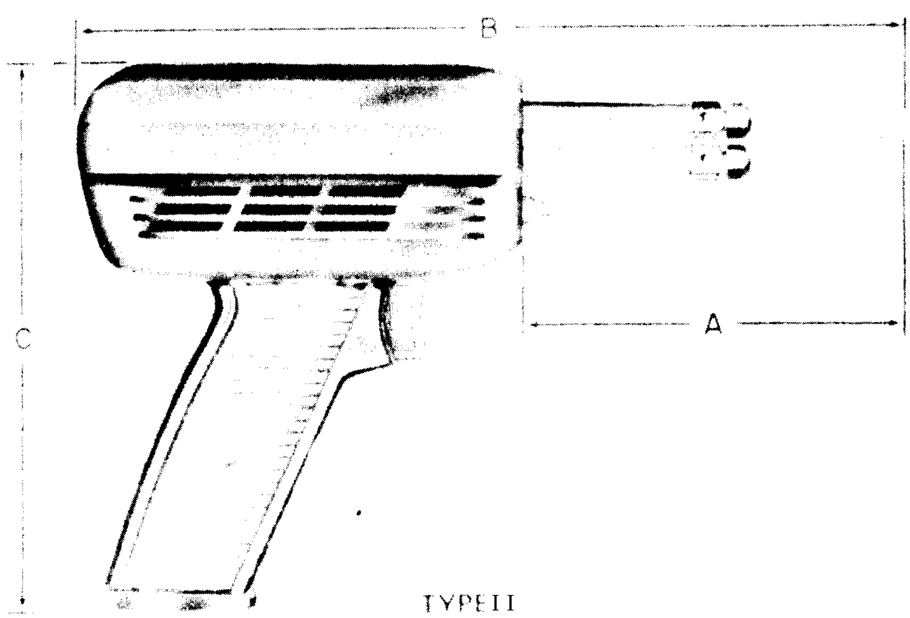


Figure 3-4. Soldering Guns

Table 3-9. Soldering Gun Tips

CLASS	DUTY	WEIGHT WITHOUT CORD (OUNCES)	A TIP LENGTH (INCHES)	B OVERALL LENGTH (INCHES)	c HEIGHT (INCHES)	D WIDTH (INCHES)
(Type I Soldering Guns)						
1	Heavy	50	5-7/8	12	7	3
2	Medium	48	5-3/8	12	7	3
3	Light	40	5-3/8	12	7	3
(Type II Soldering Guns)						
1	Heavy	50	6-1/2	12	6	1-1/2
2	Medium	16	6	10	5-1/2	1-3/8
3	Light	10	5	9	5	1-1/4

of taps: the taper, the plug, and the bottoming tap. All three styles will cut the same size thread required but the style selected is determined by the situation and/or depth requirement. The taper tap diameter will gradually increase in size and may be used when the work permits the tap to be run entirely through the hole. The plug tap, whose first few threads are chamfered, will produce threads almost to the bottom of a hole. When threads are required to the very bottom of a hole, the plug tap is used and then removed and the bottoming tap is used since it will cut through to the bottom of the hole. The tap is held in a special holder known as the tap wrench. There is the straight handle type and the T-handle type wrench. The three styles of taps and the two types of tap wrenches are shown in Figure 3-6.

3-3.2.3 Dies

The die is a thread-cutting device used to cut threads on outaide surfaces, whereas taps are used to cut threads on inside surfaces. Dies are made to cut right-hand or left-hand threads and are found in a variety of forms. There are adjustable round split dies for screw and bolt threading; square solid dies for hose fittings; hexagon solid dies for dressing over bruised or rusty threads; and various types for pipe threading. The die-holder is called a die stock. A die and die stock are shown in Figure 3-6.

3-3.2.4 Reamers

A reamer is used to make a true circular hole, or to enlarge a hole. Unless a hole has been drilled perfectly true, it will be slightly eccentric or slightly oversize. There are various styles of reamers such as the solid spiral, solid straight and the tapered hand reamer used in sheet metal work for enlarging or correcting small holes to the desired size. The various styles and types of reamers are shown in Figure 3-6.

3-3.2.5 Countersinks

A countersink is a reamer which is used to bevel the edges of a hole. It is generally used in the electronics maintenance shop to countersink screw holes so that flat-head machine screws will be flush with the chassis surface. The countersink is found in many angles and the one selected should have the same angfe as the head of the flat-head machine screw being used. In an emergency, a drill twice the diameter of the screw hole may be used. A countersink is shown in Figure 3-6.

3-3.2.6 Rotary Cutting Tools

Rotary cutting tools commonly used in electronics work (Figure 3-7) are: the circle cutter, the rotary hacksaw, and the carbide cutter. These tools are used to cut large circular holes from 1 to 5-1/2 inches in diameter in materiaf up to 1 inch in thickness.

3-3.2.6.1 Circle Cutter

The circle cutter (commonly called a “fly-cutter”) is used in a drill press to cut large holes. It consists of a body provided with a square tapered bitstock shank, fitted with a replaceable l/4-inch straight diameter shank twist drill and an adjustable round bar carrying a renewable cutter bit. To use the circle cutter, determine the size of hole to be cut and use the following procedure:

1. Adjust the round cross-arm so that the distance from the point of the guide bit to the tip of the cutter bit is one-half the diameter of the hole to be cut. Securely tighten the cross-arm locking screw in the cutter body.

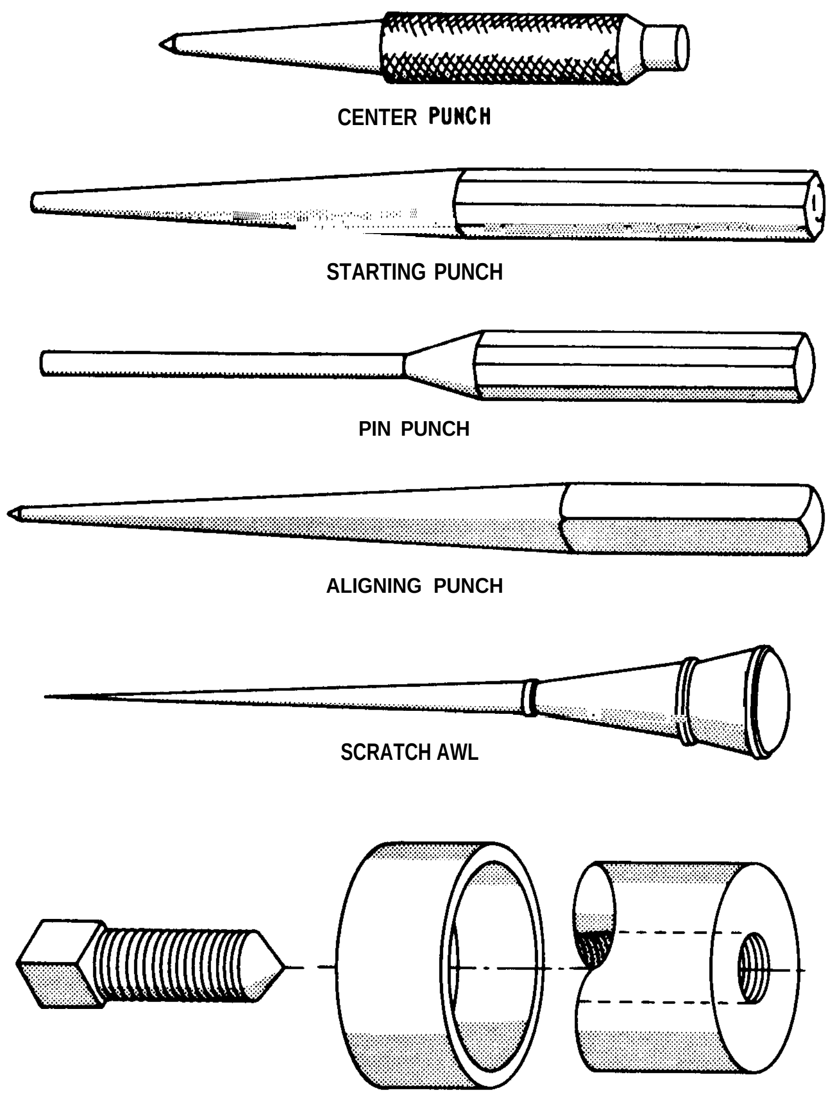


Figure 3-5. Punches

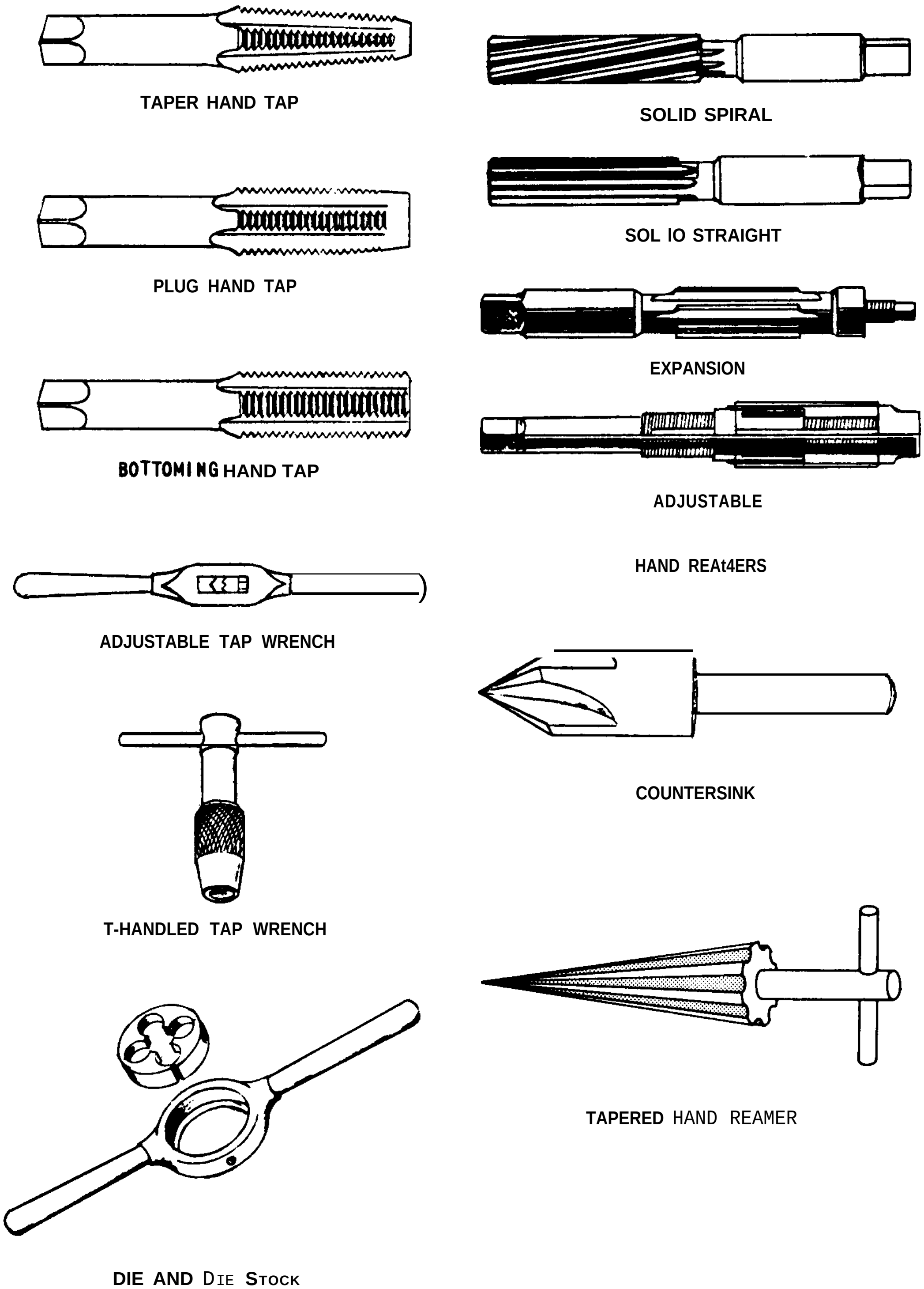
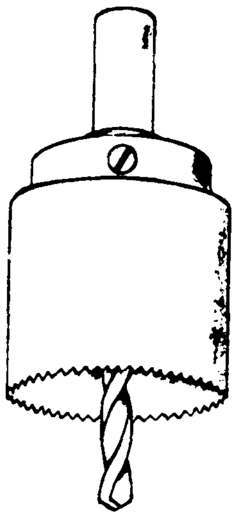
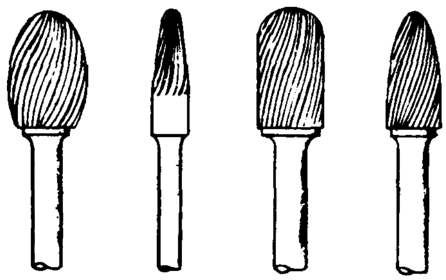


Figure 3-6. Taps, Dies, and Reamers



ROTARY HACKSAW



CARBIDE ROTARY CUTTERS

Figure 3-7. Rotary Cutting Tools

2. Adjust the guide bit so that it extends approximately l/2-inch beyond the tip of the cutter bit and then tighten the guide bit locking screw in the cutter body.

3. Place the shank of the circle cutter in the chuck of the drill press.

4. Clamp the work on a wooden block which will support the entire area of the circle to be cut. Tighten the clamps to ensure that work will not rotate with the cutter.

5. Center-punch the center of the circle to be cut.

6. Place the tip of the guide bit on the punch mark and commence drilling the hole.

7. Continually apply pressure until the cutter bit has cut through the material.

3-3.2.6.2 Hacksaws

The rotary hacksaw, shown in Figure 3-7, can be used to cut large holes through any machinable material up to 1 inch in thickness. The rotary hacksaw is for use in drill presses or portable electric hand drills. It has a high-speed steel cutting edge which is electrically welded to a tough, alloy steel body; it has a high-speed steel pilot drill, heavy hexagonaf shanked arbors and a sufficient set for deep drilling. Rotary hacksaws are self-aligning, as the larger diameter saws float on their arbors and are driven by double drive pins. The material should be center-punched for the pilot drill and clamped in a vise or on the drillpress table. When using an electric hand drill, the drill should have a no-load speed of not more than 1500 r/rein.

3-3.2.6.3 Carbide Cutters

Carbide cutters, shown in Figure 3-7, are rotary cutting tools made of solid carbide and are used in drill presses, portable electric hand drills, and flexible shaft tools for grinding, filing, burring, countersinking and cutting metal. They are available in various lengths and sizes with both 1/8- and l/4-inch diameter shanks.

3-3.2.7 Wire and Thread Gauges

Wire and thread gauges are used to determine the size of wire and the number of threads per inch on a screw, respectively. There are various types and styles of wire and thread gauges in use today. The most common types of these gauges are shown in Figure 3-8.

3-3.2.7.1 Wire Gauges

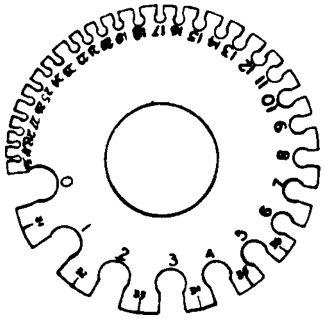
The wire gauge is used to determine the size of a wire. It is usually circular in shape with notches around its edge and an adjacent number. To use this gauge, insert the wire into the smallest notch that will accept it and note the corresponding number.

3-3.2.7.2 Thread Gauges

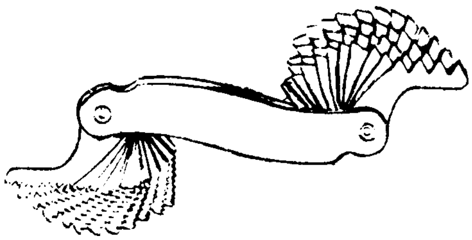
The thread gauge is used to determine the number of threads per inch of a screw. It consists of a number of leaves attached to a handle. The leaves are accurately machined on one edge to conform to the standards of the cross-sectional shape of the screw threads they are made to measure. The threads per inch of a screw are determined by placing the screw against each leaf of the gauge until the threads of the screw exactly match those of the leaf. The markings of this leaf indicate the number of threads per inch.

3-3.2.8 Wire Strippers

When preparing wires for terminations and connections, the removal of the insulation without damaging the conductor is of prime importance. It has been established by experience that the only practical way of preventing damage to conductors when removing



WIRE GAUGE



SCREW THREAD GAUGE

Figure 3-8. Wire and Thread Gauges

insulation from wires is by using tools designed for this purpose. Two types of wire strippers are shown in Figure 3-9. The first type is the simpler of the two, and is especially useful for stripping insulation in tight quarters. To use it, place the end of the lead into the cutting groove of the stripper; hold the wire in one hand, the stripper in the other hand and pull downwards, away from the cutting edges of the groove. The second type is used when stripping many wires. When using this type of wire stripper, place the wire into the correct groove to avoid cutting the end off the conductor instead of stripping off the insulation.

3-3.2.9 Tube Puller

The tube puller shown in Figure 3-10 is used to pull a hot tube without waiting for it to cool down. The puller holds on to the tube by suction. To use it, push the button, seat the puller on the tube, release the button, and pull the tube.

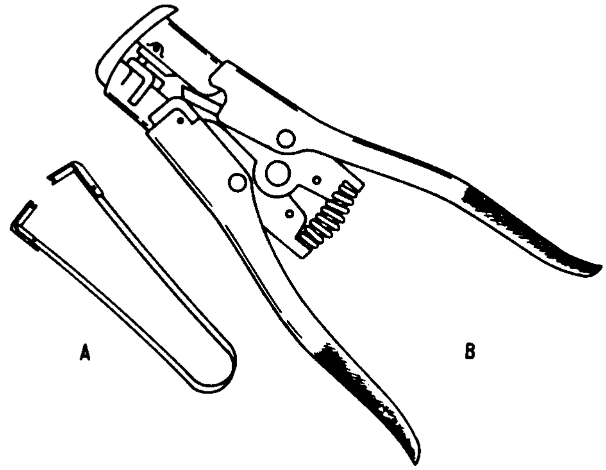


Figure 3-9. Wire Strippers

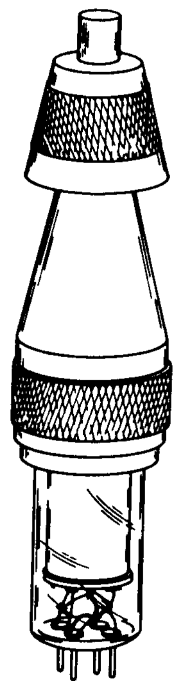


Figure 3-10. Tube Puller

3-3.3 REFERENCE PUBLICATIONS

Various publications, some of which are discussed below, are available for guidance in maintenance work, or for reference and study by electronics personnel. Some of these publications are as vital to intelligent maintenance as is test equipment. In general, publications are available from the U.S. Naval Publication and Forms Center, Philadelphia. However, before requisitioning such material, consideration should be given to the equipment installed, the mission of the ship or activity, the purpose of and distribution policy for the individual publications, and the available stowage space. Because it is essential that reference material be as current and accurate as possible, publication changes and corrections should be entered as they become available. For example, if the current issue of the EIB corrects information appearing in an earlier issue, the earlier issue should be changed. If the change affects other publications (technical manual, field change bulletin, and parts allowance list, for instance), these also must be corrected. The changes must be legible and accurate. If no page is furnished for recording completed changes, some method for recording these changes should be devised. One method is to make notes in the margin of the new material to indicate the publications in which the change has been entered. By assigning to specific individuals the responsibility for making all changes in designated publications, and by checking their entries from time to time, the Electronics Officer will do much toward eliminating the possibility of his crew using incorrect repair information. In order that an activity's file of publications may be kept up to date, current issues of the Naval Ships Technicrd News, the EIB, and the Index of Forms and Publications (NAVSUP 2002) should be examined for information on the availability of handbooks, final technical manuals, revision supplements, and changes pertaining to the equipment on board.

3-3.3.1 Naval Ships Technical Manual

The Naval Ships Technical Manual is the most complete and authoritative reference available on NAVSEA equipment. This manual is issued as an informative and comprehensive guidance to Naval personnel, afloat and ashore, who are responsible for, or engaged in, the installation, operation, maintenance, and repair of equipment under cognizance of the Naval Sea Systems Command.

3-3.3.1.1 Scope

The manual contains administrative and technical instructions not included in the U.S. Navy Regulations or other publications of higher authority but which are deemed necessary for a clear understanding of the requirements of the technical work and equipment under the cognizance of the Naval Sea Systems Command. The data and instructions in the manual are in accordance with what is considered the best engineering practices for operation, maintenance, testing, and reliability of the equipment and for the safety of the personnel concerned. Chapter 400 of the manual, titled "Electronics," is required reading for electronics personnel. This chapter rdso lists other chapters containing information of value to electronics personnel. The instructions and data contained in this manual do not intrude on or interfere with the internal organization of a ship or with prerogatives of the operational commander. In order to make the instructions clear, brief descriptions and illustrations of type units or outstanding examples of subtypes in the same class have been included. However, for complete information of design details, operation, adjustment, and care of equipment, the specific equipment's technical manual must be consulted.

3-3-3.1.2 Distribution

Each chapter of the manual is prepared as a separate pamphlet so that individual chapters may be issued to Naval vessels or other Naval activities for use in the instruction of Naval personnel. Copies of individual chapters shall be requisitioned directly from the U.S. Naval Publications and Forms Center, Philadelphia, Pa. 19120, in accordance with NAVSUP Publication 2002, using DD Form 1348 (MILSTRIP). Specific requests from U.S. Naval Activities for the individual chapters are required. Requisitions from other Departments of Defense, other Government agencies, and foreign nationals for the subject manual still require Command approval and are to be forwarded to the Naval Sea Systems Command.

3-3.3.2 Equipment Technical Manual

The equipment technical manuals which are presently being prepared in accordance with MIL-M-15071( )(Type 11) provide all the information necessary to install, operate, and maintain the equipment. Unless otherwise specified, the maintenance information applies to organizational, intermediate and depot-level maintenance. In addition, the information fulfills requirements for logistic, engineering and training support of the equipment. The manual utilizes cross-referencing techniques to reduce the time required to locate maintenance data and to simplify the troubleshooting process. It is intended that the technician shall never be dead-ended in access to technical manual information during maintenance and troubleshooting actions. Each equipment manual contains eight specific chapters of data. The chapters may be arranged sequentially in one volume or conveniently arranged in multiple **volumes.** The contents of each chapter are described as follows.

CHAPTER 1 – GENERAL INFORMATION AND SAFETY PRECAUTIONS

All safety precautions necessary for the protection of personnel, the ship and the subject equipment are emphasized prior to the general content of this chapter. Statements regarding the WARNINGS and CAUTIONS applicable to all procedures presented in the manual are included or cross-referenced as a safety summary. The generaJ content of this chapter is such that command level, supervisory personnel and other users having a general interest in the equipment can determine the purpose, physical, functional and operational characteristics of the equipment and various equipment configurations. An introduction to the manual provides an explanation of the purpose, scope and applicability of the manual. Illustrations of each unit are provided for physical identification and their relationship to other units. Tabular listings include all equipment, accessories, and documents supplied and/or required for use with the equipment.

CHAPTER 2 – OPERATION

This chapter contains all the procedures necessary to enable operating personnel to efficiently and effectively use the equipment. These include routine and emergency operating instructions, safety precautions, operating limits, complete starting (tum-on) and stopping (turn-off) procedures, including emergency turn-off, and any instructions required by the operating personnel to prepare the equipment for use. Where operating procedures are to be performed to a specific sequence, step-by-step procedures are given; initial safety requirements and connections of accessory equipment are also given. Tables and charts are provided for the presentation of operating instructions for different modes of operation. Warnings and cautions for conditions that may create hazards are located appropriately. Instruction for operator's maintenance and the use of test equipment incorporated in the equipment is also included. Illustrations which show the location of controls, checkpoints, and adjustments (with normal indications listed) are included to facilitate use and understanding of the procedures.

CHAPTER 3 – FUNCTIONAL DESCRIPTION

This chapter provides the technician with an understanding of the circuit theory and functional operation necessary for efficient troubleshooting and repair of the equipment. Included is a detailed analysis of the principles of operation of the overall equipment and its functions. The functional development of the equipment outputs in every mode of operation is described. The descriptions are presented in successive levels of increasing detail: overall level, major functional level and circuit level. Circuit level descriptions are limited to those not described in the EIMB, NAVSEA SE000-00-EIM-120. The text is directed to and supported by functional block diagrams and simplified schematic diagrams in this chapter, and to the functional troubleshooting diagrams and detailed schematic diagrams in Chapter 5, Troubleshooting. Digital circuits are described using conventional logic symbols and notations, with adequate flowcharts and functional descriptions for complete understanding. The organizational structure of this chapter parallels, as much as possible, the functional arrangement of data in Chapter 5.

CHAPTER 4 – SCHEDULED MAINTENANCE

This chapter contains preventive maintenance procedures and performance tests required which will establish confidence that the equipment and the functions being tested will perform within allowed tolerances until the next scheduled test or preventive maintenance action. It is intended that the procedures provided in this chapter shall reflect the specific scheduled maintenance procedures developed for the Preventive Maintenance System (PMS) Maintenance Requirement Cards (MRC). However, the scheduled performance test provided by the technical manual shall include references to troubleshooting or corrective maintenance actions if the test values are not within tolerances. In case of conflicts between the PMS documentation and the technical manual, the PMS documentation shall take precedence.

CHAPTER 5 – TROUBLESHOOTING

The troubleshooting chapter provides sufficient information to localize mrdfunctions to a repairable assembly. Troubleshooting aids supplied include a troubleshooting index; relay, lamp and protective device index; maintenance turn-on procedure, system troubleshooting information, and individual equipment function troubleshooting procedures. The troubleshooting index provides a listing of the major and supporting functions of the equipment with references to the appropriate troubleshooting diagrams, procedures, and supporting functional descriptions. The maintenance turn-on procedure provides a method of turning on the equipment when the normal procedures fail due to internal malfunctions. The procedure normally is used when problems occur during the normal turn-on procedures or the equipment is shut down due to overloading. The procedures are helpful in localizing primary power malfunctions to an area on a troubleshooting diagram from which circuit tracing can be started. The relay, lamp, and protective device indexes provide a listing of these items by reference designation. For each item the functioned name, energizing parameters, and direct reference to an appropriate troubleshooting diagram are included. Troubleshooting procedures support the troubleshooting diagrams. These procedures guide the technician in the logical order of isolating a fault to defective items within each equipment function. This information directs the technician to observe meters, fuses, circuit breakers, valves, built-in test equipment and other available indications showing the presence of trouble. Troubleshooting diagrams consist of signal flow diagrams, power distribution diagrams, piping diagrams, control diagrams, logic diagrams, maintenance schematic diagrams, and dependency diagrams, as required. Signal flow diagrams, the most significant troubleshooting aid, consist of detailed block diagrams illustrating the functional development of each major function from its ongin to its output. The flow path begins with one or more initial inputs and proceeds through each unit, assembly, and subassembly influencing the signal flow. All check or test points necessary to isolate the trouble to lowest level hardware block are highlighted. Test equipment setup and test parameters are provided to define satisfactory operation. Either fault logic diagrams or maintenance dependency matrix charts are included in this chapter. These troubleshooting aids enable the lesser trained or less experienced technician to isolate malfunctions of the equipment.

CHAPTER 6 – CORRECTIVE MAINTENANCE

This chapter contains instructions, within the ability of the electronics technician, to adjust and align the equipment, remove, repair and reinstall and align all repairable parts and modules, subassemblies and assemblies. These instructions identify the action to be accomplished, safety precautions to be observed, tools, parts, and test equipment and materials required. It lists preliminary control settings, test equipment set up instruction, and step-by-step instructions with supporting illustrations to accomplish the maintenance task. This chapter is usually broken down into two sections, alignment and repair.

CHAPTER 7 – PARTS LIST

This chapter lists and identifies all shipboard, tender and shore-based repair parts and attaching hardware. Included are a list of units, parts list, list of common items, list of attaching hardware, list of manufacturers and parts location illustrations. The parts listing is in order of item reference designation and provides a description, part number, manufacturer's code, attaching hardware and figure reference for each item. The list of common items, list of attaching hardware and list of manufacturers provide expanded data as referenced in the parts list. Parts location illustrations appear in reference designation sequence at the end of the chapter.

CHAPTER 8 – INSTALLATION

This chapter contains drawings and information pertaining to site selection, special tools and material requirements, unpacking and handling, preparation of foundations, assembly procedures, mounting instructions, bolting diagrams, safety precautions, clearance requirements, cooling requirements, and recommendations for reducing electric and magnetic interference. Installation checkout procedures provide for equipment checkout in three phases: installation inspection and pre-energizing procedures, turn-on and preliminary tests, and installation verification tests. An installation standards summary sheet provides a checklist with spaces for recording the results of all installation verification tests.

3-3.3.2.1 Distribution

Two copies of the TM for a particular equipment are provided for each equipment. In addition, the Command supplies file copies to activities concerned with the installation and maintenance of the equipments or with the training of electronics personnel. Supplies of manuals remaining after initiaf distribution are stored at the Navy Publications & Forms Center, Philadelphia, for issue to individual activities. When the supply of manuals is extremely limited, special justification may be required to obtain copies. Manuals for instruction and study can be issued only to Navy and Marine Corps schools, and then only in quantities consistent with the available stock. Advance, preliminary, or temporary technical manuals may be furnished where a delay in completing the final manual is anticipated. As a general rule, return postcards are included under the front covers of the manuals. These cards provide a ready means for informing Contractors of where the completed final manuals are to be sent. To ensure receipt of the final manuals, the postcards should be filled in and returned promptly. Advance, temporary, and preliminary publications are to be destroyed upon receipt of final technical manuals, as indicated in the promulgating letter in the final books. If the manuals to be destroyed are classified, disposal must be in accordance with existing regulations covering the destruction of classified material. The instructions which accompany changes to technical manuals indicate the desired disposition of material removed from the basic publications.

3-3.3.3 Functionally Oriented Maintenance Manual

The differences between a Functionally Oriented Maintenance Manual (FOMM) and a conventional manual are: the use of color, unique diagramming techniques, and the maintenance dependency charts. Color is used to define hardware boundaries, show functional entities, and show control locations. A functional entity may be a piece part, piece parts formed into a circuit, a group of circuits, or a major function. Hardware boundaries are shown as shades of grey. When a unit, assembly, and subassembly are shown on the same diagram, the lightest shade of grey represents the unit, the next darkest shade of grey represents the assembly, and the next darkest shade of grey represents the subassembly. A diagram showing an assembly uses the lightest shade of grey to represent the assembly and darker shades for subassemblies. Functional entities are shown within shades of blue. The lightest shade of blue may represent a single functional entity, or a functional entity with two or more subfunctional entities within the next darkest shade of blue. Front panel controls are shown in white boxes within black borders. Internal controls are shown in grey boxes that represent the proper hardware level. The white and grey boxes are shown within blue shades, whenever possible. Diagraming is the heart of tbe FOMM, not because of the pretty shades of blue and grey, but because of the functional diagraming technique. Each diagram, whether it be overall function, major function, or blocked schematic, is functionally reduced until it fits on one right-hand page. Functions removed from the main diagram are placed on the following right-hand pages. Each diagram on a right-hand page becomes the focal point for troubleshooting and repair information. Diagrams and their corresponding maintenance dependency charts (MDCs), or fault logic diagrams (FLDs) are used for troubleshooting. MDCS are preferred. FLDs are used with major functional diagrams containing complex digital circuitry. The maintenance dependency chart displays the sequence of power or signal flow in the equipment. Each horizontal line displays an event such as a lamp lighting, a relay energizing, or an availability of a signal or voltage. Symbols on the event lines indicate the functional entities, circuit elements, or previous events that the event is dependent on. The symbols are located within the vertical columns, which identify the functional entities and circuit elements. When an event or signal availability is not present, the previous events, signal availabilities, functional entities, and circuit elements on which the event is dependent can be readily ascertained. An event box indicates input or output signal or indication. Nomenclature in the event box specifies the type of action and availability of the event. A black event box with white lettering indicates front panel observable. A white event box with black lettering indicates a circuit point at which an event or availability may be measured. The circuit identifier codes and all symbols used on the diagrams and maintenance dependency charts are shown in tabular form with an explanation of their meanings in each manual. In order to use diagrams and maintenance dependency charts effectively, the technician must familiarize himself with symbols used and their meanings. The FOMM provides support, and troubleshooting and repair information for a particular equipment or system. For convenience, support information is separated from troubleshooting and repair information by volumes. Depending on the size of the FOMM, volumes may be further subdivided into parts.

VOLUME 1 – SUPPORT INFORMATION

The support volume includes front matter and sections entitled: general information, operation, theory of operation, scheduled maintenance, installation, and parts list. This volume uses 8% x n-inch pages.

FRONT MATTER

Front matter consists of conventional information and a functional index.

SECTION 1– GENERAL INFORMATION

This section provides information for easy and rapid determination of the purpose, physical and functional characteristics, and operational capability of the equipment or system.

SECTION 2 – OPERATION

This section contains manual and automatic procedures for routine and emergency operation, safety precautions, operating and equipment limitations. Controls, relationship of controls to each other, and their effects on displays are described.

SECTION 3 – THEORY OF OPERATION

This section contains a description of the generaI principles of operation beyond the actual functioning of the equipment or system contained in Volume 2. Examples of this generaJ information would be gun-fire control problems, sonar or radar principles, concepts of a communication system, etc. Also, there is an amplification of the keyed text used in Volume 2 to explain the operation of a function or circuit.

SECTION 4 – SCHEDULED MAINTENANCE

This section contains preventive maintenance procedures and performance test instructions.

SECTION 5 – INSTALLATION

This section contains drawings and information required for installation.

SECTION 6 – PARTS LIST

This section contains a top-down breakdown of all the parts. This separate parts list is provided when requested in a contract. Volume 1 of a FOMM System Manual contains **all** six of the preceding sections numbered differently, and two additional sections: safety precautions, and alignment.

SECTION 2 – SAFETY PRECAUTIONS

This section describes the hazards associated with the system operation and maintenance.

SECTION 6 – ALIGNMENT

This section contains corrective adjustment procedures and support information necessary to restore electrical and mechanical alignment between various system equipment.

VOLUME 2 – TROUBLESHOOTING AND REPAIR

The troubleshooting and repair volume provides information for troubleshooting from the overall function, through the major functions, down to the faulty circuit or piece part in progressive stages. This volume includes front matter, overall function, major function, and hardware information. This volume uses 11 x 17-inch pages.

FRONT MATTER

Front matter consists of conventional information and a functional index, a description of special terms and symbols, integrated circuit data, and an explanation of MDC usage.

OVERALL FUNCTION INFORMATION

Overall function information consists of a functional family tree, a hardware family tree, an interconnecting cabling/piping diagram, a turn-on/check-out chart, and functional diagram, keyed text, MDC, and alignment instructions. A functional family tree shows the major functions and subordinate functions. A hardware family tree shows the units, assemblies and subassemblies. An interconnecting cabling/ piping diagram shows and identifies cabling and piping used to connect units and interfaces with the ship services. A turn-on/check-out uses the sensory indications to bring the equipment from a cold state to a hot state, and check it out. The overall functional diagram shows each major function as a first level blue shaded block with front panel controls. The signal flow between the major functions and interfacing equipment is shown. This diagram with the overall MDC is used to isolate a faulty function. A keyed text is used to describe the overrdl functional diagram. The overall MDC matches the signal flow through the overall functional diagram. Overall alignment procedures adjust and align all adjustable parts including interacting adjustments.

MAJOR FUNCTION INFORMATION

The major function information consists of a diagram, keyed text, and maintenance dependency chart or fault logic diagram. Major function diagrams fall into four general categories: analog, logic, power distribution, and ground/return. The diagrams are constructed to show the functional flow of signals through units with their piece parts, assemblies, and subassemblies as they are connected in the major function. The diagrams, with their MDCS, are used to isolate a faulty assembly or piece part within the major function. A keyed text is used to describe the major function diagram. The major function MDC matches the signal flow through the major function diagram.

HARDWARE INFORMATION

A separate hardware information package is made for each unit. When the unit blocked schematic diagram is too large for a 11 x 17-inch page, a separate hardware information package is made for one or more of the unit's assemblies. The same technique is used for assemblies and subassemblies. A hardware information package consists of a blocked schematic diagram, a keyed text, an MDC, alignment and repair data, parts data, and a wiring diagram or wire list. Blocked schematic diagrams are constructed to show the functional flow of signals through functional entities of a unit, assembly, or subassembly. A functional entity is two or more parts grouped into a circuit, or a separate piece part. The diagrams, with their MDCS, are used to isolate a faulty functional entity. Voltage information on the diagram is used for fault isolation within functional entities containing vacuum tubes or transistors. A keyed text is used to describe the blocked schematic diagram. The hardware MDC matches the signal flow through the blocked schematic diagram. Alignment and repair contains procedures used for access, and to return the equipment or system to normal operation after corrective maintenance. Parts data contains part location diagram and a parts list. A wiring diagram is a pictorial presentation of point-to-point wiring. A double-entry wire list may be substituted for a backplane wiring diagram.

3-3.3.4 Electronics installation and Maintenance Books

The Electronics Installation and Maintenance Books (EIMB) is a series of authoritative publications which provide field activities with information on the installation and maintenance of electronic equipment under the technical control of the Naval Sea Systems Command. The EIMB consists of thirteen separate volumes or handbooks in order to ensure coverage of all Naval electronic equipment. The following is a list of each handbook by title and NAVSEA number.

Title	NAVSEA No.
The Complete ELMB Series	SEOOO-OO-EIM-OOO
General Handbook	SEOOO-OO-EIM-1OO
Installation Standards Handbook	SEOOO-OO-EIM-11O
Electronic Circuits Handbook	SEOOO-OO-EIM-120
Test Methods and Practices Handbook	SEOOO-OO-EIM-130
Reference Data Handbook	SE000-00-EIM-140
RFI Reduction Handbook	SEOOO-OO-EIM-150
General Maintenance Handbook	SEOOO-OO-EIM-160
Communications Handbook	SEOOO-OO-EIM-O1O
Radar Handbook	SEOOO-OO-EIM-020
Sonar Handbook	SEOOO-OO-EIM-030
Test Equipment Handbook	SEOOO-OO-EIM-040
Radiac Handbook	SEOOO-OO-EIM-050
Countermeasures	SEOOO-OO-EIM-070
Tabular Separators (Equipment Books Only)	(Stock#)0967-LP-000-0009

The information contained in the ELMB series is supplemental to equipment technical manuals and related publications.

3-3,3.4.1 Scope

The handbooks of the EIMB series are divided into two categories: general information handbooks, and equipment-oriented handbooks. The general information handbooks contain data of interest to all personnel involved in installation and maintenance, regardless of their equipment specirdty. The equipment handbooks are devoted to information on a particular equipment class; they provide specific equipment test procedures, important adjustments, circuit applications, general servicing information, and field change identification data. The technician, by using the **EIMB,** will tend to reduce time-consuming research, and obtain supplementary information helpful in servicing and maintaining his equipment.

3-3.3.4.2 Distribution

The distribution of the EIMB handbooks and handbook changes is a joint effort by the Naval Sea Systems Command, SEA 05 **L341,** National Center #2, Room 7E48, Washington, D.C. 20362, and the Navy Publications & Forms Center, Philadelphia. Distribution policy is established by NAVSEA 05L341 Activities not already on the EIMB distribution list and those requiring changes to the list should submit correspondence to:

Naval Sea Systems Command, SEA 05L341
National Center #2, Room 7E48
Washington, D.C. 20362

3-3.3.5 Electronics Information Bulletin

The Electronics Information Bulletin (EIB), Stock Number 0967-LP-O01-3XXX, is an authoritative publication, published bi-weekly, and forwarded to all Naval ships and Naval electronics installation and maintenance activities. The EIB contains advance information of field changes, installation techniques, maintenance notes, beneficial suggestions adopted by various yards and bases, and notification of technical manual and EIMB revisions and changes with the latest applicable data and stock numbers. Unless otherwise indicated, the maintenance requirements prescribed in the various issues of the EIBs are consistent with those contained in the Planned Maintenance System. All articles, including those under the cognizance of Naval Electronic Systems Command (NAVELEX), have been authenticated and are authoritative in nature. Accordingly, reference may be made to a particular issue of the autbority for adoption of ideas contained therein. Nothing in the EIB publication authorizes interface changes between equipment and systems, or between equipment and ship. Articles of lasting interest are later transcribed into the EIMB except for field changes and corrections to publications. EIB indexes (A and B) are distributed automaticrdly as a change to the General EIMB handbook, NAVSEA SEOOO-OO-EIM-1OO. EIB indexes (A and B) provide a comprehensive listing of articles published in the EIB and identify the EIB in which each article appears. Index A lists, by equipment type number and/or name, articles pertaining to specific equipments (i.e., AN/SPS-10, LS-458/SIC, MK 23 MOD 3 GYRO COMPASS, TACAN, TED-1, TEKTRONIX TYPE 316 OSCILLOSCOPE, etc.). This index is prepared using an automatic data processing system with a basic columnar sort sequence, and, therefore, many entries are not in their true numeric sequence. For example: R-1051/URR precedes R-390/URR and AN/SPA-33 precedes AN/SPA-4. Field changes are identified by "FC" following the equipment type numbers, i.e., R-390 A/URR-FC-5. Index B lists, by subject, all articles of general information not pertaining to specific equipment (i.e., Coxial Lines-Prevention of Corrosion Due to Salt Spray on).

3 4 SOLDERING AND REPAIR SKILLS

The majority of modem electronic equipment incorporate small (miniature) or very small (microminiature) components. Such components range in size from large-scale integrated circuits (LSI) to the now familiar transistor. Because of their size and composition, mostminiature and micro-components are heat sensitive, and many are static sensitive. The technician must develop the proper soldering skills to service these componentswithoutdamaging them. The following sections will aid the technician in developing such skills. Prior to performing any microminiature repair, the technician must have acquired general high-reliability soldering skills. Section 4 will therefore be devoted to discussing these essential skills. Repairs of miniature, microminiature components and circuits will then be discussed in Sections 5, 6 and 7.

SECTION 4

SOLDERING TECHNIQUES

4-1 INTRODUCTION

The efficiency of electronics equipment is dependent, to a very large degree, upon the quality of workmanship employed and the type of materials used in the soldering of its electrical connections. An appreciable portion of equipment failure can be traced directly to poorly soldered connections or joints. Electronics equipments aboard ship are subjected to continual vibration and frequent shock. Therefore, it is imperative that all soldering be done with the utmost care.

4-2 SOLDER TYPES

Solder is a metal alloy consisting of two or more metals used in various percentages to form the solder alloy. The alloy most widely used in electronics soldering consists of TIN and LEAD without special additives. The most common TIN/LEAD solder alloys are 60/40 and 63/37. TIN/LEAD solder alloys are always given as a percentage with the TIN content listed first; that is, 60/40 solder consists of 60% TIN and 40% LEAD. The TIN/LEAD fusion diagram (Figure 4-1) shows a plot of various TIN/LEAD solder alloys versus temperature. Note that at 361“F all TIN/LEAD solders (from 15/85 to 95/5) change from a solid to a plastic (partial liquid) state except one. An alloy which has a single sharp melting point and changes directly from a solid to a liquid with no plastic state is called a EUTECTIC alloy. The only TIN/LEAD solder alloy with eutectic characteristics is 63/37, as the diagram indicates. The 63/37 solder is known as Eutectic Solder. An overall

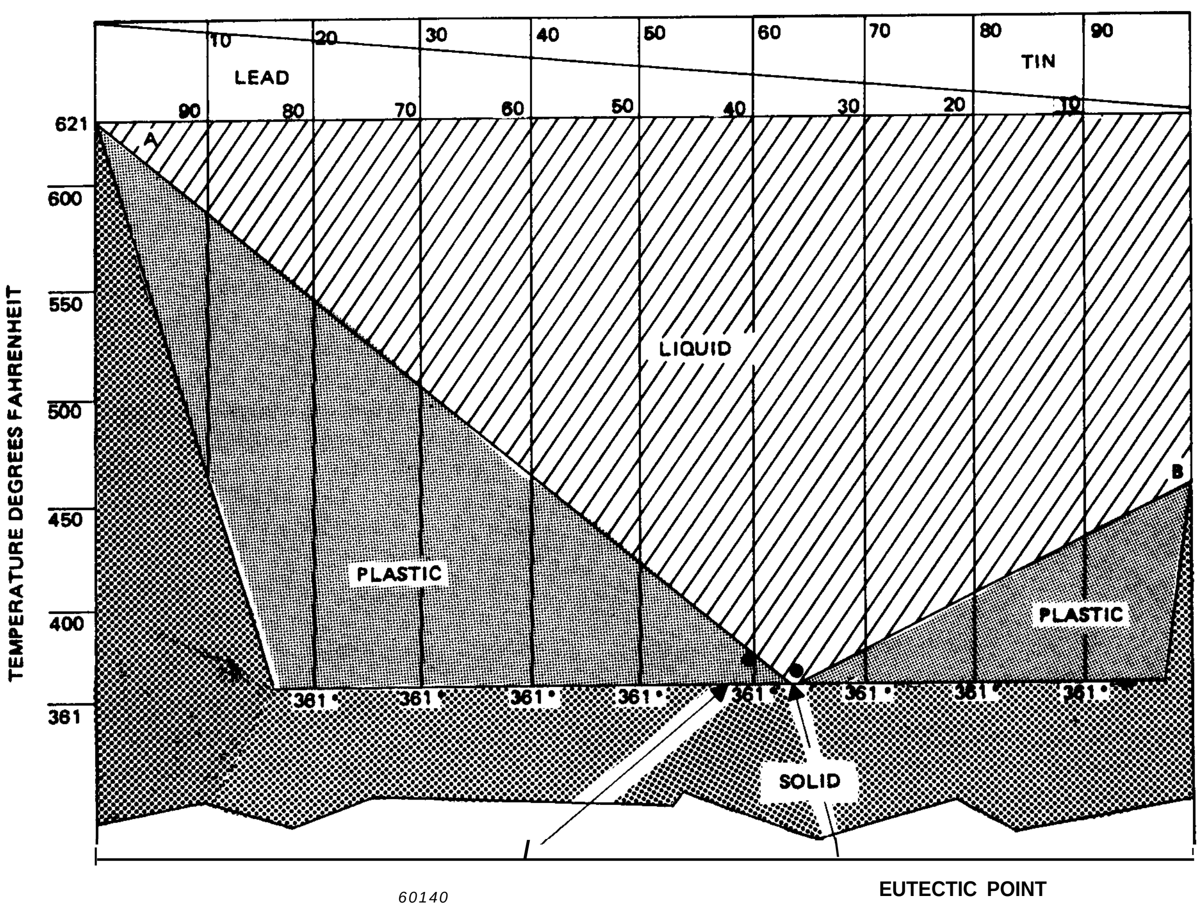


Figure 4-1. TIN/LEAD Fusion Diagram

evaluation of Figure 4-1 diagram reveals that different alloys reach full liquid state at different temperatures. It also reveals that as solder is heated, it passes from a solid state through a plastic state and then into a liquid state, with the exception of the eutectic point at which no plastic state exists. The most critical area of concern during a soldering operation is the time-temperature range during which the solder is in a plastic state. While in this plastic state the solder is a combination of liquid TIN/LEAD alloy with solid pure metal crystals of either TIN or LEAD. Any physical movement of the solder itself, while cooling through the plastic state, will permanently damage the structure of the solder alloy, resulting in a fractured solder connection. For this reason, eutectic solder (63/37) is the best general purpose, high-reliability, electronics solder. Although 60/40 solder is less acceptable for electronics soldering, it has the advantage of forming a slightly stronger joint than does the 63/37 solder. It has, however, the disadvantage of lying in the plastic range from 361 “F to 370 “F, with the attendant chance of fractured solder connections.

4-3 SOLDERING FLUX

The purpose of soldering flux is to remove surface oxides from metals to be soldered. All metals oxidize when exposed to air. The process of oxidation causes a thin film of oxide, which is non-metallic, to form on the surface of the metal. Good metal-to-metal contact must be obtained before soldering action may take place, but the oxide film prevents this contact and must be neutralized or removed. Soldering flux chemically breaks down surface oxides, causing the oxide film to loosen and come free from the metals being soldered. These fluxes may be divided into three general types or classifications:

1. Chloride (commonly called “acid”) type flux.
2. Organic type flux.
3. Rosin or resin type fluxes.

Each group of fluxes has characteristics specific to that group. The chloride fluxes are inorganic salts and are the most active of the three flux groups. They are not suitable for electronics soldering since they are highly corrosive, usually electrically conductive, and are difficult to remove from tbe workpiece. The organic fluxes are nearly as active as inorganic fluxes, somewhat less corrosive, but are unsatisfactory for shipboard electronics soldering because they must be removed completely to inhibit corrosion. Rosin-type flux is ideally suited to electronics soldering due to its unique characteristics. Inert at normal temperatures, flux becomes highly active at soldering temperatures. This characteristic makes rosin totally noncorrosive, except at soldering temperatures. Resin fluxes are rosin-based, with additives that change some of the characteristics of the pure rosin flux. To attain highest reliability in making electronics solder joints, the use of flux is a necessity. Flux is available as both an external agent and as an integral part of the solder. As an external agent, the flux is applied to the connection by hand prior to soldering. Externsd fluxes range from a very thin liquid to a thick, heavy paste. Most paste fluxes contain zinc chloride as an activating additive. If zinc chloride has been added, it will be so stated on the container. (NOTE: Fluxes containing zinc chloride must never be used as they are corrosive.) Nearly all electronics soIder in use today contains flux as an integral part of the solder by making the solder with an integral flux core. However, it is often highly desirable to use an external flux, even when also using a flux cured solder. Two types are recommended:

1. Kester Solder Co., No. 1544 with No. 104 thinner.
2. Alpha Metals Co., No. 711 with No. 412 thinner.

Although solder forms an actual intermetallic bond with solderable metals, it does not do so by fusion, as in brazing or welding, where all metals to be bonded are molten and fused together. The wetting action of solder lies in the degree of ease and completeness with which the solder spreads over the surface of the metal being soldered. The completeness of the wetting action is measured by the tangent angle where the solder meets the surface of the metal being soldered. A very small angle is an indication of thorough and complete wetting. A large angle formed by a sphere or bubble of solder (similar to a drop of water on a waxed surface) is an indication of poor wetting action and may involve an unsatisfactory “cold solder” joint. The completeness of the wetting action is one of the prime indicators of quality and reliability when inspecting a solder joint.

4-4 METALLIC PLATINGS

It is the function of metallic platings to protect the associated metal from oxidation, and to assure the solderability of normally non-solderable metals. Non-solderable metals are used to closely match the thermal expansion of glass seals on capacitors, transistors, diodes and other electronic components. Plating on this type of lead is normally gold, which is very porous, and is applied relatively thickly. Care must be taken not to remove the plating from this type of lead.

4-4.1 CHARACTERISTICS AND FABRICATION OF A QUALITY SOLDER JOINT

The physical appearance of a quality solder joint shall be as follows:

1. Smooth, shiny, mirror-like surface.
2. Free of pits, protrusions, or other blemishes.
3. No base metal showing at any point.
4. Smooth, concave fillet at all points of contact.
5. Complete wetting action which shall show no distinct inlets at the edge of the soldered area.

Also the solder must wet and flow smoothly over afl surfaces, with no sharp edge or ridge at any point. The preferred quantity of solder forms a smooth, concave fillet from a point haff-way up the side of the lead. The contour of the wire should be clearly visible through the solder. (If stranded, the individual strands must he visible.)

4-4.2 RECOGNITION AND CAUSES OF SOLDER JOINT DEFECTS

Common defects include: dirty solder joint due to lack of good wetting; cold solder joints due to dewetting around all or most of the connections; and small protrusion or tip of solder where the soldering iron was removed. Fractured or disturbed solder joints are usually semi-shiny with good wetting. A prime indication is a spiderweb or cracked, fissured appearance. In an overheated solder joint, the surface is quite dull, with a rough, grainy appearance. A “dead” solder joint is crusty, wrinlded, and a very dark dull color.

4-4.2.1 Causes of Common Defects

Dirty solder joints are caused by oxidation or other foreign matter interfering with the wetting action. Cold solder joints are caused by insufficient heat or poor heat transfer to the joint. Fractured joints result from physical movement of the join while the solder is in the plastic state. An overheated solder joint is caused by excessive heat for too long a time. Dead solder is due to extreme overheat and is generally only found on the tip of a soldering iron when the iron is not in use.

4-5 INSTALLATION AND SOLDERING OF COMPONENTS

4-5.1 COMPONENT POSITIONING

Proper positioning of a component on the board is as follows:

1. In repair, replacement components should always be installed in conformance with the original configuration.
2. Component bodies shall be centered between the lead mounting points whenever design permits.
3. Replacement components shall be mounted so as to make afl possible identification markings readable without disturbing the component.
4. When a series of components are mounted in the same style and direction, they should be placed so that all markings are all readable from a single point, giving due regard to polarity requirements.
5. Any mounting hardware removed during disassembly shall be replaced when installing new components.

4-5.2 COMPONENT LEAD SHAPING

Proper methods of shaping component leads for mounting on a printed circuit board are as follows:

1. Component leads shall always he straightened and cleaned prior to bending.
2. Leads may be straightened by hand, using anything that will not cut or scrape the lead.
3. Erasure cleaning of leads is preferred. Use an ink-type eraser (white), as other types will leave an oily film on the lead. After cleaning the lead, the final cleaning step should- be to wipe the lead thoroughly with solvent to remove all residue left during cleaning.
4. The minimum distance between the seal, where the lead enters the body of the component, and the start of the lead bend shall be not less than a distance equal to twice the diameter of the lead itself.
5. The minimum distance between any weld bead on the lead and the start of the bend shall be not less than a distance equal to twice the diameter of the lead itself and the bend shall not be between the weld bead and the component body.
6. The minimum radius of the bend itself (sharpness of the bend) shall be not less than a distance equal to the diameter of the lead, and the bend shall be 900 at all times, except when forming a stress relief bend.

7. After bending leads, and before inserting component on the board, always reclean the leads with solvent to remove skin oils and salts present due to finger contact.

4-5.3 CIRCUIT BOARD PREPARATION

The first step in preparing for component installation is to thoroughly clean the circuit board. A white ink-type eraser will remove light oxides. Always clean circuit board with solvent and a Kimwipe after abrading. Never allow the solvent to evaporate, but wipe up promptly with a clean dry Kimwipe. Solvent type cleaning may also be done with an acid brush which has soft bristles and will not scratch the conductor surfaces. Wipe dry with a KimWipe.

4-5.4 PROPER SHAPING TECHNIQUES

The next step in component installation involves bending and cleaning the component lead, prior to insertion in the board, as follows:

1. A nylon rod or orangewood stick may be used to bend component leads. Always hold the component body immobile and bend only the pigtail end of the lead with a smooth wiping motion of the finger.

2. When using round-nose pliers to form bends and stress relief loops, always cover such jaws with masking tape to cushion them. Use extreme care not to dent the component lead.

3. The initial step in forming stress-relief loops is to make a standard 90" bend in the lead.

4. To finish the stress relief bend, grip the lead just beyond the 90" bend and wipe the pigtail end smoothly around the plier jaw, forming a 180 " **loop.**

5. After bending and inserting the component into the board, the next step is to properly form the lead termination.

6. In forming a straight-through termination, the lead is simply cut to proper length, using flush-cutting pliers.

7. To form a semi-clinched termination, grip the lead with pliers and bend in the direction of a run to a 45" angle. Avoid pulling on the lead, as this **will** place unwanted stress on the component body.

8. After bending, cut the lead with flush-cutting pliers. The flush side of the cutter must always be kept toward the board, butat900 with the lead.

9. For full clinched terminations, the bending and cutting procedure is the same as for semi-clinched leads.

10. An orangewood stick, which will not damage the run or pad area in any way, may be used to fully clinch the pigtail down to the run surface.

4-5.5 COMPONENT LEAD TERMINATION

Component Lead Terminations are to be made as follows: (refer to Figure 4-2)

1. After installing the component on the board, the proper lead termination must be made prior to soldering.

2. Prior to shaping lead termination, excess lead may be cut off with a flush cutting tool.

3. On clinched terminations the lead length shall be not less than the radius of the pad and not greater than the diameter of the pad.

4. Semi-clinched termination shall have the same Ieadlength specifications as full clinched.

5. All clinched terminations must be bent in the direction of the run.

6. Clinched terminations must contact the run surface and not overhang any part of the run edge.

7. The lead length on straight-through terminations shall be not less than one lead diameter and not more than two lead diameters above the board surface.

4-5.6 SOLDER CONNECTION CHARACTERISTICS

The characteristics of high-quality printed-circuit solder connections are as follows:

1. The solder area extends beyond the cut end of full-clinch leads sufficiently to form a fillet.

2. Solder flows to the edges of the pad in all cases.

3. If the run or pad is plated and plating has been removed, solder must have flowed over all exposed base metal.

4. On a single-sided board, the solder forms concave fillets between the lead with no internal voids.

5. On a double-sided board with plated through-holes or flat-set eyelets, the solder should completely fill the hole and cover the pads on both sides of the board.

6. The soldered area of a funnel-set eyelet forms three separate solder joints: one on each side between the outer flanges and the board, and one through the hole between the inside of the eyelet and the lead.

7. The solder finish must exhibit a smooth, gleaming, mirror-like appearance, no pits or holes shall be in evidence, and all fillets must he concave.

4-5.7 HIGH-QUALITY SOLDERING Techniques

The techniques for making high-quality printed-circuit solder connections include the following:

1. Correct application of proper flux.

2. Only flux-cored solder should be used, as it provides automatic application of flux to the connection while soldering.

3. For large areas or rapidly oxidizing surfaces, a quantity of external flux may also be applied to the joint prior to soldering.

4. Proper heating can only be accomplished with the correct soldering tool.

5. A typical soldering iron employed in high-reliability soldering has several tip styles which are used for different masses to be soldered.

6. The tip is inserted into the bottom of the iron's hole and the set screw tightened gently but firmly. Excessive force will cause the screw to heat-seize.

7. The soldering iron is voltage-controlled to more closely match tip temperature to the mass to be soldered.

8. Upon completion of cooling, loosen and remove tip to prevent heat-seize caused by oxidation.

9. Normally, tips used in high-reliability soldering are clad, and should therefore be cleaned only with a platers brush or crocus cloth if heavily oxidized.

10. When the tip reaches soldering temperatures, a quantity of solder is to be melted onto the tip and then left there to prevent oxidation until ready to use.

11. Before using the soldering iron to make a joint, all solder must be removed from the tip, using a brush and a Kimwipe.

12. After the excess solder has been wiped off, thermal-shock the tip on a wet sponge to provide a clean, dry tip for soldering.

13. To achieve proper heating of the connection, the tip mass and tip temperature must be capable of rapidly heating the mass of the joint to be soldered to the melting temperature of solder.

4-5.8 APPLICATION OF SOLDER

Before applying heat to a joint, a thermal shunt should be attached to component leads when dealing with heat sensitive components such as diodes and transistors. When component leads do not provide access for the thermal shunt attachment due to the use of mounting hardware, EXTREME care must be used to prevent heat damage. A solder bridge is formed by melting a small amount of solder at the junction of the tip and the joint. This allows maximum possible heat transfer rate from the tip to the joint. After the prepared tip is placed in physical contact with both the lead and the pad and the heat bridge has been established, the solder is applied to form the solder bond.

NOTE

Use only clean solder.

The iron or joint should not be moved during the soldering operation, even on double-sided boards, since cleaning and heating of the joint area will allow the solder to flow through the hole and from the entire joint with a single application (except for holes without metallic reinforcement). Solder is applied to the connection by "painting" the solder into the area to be soldered, using a circular motion. Start by forming fillets along the sides of the lead; finish by filling in the large flat area of the pad.

4-5.9 CLEANING AFTER SOLDERING

After soldering, all flux residues must be removed by solvent cleaning. Two solvents are approved for circuit board cleaning. The recommended, in order of their cleaning ability, are:

1. 99.5% pure ethyl alcohol (normally not available); and

2. 99.5% pure isopropyl alcohol.

4-5.10 QUALITY INSPECTION STANDARDS

All printed circuit board soldered connections should be inspected for quality of workmanship. The standards of acceptance and indications to look for include the following:

1. Solder quantity:
   - a. Concave fillets
   - b. Lead contour visible
2. Solder finish:
   - a. Bright, gleaming finish
   - b. No pitx or holes

3. Wetting action:
   a. Smooth feathering of all solder edges.
   b. No bays or crevices in the edge of the solder flow.
4. Lead termination:
   a. Proper length
   b. Proper positioning
   c. Pigtail properly flush-cut
5. Board, conductor and component damage:
   a. Overheated board
   b. Conductor delamination
   c. Conductor nicks and scratches
   d. Proper component installations

4-5.11 FINAL INSPECTION

A final inspection of the repaired printed circuit board should include the following standards of acceptance and indications of reliability:

1. Board restored to its original configuration.

2. No visible degradation to any part of the assembly.

3. Repair made with the same type components and materials as used initially by the mrmufacturer.

4. Repairs made should be nearly indistinguishable by visual inspection, unless they are of a higher quality than the original work of the manufacturer.

4-5.12 CON FORMAL COATING IDENTIFICATION

The six basic types of conformrd coatings and their specific characteristics are as follows:

1. Epoxies:
   a. Normally hardest of the six types.
   b. Application of heat at or near the solder melting temperatures causes the epoxy to overcure, resulting in its breakdown into a powdery substance.
   c. Epoxy forms the strongest surface adhesion bond of all the conformal coatings. It will not chip or peel, and may be considered nearly unbreakable under physical stresses.
   d. Very few solvents will attack epoxy, and the destructive ones will also attack the board and ita components.
   e. The texture of epoxy is normally hard, smooth and non-porous.
2. Acrylic Lacquer:
   a. Acrylics are relatively hard and similar in appearance to epoxies, but yield more readily to scraping and cutting.
   b. Heat readily softens most acrylics; however, a gummy residue often results.
   c. The adhesion of acrylics is usually a surface bond and will often chip and flake, although it is relatively strong.
   d. Solvents such as 1.1.1, trichlorethane and xylene, readily attack and soften most acrylics.
   e. The texture of acrylics is normally smooth, non-porous, medium hard with a glossy finish.
3. Polyurethane:
   a. Some polyurethane coatings have widely varying degrees of hardness which range from an extremely hard type, similar to epoxy, to a relatively soft consistency which is similar to an RTV compound.
   b. Most polyurethane tend to soften rapidly and exhibit a putty-like consistency at or near soldering temperatures.
   c. Plastic solvents are generally the only type that will attack polyurethane; they will also attack the components and circuit board.
   d. Texture is normally smooth, glossy and non-porous but may be dented or scratched under light pressure.
4. Varnish:
   a. The hardness of varnish will vary with age: new varnish is relatively hard and tough, while old varnish tends to be brittle and flakes very easily.
   b. Heat, at or near soldering temperature, causes varnish to liquify and give off a very strong odor of linseed oil.
   c. Organic solvents such as alcohol and mineral spirits readily attack varnish, but tend to leave a gummy residue upon evaporation.
   d. Varnish is often lumpy in appearance and has a semi-glossy look.
5. RTV:
   a. RTVS have a rubbery, pliable consistency.
   b. Heat, chemicals and solvents have little or no effect on RTVS.
6. Parylene:
   a. Parylene is considered to be a hard coating, normally as hard as epoxy.
   b. Normally, solvents have no effect upon parylene.

c. High heat (approximately 480-500 "F) will remove parylene but will also probably damage the workpiece.

d. Texture is smooth, dull and normally clear.

4-6 RESOLDERING AND REMOVING COMPONENTS

The resoldering and removal of components from printed circuit boards is just as critical as the installation and soldering of circuit board components. The following subparagraphs discuss the recognition, identification, resoldering methods, and procedures of solder joints as well as proper tool usage, cleaning, and inspection.

4-6.1 RECOGNITION OF SOLDER JOINT TYPES

To recognize the various solder joint types, the board circuitry style, the lead termination style, and the style of reinforcement must be considered. Of the three considerations, the board circuitry style (Figure 4-2) is the easiest to recognize, namely:

1. The single-sided board which has conductors on one side only;
2. The double-sided board which has conductors on both sides; or
3. Multilayer boards, which have internal conductor runs and runs on one or both sides.

The degree of hole support is generally the hardest to identify because it is often hidden beneath the solder. The various styles of support are:

1. No hole support; single-sided board.
2. Plated-through hole; single-sided board.
3. Eyelet; single-sided board.
4. Plated-through hole; double-sided board.
5. Eyelet; double-sided board.

Component lead termination styles include:

1. Fully clinched lead; a common type often used in machine soldering as well as hand soldering.
2. Semi-clinched lead; easier to remove than a fully clinched lead.
3. Straight-through lead; these provide the greatest degree of reliability.
4. Offset pad termination which has the hole drilled outside of the pad area.
5. Crimped lead on the component side, which provides component clearance for improved solvent cleaning and air circulation. This also provides clearance to prevent components with high operating temperature from scorching the circuit board. (Note that this is NOT a lead termination, but is a component mounting method.)
6. A spaded lead termination in which the end of the lead is crimped after being passed through the printed circuit board. (Note that this style of termination is easily hidden by the solder and that the lead must be cut between the component and the spaded portion before attempting to remove the lead from holes.)
7. Lap solder joint lead termination is a form or style in which the component lead does not pass through the circuit board.

4-6.2 IDENTIFICATION METHODS

NOTE

More than one type of solder joint connection may be found on a single circuit board.

1. Welded leads:

a. Welded leads have a fine black line across the component lead.

b. Do not attempt to remove this type of joint. Take to the closest 2M station.

2. Use the following means to identify lead termination style:

a. Inspect visually.

b. Remove solder from joint to determine if there are any hidden termination characteristics.

3. Use the following means to identify hole support styles:

a. Inspect visually.

b. Carefully remove all solder from connection to determine hidden hole reinforcement characteristics.

4-6.3 RESOLDERING METHODS FOR PRINTED CIRCUIT SOLDER JOINTS

1. Removal by wicking. Solder removal by wicking consists of carefully heating the joint and using finely braided wire soaked in liquid flux. Capillary action draws the solder into the braids aided by the increased wetting action of the heated flux.

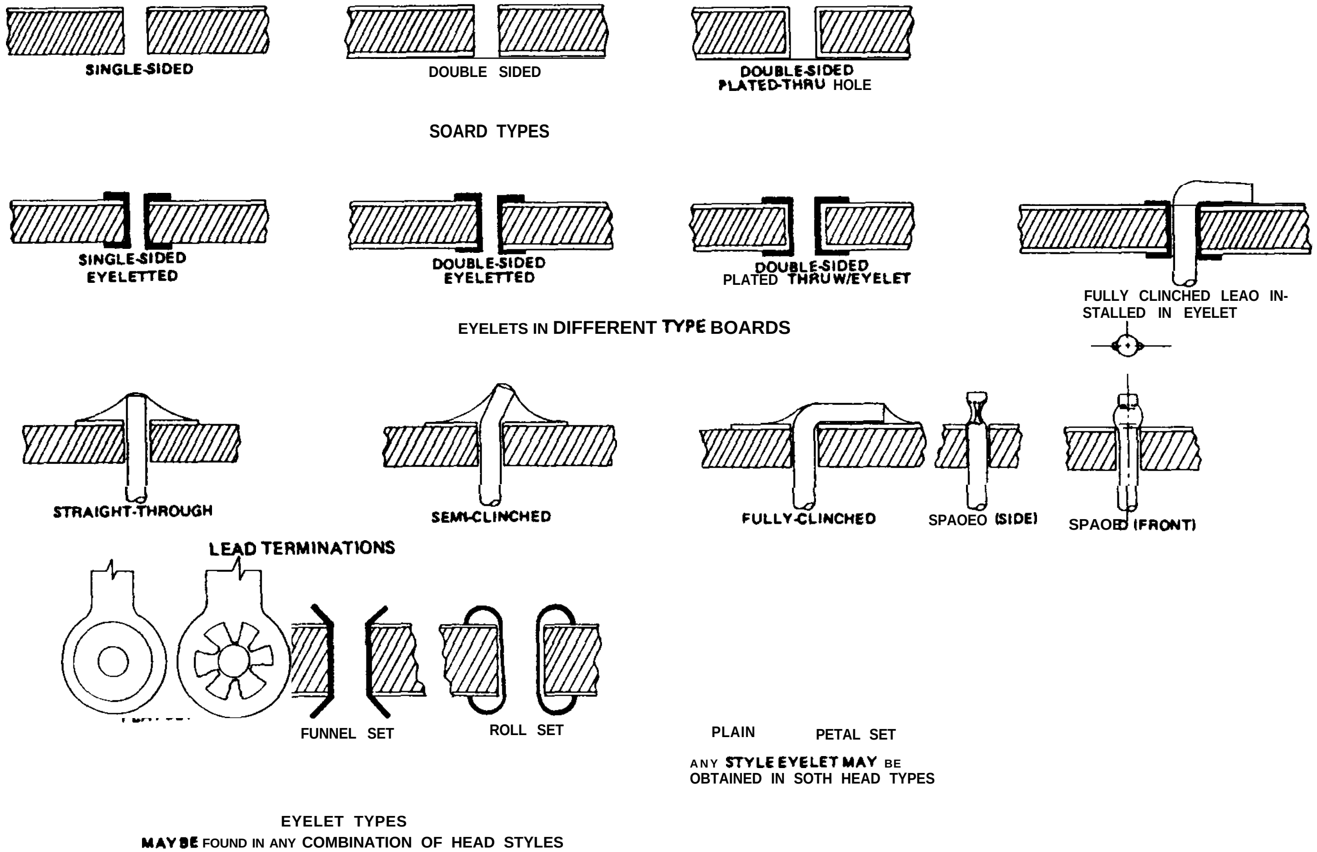


Figure 4-2. Typical Types of Circuit Board Lead Terminations

2. Manual vacuum extraction. Solder removal by the manual vacuum method consists of a manually controlled and operated one-shot vacuum source used in conjunction with heat to create a vacuum air flow which pulls molten solder from the joint. Manual vacuum usually has the advantage of instant vacuum rise-time, but may have one or more of the following disadvantages:

a. Extremely high vacuum levels, which may cause damage by lifting conductors from printed circuit boards, since the conductor bonding material has greatly reduced strength at solder melting temperatures.

b. Several applications of the soldering iron and extractor may be required for complete solder removal with the possibility of over-heating the printed circuit board.

c. There may be inability, in some cases, to apply the vacuum tip and the source of heat to the solder joint at the same time.

d. Short duration of vacuum, or physical movement of the vacuum tip caused by manual operation of the vacuum source, may cause incomplete solder removal.

4-6.4 SELECTION AND USE OF RESOLDERING TOOLS

The selection of tools and techniques to be used in a particular resoldering operation will be governed by the type of solder joint and lead termin-ation. A thorough physical examination must be made to determine the solder joint characteristics, the most effective resoldering technique, and the tools to be used in applying these techniques. The tools and techniques must be those least likely to cause damage of any nature. To avoid damage, the following factors should be considered:

1. Effect on the board materials.
2. Effect on circuit conductors.
3. Effect on the adjacent components.

NOTE

Testing and evaluation have shown the following techniques have effective and reliable applications. The technician must decide which technique is the best for a specific task, keeping in mind at all times the requirement of causing no damage.

4-6.5 INFERIOR METHODS OF SOLDER EXTRACTION

Solder removal methods which should NOT be used or which have limited applications are as follows:

1. Heat and shake method. This does not remove all the solder and causes solder splatter on circuit board.

2. Heat and pull method. The hidden lead terminations may cause damage when lead is pulled through the board.

4-6.6 WICKING PROCEDURES

The procedures for wicking solder removal are as follows:

1. Select wicking material which is smaller than the area being resoldered.

2. Spread the wicking with liquid flux and place it on the area to be resoldered, taking care to ensure that there is no overlap of wicking onto the board material.

3. Apply a clean, heated, dry soldering iron tip to the braid using gentle pressure.

4. The wicking may be drawn across the area to be resoldered after the solder melts and begins to soak into the wicking.

5. If solder stops flowing into the wicking before it has all been removed, or if all the flux is boiled away, the operation must be repeated after cutting off the solder-filled portion of the wicking.

6. Better wicking action is afforded as the number of strands increases and the size of the strands decreases.

7. Ensure that heat is not excessive. Excessive heat will boil away the flux and cause scorching.

8. Ensure that wicking does not contact board material. "Measles" (pitting) will result from hot wicking overlapping the pad area and contacting board material.

4-6.7 MANUAL SOLDER EXTRACTION PROCEDURES

The procedures for solder removal using a manual solder extractor are as follows:

1. Simultaneously apply the soldering iron tip and the extractor tip to the area to be resoldered. (Note that space may be a limiting factor.)

2. Upon observing a complete solder melt, press the release trigger which creates a vacuum to extract the solder.

3. Hold extractor firmly to minimize recoil and give better solder extraction.

4. This manual method may not remove all the solder and may even cause circuit pad lifting due to high vacuum generated and movement of the extractor tip.

5. To maintain efficient operation, disassemble, clean and lubricate the extractor thoroughly on a regular basis.

4-6.8 COMPONENT REMOVAL

Component removal procedures after solder extraction are as follows:

1. Straight-through terminations allow the component to be lifted gently from nonconformal coated boards.

2. The various clinched-style terminations may require the breaking of a sweat joint. This may be done by gripping the lead with pliers or tweezers and then rotating the clinched portion approximately 300 parallel to the board.

3. After breaking the seat joint the lead may be lifted gently to a straight-up position.

NOTE

Do not attempt to lift or straighten the lead until the sweat joint is broken.

4-6.9 FINAL RESOLDERING INSPECTION

The completed work should be inspected for damage to the circuit board or to the remaining components. With respect to component damage, inspect for cracked, broken, or heated components; deformed or broken leads; poor solder jointa and loose or splashed solder which may cause shorts. Additional inspection should be conducted for the following damaged conditions:

1. Scorching or charring caused by component failure or improper repair techniques.

2. The appearance of white spota indicates small areas of the fiberglass strands have been exposed by heat, abrasion or solvent action.

3. Possible cracks or breaks in the board material.

4. Missing pads or conductors.

5. Nicked or cracked conductors.

6. Lifted or delaminated pads or conductors.

NOTE

If any of the above conditions exist, deliver the board to a 2M station for repair.

4-7 SOLDERING OF WIRE TERMINALS

The most widely used terminals are the turret, hook and tab types. The identification, preparation, and soldering of turret, hook, and tab terminals are described in the following subparagraphs.

4-7.1 TERMINAL TYPES, SIZES, AND USAGES

The three general types of terminrds (Figures 4-3, 4-4) in common usage are the turret, hook, and tab. Turret terminals can be either single or multiple sectioned, and are designed to protrude from one side of the mounting surface only, or protrude from both sides (feed-through types). The most common types of hook terminals used are the “J” style and “?” mark style. The most commonly used tab terminal is the pierced tab eyelet type. When selecting terminals, ensure that the terminal size and conductor or component size are compatible. Conductors and components that are too large for a given size terminal will place an undesirable stress on that terminal. Turret terminals are used for interracial connections on printed circuit boards, terminal points for pointto-point wiring, for mounting components, and as tie points for interconnecting wiring. Hook and tab terminals are used to provide connection points on sealed devices and terminal boards. Tab terminals on connector pins are normally made end-on.

4-7.2 TERMINAL PREPARATION FOR SOLDERING

Prior to soldering, all terminals must be thoroughly cleaned to ensure a well-soldered joint. The initial cleaning may be accomplished by adding and then removing excess solder from the terminal. For old, used, or very dirty terminals, some abrasion may be required to clean completely. Solvent cleaning is required after any of the other cleaning methods is completed. After completion of cleaning and prior to soldering the connection, all terminals must be tinned.

4-7.3 CONDUCTOR PREPARATION FOR SOLDERING

In preparing the conductor end for termination, first determine the length of insulation that should be removed. Cut the insulation, using thermal strippers (preferred) or non-adjustable factory-set strippers. Next, using the fingers, slowly remove the piece of cut insulation allowing it to turn and follow the lay of the conductor strands. Do not change the rate of twist of conductor strands when removing insulation. Ensure there is no damage caused by

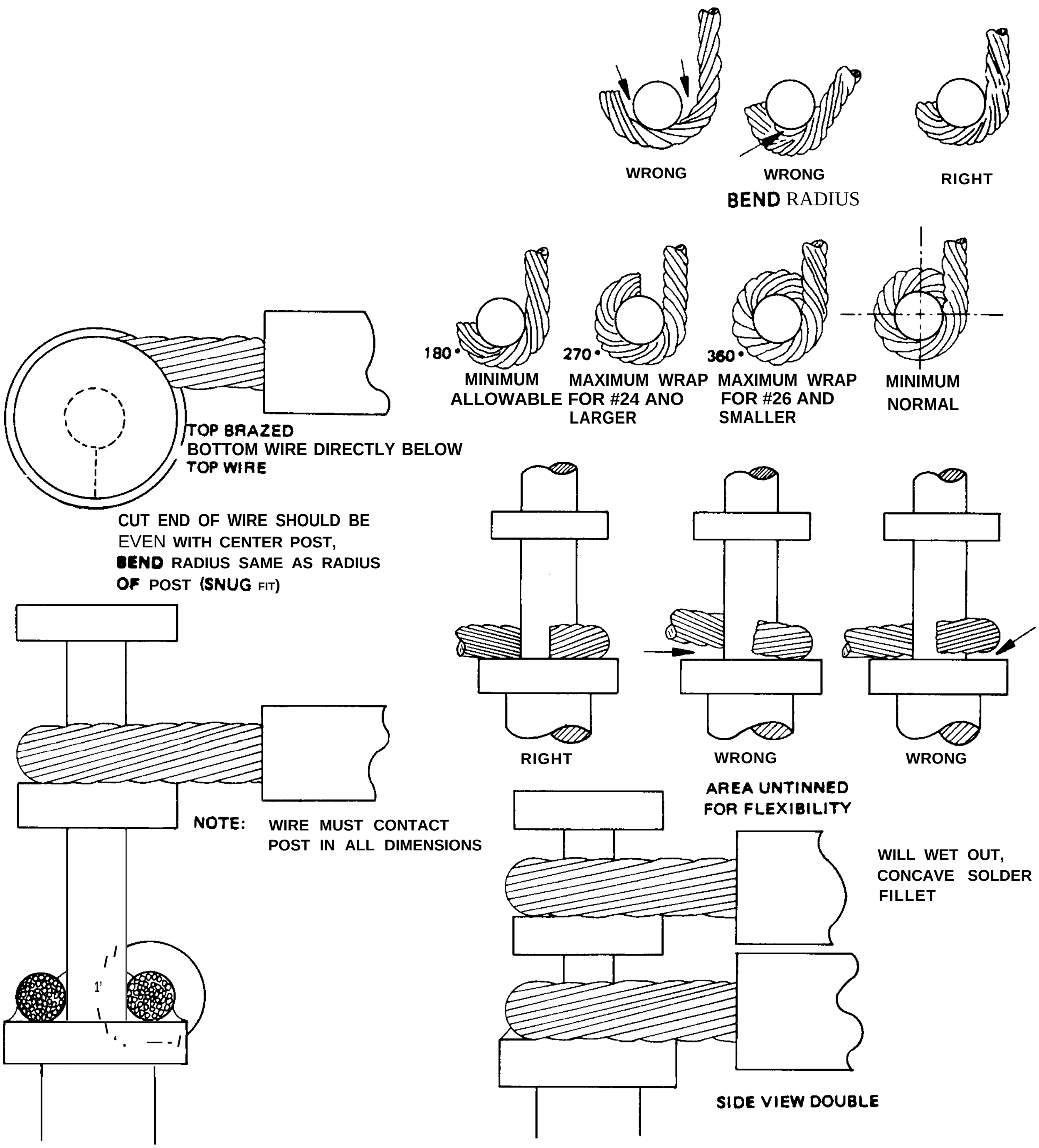


Figure 4-3. Turret Terminal Types and Wire Wrappings

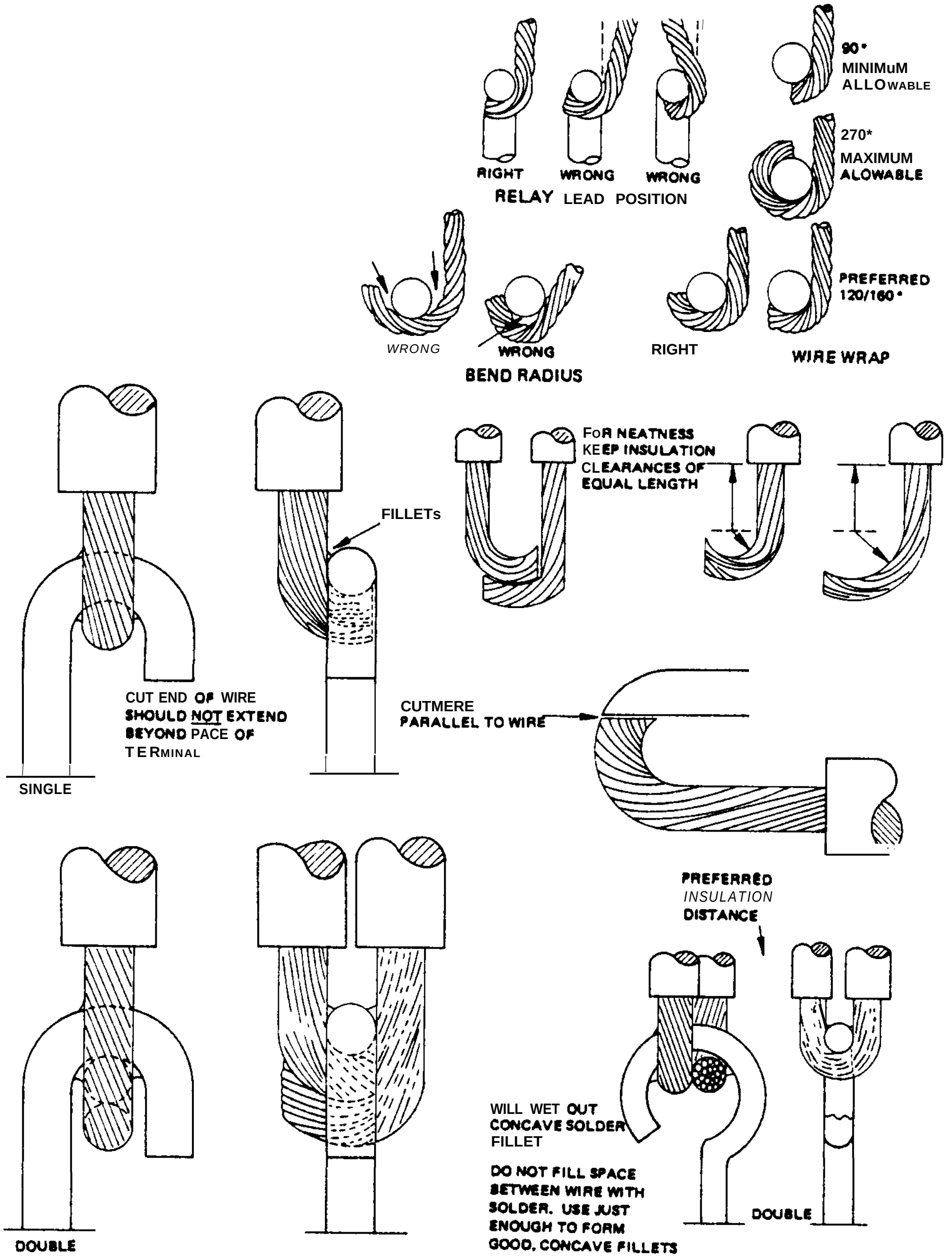


Figure 4-4. Hook and Tab Terminal Types and Wire Wrappings

stripping, such as cuts, nicks, or birdcaging. Any of these is cause for rejection. After completion of stripping, the conductor must be tinned. Tinning is required to prevent damage incurred in the bending process. The use of an antiwicking device is recommended to prevent capillary action from pulling solder under the insulation. When tinning while using the antiwicking device, bring the clean, dry soldering iron in behind the conductor about one-half the distance from the antiwicking tool. Next, apply solder to junction of iron and conductor, allowing solder to soak into conductor strands. Move the iron and solder toward the antiwicking tool, hesitating just enough to overcome heat-sinking and then move the iron and solder hack down and off end of conductor. If properly tinned, the individual conductor strands will still be visible. The tinned conductor end may now be bent or shaped, using any method that does not damage the conductor in any way. Typical bending tools are round-nose pliers, nylon rod, orangewood sticks, and dummy terminals.

4-7.4 ATTACHMENT OF CONDUCTORS TO TERMINALS

Attaching the conductor properly to the terminal prior to soldering is as important as the soldering operation itself. Figure 4-3 illustrates both correct and incorrect methods of attaching conductors to turret terminals in preparation for soldering. Figure 4-4 illustrates both correct and incorrect methods of attaching conductors to hook and tab terminals prior to soldering. The following requirements should be followed to ensure a good firm connection ready for soldering:

1. On turret terminals, the minimum wire wrap is 180” and the maximum is 2700 for AWG-24 and larger conductors, and 360” for AWG-26 and smaller conductors. The preferred wrap dimension is 180”.

2. On hook and tab terminals the minimum wire wrap is 90” with the maximum wrap being 2700. The recommended wrap for hook terminals is 120”, while the wrap dimension is 180” for tab terminals. When the wrap is 1200, the wire is not cut straight across but at an angle to form a flush surface with the terminal when installed.

3. The size of the bend shall be such that it will tit snuggly against the terminal.

4. On turret terminals, the conductor should lie flat against the pad.

5. For multiple connections on turret terminrds, all conductors should be wrapped in the same direction and trimmed to the same length. The conductors should be positioned directly above each other.

6. On hook terminals, the conductor entry should be vertical. On tab terminals, the conductor entry need not be vertical to the terminal mounting surface.

7. For multiple connections on hook terminals all conductors should approach the terminal from the same direction, but the wrap is laid in alternating directions. If necessitated by conductor and terminal sizes, the conductors can be piggybacked.

8. The insulation gap shall be no greater than two times the overlap diameter of the conductor, including the insulation. The preferred distance is one conductor diameter.

4-7.5 SOLDERING OF CONDUCTORS TO TERMINALS

When applying heat and solder to the prepared termination, care shall be taken to prevent wicking and damage to the insulation from excessive heat. When soldering conductors to turret terminrds, the iron should not contact the conductor as it may cause displacement (See Figure 4.5). The majority of the heat must be on the pad, with transfer to the conductor through the solder heat bridge. This will also decrease the chances of wicking. When soldering conductors to hook terminals, the iron must contact the conductor for heat transfer (see Figure 4-6). Use care to keep the iron from pushing against the conductor and causing misalignment. The completed solder joint should have adequate solder coverage without spillage of solder over sides of the terminal and with the contour of the conductor strands visible. The solder should present a bright shiny surface and there should be fillets at all points of contact.

4-8 ELECTRICAL WIRE SPLICING AND HEAT-SHRINK TUBING

Wire splicing is frequently required due to poor maintenance practices or poor manufacturing techniques which allow stress or vibration to break wires. Three methods for splicing wire are possible, as shown in Figure 4-7. In some digital type equipment, splicing cannot be used because it may tend to change conductor characteristics and add noise to signal. This type of wire must be rerun or a spare wire used. The size of replacement wire and its type of insulation must match the original wire.

4-8.1 TYPES OF SPLICES

The wrap splice is mechanically prepared by laying two tinned wires across each other in an “X” pattern and wrapping them around each other

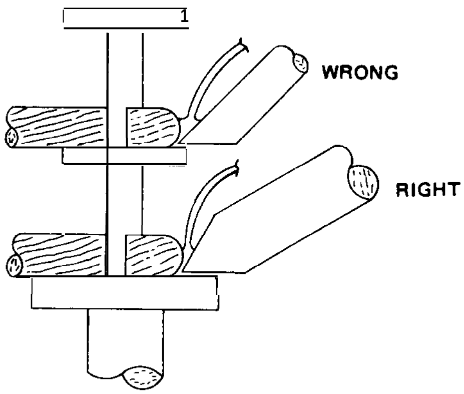


Figure 4-5. Turret Terminal Soldering Using Heat Bridge (Thermrd Linkage)

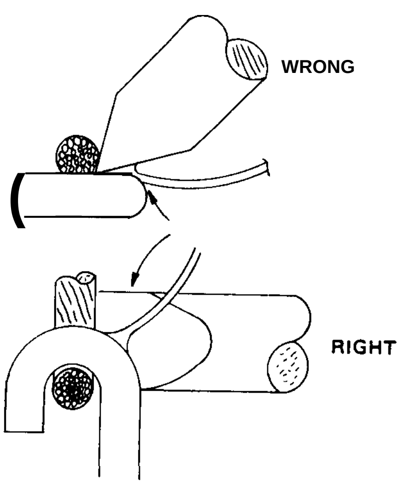


Figure 4-6. Hook Terminal Soldering Using Heat Bridge (Thermal Linkage)

several times, using a twisting motion of the fingers. To give proper strength and reliability, both wires must twist (not one straight wire with the other wrapped around it). The twisted portion should be tight, with the cut end of the wire flush cut and not protruding from the splice. The hook splice forms the strongest mechanical connection. However, it is also the largest diameter splice, which is often undesirable. This splice also requires a relatively long section of tinned wire. The splice is formed by making a "J" bend in each of the two tinned wire ends, and then linking the hooks together, with each wire then wrapped back around itself. The cut end of the wire must be flushed-cut, and must not protrude from the splice. The mesh splice has the smallest diameter and is the most flexible splice, but it unfortunately provides the least mechanical strength. This type of splice does not use tinned wires, a fact which is often an advantage. To form the mechanical connection, the wires are first fanned out into a cone shape. The wires are then pushed straight into each other so that the strands interlace evenly and without bunching. Finidly, the wires are gripped gently with the fingers and twisted in such a manner as to approximate the original wire lay. (This type of splice cannot be used for double twisted wires as the center core of the wire is laid reversed of the outer strands and therefore will not form the cone shape required.) The solder connection is also important in making splices. The specifications are the same as those for soldering any wire, namely:

1. Smooth concave fillets at all points of contact.
2. Bright, shiny surface to the solder.
3. Individual strands must be clearly visible through the solder.
4. No wicking.
5. No heat darnage to the insulation.

4-8.2 HEAT SHRINK TUBING

The use of some type of insulation is mandatory if splicing of a wire leaves an uninsulated area. Heat- shrink tubing provides the best material for insulating this area. The size of tubing used should be such that it will firmly seal over the original insulation when fully contracted, but not fit so tight that it will present a danger of splitting when the wire is flexed. The sleeving must he placed over the wire before making the solder connection. The tubing should never be positioned over the splice area until the solder connection has been thoroughly cleaned and inspected. The only reliable method of shrinking tubing involves the use of hot air since other methods (such as a soldering iron tip or open flame) are very likely to cause damage. When shrinking tubing, care must be taken to keep the hot air source moving so as not to concentrate the heat in one place, as this would cause the tubing to lose some of its insulating properties.

4-9 SO LDERABLE CONNECTOR PINS

There are two types of connector pins: solderable type, and crimp type. Crimp type connector pins shall not be soldered, and solderable type connector pins shall not be crimped. Electrical connector

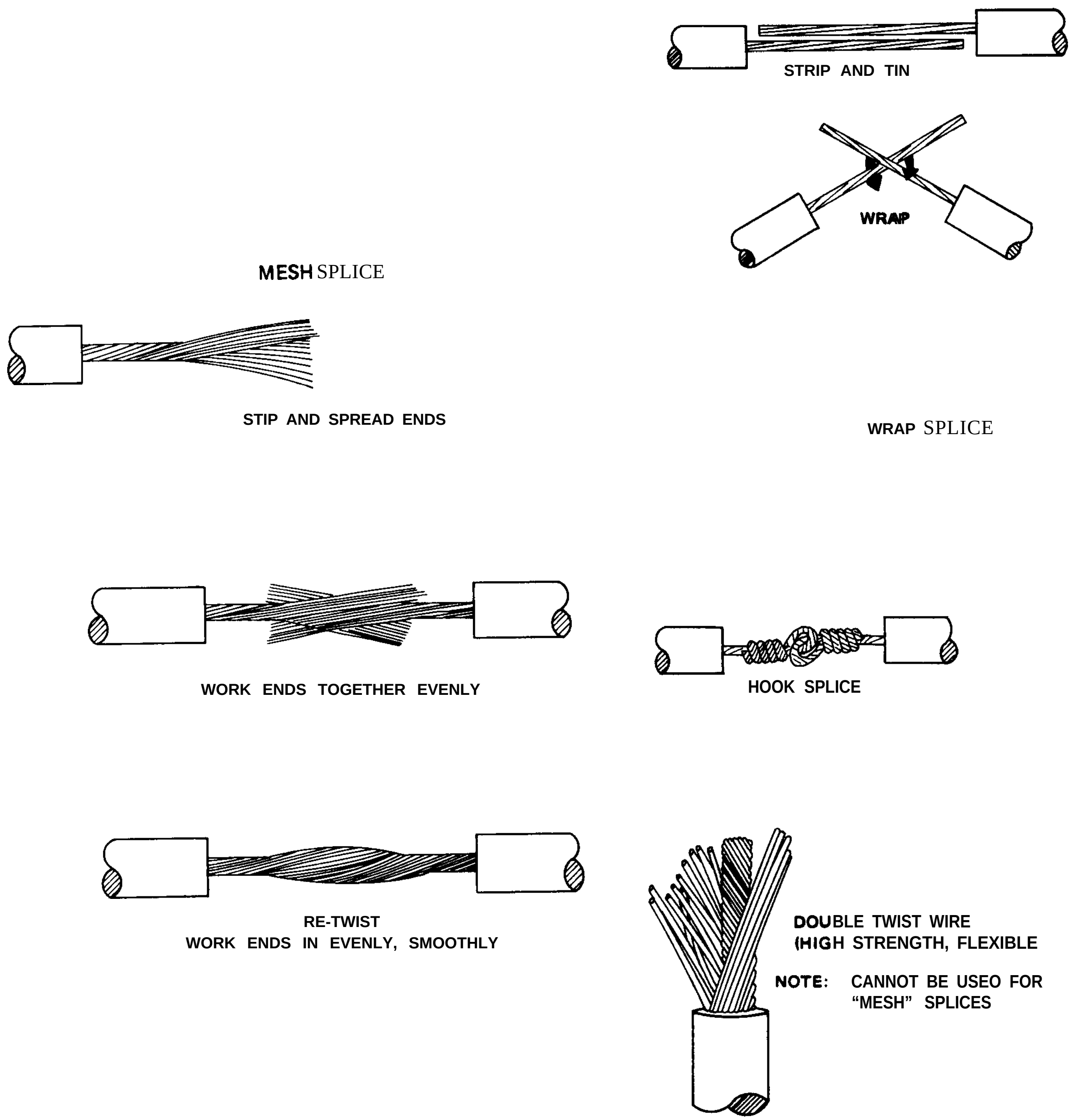


Figure 4-7. Wire Splicing Methods

pins designed for soldering are normally identified by a curve cut-out on one side of the solder cup of the pin, as shown in Figure 4-8. Coaxial connector pins designed for soldering do not have the curved cut-out, but instead have a small hole at the base of the solder cup for solder injection. The shape of solderable connector pins makes cleaning difficult, therefore tinning is the preferred method of cleaning. After cleaning, the connector pin should be prefilled by placing the correct amount of solder in the solder cup so as to form a finished soldered joint. When prebilling, ensure that a flux pocket does not exist at the bottom of the solder cup. The procedures and requirements for preparing conductor ends for terminal attachment also apply to connector solder pins. The conductor insulation should be cut back by using the pin solder cup as a gauge and the clearance between cut-back insulation and edge of the pin top is one conductor diameter. Insulated sleeving should be placed over all soldered pin connections to prevent possible short circuits. Electrical connectors that have insulating rings as part of the assembly do not require the individual insulating sleeving. Insulated sleeving cannot be used on coaxial connector pins.

4-9.1 SOLDERING REQUIREMENTS

The following requirements are necessary for obtaining quality workmanship when soldering electrical connector pins:

1. The conductor must be afigned exactly with the pin cup axis.
2. The conductor must be firmly bottomed in the solder cup to prevent flux or air entrapment.
3. Solder shall not extend beyond the confines of the solder cup or spill down over the sides of the pin (see Figure 4-8).
4. Edges of the cutaway portion of the cup shall be visible beneatb solder, with no portion of the internal face of solder cup showing.
5. There shall be a circular, concave fillet around the conductor where it enters the solder cup.
6. There shall be no evidence of heat damage to insulation.
7. There shall be no evidence of wicking.
8. There shall be a bright shiny surface to the solder.
9. Soldering iron shall be of correct size and shape to provide sufficient heat.

4-9.2 APPLICATION OF SOLDER

In connector pin soldering, the tinned conductor is applied to the solder, rather than applying the solder to the conductor. The following steps are necessary to accomplish a properly soldered pin:

1. Place antiwicking tool on conductor (preferably using antiwicking tweezers).
2. Apply soldering iron and observe the pin for solder melt. Position the iron as low as possible on solder cup to assure boiling-out of flux and gasses from bottom of cup.
3. Immediately insert the tip of the conductor partially into the solder cup at about 700 angle. Hesitate long enough to allow heat-sinking action of the conductor to be overcome.
4. After the solder remelts, very quickly move the wire to a full vertical position and then bottom it in the solder cup.
5. Maintain a slight downward pressure on the conductor until the soldering iron has been removed and the solder has solidified. This will aid in preventing formation of stress lines in solder.
6. Clean with a bristle brush and solvent.
7. Apply heat-shrinkable sleeving.

4-1o SOLDERING TOOLS AND CONSUMABLES

Correct soldering iron tip temperature is important, and can be controlled by varing the voltage to the iron. This is advisable because, in performing high quality work, the tip temperature must be proportional to the mass of the piece to be soldered. Also, excessive heat can deteriorate wire insulation or damage an “eye pad” on a printed circuit card. Commercial companies, such as PACE and WELLER, offer several voltage control models which can vary the tip temperature of their irons. If none of these commercial controls can be procurred, a voltage-controlled outlet box, such as depicted in Figure 4-9, can be constructed by the technician, using the parts listed in Table 4-1 and performing the following steps in sequence:

1. Split dark-colored side of receptacle (Figure 4-9).
2. Connect black wire from power cord and wire from switch (located on back of pot on voltage control) to one dark terminal.

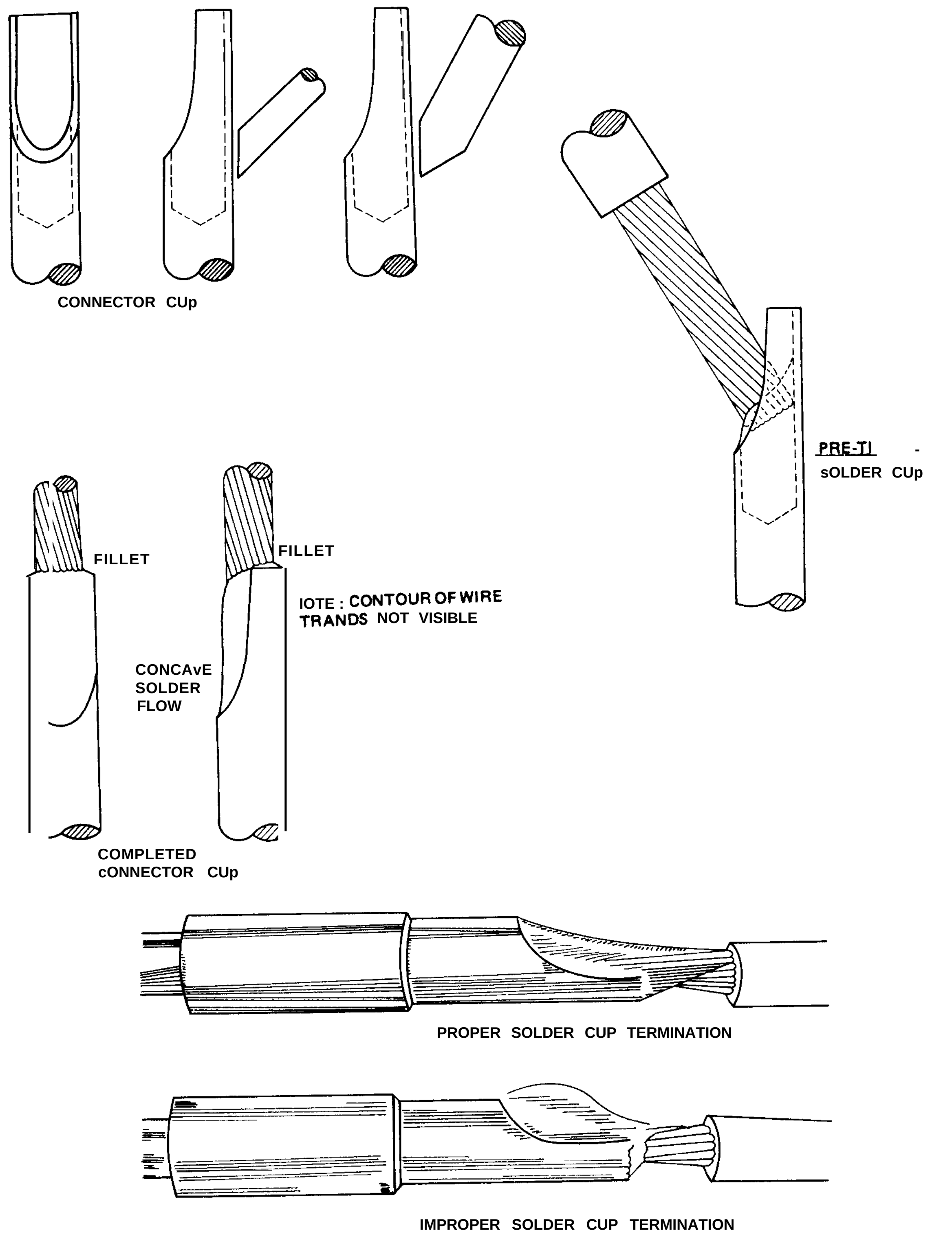


Figure 4-8. Electrical Connector Pin Solder Cup

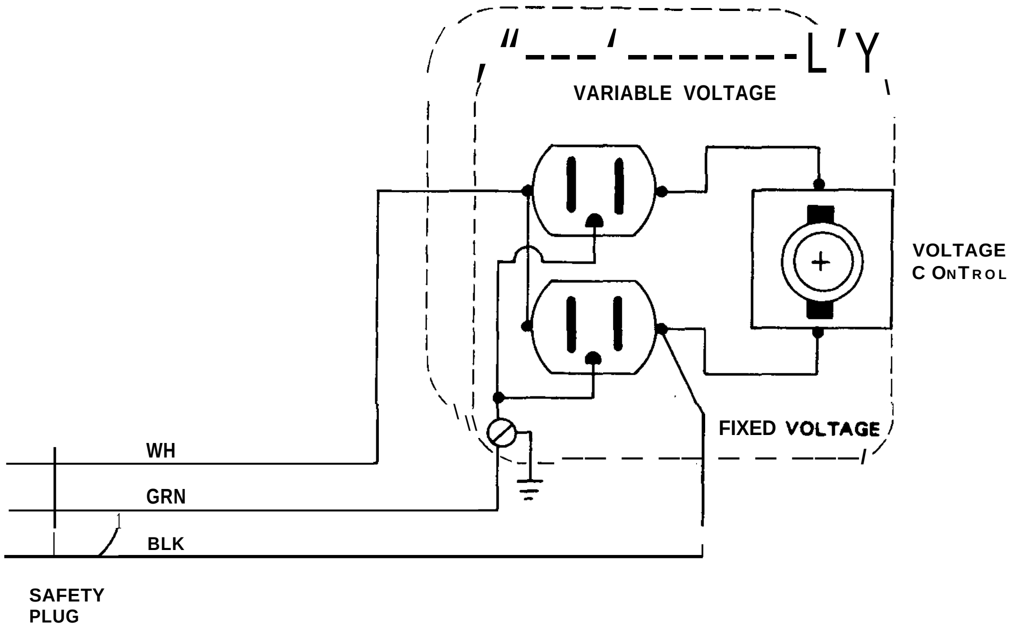


Figure 4-9. Voltage Control for Soldering Iron

Table 4-1. Voltage Control Parts List

ITEM NAME	EST. PRICE	STOCK NUMBER
Box, Electrical	$0.43	5975-00-194-8878
Cover, Box, Electrical	0.26	5975-00-281-0053
Control, Voltage	5.74	6210-01-035-8680
Receptacle, Duplex	0.94	5935-01-012-3080
Cord, Power, Three-Wire	1.12	6150-00-431-8027
Connector, Box, Electrical	0.14	5975-00-152-1144
Knob	0.44	5355-00-680-1357

3. Connect remaining black wire from voltage control to remaining dark terminal.

4. Connect white wire to light terminal.

5. Connect green wire to ground terminal.

6. Voltage control will cover hole in plate by moving it to one end of slot.

Other recommended soldering tools and accessories are listed in Table 4-2. Soldering consumables are listed in Table 4-3.

Table 4-2. Recommended Soldering Tools

ITEM	FSCM	REF/DISCR	ITEM NAME	UI	STOCK NUMBER
1	71827	Clauss #AW-20	Antiwicking tweezers	EA	9G 3439-00-954-1269
2	72827	Clauss #AW-22	Antiwicking tweezers	EA	9G 3439-00-954-1270
3			Brush, acid	GR	9Q 7920-00-514-2417
4			Dispenser, liquid, 2 oz.	EA	9L 6520-00-142-9039
5	33094	613	Dispenser, SLVT	EA	
6	81348	ZZE061	Eraser, ink, white	EA	9Q 7510-00-634-5035
7	13102	HS1	Heat-sink	EA	9N 5999-00-677-9839
8	13102	HS2	Heat-sink	EA	9N 5999-00-677-9849
9	13102	HS3	Heat-sink	EA	9N 5999-00-677-9861
10	19915	MS54-5	Pliers, dgl ctg, 4 inch (flush cut)	EA	9Q 5110-00-596-7164
11	19915	DN-54	Pliers, flt nose, med	EA	9Q 5120-00-234-1913
12	19915	LN-54	Pliers, lng nose chn, 4-1/2 inch	EA	9Q 5120-00-541-4078
13	19915	RN-54	Pliers, rnd nose, 4 inch	EA	9Q 5120-00-126-2076
14	02105	3108-s3	Soldering iron (use advice code 2B)	EA	9G 3439-00-134-9202
15	21325	DS017	Solder removaf tool	EA	9G 3439-00-132-1331
16	03051	SN63-20-1	Solder, awg 20	LB	9QS3439-01-O08-7578
17	03051	SN63-22-1	Solder, awg 22	LT	9QS3439-01-O08-7577
18	34605	40-1-5	Solder, wick #l	EA	9G 3439-00-545-3396
19	34605	40-2-5	Solder, wick #2	EA	9G 3439-00-403-5321
20	34605	40-3-4	Solder, wick #3	EA	9G 3439-00-009-2334
21	02105	Paragon 501	Tip, soldering 1/8 inch	EA	9G 3439-00-525-7393
22	17794	1121-0131	Tip, soldering 1/12 inch	EA	9G 3439-00-149-8197
23	81348		Tweezers, Craftsman	EA	9Q 5120-00-293-0149
24	81348	GGGV41O	Vice, work positioning	EA	9Q 5120-00-991-1907
25	78976	8000	Holder, Soldering Iron	EA	9G 3439-00-045-6527
26	81348	RRC 00140	Cash box (tools storage)	EA	7520-00-281-5931
27	18876	9177208-1	Wirestnpper, hand	EA	5110-00-542-4487

Table 4-3. Consumable Supplies

ITEM	FSCM	REF/DISCR	ITEM NAME	UI	STOCK NUMBER
1			Alcohol, isopropyl	GL	9G 6810-00-286-5435
2	81348	GGA616	Applicator-CTN TIPPED	PG	9L 6515-00-303-8250
3	75297	1544	Ffux, soldering	GL	9G 3439-00-752-8728
4	33591	9002	Wiper, disposable (large)	HD	9Q 7920-00-543-6492
5	33591	9005	Wiper, disposable (small)	BX (case)	9Q 7920-00-721-8884
6	80063	SCB9G203	Alignment tool/orangewood sticks	EX	
7	81348		Heat-shrink tubing	FT	

SECTION 5

MINIATURE REPAIR

5-1 INTRODUCTION

Tools not ordinarily used in servicing the conventional wired-circuit chassis are to be used in servicing a modular assembly or printed circuit board. Transistors and associated components used in this type of assembly are extremely small and require the use of tools of greatly reduced size in order to cope with the limited space encountered with this type of construction. In addition, special devices which extend the vision, aid the reach, and sometimes act as a third hand are required. Some of the tools required in this type of repair are shown in Figure 5-1. Many of these tools may be obtained through the ship's medical or dental officer. Others, if not carried in the normal supply system, may be procured tbrough commercial supply sources. All other tools normrdly required are standard handtools and are listed in the Electronics Tools Allowance List. The number of micro-miniature tools should be held to a minimum compatible with the actual maintenance needs.

5-2 REMOVING AND REPLACING PARTS

The removing and replacement of a part without damaging the modular assembly or printed circuit board and its associated parts require that the soldering tool and other handtools required be used with precision and skill. Thought should be given to the most appropriate procedure or method to use in the removal and replacement of the part involved. A part to be removed may be too close to a heat-sensitive semiconductor or other part to allow a hot pencil-soldering iron to be applied. A quick test to determine this safe distance is to place a finger between tbe semiconductor (or heat-sensitive part) and the part to be removed. Place the hot soldering iron in the position it is to be used. If the heat is too great for the finger, it is too hot for the semiconductor. After determining that the heat-sensitive parts are too close, place a shield between the parts before applying the hot soldering iron, and place heat-sink clamps on all leads from the heat-sensitive part. Solid-state parts and their associated circuitry are extremely sensitive to thermal (heat) changes. Therefore, particular care must be taken to prevent exposing them to heat. Heat-sinks and shunts must be applied with shields inserted to protect the associated parts any time repair or removal of a part requires the use of a hot soldering iron. Solid-state parts and associated assemblies require the same care in handling and skill of repairing that is applied to assemblies in equipment of unitized or modular construction containing transistors, tantalum capacitors, crystals, etc. Removal of an axial-lead part that has been bonded to a printed circuit board (with epoxy resin or similar compound) may be accomplished by breaking the defective part or by applying heat to the bonding compound. The method to use depends upon the part itself and its location. If the defective axial-lead part cannot be removed by heat, cut or break the part away from the bonding compounds as illustrated in Figure 5-2. "A" and "B" of Figure 5-2 illustrate two different methods of breaking the part away from the bonding compound where the part is too close to the other parts to use cutting pliers. In some instances, the part to be replaced is so closely positioned between other parts that one lead must be cut close to the body of the defective part to permit application of the prying tool as illustrated in "A." Wherever possible, cutting the defective part with end-cutting pliers or diagonals, as illustrated in "C," is the preferred method to use. Regardless of which tool is employed (round-pointed or spade-type), great care must be used in its application to prevent the printed circuit board or other parts from being damaged or broken. Apply the point of the tool against the bonding compound between the part and the printed circuit board. Use the tool in such a manner that it works away the bonding compound from the part to be broken away until enough has been removed by the tool to exert pressure against the part. Keep the leverage surface area of the tool flat against the surface of the printed circuit board; this helps to prevent the tool from gouging or breaking the board. BE CAREFUL – NEVER APPLY MUCH PRESSURE AGAINST THE PRINTED-CIRCUIT BOARD. After the defective part has been removed from the bonding compound, remove the leads or tabs from their terminals on the printed circuit board and clean the area thoroughly before installing the new part. Do not remove the bonding compound left on the board under the removed part unless its condition requires it. The mold left in the compound should be the same as for the new part; thus, inserting the new part in this mold helps secure it from vibration. Install the new part and, after repairs have

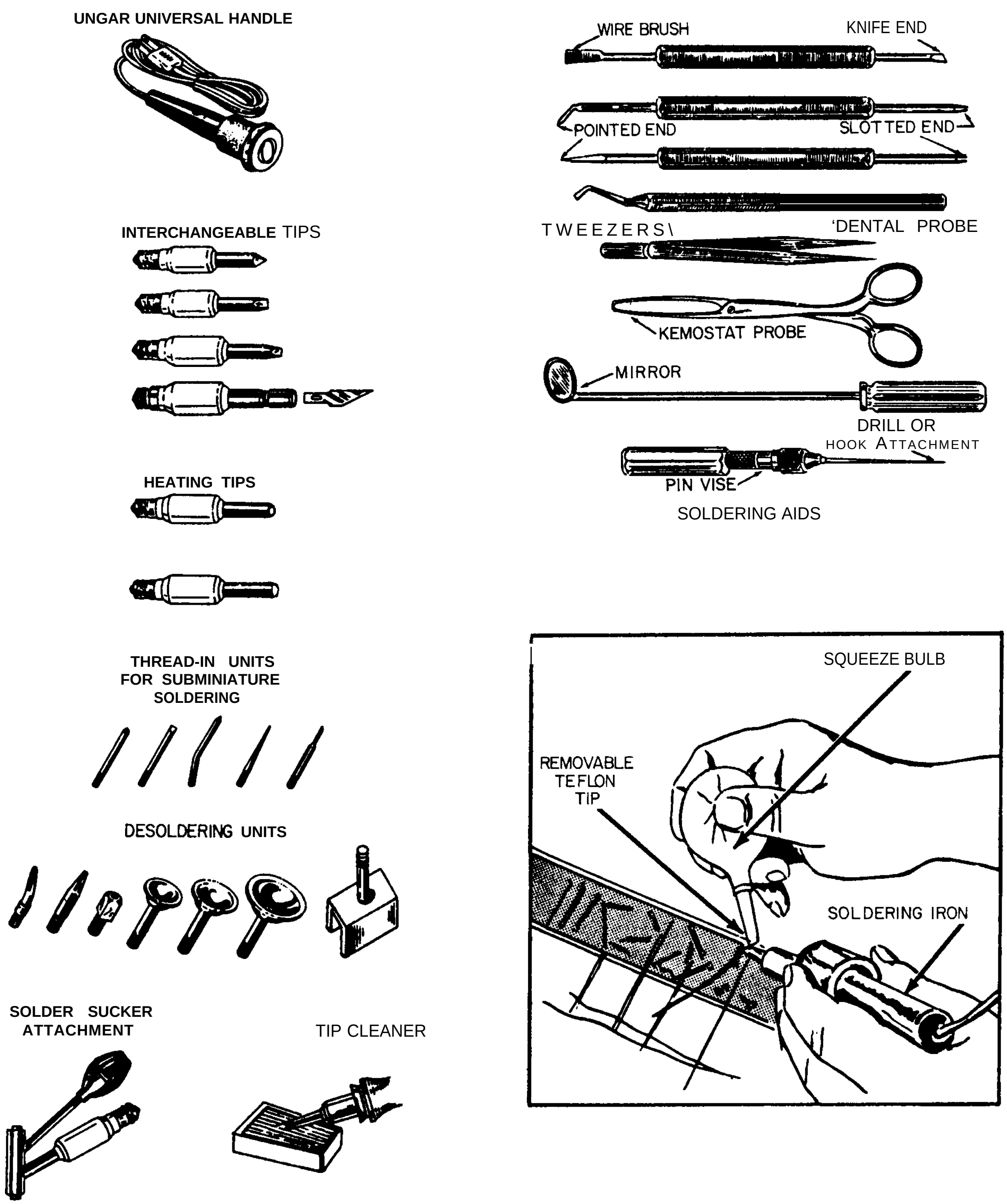


Figure 5-1. Miniature Tools

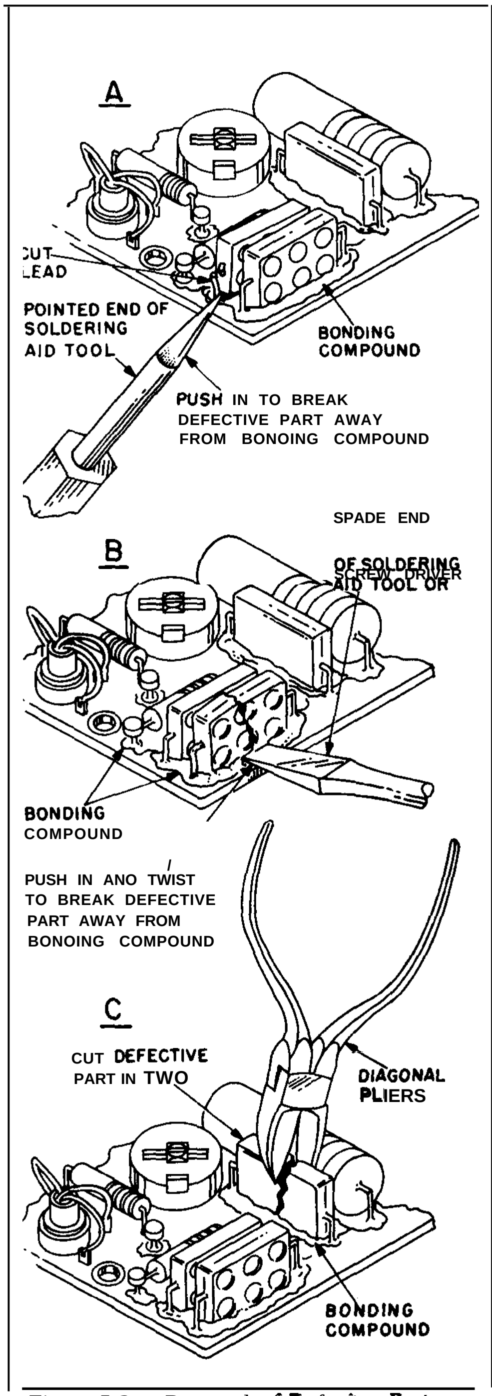


Figure 5-2. Removal of Defective Parts

been completed and the circuit tested, spray the newly soldered area with an insulating varnish (MIL-V-1137A or equivalent). Coat the new part or parta with a bonding compound (Epibond by Furane Plastics or equivalent). To remove a proven defective transistor, first cut all of its leads, and then remove it from the assembly. Transistors are mounted on circuit boards in many different ways; therefore, it is necessary to study how the transistor is mounted before attempting to remove it. A transistor with clamp-type mounting requires only a pointed tool between the clamp and the transistor to remove it. A transistor mounted in a socket may have a wire spring clamp. Remove the clamp before pulling the transistor out of its socket. Where the transistor is bolted through the board, remove the nut and washer, and then remove the transistor. Where vibration is a prime factor, the manufacturer will mount the transistor through the circuit board and bond it with epoxy resin or similar compound. For this type of mounting, a flat-ended round-rod-type tool (drift punch) of a diameter less than that of the transistor case is required. Before removing the transistor, ensure that the printed circuit board, on which the transistor is mounted, is secured in a proper device as illustrated in Figure 5-3 and in such a way that the pressure exerted against the circuit board will be relieved by a proper support on the other side. Apply a hot-pencil soldering iron to the bonding compound and simultaneously apply the drift punch against the top of the transistor, exerting enough pressure to remove the transistor from the softened compound, and then on through and out of the circuit board as illustrated in Figure 5-3. After the defective transistor has been removed, remove the remaining pieces of the leads from the terminals on the board. Clean and prepare the terminafs on the board before installing the new part. Before installing a new transistor, great care must be taken to prepare the new part for installation. Test the transistor in a transistor tester (TS-1100/U or similar equipment) before installing. This precaution will assure that the transistor is good before it is installed. Pre-shape and cut the new transistor leads to the shape and length required for easy replacement. Use sharp cutters and do not place undue stress on any lead entering the transistor. The leads are fragile and are therefore susceptible to excessive bending or too sharp a bend. Shape and bend as required in a gradual curve, at least l/4-inch to 3/8-inch from the base of the transistor. A safety measure which can be taken to ensure that the lead does not break off at the base is to use two pairs of needle-nose pliers. Grasp the lead close to the transistor base with one pair of pliers, whife shaping the rest of the lead with the other pair. The above procedure and precaution is applicable to

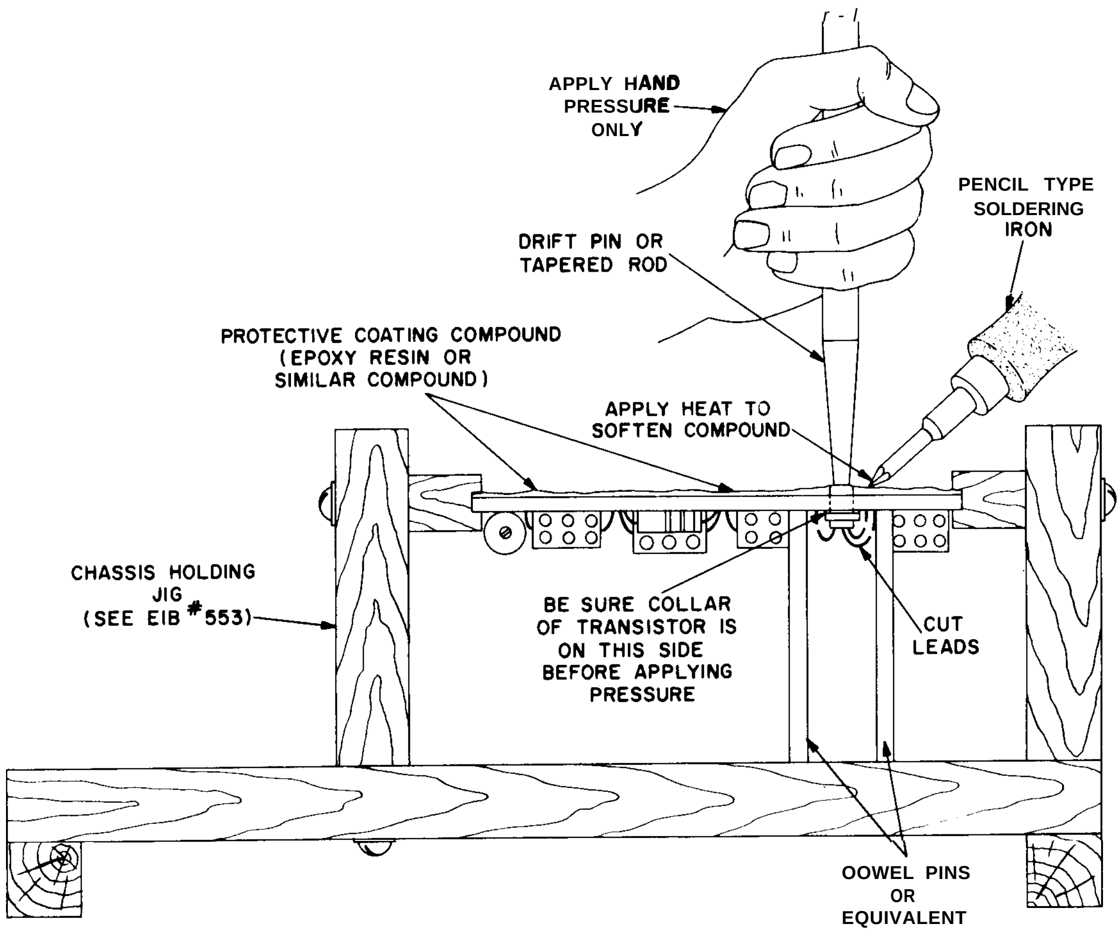


Figure 5-3. Transistor Removal

any and all semiconductors, tantalum capacitors, and other miniaturized parts in equipment of modular or unitized construction. Where the defective transistor was removed from a through-board mounting and bonded, care must be taken that the new transistor clears the hole before it is connected to its terminals. If the hole is too large, shim with a thin plastic sleeve (fabricated). If the hole is too small, ream it to accept the new transistor. Rebond the fitted transistor after testing the repaired circuit and it is proven to be operative. DO NOT use heat to rebond semiconductors. To remove and replace a multi-lug part, such as a transformer, choke, filter, or other similar potted, canned or molded part, release the part from its mounting before disconnecting or cutting its conductors. Before applying pressure to remove the part, carefully inspect it to be sure that the part is completely free of all its connections to the printed circuit board, and that all bent or twisted mounting lugs have been straightened; otherwise, it is possible to break the board by applying undue pressure to it. Never wrench or twist a multi-lug part to free it, because this will cause the conducting strip to become unbended from the board. Work this type of part in and out in line with its lugs, as shown in Figure 5-4, while applying a hot-pencil soldering iron (using a bar-type tiplet adapter or resoldering tool). Whenever possible, cut the conducting leads and lugs of the defective multi-lug part on the mounting side of the board, as shown in "B" of Figure 5-4. Heat and straighten the clipped leads with a hot-pencil soldering iron and a slotted soldering-aid tool (or slotted soldering iron tiplet adapter or similar resoldering tool) applied to the circuit side of the board; then pull the leads or tabs through with pliers as shown in "C" of Figure 5-4. When installing a new multi-lug part,

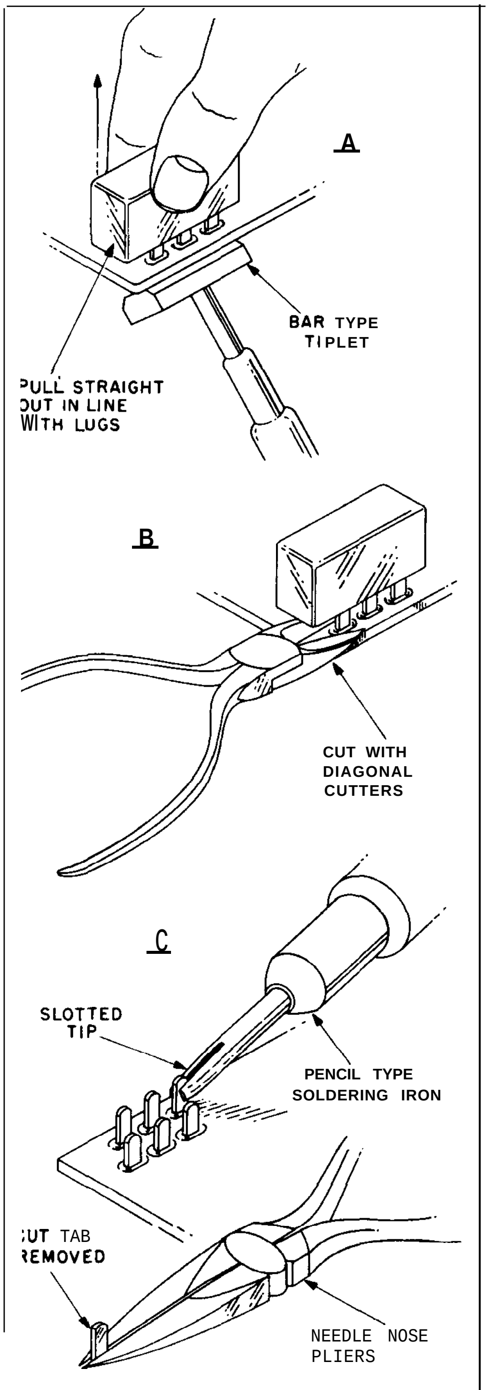


Figure 5-4. Removal of a Multi-Lug Part

be sure that all of the lead holes or slots are free and clean, allowing easy insertion of the part. If the part does not position easily, check and rework the terminals and holes (or slots) until it does seat freely.

DO NOT force any part into position on a printed circuit board. The board may break or may lift the printed circuit strip and eyelet terminal. Considerable care must be taken when replacing a defective part that terminates on miniaturized standoffs, feedthrough terminals, and such. These small terminals break easily from applied pressure (too heavy an application when applying a tool or soldering iron), or they may melt loose due to excessive heat produced by prolonged application of the hot soldering iron.

5-3 SPECIAL SOLDERING TECHNIQUES

Replacement of miniature and subminiature parts found in modular assemblies requires more consideration than is normally given to parts in the servicing of other electronic equipment. Before attempting repair, maintenance personnel should become thoroughly familiar with the correct repair and soldering techniques, since servicing procedures used differ in a number of ways. The compactness of modular assemblies makes it imperative that a small, low-wattage pencil iron be used. The soldering iron should have a small tip so that heat can be applied directly to the terminal of the part to be removed or replaced, without overheating the printed circuit board or adjacent parts. practical soldering irons, with tips specially designed for soldering and unsoldering parts from printed circuit boards, have been developed by a number of companies. The off-set or straight-slotted tiplets will simultaneously melt the solder and straighten the leads, tabs, and small wires bent against the board or terminal. The bar tiplet will remove straight-line multiterminal parts quickly and efficiently. The cup-shaped tiplets, the triangle tiplet, and the hollow-cube tiplet are specially designed to withdraw solder from circular or triangular mounted parts in one operation. The most important requirement for repairing modular assemblies and printed circuit boards is for skill in the soldering and unsoldering of parts. Careless work creates damage. Take time and be precise. When applying solder, remember that the iron must heat the metal to solder-melting temperature before actual soldering can take place. The solder-melting temperature is reached in a matter of seconds (5 to 10 seconds); therefore, the soldering iron and the solder strand must be applied simultaneously. Make certain to apply the solder to the joint, wire, or contact to be soldered, not to the soldering iron. Before applying any solder to a part be sure that the terminal, or any portion of the part to be soldered, is properly cleaned and tinned before positioning it for soldering. Do not tin printed circuit terminals; just clean any moisture, grease, or wax from the printed ribbon with a stiff-bristle brush and methyl chloroform or alcohol. Be sure the cleaning solvent has dried before applying the hot soldering iron.

CAUTION

Alcohol is flammable. Methyl chloroform is not flammable, but heating it increases its toxic hazard.

Use methyl chloroform only with adequate ventilation and avoid prolonged or repeated breathing of its vapor or contact with the skin.

5-4 PRINTED CIRCUIT AND MICROELECTRONICS TECHNIQUES

Because printed circuits are small and compact, it is essential that maintenance personnel become familiar with the special servicing techniques required for this type of repair. In all instances, it is advisable to first check the defective printed circuit before beginning work on it to determine whether any prior servicing has been performed. Not all personnel having access to this type of equipment have the skill and dexterity required; hence, some preliminary service may be necessary. Observing this precaution may save a great deal of time and labor. The defective part should be pin-pointed by a study of the symptoms and by careful and patient analysis of the circuit before attempting to trace trouble on a printed circuit board. It must be ascertained whether the lands (conducting strips) are coated with a protective lacquer, epoxy resin, or similar substance. If any of these protective coatings have been applied, they must be removed and the surface must be properly cleaned before corrective maintenance can be performed on the equipment.

5-4.1 REMOVAL AND REPLACEMENT OF PROTECTIVE COATINGS

Many manufacturers of equipments used by the Navy apply protective coatings (also called conformal coatings) to their equipment. These protective coatings include epoxies, silicones, polyurethane, varnishes and lacquers. Most of the coatings consist of a synthetic resin dissolved in a volatile solvent. When properly applied to a clean surface, the solvent evaporates, leaving a continuous layer of solid resins. After curing, this coating protects against environmental stress, corrosion, moisture, and fungus. These protective coatings may be removed by chemical or mechanical means. The application of chemical solvents is not recommended, however, as they may cause damage to the printed circuit boards by dissolving tbe adhesive materials that bond the circuits to the boards. These solvents may also dissolve the potting compounds used on other parts or assemblies. Most polyurethane protective coatings can be removed by applying heat to the area to be cleaned, then gently scraping the coating with an X-acto knife. Detailed procedures for the removal and replacement of conformal coatings by this method and the tools and materials required are given in the following subsections.

54.1.1 Tools and Materials

The tools and materials in the following list are required to remove and replace protective coatings. The FSN or manufacturer’s part number is given in Table 5-1.

- Printed circuit card holder
- Teflon tape
- Soldering iron
- Brush, nylon
- X-acto knife
- Cotton swabs
- Alcohol, isopropyl
- 3X, 4X, and 12X viewers
- Polyurethane coating or epoxy-resin compound

5-4.1.2 Removal of Protective Coating

To remove the protective coating from the printed circuit board the following procedure is recommended:

1. Place the printed circuit board in the card holder as shown in Figure 5-5.

2. Mask the area that is not to be stripped of the protective coating with Teflon tape as shown in the figure.

CAUTION

Excessive heat may damage the printed circuit board or surrounding parts.

Table 5-1. Tools and Materials for Parts Removals

Item	Quantity	FSN or Mfg. Part No.	Manufactured by or Equivalent
Part 1– Required Tools			
Ungar Universal Handle	1	’777	Ungar
Thread-in Element, 23-1/2 Watts	1	535	Ungar
Thread-in Element, 37-1/2 Watts	1	1235	Ungar
Thread-in Element, 47-1/2 Watts	1	4045	Ungar
Pencil Tip	1	PL331	Ungar
Pencil Offset Tip	1	PL332	Ungar
Chisel Tip, Long Taper	1	PL333	Ungar
Tapered Needle Tip	1	PL338	Ungar
Stepped Pencil Tip	1	7154	Ungar
Ungar Hot-Knife Tip	1	4025	Ungar
Offset Slotted Tip	1	862	Ungar
Straight Slotted Tip	1	857	Ungar
Hollow Cube Tip	1	863	Ungar
Cup Tip, 5/8” Dia.	1	856	Ungar
Cup Tip, 3/4” Dia.	1	855	Ungar
Cup Tip, 1“ Dia.	1	854	Ungar
Desoldenng Tip (DIP)	1	859	Ungar
Desoldenng and Cleaning Tool	1	7800	Ungar
Soldering Iron Holder	1	8000	Ungar
Kleen-Tip Sponge and Tray	1	400	Ungar
Low-Voltage Soldering Iron	1	6970	Ungar
Printed Circuit Card Holder	1	371	Henry Mann Co.
Steel Bench Clamp	1	356	Henry Mann Co.
Miniature Vise	1	353	Henry Mann Co.
Illuminated Magnifier, 3 Power	1	LFM-1	Henry Mann Co.
Clip-on Lens, 4 Power	1	No. 1	Henry Mann Co.
Desoldenng and Cleaning Tip, 0.33”	1	7812	Ungar
Hemostat	1	8-907	Fisher Scientific Co.
Hand Tool - lead trimmer (TO type package)	1		Henry Mann Co.
Resoldering and Cleaning Tip, 0.057”	1	7806	Ungar
Desoldenng and Cleaning Tip, 0.069”	1	7813	Ungar
High-Intensity Lamp	1	5975	Tensor
Lead-Forming Tool	1	ATH-3260	Astro Tool Co.
DIP Package Puller	1	6982	Ungar
45 ‘Chain-Nose-Tip Cutter	1	A119	Henry Mann Co.
Toothpicks, Round	1 Box		
Wooden Dowels, 1/4” x 6“	10		
Triceps Tweezer, 8“	1	T8	Henry Mann Co.

Table 5-1. Tools and Materials for Parts Removals - Continued

Item	Quantity	FSN or Mfg. Part No.	Manufactured by or Equivalent
Part II – Required Materials			
Insulating Varnish	1 pt	5970-280-4920	
Epoxy-Resin Compound	1 Kit	8040-777-0631	
Potting Syringes	12	E-602	Fishman
Epibond	1 Kit	H-1331	Furane Plastics
Acid Brushes	12		
Solvent Dispensers	4	613	Henry Mann Co.
Polyurethane Coating	1 Kit	**CE-1155**	Conap, Inc.
Isopropyl Alcohol	1 pt	TT-1-735	
Methyl-Ethyl Ketone	1 pt	‘IT-M-261	
Acetone	1 qt	6810-281-1864	
Copper Shim Stock	.003”		
Aluminum Oxide Abrasive Paper	10 Shts/Box	5350-967-5080	
Cotton Swabs			Johnson & Johnson
Teflon Tape - 1“	1 Roll		

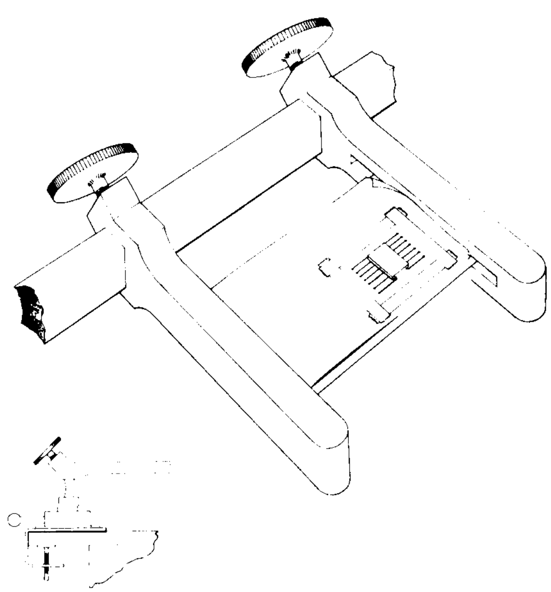


Figure 5-5. Printed Circuit Card Holder

3. Heat a small area of the coating to be removed by holding a soldering iron close to the surface, but do not touch the board with the iron.

CAUTION

Do not apply excessive pressure during scraping as this may cause nicks on the lands of the board or damage to the leads of other parts.

4. When the protective coating softens, gently scrape it away from the surface with an X-acto knife.

5. Remove loosened particles of protective coating by gently brushing. Assure that loose particles of coating do not contaminate any moving parts.

6. Repeat steps 3 through 5 until all coating has heen removed from the area exposed by the mask.

7. Cleanse the area with a cotton swab that haa been dipped in alcohol to remove all loose particles of protective coating that remain after brushing.

8. Remove the mask and clean the area with a cotton swab and alcohol to ensure that no loose particles of coating remain on the perimeter of the stripped area.

9. Using a 12X viewer, visually examine the cleansed area to assure that the area is clean and that no darnage was done during the cleaning operation.

4

5-4.1.3 Replacement of Protective Coating

To replace the protective conformal coating on the printed circuit board the following procedure is recommended:

CAUTION

Protective coatings may affect the capacitance (air dielectric capacitance between leads) and the Q of inductors in RF assemblies. Refer to the appropriate maintenance procedures in the equipment technical manual concerning alignment procedures and the proper use of protective coatings for RF assemblies.

1. Using a 12X viewer, visually inspect the repaired board for foreign particles.
2. Clean area to be coated with a cotton swab that has been dipped in alcohol.
3. Allow the printed circuit board to dry thoroughly. Drying time will depend on the cleansing agent used (alcohol is recommended).
4. Mask the area that is not to be coated as shown in Figure 5-5. The unmssked area should be large enough to allow some overlapping with the old coating to assure adequate protection.
5. Spray the exposed area with three layers of protective coating material, allowing sufficient time for curing between successive coats. Several thin coats are more effective than one heavy coat. If the coating material has a tendency to porosity, it is unlikely that the pinholes will occur in exactly the same positions on successive coats.
6. Remove the mask and inspect the reworked area, using a 12X viewer, for any voids or pinholes. If any voids or pinholes are observed, add another coat of protective coating.

5-4.2 REPAIR OF PRINTED CIRCUIT BOARDS

Printed circuit assembly wiring patterns are formed in three basic ways: by painting, chemical deposit, and as stamped or etched metal foil. Shipboard repair of painted and chemically deposited printed wiring patterns is not recommended because the necessary specialized equipment is not always available. The metal foil printed wiring patterns consist of a thin metal foil bonded to a nonconductive base. The wiring pattern is produced by stamping the foil before bonding it to the base, or by chemically etching away unwanted portions of the metal foil after bonding to the base. Because metal foil is the most readily repairable and most commonly used type of printed wiring board, the repair techniques described in the subsection apply to metal foil printed circuits only. The major cause of printed circuit board failures attributable to maintenance actions is mishandling during fault isolation and replacement of parts. It is important, therefore, that care be exercised in performing maintenance. After isolation of a fault to a printed circuit board, the board should be visually examined to determine the possible cause of the fault. If the cause is not readily apparent, the lands on the boards should be checked for continuity, using an ohmmeter and needle probes. Place the probes at each end of the land. If the land is open, remove one probe along the board until continuity is observed on the meter. Then locate the break in the land with the aid of a 12X viewer. The three major types of circuit failures are caused by cracks, voids, or peeling of the lands. During the visual examination, it may be observed that the copper laminate used for the contact fingers has separated or peeled away from the board. This type of damage can be repaired by following the procedures described in the following subsections.

5-4.3 VOID REPAIRS

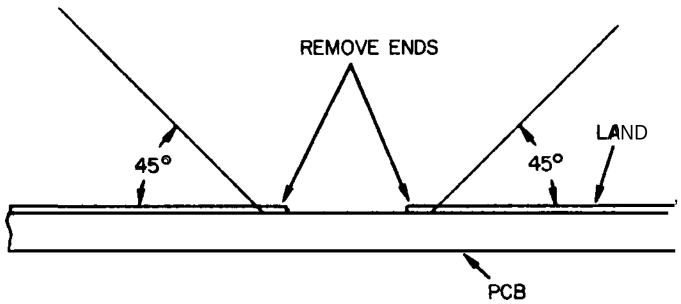
To repair a void in a land, the following procedure may be used:

1. If the land has been covered with a conformal coating, remove it in accordance with the procedure outlined in 5-4.1 above.
2. Using an X-acto knife, trim each end of the broken land at a 45-degree angle as shown in Figure 5-6(a). Ensure that the remaining end of each land is firmly attached to the board.
3. Strip the insulation from a small piece of AWG 22 hook-up wire. Lay the stripped wire on the board and solder as shown in Figure 5-6(b).

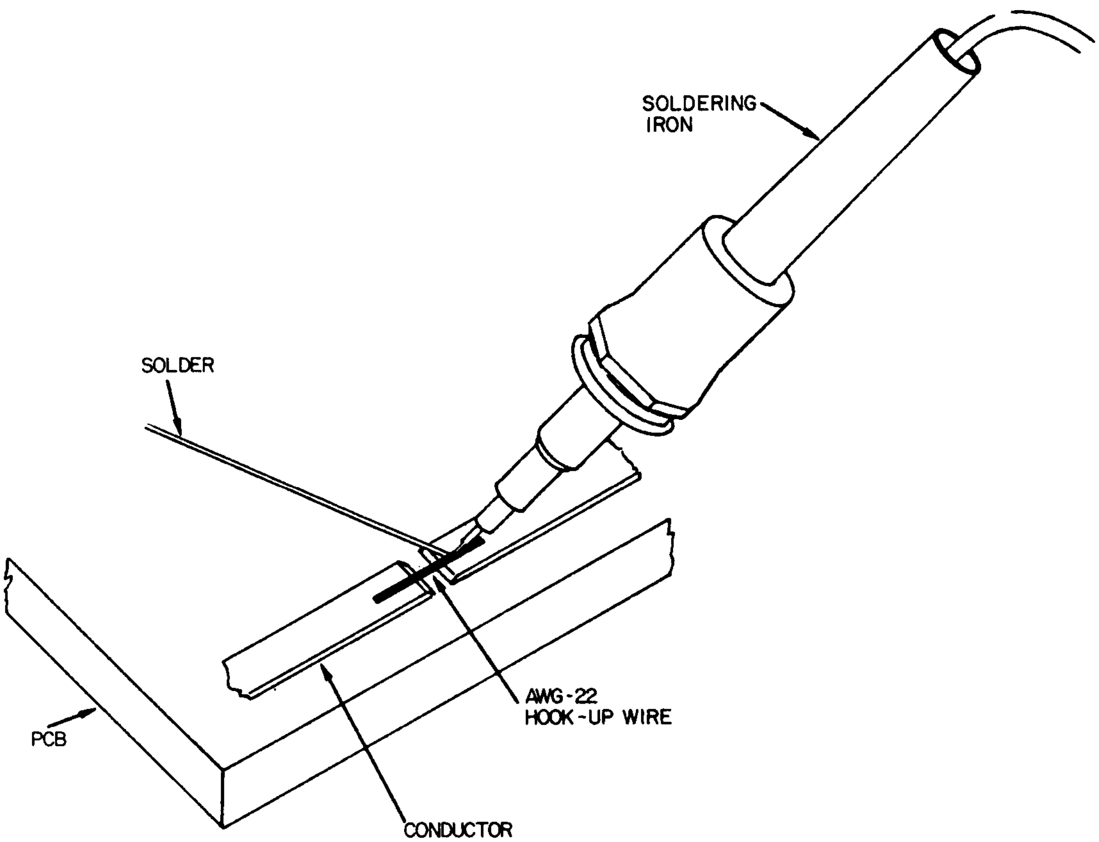
CAUTION

Excessive heat may cause the ends of the conductor to lift from the board.

4. Clean the soldered areas with cotton swabs that have been dipped in alcohol.
5. Using a 3X viewer, visually inspect the area for solder flux and solder splashes and remove any residue.
6 Check repaired area for continuity.
7. Replace the conforrnal coating as described in 5-4.1 above.



(a)



(b)

Figure 5-6. Void Repair Procedure

5-4.4 LANDS REPAIRS

To repair cracked lands, the following procedure may be used:

1. If the land has been covered with a conforrmd coating, remove it in accordance with the procedure outlined in 5-4.1 above.

2. Flow-solder the cracked sections togetber as shown in Figure 5-7.

CAUTION

Ensure that solder does not flow over the edges of the land as this will reduce the spacing between lands and affect the electrical performance characteristics of the board.

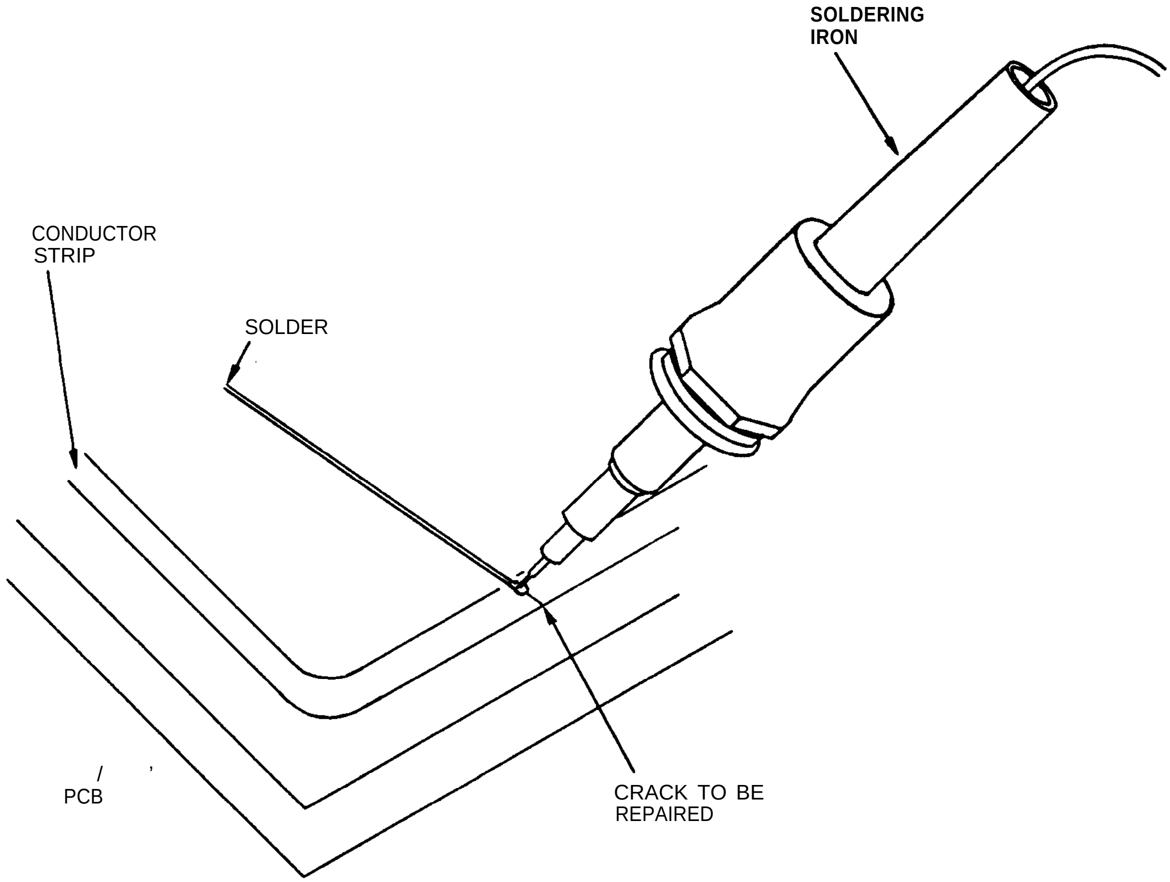


Figure 5-7. Lands Repair Procedure

3. Clean all residue from the board with a cotton swab that has been dipped in alcohol.

4. Using a 3X viewer, visually inspect the area for solder flux and solder splashes and remove any residue.

5. Replace the conformal coating as described in 5-4.1 above.

5-4.5 PEELED CONDUCTORS

To repair peeled conductors, the following procedure may be used.

1. If the land has been covered with a conformal coating, remove it in accordance with the procedure outlined above.

2. Using an X-acto knife, trim each end of the land at a 45-degree angle. Ensure that the remaining end of each land is firmly attached to the board.

3. Use a length of AWG 22 hook-up wire with teflon insulation that will span the void in the conductor. Strip both ends and tin.

4. Position the wire as shown in Figure 5-8 and solder ends to terminals.

5. Pot the wire to the board with general-purpose adhesive to prevent breakage during handling of the board.

6. Using a 3X viewer, visually inspect the area for solder flux and solder splashes and remove any residue.

7. Check for continuity.

8. Replace the conformal coating as described in 5-4.1 above.

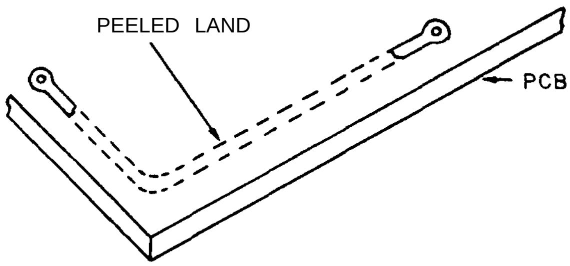
5-4.6 LOOSE CONNECTOR TABS

The repair of loose connector tabs may be done in the following manner:

1. Place the edge of an X-acto knife between the board and the loose tab, lifting tab as shown in Figure 5-9.

CAUTION

Do not allow the tab to curl or form right-angle bends as this will damage the tab.



PEELED LAND

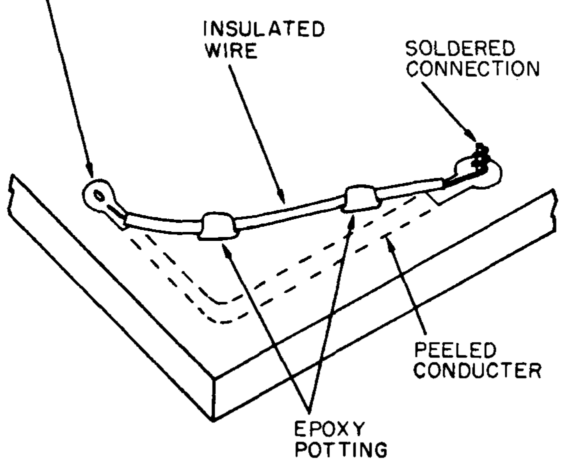


Figure 5-8. Peeled Conductor Repair

2. Place a piece of teflon on the top part of the tab and clean the underside of the tab with aluminum oxide sandpaper until it is a bright copper color.

3. Remove all old adhesive from the board by gently scraping with an X-acto knife.

4. Gently wipe the underside of the tab and board with cotton swabs that have been dipped in acetone.

CAUTION

Acetone is flammable,

5. Using potting syringe, apply adhesive to the tab and board surfaces.

6. Place teflon on top of the tab and clamp both to the board with a "C" clamp, as shown in Figure 5-9(a).

CAUTION

Do not move teflon or rotate clamp while tightening clamp. Such movement may result in improper orientation of the tab.

7. Allow adhesive to cure in accordance with the manufacturer's specifications.

8. Remove clamp and teflon.

9. Gently scrape the board with an X-acto knife to remove excess adhesive.

10. Clean tab by wiping with a cotton swab that has heen dipped in acetone.

11. Assure that" the repaired contact fits into the connector.

12. Check continuity.

5-4.7 BROKEN CONNECTOR TABS

The repair of broken connector tabs may be done in the following manner:

1. Using an X-acto knife, cut off the rough edge of the broken tab by making a 45-degree angle cut as shown in Figure 5-9(c).

2. Ensure that the undamaged section of the tab is still bonded to the board.

3. Clean the board by scraping off any residue and wipe with a cotton swab that has been dipped in acetone.

4. Cut a replacement contact from a piece of copper foil stock 0.002-inch thick of the same dimensions as the tab to be replaced, allowing l/4-inch for a lap-joint at the point of contact with the existing copper land.

5. Clean the replacement contact by hoMing it with tweezers and dipping in acetone. Place the cleaned contact on a clean piece of paper.

6. Using the potting syringe, prepare adhesive in accordance with manufacturer's directions and apply to the board.

7. Using tweezers, align the replacement contact and press flat.

8. Using an X-acto knife, scrape off excess adhesive, leaving a thin film on the board.

9. Place a piece of teflon over the replaced tab and clamp with a "C" clamp as shown in Figure 5-9(d).

CAUTION

Do not move teflon or rotate clamp while tightening. Such movement may result in improper orientation of the tab.

10. Allow adhesive to cure in accordance with the manufacturer's specification. To decrease curing time, place a lamp (60 to 100 watts) approximately 5 inches from the board.

11. Remove clamp and teflon.

12. Solder at the point of overlap between the new and original circuitry, using a miniature low-voltage soldering iron.

13. Using a small, flat file, bevel the edge of the tab at a 45-degree angle to conform to the bevel of the board, as shown in Figure 5-9(e).

14. Gently scrape the board with an X-acto knife to remove excess adhesive.

15. Clean contact and solder joint by wiping with cotton swabs that have been dipped in alcohol.

16. Assure that the repaired contact mates evenly with the proper connector.

17. Check continuity.

5-4.8 REMOVAL AND REPLACEMENT OF FLAT PACKS

Because of their small size, extreme care must be exercised in soldering and unsoldering flat-pack leads. Careless work may cause damage to the mounting surfaces and/or the circuits. Orientation of the flat pack with respect to the mounting surface is also of major importance. All flat packs have index points, usurdly located in one corner or on the package centerline. Before removing any flat pack, the board to which it is attached should be marked or a sketch made of the location of the index point so that the replacement device may be properly oriented as shown in Figure 5-10.

5-4.8.1 Tools and Materials

The tools and materials in the following list are required to remove and replace flat packs. The FSN or manufacturer's part numbers are given in Table 5-1.

45-degree chain nose tip cutter
Desoldering and cleaning tool (solder sucker)
Low-voltage soldering iron
Solder sucker
X-acto knife
Printed circuit card holder
Teflon tape
Epoxy resin compound
3X, 4X, and 12X viewers
Alcohol, Isopropyl
Cotton swabs
Tricep tweezers
Lead cutting and forming tool
(or wooden form)
Potting syringe

5-4.8.2 Removal and Replacement of Soldering-In Flat Packs

Upon completion of subsystem checkout and the localization of the defective flat pack, the following removal and replacement procedure is recommended:

1. Insert the printed circuit board in the card holder with the flat pack face up, as shown in Figure 5-10.

CAUTION

Solvents and abrasives may damage the board or surrounding parts and are not recommended for shipboard maintenance. They should be used only under controlled conditions.

2. If the flat pack has been covered with a conformal coating, remove the coating in accordance with procedures given in 5-4.1 above.

3. Mark board to show the location of the index mark on the flat pack, as shown in Figure 5-10.

4. Using a pair of sharp chain nose tip cutters, cut the flat pack leads hrdfway between the soldered joints and the body of the flat pack, as shown in Figure 5-10.

5. If thermally conductive adhesive has been used between the flat pack and the board, hold the device with tricep tweezers and place the heated blade of an X-acto knife between the flat pack and the printed circuit board on one side of the flat pack and gently move the knife back and forth in a cutting motion. Repeat this process on all four sides until the flat pack has been loosened.

CAUTION

Do not tap board to remove excessive solder as this may cause bridging of lands on other parts of the board.

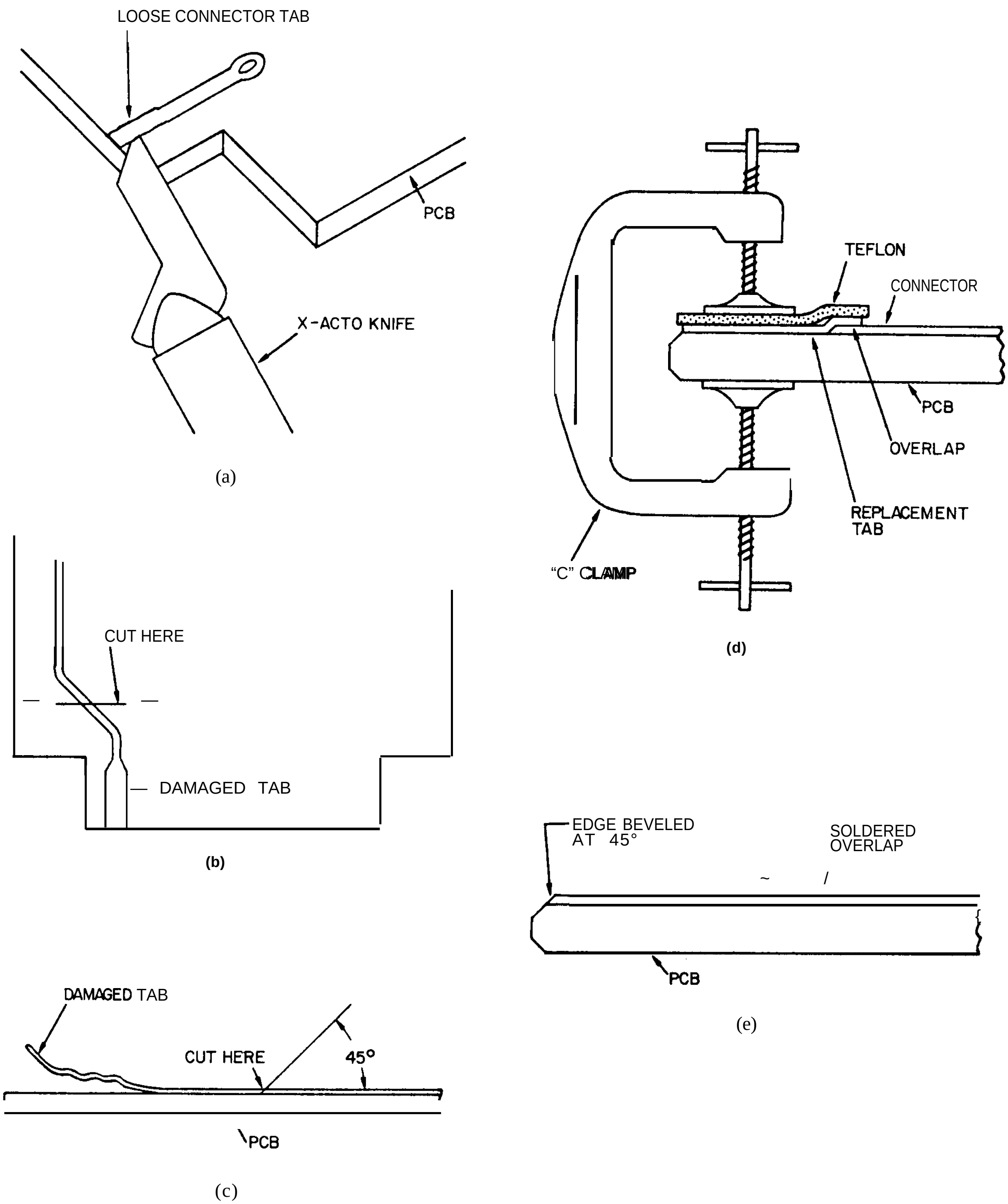


Figure 5-9. Peeled Connector Tab Repair/Replacement

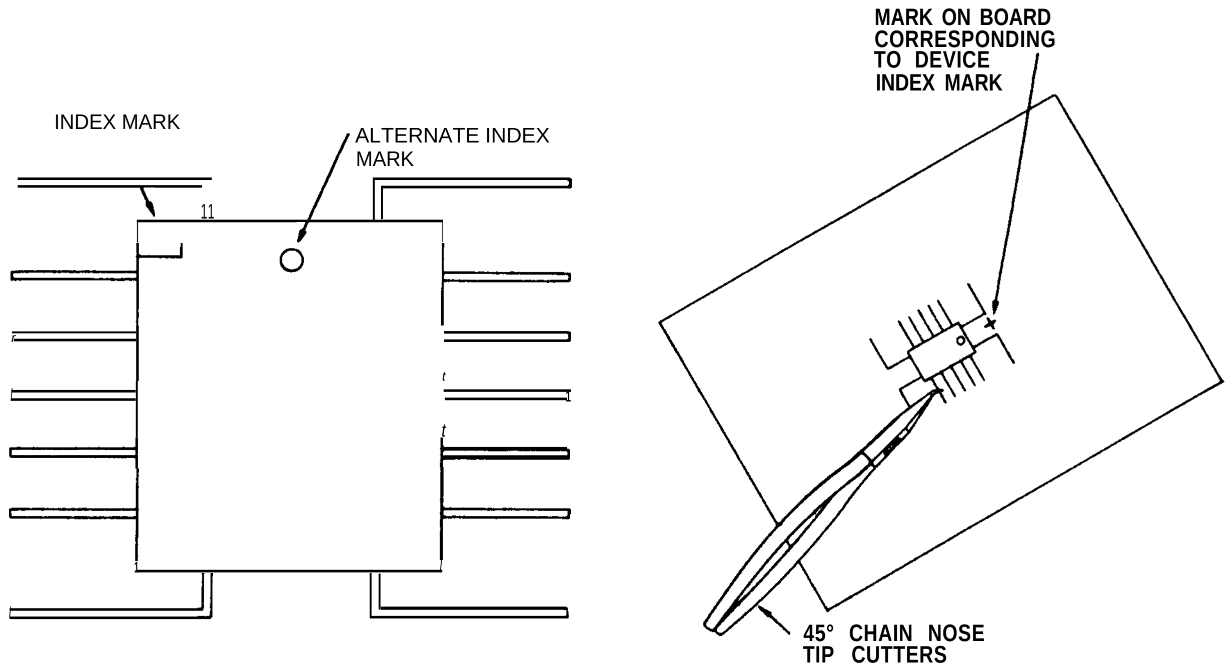


Figure 5-10. Removal and Replacement of Flat Packs

6. Unsolder the remaining leads, one at a time, using a resoldering iron and solder sucker attachment to remove excess solder.

7. After removing the flat pack, remove mask and visually examine the printed circuit board with a 12X viewer. Remove all residue (conformal coating, solder flux, and solder splashes) and clean the board with a cotton swab that bas been dipped in alcohol.

CAUTION

Assure that cleaning solvent has dried before applying a hot soldering iron. Alcohol is flammable.

8. Examine the replacement device for signs of damage. Review applicable circuit specifications and test circuit in accordance with the applicable technical manual.

9. Remove the flat pack from the handling container. If a suitable lead cutting and forming tool is not available, place the flat pack on a wooden form and cut the leads to the proper length, one at a time, with a sharp X-acto knife, as shown in Figure 5-11.

CAUTION

Make certain that the replacement flat pack circuit is properly oriented with respect to the index mark previously scribed on the printed circuit board. Incorrect positioning of the package will result in destruction of the circuit and have a deleterious effect on system performance.

10. Using the potting syringe, apply epoxy resin compound to the underside of the flat pack and place the package in position, using tncep tweezers.

11. Allow the adhesive to cure in accordance with the manufacturer's requirements.

CAUTION

Use a miniature low-voltage soldering iron. Excessive heat will damage the flat pack and/ or the printed circuit board.

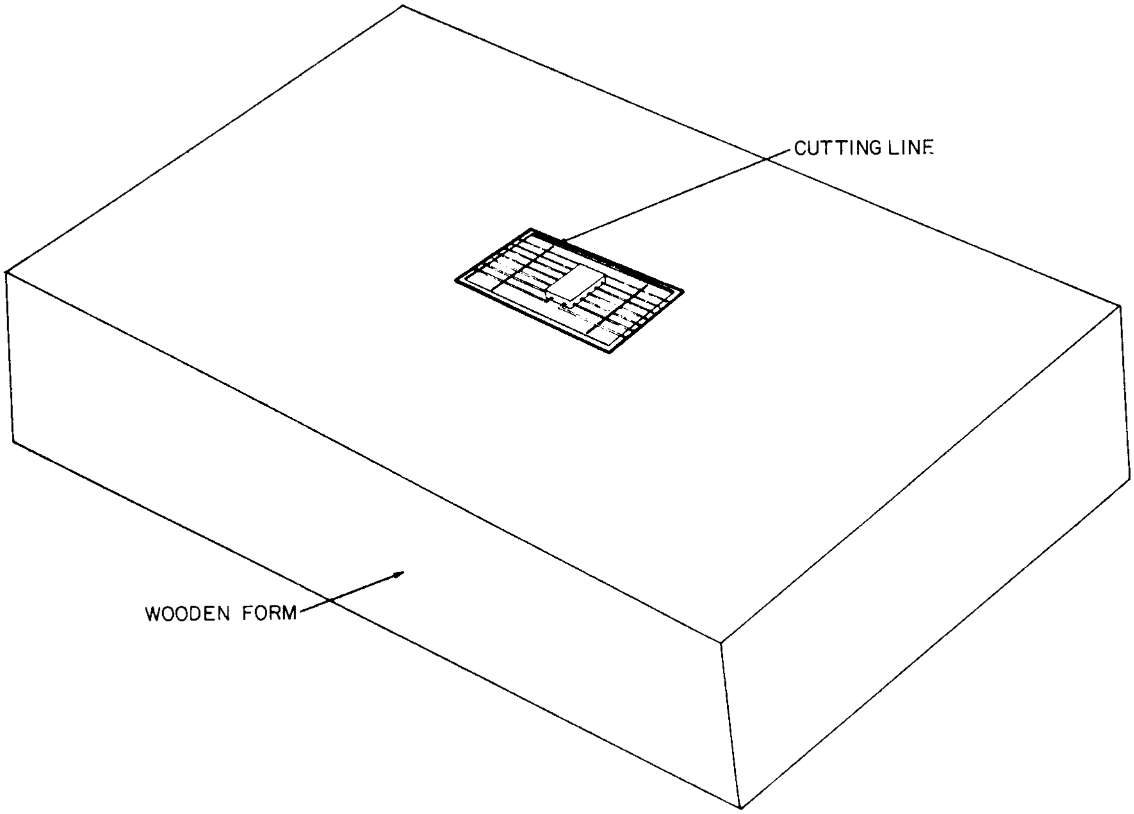


Figure 5-11. Flat Pack Lead Cutting Procedure

12. Flow-solder the flat pack leads to the board, one at a time, using a miniature low-voltage soldering iron, as shown in **Figure 5-12.**

13. Using a 12X viewer, visually examine the area surrounding the replaced device for bad solder joints, bridging of solder between the leads, flux residue, or excessive adhesive.

14. Clean all residue from the leads and printed circuit board, using a cotton swab that has been dipped in alcohol.

15. Place the printed circuit board in the system, if the system is available, for final test and checkout. If the system is not available, the proper inputs should be duplicated in accordance with specified test procedures and the output monitored using bench test equipment and procedures described in the appropriate equipment test and checkout manual.

16. Replace conformal coating as described in 5-4.1 above.

5-4.8.3 Removal and Replacement of Welded-In Flat Packs

Welded-In flat packs are removed and replaced by following the procedure given for Soldered-In flat packs except that the portions of the leads remaining on the printed circuit board, after removal of the package, are clipped as closely as possible to the welded joint to facilitate the soldering of the lapped joint of the replacement leads.

5-4.9 REMOVAL AND REPLACEMENT OF DIPs

Because of their smallness, extreme care must be exercised in soldering and unsoldering DIP leads. Careless work may damage the mounting surface and/or circuits. Orientation of the DIP with respect to the mounting surface is also of major importance. All DIPs have index points, usually located in one corner or on the package centerline. Before moving any DIP, the board to which it is attached should be

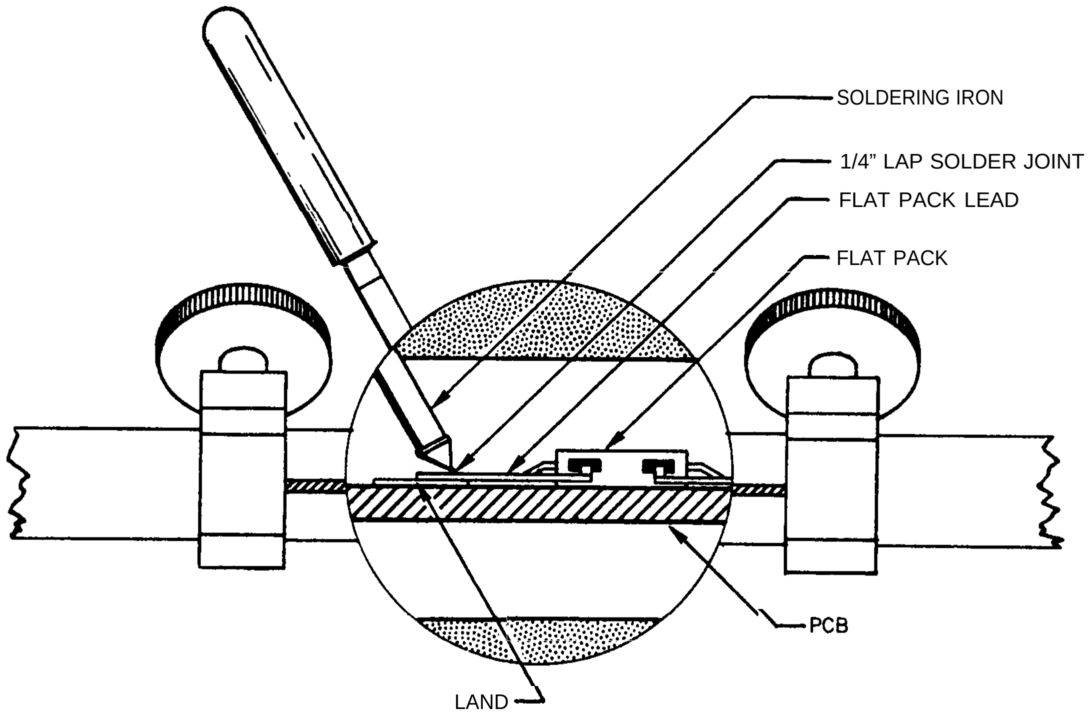


Figure 5-12. Flow Soldering Technique

marked or a sketch made of the location of the index point so that the replacement device may be properly oriented, as shown in Figure 5-13.

5-4.9.1 Tools and Materials

The tools and materials in the following list are required to remove and replace DIPs. The FSN or manufacturer's part numbers are given in Table 5-1.

45-degree chain nose tip cutter
Resoldering and cleaning tool (solder sucker)
Low-voltage soldering iron
Solder sucker attachment
X-acto knife
Printed circuit card holder
Teflon tape
Epoxy resin compound
3X, 4X, and 12X viewers
Alcohol, isopropyl
Cotton swabs
Tweezers, straight
Insulating varnish
DIP package puller
Toothpicks

5-4.9.2 Removal and Replacement of DIPs on Boards With Conformal Coating

Upon completion of subsystem checkout and localization of the defective DIP, the following removal and replacement procedure is recommended:

1. Insert the printed circuit board in the card holder as shown in Figure 5-3.

2. Construct a teflon tape mask over the circuit board, exposing the DIP to be removed as shown in Figure 5-3 and remove conformal coating in accordance with procedure given in 5-4.1 above.

3. Mark board or make a sketch indicating location of the index mark on the DIP.

4. Using a pair of 45-degree chain nose tip cutters, cut the package. leads, one at a time, as shown in Figure 5-14(1).

5. Lift the portion of the leads attached to the package, one at a time, with tweezers, bending the leads upward, as shown in Figure 5-14(2).

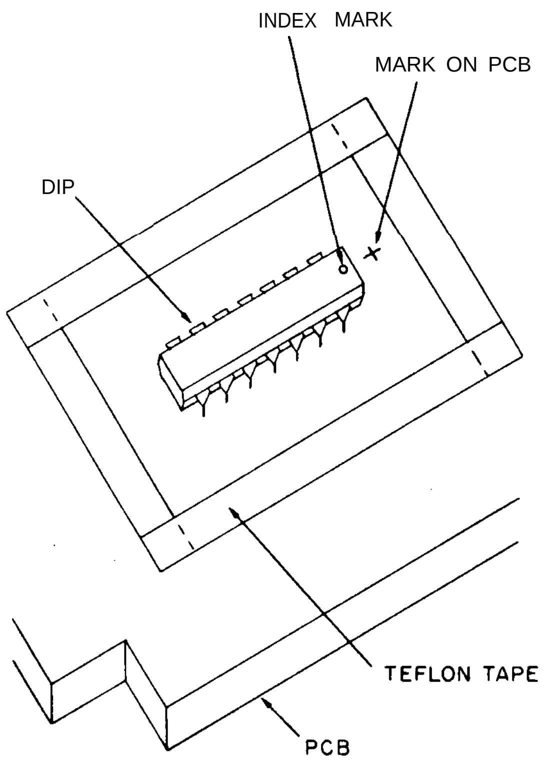


Figure 5-13. DIP Orientation for Repair

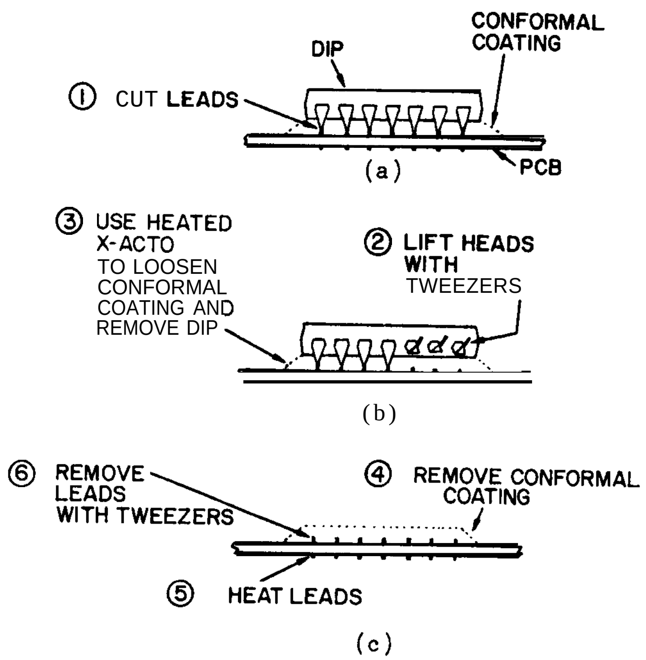


Figure 5-14. DIP Lead and Coating Details

CAUTION

Do not apply a prying or lift-motion with the X-acto knife as this may damage the printed circuit board.

6. Using a heated X-acto knife blade, loosen the conformal coating beneath the package and gently lift the package.

7. Remove conformal coating remaining on the board in accordance with the procedure previously described.

8. Remove solder from each lead remaining in the board, using a soldering iron and solder sucker and heater. Simultaneously remove leads with tweezers.

9. Clean holes in the printed circuit board, using a toothpick.

10. Remove all residue (conforrnaJ coating, solder flux, and solder splashes) and clean board with a cotton swab that has been dipped in alcohol.

11. Examine the replacement device for signs of damage. Review the applicable circuit specification and test circuit in accordance with applicable technical manual.

12. Upon satisfactory completion of the visual and electrical tests, align the circuit pins.

CAUTION

Assure that the circuit is properly oriented. Improper positioning of the package may result in destruction of the circuit and have a deleterious effect on system performance.

13. Insert DIP in the board and solder leads individurdly, using low-voltage soldering iron.

14. Using a 12X viewer, visually inspect the area surrounding the replaced device for bad solder jointa, bridging of solder between leads, and flux residue.

15. Clean all leads andsurroundingareas with a cotton swab that has been dipped in alcohol.

16. Place the printed circuit board in the system, if the system is available, for final test and checkout. If the system is not available, the proper inputa should be duplicated and the outputs monitored using bench test equipment and procedures in the appropriate equipment test and checkout manual.

5-4.9.3 Removal and Replacement of DIPs on Boards Without Conformal Coating

Upon completion of subsystem checkout and localization of the defective DIP, the following removal and replacement procedure is recommended:

1. Mark the printed circuit board or sketch the location of the index mark on the DIP.

2. Heat the solder at each lead, individually, and remove the molten solder from top of board with a solder sucker or wicking tool.

CAUTION

Do not apply twisting or prying forces as this may damage the printed circuit board or break DIP pins within the board.

3. Using a DIP package puller, illustrated in Figure 5-15, grasp the DIP as shown. Heat all leads simultaneously, using the solder sucker attachment. Gently pull the DIP away from and perpendicular to the board. The DIP should be easily freed from the printed circuit board.

4. Clean holes in the printed circuit board, using a toothpick.

5. Remove all residue (solder flux and solder splashes) and clean board with a cotton swab that has been dipped in alcohol.

6. Examine the replacement device for signs of damage. Review the applicable circuit specification and test circuit in accordance with the applicable technical manual.

7. Upon completion of the visual and electrical tests, align the circuit pins.

CAUTION

Assure that the circuit is properly oriented. Improper positioning of the package may result in destruction of the circuit and have a deleterious effect on system performance.

8. Insert DIP in the board and solder leads individually, using low-voltage soldering iron.

9. Using a 12X viewer, visually inspect the area surrounding the replaced device for bad solder joints, bridging of solder between leads, and flux residue.

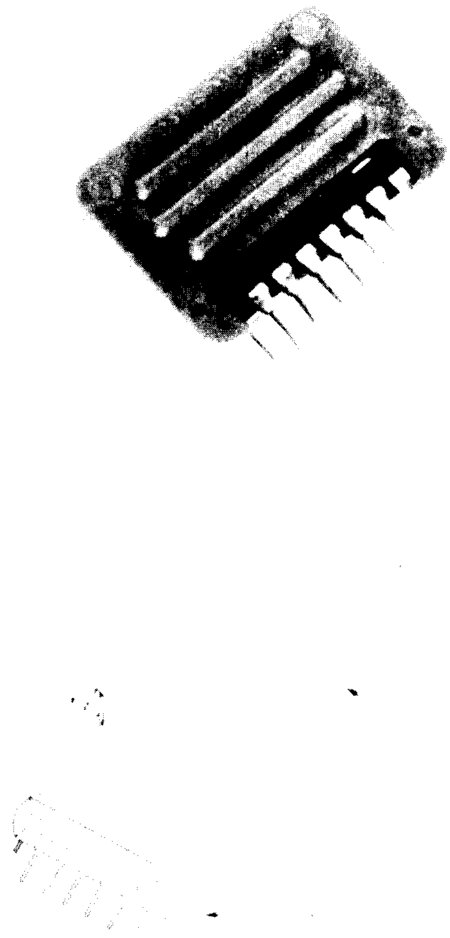


Figure 5-15. DIP Package Puller

10. Clean all leads and surrounding areas with a cotton swab that has been dipped in alcohol.

11. Place the printed circuit board in the system, if the system is available, for final test and checkout. If the system is not available, the proper inputs should be duplicated and outputs monitored using bench test equipment and procedures in the appropriate equipment test and checkout manual.

5-4.10 REMOVAL AND REPLACEMENT OF TO-TYPE PACKAGES

The TO-type packages containing integrated circuits are available with 8 to 12 leads. The leads are usually arranged in a symmetrical pattern and mounted directly to lands on the printed circuit board. Two of the most common mounting techniques are the embedded and the plug-in. The procedures currently used to remove and replace transistor TO packages are also applicable to modified TO packages containing integrated circuits. The major difference between the two packages is that the number of leads on modified TOS is greater and the space between leads is less than on standard TOS, thus limiting the space available for lead clipping, resoldering, and soldering. The smaller packages also require greater manual dexterity on the part of repair personnel. Other constraints, such as spacing of lands on the printed circuit board, removal of conformrd coatings and such, present additional problems to the maintenance technician. Protective conformal coatings contribute to the difficulty in unsoldering leads, removing devices from the mounting surface, and preparing the mounting surface for device replacement. Subsection 5-4.1 of this handbook contains procedures on removal and replacement of conformal coatings. After the protective coating has been removed, device leads must he disconnected and the device removed, but the procedure to be followed in removing the TO will depend on the mounting configuration. If the package to he removed is embedded or plugged in without a spacer, the leads should be clipped and the package removed before those segments of the leads remaining in the board are unsoldered. If this is not possible (as would be the case with packages that are flush mounted or plugged-in with a spacer) all leads should be heated simultaneously to allow package removal. Procedures for removing embedded, plug-in, and flush-mounted packages are given in the following subsections. Replacement TO circuits should be electrically tested in accordance with the applicable detailed specifications and subsystem operating requirements.

5-4.10.1 Tools and Materials

The tools and materials in the following list are required to remove and replace TOS. The FSN or manufacturer's part numbers are given in Table 5-1.

- Teflon tape
- Resoldering and cleaning tool (solder sucker)
- Low-voltage soldering iron
- 45-degree chain nose tip cutter
- Long-nose pliers
- Printed circuit card holder
- Toothpick
- Hemostat
- Alcohol, isopropyl
- Cut tip
- Cotton swabs
- 3X, 4X, and 12X viewers

5-4.10.2 Removal and Replacement of Embedded TOS and TOS Without Spacers

Upon completion of subsystem checkout and localization of the defective TO, the following removal and replacement procedure is recommended:

1. Place the printed circuit board in the card holder as shown in Figure 5-16. If the board has been covered with a conformal coating, mask all portions of the board except for the TO that is to he removed.

CAUTION

Excessive heat may damage the TO package and/or printed circuit board.

2. Remove coating from the terminal areas and area where the package is inserted into the board. This can best be accomplished by holding a soldering iron close to the board and gently scraping the conformal coating with an X-acto knife.

3. Using a 45-degree chain nose tip cutter, clip the leads near the TO package.

4. Apply pressure to top of TO package with a wooden dowel to remove TO from the board, as shown in Figure 5-16.

5. Heat terminals with a resoldering iron and remove molten solder with a solder sucker attachment.

CAUTION

Do not forcibly pull or apply twisting motion to leads. This may damage terminals.

6. Remove those segments of leads remaining in the board by applying the resoldering iron to the land on the board and gently pull downward on the lead, using long-nose pliers.

CAUTION

Wait until alcohol has dried before using soldering iron. Alcohol is flammable.

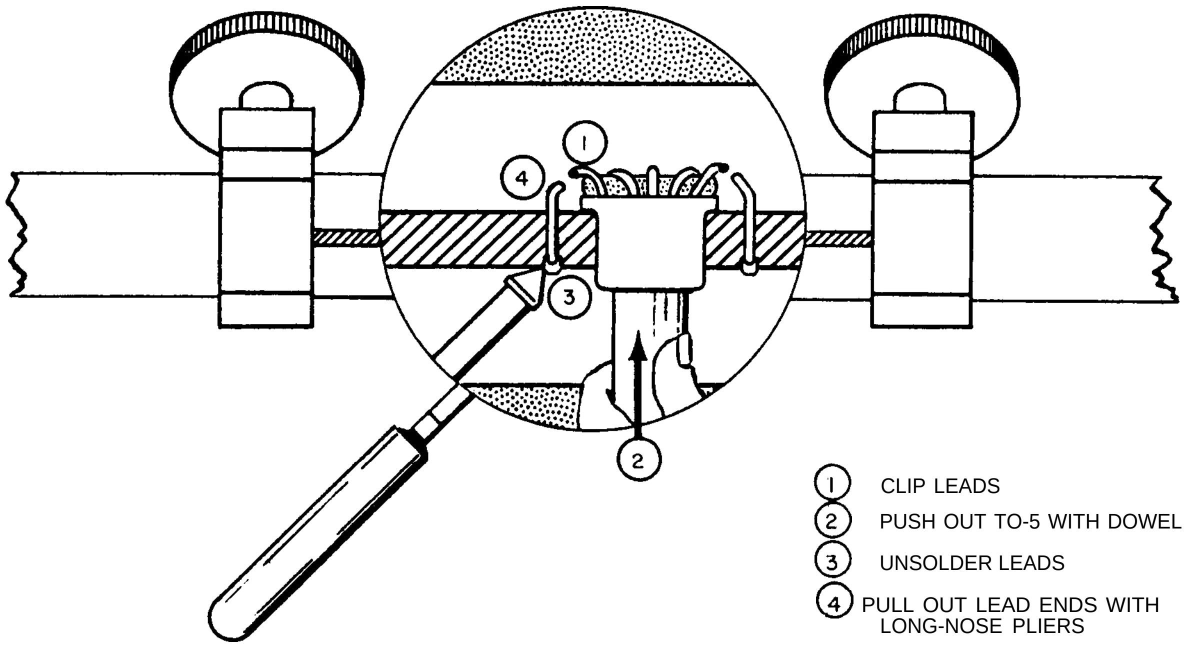


Figure **5-16.** TO Removal Procedure

7. Clean all terminal areas with a cotton swab that has been dipped in alcohol.

8. Using **a** 12X viewer, inspect terminals for loose solder, solder flux residue, and damage to terminals.

9. Visually examine replacement device for damage; review applicable circuit specification; and test replacement circuit in accordance with requirements of the appropriate operational specification and MILSTD-883.

10. Align leads and insert tested TO package into the printed circuit board.

11. Solder leads individually with a miniature low-voltage soldering iron, using long-nose pliers as a heat sink.

12. Inspect repaired area with a 12X viewer and remove any solder splashes or foreign materials with a cotton swab that has been dipped in alcohol.

13. If required by the equipment maintenance manual, apply conformrd coating in accordance with details in 5-4.1 above.

14. Place the repaired printed circuit board in the system, if the system is available, for final test and checkout. If the system is not available, the proper inputs should be duplicated and the outputs monitored using bench test equipment and following procedures in the appropriate equipment test and checkout manual.

5-4.10.3 Removal and Replacement of Flush-Mounted TOS and Plugged-In TOS With Spacers

Upon completion of subsystem checkout and localization of the defective TO, the following removal and replacement procedure is recommended:

1. Place the printed circuit board in the **card** holder, as shown in Figure 5-5. If the board is covered with a conformrd coating, mask all portions of the board except for the TO that is to be removed.

2. Heat each lead individually and remove molten solder from the board with the solder sucker attachment.

CAUTION

Do not apply twisting motion to TO package. This may damage the printed circuit board or terminals.

3. Heat all leads simultaneously with the cup-type tiplet adapter to the resoldering iron as shown in Figure 5-17. Using hemostats, gently grasp the package and remove from the printed circuit board.

CAUTION

Wait until alcohol has dried before using soldering iron. Alcohol is flammable.

4. Clean all terminal areas with a cotton swab that has been dipped in alcohol.

5. Using a 12X viewer, inspect terrn-inals for loose solder, solder flux residue, and damage to terminals.

6. Visually examine replacement device for signs of damage. Review applicable circuit specifications and test circuit in accordance with requirements of the appropriate operational specifi-cation and MIL-STD-883.

7. Align leads and insert new TO package in printed circuit board.

CAUTION

Excessive heat may destroy the terminrd or the replace-ment circuit.

8. Solder leads, one at a time, using a miniature low-voltage soldering iron.

9. Using a 12X viewer, inspect the repaired area and remove any solder splashes or foreign materials with a cotton swab that has been dipped in alcohol.

10. If required by the applicable equip-ment maintenance manual, apply conformrd coating in accordance with subsection 5-4.1 above.

11. Place the printed circuit board in the system, if the system is available, for final test and checkout. If the system is not available, the proper inputs should be duplicated and the outputs monitored using bench test equipment and following procedures in the appropriate equipment test and checkout manual.

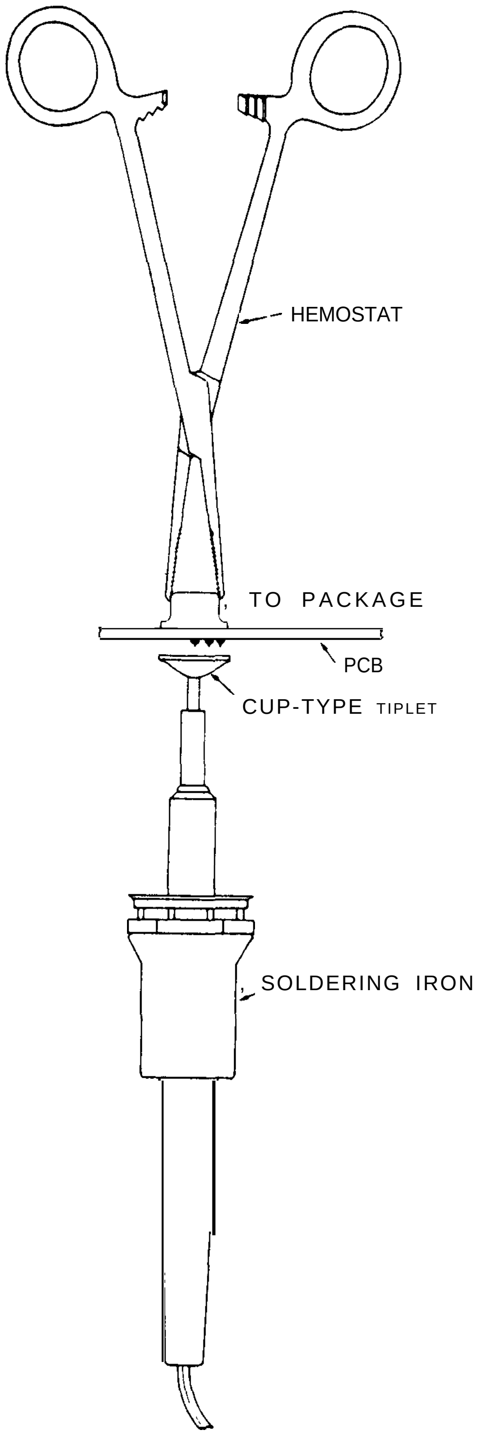


Figure 5-17, Resoldering Iron With Cup-Type Tiplet Adapter

SECTION 6

MICROMINIATURE REPAIR

6-1 INTRODUCTION

The complexity of modem military electronics systems has made the use of micro-electronic circuits a necessity. The widespread use of such micro. circuits has given rise to a major maintenance problem. The average electronics technician can no longer employ the familiar basic hand tools to effect microminiature repairs. The technician must now learn how to use entirely new repair techniques and specialized tools. The term "micro-electronics" refers to that area of electronics technology associated with extremely small components. Micro-electronics includes extremely small circuits having a high equivalent circuit density, and are considered as a single part or entity, composed of interconnected elements mounted on a single substrate and designed to perform a specific electronic circuit function. This technology includes all types of "Flat Packs," "Dips," and "TOS." Micro repair procedures include all techniques covered in the miniature repair section of this publication including, but not restricted to, the following component repair and installation:

1. multilayer printed circuit boards
2. small, complex, and very dense printed circuit boards
3. flexible printed circuit boards
4. installation of special connectors, eyelets and terminals.

Repairs to such entities may involve electroplating techniques, microsoldering (using a stereo microscope), and/or the complete rebuilding of a printed circuit board (PCB) (refer to Table 6-1 on microminiature tools and equipment for repair of electronic equipment).

6-2 REMOVING AND REPLACING MICROMINIATURE PARTS

One of the major problems in the repair of electronic assemblies and modules is the removal and replacement of coatings that were applied during original manufacture. Use of the terminology "Coatings," in some instances, is erroneous since the thickness of the coating that some manufacturers apply is well beyond the point that could normally be considered a coating. There are several basic ways in which liquids that have been formed into a flexible plastic (rigid, solid or foamed state) are used to support, seal and insulate electronic parts, sub-modules, modules and assemblies. Some of these are defined as:

1. Impregnation – A method used for sealing porous materials, securing coil windings and other parts. Impregnation is accomplished by spraying, dipping or vacuum processing with very thin liquids.
2. Encapsulation – The process of coating the surface of an object with a viscous material to establish a continuous thick protective layer which usually conforms to the shape of the object being encapsulated.
3. Potting – When a part and its container or housing are made integral by filling the container with a material which sets-up so as to prevent shifting of the part within the container. Potting also prevents the entry of moisture or dirt.
4. Embedding – This is similar to Potting except that the container is a temporary mold which is removed after the material sets-up.
5. Coating – A relatively thin protective layer which covers the surfaces of the object and is sometimes referred to as a "Conformal Coating. "

The following procedures will be concerned primarily with coating and encapsulation in the repair of modules, since the potting and embedding techniques are usually associated with items requiring less frequent repair. Both the coating and encapsulation techniques can be combined into the overall category of coatings, since the basic differences between them is thickness.

6-2.1 REASONS FOR COATING

Coatings are used for various protective and functional purposes including: humidity, fungus, mechanical shock and vibration, electrical insulation, mechanical pentration and abrasion, heat sinking and bonding. To meet the specific usage for one or more of these reasons, the coating material selected by the manufacturer may require the following characteristics:

1. Good thermal conductivity to carry heat away from the components.
2. Low shrinkage factors during application and cure to prevent the coating from applying strains or stresses to the components, their leads or their seals.

Table 6-1. Tools and Equipment Microminiature Electronic Repair

Microminiature Tools and Equipment for repair of electronic equipment – 2M Microminiature Repair Program Support Equipment/Tools are to be provided only to those activities that have a minimum of two properly trained and certified personnel on board

FSCM	Item Name	NSN
(81343)GGA616	Applicator, Disposable	9L 6515003038250
(81343)GGBO0821	Ball Mill, No. 2	9L 6520010032269
(81343)GGBO0821	Ball Mill, No. 4	9L 6520010032270
(81343)GGBO0521	Ball Mill, No. 6	9L 6520010032271
(81348)GGBO0821	Ball Mill, No. 8	9L 6520010033131
(81348)GGBO0821	Ball Mill, No. 1/2	9L 6520010033132
(81348)GGBO080	Blade, Surgical Knife, Sz. 11	9L 6515006600010
(81348) GGHO080	Blade, Surgical Knife, Sz. 15	9L 6516006600008
(81348)GGHO080	Blade, Surgical Knife, Sz. 20	9L 6515000441921
(81348) GGH80	Blade, Surgical Knife, Sz. 25	9L 6515002998055
(02105)105146	Blade, Thermrd Scraper, Short	9G 3439010450316
(02105)105143	Blade, Thermal Scraper, Long	9G 3439010450315
[81348) HB0064-3TYPE2CL1SZ1	Brush, Acid Swabbing	9Q 7920005142417
(17794)SX11O-81	Brush, Bristle	9Q 7920000187052
[17794)1127-0002		
[18037)BR-416	Brush, Dental	9L
(89630)E112	Brush, Replacement	9Q 5120010288462
[81348) 11B00681	Brush, Typewriter	9Q 7510005508446
[17794)SX11O-83	Brush, Wire	9Q 7920000187091
[17794)1127-006		
[08807) 15R14SC/FL	Bulb, Flood	9G 6240010291113
(08807)15R14SC/SP	Bulb, Spot	9G 6240010295988
:81348) GGBO0821	Burr, Ball, Latch, #1/2	9L 6520005033000
(81348)GGB00821	Burr, Ball, Latch, #2	9L 6520010032274
(81348)GGB00821	Burr, Ball, Latch, #4	9L 6520010032275
(81348)GGB00821	Burr, Ball, Latch, #6	9L 6520010037703
(81348)GGB00821	Burr, Ball, Latch, #8	9L 6520010032276
:18037)11-4/0	Burr, Dental #1/4 (Straight Handpiece)	9L
:81348) GGBO0821	Burr, Inverted Cone, #33-1/2	9L 6520005041000
(81348)GGB00821	Burr, Inverted Cone, #35	9L 6520010032272
:81348) GGBO0821	Burr, Inverted Cone, #37	9L 6520010035346
“81348)GGBO0821	Burr, Inverted Cone, #39	9L 6520010032273
“81348)GGBO01275	Burr, Needlepoint, Interproximal	9L 6520002999677

Table 6-1. Tools and Equipment Microminiature Electronic Repair (Continued)

FSCM	Item Name	NSN
(18037)R-4/0	Burr, Round, Latch Type, #1/4	9L 6520009357249
(81349)MILB36179	Burr, Trimming, Round	9L 6520000768683
(27552) 101-OOOA	Cable, Flex	IRW513001 024 5071TX
(81348)GGCO01265	Carver, Cleoid, Discoid No. 89-92	9L 6520009357254
(81348)GGCO01265	Carver, Hollenback #1/2	9L 6520009357151
(81348)GGCO01265	Carver, Hollenback #3	9L 6520005115450
(81348)GGCO01265	Carver, Tanner No. 5T	9L 6520009357252
(17794)1265-0003	Chamber, Solder Extractor	9G 3439001498190
(19204)12000647-15		
(81348)GGT555	Chest, Tool	9Q 5140003195079
(75206)520		
(19204)7540802		
(81348)GGCO01433	Chisel, Dental, Black #81	9L 6520005363905
(81348)GGCO01433	Chisel, Dental, Black #84	9L 6520005364025
(81348)GGCO01433	Chisel, Dental, Black #36	9L 6520005364125
(81348)GGCO01433	Chisel, Wedelstaedt #42	9L 6520005151550
(81348) QQC576	Copper Foil .004	9Z 9535002689571
(81348) QQC576	Copper Sheet .005	9Z 9535005067101
(19915)GA54	Cutters, Angled, Flush	9Q 5110007644801
(81348)GGP00468	Cutters, Diagonal	9Q 5110005421350
(75347)D209-5C		
(30879)1127AS200	Dies, Eyeletting, Sizes 2,3, and 4 (set)	
(81348)GGDO0426	Disc, Abrasive, Silicon Carbide	9L 6520005232150
(81349)MILD36456	Disc, Abrasive, 150 Grit	9L 6520002260571
(81349)MILD36256	Disc, Abrasive, 280 Grit	9L 6520002260573
(81349)MILD36256	Disc, Abrasive, 80 Grit	9L 6520002260576
(33092)613	Dispenser, Alcohol	9G 3439005529309
NOREF	Dispenser, Liquid, 2. oz.	9L 6520001429039
(81348)GGD751	Drill, Long No. 30	9Q 5133005958850
[17794)6010-0013	Element, Solder Extractor	9G 3439008081806
[19204)12000647-16		
(04347)0151	Epoxy Resin, Synthetic	9Z 8040000618303
(81348)ZZEO0661	Eraser, Rubber, Pencil	9Q 7510006345035
(89630)E111	Eraser, Fiberglass	9Q 5120010284285
(73685)812	Eraser, Ink, Block	9Q 7510002812801
(81348)GGE00916	Explorer, No. 6	9L 6520005280000
(81348)GGE00916	Explorer, No. 23	9L 6520005281000
(04264)CME36B	Eyelet	9Z 5325010577256
(04264)CME44	Eyelet	9Z 5325010308486

Table 6-1. Tools and Equipment Microminiature Electronic Repair (Continued)

FSCM	Item Name	NSN
(04264)CME33	Eyelet	9Z 5325000976527
(04264)CME23	Eyelet	9Z 5325010290816
(81349MILF36733	File, Bone, Seldin No. 11	9L 6520005285050
(81348)GGGF331TYPE18CL1T0 12	File Set, Needle	9Q 5110002042685
(24123)AA928	Filter, Felt	9C 4310008825336
(75297)1544	Flux, Rosin	9G 3439007528728
(24123)AA932	Gasket, Pump Filter	9Z 5310002914104
(81348)GGG531	Goggle, Industrial	9G 4240000423776
(81348)GGH0080	Handle, Surgical Knife #4	9L 6515003447820
(81349) GGHO080	Handle, Surgical Knife, Sz. 9	9L 6515003447920
(30879)1127 AS162	Hand Piece, Thermal Scraper/	
(02105)105142	Lap flow Soldering	9G 3439010450317
(30879)1127AS161	Handpiece, Rotary Drive,	1RM513001 0207944 TX
(30879)02611-1	Contra-Angle	
(27552) 555CA		
(30879) 1127 AS160	Handpiece, Rotary Drive, Flexible	1RM513001 0207943 TX
(30879)02610-1		
(27552)79D		
(30879) 1127AS156	Handpiece, Rotary Drive, Large	1RM513001 0245073 TX
(30879) 02605-1		
(27552)330		
(30879)1127 AS1O5	Handpiece, Solder Extractor	
(30879) 02604-1		
(17794)SX200		9G 3439008082144
(13102)HS1	Heat Sink	9N 5999006779839
(18876)11066463-001		
[13102)HS2	Heat Sink	9N 5999006779849
(13102)HS3	Heat Sink	9N 5999006779861
[18876)11066463-003		
[24123)AA935A	Jar, Filter	9C 4310008695590
[08292)K24M	Kit, Tool, Miniature, No. XK24M	9Q 5180000529885
[08807)308338	Lamp, Drill Press	9G 6240007563524
[06175)31-26-18	Lens, 0.5X Supplementary	906760009993567
[81348)GGMOO1O8	Mandrel, Screwtype, 64 T.P.I. Latch for Cutting Disc	9L 6520009268845
[81348) GGMOO1O8	Mandrel, Straight for Cutting Disc	9L 6520009268846
(11915)MS54-5	Pliers, Diagonal Cutting, Flush	9QS511O 009586507
:19915)DN-54	Pliers, Duckbill	9Q 5120019280937
(50172)PL281	Pliers, Duckbill, Microminiature	9QM512001 0287102

Table 6-1. Tools and Equipment Microminiature Electronic Repair (Continued)

FSCM	Item Name	NSN
(81348)GGP471TYPE11 CL1STYLEB	Pliers, Long Nose	9Q 5120005414078
(19915)LN-54		
(81348) GGP00471	Pliers, MuIt. Tongue and Groove	9Q 5120002780350
(50172)PL286	Pliers, Needlenose, Microminiature	9Q
(19915)RN-54	Pliers, Round Nose	9QS5120 001262076
(50172) PL291	Pliers, Round Nose, Microminiature	9QM512001 0274907
(81348) GGP001278	Plugger, Woodson No. 2	9L 6520005365405
(81348)GGP831	Punch Drive Pin, 1/4”	9Q 5120002406083
(81348) GGGP831	Punch, Drive Pin, 5/32”	9Q 5120002406104
(79687)1400	Respirator, Dust	
(81348)GGGS278TYPE2CL6	Scissors, Electricians	9Q 5110002550420
(O21O5)375Q	Screw, Set, S.S. Slotted, Short	9Z 5305010290653
(17794)SX1.75-61 “	Seal, Rear, Solder Extractor	9G 3439000142557
(81348) DDM440	Slab, Dental Mixing	9L 6520005562000
(81348) QQS571	Solder, Eutectic, AWG-22 (.025)	9G 3439002013866
(81348) QQS571	Solder, Eutectic, AWG-20 (.032)	9C 3439007703949
(81348) QQS571	Solder, Multicore, Eutectic, AWG-28 (.013)	9G 3439007704233
(02105) 3108-S3	Soldering Iron, 25-Watt	9G 3439001349202
(34605)40-1-5	Solder Wick #l	9G 3439005453396
(34605)40-2-5	Solder Wick #2	9G 3439004035321
(02105)40-3-5	Solder Wick #3	9G 3439000092334
(81348) GGSO0590	Spatula, Dental No. 324	9L 6520005568000
(30119)45-181	Stripper, Wire, Mechanical	9Q 5110007683797
(02105)10517	Stripper, Wire, Thermal	9Q 5120010287142
(81349)MILT23594	Tape, Insulating, Teflon	9G 5970008127387
(17794)1121-0213	Tip, Extractor .018”	9G
(17794)1121-0214	Tip, Extractor .025”	
(17794)1121-0215	Tip, Extractor .036”	
(17794)1121-0217	Tip, Extractor .061”	
(02105)105147	Tip, Lapflow Soldering	9G 3439001477258
(17794)1121-0131	Tip, Soldering Iron,	9G 3439001498197
(O21O5)PARAGON5O3	Chisel 1/16”	
(O21O5)PARAGON5O1	Tip, Soldering Iron, Chisel 1/8”	9G 3439005257393
(O21O5)PARAGON51O	Tip, Soldering Iron, Cone	9G 3439001498196
(02105)105134	Tip, Tweezers, Resistance, Micromin.	9GS343901 0375773
(02105)10542	Tips, Resistance Soldering	9G 3439010445749
(02105)10529	Tips, Thermal Wire Stripper	9GS343901 0372495
(80063)SCB98203	Tool, Alignment, Elect. Equipt.	9Q 5120002932081
(81348) GGT870TYPE4CL1STYLE1	Tweezers, Curved Point, Smooth	9Q 5120002889685

Table 6-1. Tools and Equipment Microminiature Electronic Repair (Continued)

FSCM	Item Name	NSN
(02105)10541	Tweezers, Resistance Heating	9G 3439004063047
(71827)AWG20	Tweezers, Antiwicking	9Q 5120009541269
(71827)AWG22	Tweezers, Antiwicking	9Q 5120009541270
(71827)AWG24	Tweezers, Antiwicking	9Q 5120009541272
(71827) AWG28	Tweezers, Antiwicking	9Q 5120009541276
(02105)105133	Tweezers, Resistance, Micromin.	9Q 5120010287145
(81348)GGGT870TYPE5CL2	Tweezers, Self-Locking	9Q 5120002930149
(81348)GGGV41O	Vise, Work Positioner	9Q 5120009911907
(81348)GGW239	Wheel, Abrasive, Ball, 1/8"	9L 6520005468000
(17794)1129-0008 (86297)8C	Wheel, Abrasive, Bullet, Coarse	9Q 5130001723418
(86297)8XF	Wheel, Abrasive, Bullet, Extra Fine	9Q 5130001650929
(17794)1129-0007 (86297)8F	Wheel, Abrasive, Bullet, Fine	9G 3460002251955
(81348)GGW239	Wheel, Abrasive, Doughnut, 1/4" x 3/32"	9L 6520002034620
(81348)GGW239	Wheel, Abrasive, Knife Edge 3/16"	9L 6520005477160
(86297)5XF	Wbeel, Abrasive, Knife Edge, Ext. Fine, 1"	9Q
(86297)SF	Wheel, Abrasive, Knife Edge, Fine, 1"	9Q
(81348)GGWO0253	Wheel, Abrasive, Rubber 7/8" x 1/8"	9L 6520005686150
(81348)GGWO0253	Wheel, Abrasive, Rubber, Knife Edge 3/8"	9L 6520005231115
(81348) GGWO0253	Wheel, Abrasive, Rubber, Knife Edge 5/8"	9L 6520005231120
(81348)GGW239	Wheel, Abrasive, Tapered Cyl. 3/32" x 1/4"	9L 6520005480010
(81348)GGW239	Wheel, Abrasive, Square Edge 3/8" x 1/16"	9L 6520005483010
REPAIR STATION MAJOR ASSEMBLIES		
(30879) 1127AS1OO	Solder Extractor Unit	6RX513001 0241482 TX
(30879) 1127AS124	Tool Chest	6RX513001 0273418 TX
(30879) 1127AS125	Power Supply-Hand Tool	6RX613001 0258811 TX
(30879) 1127AS141	Mechanical Drive Unit	6RX513001 037 8695TX
(30879) 1127AS158	Work Handling System	IRM494000 9148427
(30879) 1127 AS164	Optical Magnifier	IRM6650 01025 8803TX
(55055)221217	Lamp, High Intensity	9G623001 0332081
ANCILLARY EQUIPMENT		
(30879) 1127AS165	Drill Press – Eltr Pwr Sup	6RX513001 0241677 TX
(30879)1127 AS166	Microscope – Stero Zoom	6RX665000 8977051 FA
(30879) 1127AS167	Plating System	6RX513001 0241493 TX
(30879) 1127AS168	Drill Press – Eltr	6RX513001 0258105 TX

3. Resilience, hardness and strength characteristics to properly support and protect the components to meet their loading conditions.

4. Low moisture absorption.

5. Inorganic materials so as not to feed fungus growth, etc.

6. Electrical insulation qualities.

7. Other characteristics, as required.

6-2.2 TYPES OF COATINGS

The general types of electronics coating materials in present day use include:

1. Varnishes
2. Two-Part Epoxies
3. Polyurethane
4. Acrylic Lacquers
5. Silicone Varnishes
6. Various types of Room Temperature Vulcanizing (RTV) Silicone Rubbers.

The primary methods for applying these coating materials include: brush on, spray on, dipping, and spread or pour on. The particular method of applying the coating is a primary factor for determining the thickness and uniformity of coating in the end product. Dipping and pouring of coatings will result in relatively thick coatings. Spraying and brushing will usually result in thin coatings. One of the great paradoxes in the use of coatings is that the type and extent of coating used will vary from manufacturer to manufacturer. Some manufacturers whose equipment is used in the same electronics system and environmentrd location may not use any coatings at all. The question which then arises is why any coating was selected and used by a given manufacturer? It all seems to be related to the prerogatives of the original designer and manufacturer and his specific technical analysis. Conformance to specification may also be a factor. It will be found that in some assemblies only one side of the board is coated. Here again, the designer may reason that certain penetration or abrasion conditions may occur and relate to one side only, or that the mechanical stability of the component side of the board is critical and, therefore, a stabilizing coating must be used on that side. To assure the continuity of a coating used for electrical insulation or moisture resistance over a given surface, some producers include a tracer in the coating material itself. Thus, ultra-violet light detection will indicate any discontinuities of surface coverage. Specifications on the inspection of coatings, as defined by various manufacturers, may run the full extreme from allowing air bubbles and pin holes within the coating, as determined by inspection under a source of ultra violet light. The extent to which this inspection is earned out is usually dictated by the individual producer. It is of interest to note that some producers make their coatings opaque. Transparent or translucent coatings would permit the repairman to observe what is below the coating. This is not possible with opaque coatings,

6-2.3 IDENTIFICATION OF COATING

When a complete set of drawings and technical data is made available from a given manufacturer, and assuming he has used the same coatings on all his assemblies, the technician would thus be aware of the coating used on a specific assembly. However, in some cases a manufacturer may inconsistently use as many as four or five different kinds of coatings. This results in never knowing for sure which particular coating was used on the specific assembly at hand. Under such circumstances it becomes valuable to establish a uniform means for identifying any variety of coating that may be used on any module. Certain physical characteristics are available to establish coating identification (refer to Table 6-2):

1. Is the coating hard or soft, or some place in between?

NOTE

This may be determined by a penetration-type test, simply pushing a pointed object against the coated surface.

2. Is the coating opaque, transparent or translucent?

3. Is the coating thick or thin? The criteria for thick or thin is nominally established as .010 to .015 being a thin coating, and anything over that thickness as being a thick coating. Thick or thin determinations are related to the methods of removal, as described in another section of this document.

4. The volubility of the coating material is another characteristic that may be identified. Almost all coating materials are soluble in some solvent. The problem is to assure that the solvent which removes or breaks down the coating will not darnage the circuit board or its associated component parts. The very nature of solvent removrd techniques

Table 6-2. Identification of Coatings

Coating	Hard	Soft	Thick	Thin	Transparent	Translucent	Opaque	Soluble	Strippable
Acrylic Lacquer	x	—	x	x	x	—	—	x	
Epoxy Resin	x	—	x	x	x	—	x	—	—
Varnish	x	—	—	x	—	x	x	—	—
Silicone Varnish	—	x	x	x	x	—	—	x	—
Poly-u	x	x	x	x	x	—	—	—	
RTV	—	x	x	—	—	x	x	—	x

NOTE: Identifiable characteristics are relative and not absolute; i.e., gradations from hard to soft can exist for many coating materials; variations from transparent to opaque may exist in the same coating, etc.

COLOR OF COATINGS

NOTE: Color variations by addition of tracer dyes (ultra-violet indicators, etc.) and fillers can provide a wide variety of coloration in the same coating material.

Acrylic Lacquer	Clear - may have dye tracers.
Epoxy Resin	Clear - Amber - may be opaque by dyeing and fillers.
Varnish	Amber - Brown.
Silicone Varnish	Clear - may have dye tracers.
Poly-u	Clear - may have dye tracers.
RTV	Translucent to Opaque - may also be colored.

also relates to whether all the coating is to be removed or whether only spot-removal is required for a given repair. Coating removal by solvent is described in the "Coatings" section of this manual.

5. One other criteria for coating identification is its "stoppability." A classification of coatings called "stnppable" is cafled out in MIL specifications. Removal of this (strippable) type of coating should merely require "slitting through" and peeling it off the surfaces, leaving the clean surface behind. Unfortunately, this type of coating is extremely rare since one of the primary criteria for the selection of a given coating is that it act as a heat sink, thus requiring it to conduct heat from the component part into the baseboard and atmosphere. If the coating is stnppable, it can be inferred that either an air space, poor adhesion, or a release agent film exists between the coating and the work surfaces, thus creating a thermal barrier. This results in a contradiction that if the coating is strippable, it would not be as effective a heat sink as one that is not stnppable.

6-2.3.1 Relative Hardness of Coatings

The relative hardness or softness of a coating can be determined by a simple penetration test using a pointed instrument applied to the surface of the coating in a non-critical area.

6-2.3.2 Transparency of Coatings

A coating may be transparent, translucent or opaque. Means of determining this is obvious, and its importance relates to not only aid in identifying the coating but indicates a factor in difficulty of removal. An opaque coating does not permit observations of underlying elements during coating removaf, hence, placing such items in jeopardy.

6-2.3.3 Thickness of Coatings

The relative thickness of a coating can be determined by visual means. A thin coating will show very sharp outlines of the components and almost no fillet at points of intersection of part leads to circuit board. Thick coatings, conversely, reduce the sharp outlines of components and show discernible fillets at points of part or lead intersections with board.

6-2.3.4 Volubility of Coatings

Most all coatings are soluble; however, the solvent required to dissolve the specific coating may afso attack the board and/or the components. Therefore, the volubility test and use of solvents should be limited to using only xylene and trichlorethane or equal. Test the coating with either of these materiafs in a non-cnticaf area by brushing on a small quantity of the solvent and observe the volubility action.

6-2.3.5 Strippability of Coatings

The stoppability of a particular coating can be determined by carefully splitting the coating with a sharp blade in a non-critical area, and then peeling the coating from the module surface. It should be noted that so-called strippable coatings are not truly strippable due to their intrinsic adhesion qualities and entrapment under part leads. Adhesion qualities are essential in selecting coating materials in order to provide heat dissipation characteristics.

6-2.3.6 Comparing Coating Characteristics

Table 6-2 listed the various physical characteristics associated with the generic types of coatings. Note that in many cases the difference in only one distinctive characteristic will distinguish one coating from another.

6-2.4 COATING REMOVAL METHODS

Once the specific type of coating has been generally identified, the appropriate removaf method can be employed. The need to remove all the conformal coating from the connections to be unsoldered (and resoldered) is based first on the fact that unless it is removed, it creates a heat barrier which makes it difficult to melt solder joints. Second, the conformal coating may cause solder joint contamination when resoldering. The better a board is cleaned of coating at the beginning of a replacement procedure, the easier it will be to restore the board to a serviceable condition. In most instances, only a spot-removal of the coating is necessary to suit the required repair action. There may be a few cases where removal of afl of a specific type of coating, by solvent means, can be performed on a production basis as easily as spot-removal. Five coating removal methods are recommended: 1) solvent, 2) stripping, 3) thermal parting, 4) abrasion, 5) hot jet. Tbe specific removal method to be employed is based on: 1) the generaJ type of coating, 2) the specific condition of the coating, and 3) the critical nature of the parts and the circuit board. Table 6-3 relates coating material type to its recommended removal method. It should be noted that in some cases two or three removaf methods are shown for a single coating type since variations in coating conditions require such diversity.

6-2.4.1 Solvent Method

Mild solvents, such as xylene or trichlorthane (or equal) may be used to remove specific soluble-type coatings on a spot basis by brushing or swabbing the local area a number of times, using fresh solvent until the area is free of coating. If warranted, afl of a soluble-type coating can be removed from the assembly by immersing and brushing the entire circuit board while immersed in a series of tanks containing mild solvent, starting with a high contamination tank and progressing sequentially to a final, fresh solvent tank. Alternately, a single step means for removing all coating may be utilized by providing a continuous flow of fresh mild solvent with a flow-off of contaminated solvent.

Table 6-3. Coating Removal Methods

Material	Thermal Parting	Mechanical Abrasion	Solvent		Hot Jet
Acrylic Lacquer			x		
Poly Urethane	x	x			x
Epoxy Resin	x	x			x
Silicone Rubber (RTV)		**x		x	
Varnish	x	*x			x
Silicone Varnish			x		

* Hard type only.
** Freon TF used to soften and expand.

CAUTION

In using the solvent method determination must be on a module-by-module basis, of hazards to parts, etc., by short-term immersion in, or entrapment of, solvents. Rapid solvent dry-off through forced evaporation, as well as neutralization, if required, should be utilized.

CAUTION

Chloride-based or other harsh solvent must not be utilized. Extreme care must be exercised to prevent damage to base laminates and component parts.

When removing RTV materials (primarily by stripping) a pre-soak in Freon TF will soften and expand the RTV, thus permitting a simplified stripping procedure.

6-2.4.2 Procedure for Solvent Removal

1. To remove solvent, dip the end of a cotton-tipped applicator in the solvent and apply a small amount to the coating around the soldered connections of part to be replaced. Because various substances have been used as conformal coatings, the time required for a given coating to dissolve will vary. Repeat this step several times, as the solvent evaporates very readily.

2. Rub the treated surface carefully with a bristle brush or the wood end of the applicator to help dislodge the conformal coating.

3. Abrade the exposed solder connections and brush away the residue.

6-2.4.3 Stripping Method

Stripping is practical only under special circumstances. For example, in removing RTV silicone materials, a pre-soak in freon TF will soften and expand the RTV silicone. This will loosen the bond between the board and RTV, which can then easily be slit and peeled off.

6-2.4.4 Thermal Parting Method

"Thermal parting" employs a controlled, low temperature, localized heating method for removing thick coatings by over-curing or softening. This method permits the removal of any thick coating material from work surfaces, as well as the release of bonds between component parts and circuit boards. Various shaped temperature-controlled tips, without sharp edges, are available in a variety of configurations to suit workpiece access. The thermal parting method does not bum or char either the coating or circuit board.

CAUTION

Do not use soldering irons for coating removal as their high operating temperatures will cause the coatings to char, as well as possibly delaminate the board materials. The use of thinned-down soldering tips or solder-iron-heated thin cutting blades are not recommended since they do not provide controlled heating or sufficient capacity. They also present dangerously sharp edges to the workpiece surface.

6-2.4.4.1 Thermal Parting Procedure

1. To separate a coating, first select an appropriate thermal parting tip to suit the workpiece configuration. Set the nominal tip temperature, using the manufacturer's recommended procedure.

2. Apply the thermal parting tip to the coating, using a light pressure. The coating material will either soften or granulate (Epoxy coating will granulate and Poly-U will soften.) The tip temperature should be regulated to a point where it will effectively "break down" the coating but without scorching or charring.

3. The coating thickness around the component body should be gradually reduced without contacting the board surface. As much coating as possible should be removed from around component leads to allow easy removal of the leads. Pre-clip leads of component parts that are known to be faulty should be pre-clipped, thus permitting removal of the part body separately from leads and solder joints. Low pressure air or a bristle brush should be used to remove waste material during the parting process. This will allow good visual access and inhibit inadvertent damage to the board.

4. With only a smafl bonded joint between the part body and board, heat the component body with the thermal parting unit or smafl soldering iron to weaken the bond beneath the component. Lift the component body free of the circuit board.

5. Once the component body has been removed from the board surface, the remaining coating material can be removed by additional thermal parting or by the miniature machining abrasive method. The remaining leads and solder joints are then removed as described in the "Parts Removaf" section.

6-2.4.5 Mechanical Abrasion Method

Several important factors must be considered when using abrasion techniques for the removaf of coating materials. A powered miniature machining system will permit fingertip control while providing low RPM at a high torque to facilitate manipulation and the handling of gumming type coatings. In addition, a wide variety of rotary abrasive materials and shapes, as well as cutting tools, will be required, including bafl mills, twist drills, rotary brushes, etc., to suit removal of the various coating types and configurations. In principle, the powered mechanical abrasive coating removal method permits consistent and precise removal of coatings by the average technician without causing mechanical damage or dangerous heating.

CAUTION

Do not use high RPM rotary systems as they will cause dangerous frictional heating, and normally do not have sufficient torque to remove the softer, gumming type coatings.

6-2.4.5.1 Abrasive Removal of Thin Coatings

Rubberized abrasives of the proper grade and grit are ideafly suited to removing thin hard coatings from flat surfaces. They must not be applied for soft coatings removal since these would cause the abrasive to "load" with coating material and thereby become ineffective. Rotary bristle brushes are better suited than rubberized abrasives for use on contoured or irregular surfaces, such as soldered connections, etc., since the bristles will conform to surface irregularities while removing hard or soft coatings. When using miniature machining abrasive techniques, the abrasive tool should be moved about in a circular motion to minimize localized heating and avoid causing damage to underlying materials by abrading through the coating too quickly. The procedure for thin coating removaf is as follows:

1. Apply appropriate rotating abrasive to the coating using various degrees of pressure and applying the degree of pressure which best suits the conditions. It may be necessary to begin with a coarse abrasive to remove the bulk of the coating, then change to a finer abrasive or bristle brush to "clean up" the area.

2. When all coating has been removed from the desired area, the area should be cleaned with an appropriate solvent to remove any remaining contaminants. The cleaned area can now be studied to determine which solder extraction technique to use.

NOTE

The abrasive method is primarily suited to the circuit side of the boards because it permits ready access of rotating devices without danger of darnage. The thermaf parting and hot jet methods should be used on the component side of the board.

6-2.4.5.2 Abrasive Removal of Thick Coatings

The procedure for removing thick coatings is primarily to reduce their thickness to a thin coating, and then to remove the remaining thin coating by the previously described thin coating removaf procedure. Use the miniature machining technique with bafl mills to rout-out thick coatings, using various sized mills to enter smafler areas.

CAUTION

Do not attempt to remove all of the coating or reach the board or part surfaces by this method as the cutting action will cause damage. The intent here is merely to thin the coating down.

The design of a bafl mill is such that ita most efficient cutting area is on the side of the ball rather than at the end. To prevent damage to the base material of the PC board, periodically remove the waste coatings by brushing or using low pressure air to allow visuaf inspection of the work surface. Once the coating around the selected component has been reduced to a relatively thin condition, use the abrasive or hot jet mode for thin coating removal. Remove the solder joints as per the appropriate solder extraction method. This abrasive method is only suited to thinning down thick coatings on the circuit and component sides of the board. Use the thermal parting and hot jet methods to release the bonds between components and circuit board.

CAUTION

Do not attempt mechanical abrasion between closely spaced component part bodies as this action can easily darnage the part.

NOTE

Both the thermal parting and hot jet methods are also ideally suited for the removal of thick coatings.

6-2.4.6 Hot Jet Method

In principle, the hot jet method uses a controlled jet of temperature regulated air to either soften or break down the coating. By control of the gas temperature, flow rates and jet shape, the hot jet can be applied without damage to afmost any workpiece configuration on both the circuit and component sides of the board. Due to the application of heat via the hot jet, there is no direct physical contact with the workpiece surfaces. Thus, extremely delicate work can be handled in this manner while permitting direct observation of the heating action.

6-2.4.6.1 Hot Jet Procedure for Coating Removal

1. Set up hot jet apparatus per manufacturer's instructions to provide minimum-sized jet. Adjust flow rate and temperature to suit specific coating removal application.

2. Apply jet to work area. With the aid of a relatively soft, non-marring edged tool (i. e., teflon, nylon or orange wood), use light pressure to remove softened or over-cured coating. All coating around individual leads, solder joints and component bodies can be removed in this manner.

CAUTION

Never set the hot jet to heating levels that will cause scorching or charring of the coating material.

3. When coating has been removed, use appropriate solder extraction method to remove lead solder.

6-2.4.7 Non-Recommended Coating Removal Methods

CAUTION

Burning the coating off with a soldering iron is not recommended since this will cause charring of the coating and heat damage to the baseboard. Scraping coatings from modules by using sharp-edged metal blades must not be attempted because of danger of board damage.

The technician does not usually have sufficient hand-control sensitivity to work to the close tolerances that are necessary to prevent damage to materials directly under the coating. It must be remembered that a thin coating is usually .010 inches or thinner. Hand-scraping coatings from circuit areas with hard metallic, sharp edged blades can result in damage to the extremely thin circuit plating and may even cut through the thin, soft copper circuit itself.

6-2.4.8 Replacement of Conformal Coating

To replace conformal coating on printed circuit boards the following recommendations should be followed:

CAUTION

Conformal coatings may affect the capacitance and the "Q" of inductors in "RF" assemblies. Refer to the appropriate maintenance procedures in the equipment technicaI manual concerning alignment procedures and the proper use of protective coatings for "RF" assemblies.

1. Use a magnified viewer to visually inspect the repaired board for foreign matter.

2. Clean area to be coated, using a cotton swab that has been dipped in alcohol.

3. Allow the cleaned printed circuit board to dry thoroughly. Drying time will depend on the cleansing agent used.

NOTE

When possible, use the same coating material as originally employed. This will assure compatibility and meet functional requirements.

4. All coatings should be applied very thinly, not only for ease of removal, but more important, to prevent stress cracking in solder jointa. The spray or brush method should be used to ensure uniform thickness.

5. Before curing the applied coating by the approved method, inspect the coating with a magnified viewer for voids and pinholes. If any such are detected, application of another coat will be necessary.

6. After curing, reinspect with the magnified viewer for any existing defects. Reinstall repaired PCB in equipment.

6-3 REPAIR OF PRINTED CIRCUIT BOARDS

Repair procedures for microminiature PCBS are basically the same as for repair of miniature PCBS except that the relative size of the components and component density will require the use of special tools and techniques, such as those listed in Table 6-1. One type of repair that should be left up to the microelectronic repair technician is the repair of multilayer boards.

6-3.1 REPAIR OF MU LTILAYER PCBS

Multilayer board repair should always be performed with the utmost care and using the best possible techniques. Only standard repair procedures, good workmanship practices, and fully qualified personnel, who have been trained in advanced soldering techniques, should be utilized in making repairs. Several very basic rules must be followed. One of the most important of these which cannot be overstressed is, of course, avoidance of excessive heat. Avoid applying excessive heat and make it a habit to apply the least possible heat to do the job properly. The following defects can arise from excessive heat:

1. Damage to the PTH.
2. Board could be scorched.
3. Electrical resistance of the epoxy glass can be lowered, making the epoxy more susceptible to a voltage breakdown.
4. Epoxy binder material may flow into a hole and cause contamination.

Another essential point to keep in mind while soldering or resoldering — do not apply heat to the same terminal area (pad) immediately if not successful on the first try. Allow the connection to return to room temperature before a second application of heat. When replacing multi-lead components, avoid working on an adjacent terminal area (pad) immediately. Most of the cost of an expensive assembly may already have been spent, but with care and patience, most of this investment can be salvaged. Removal of conformal coating is another very important point too frequently considered only lightly. All conformal coating should be carefully removed from both leads and terminal area (pad) prior to the application of heat. Any remaining conformal coating will deter solder removal and will make the resolder operation very difficult since it will contaminate the hole being soldered. The few extra minutes spent on removing all conformal coating could very well prove the best time spent on a particular repair. Urethane resin strapping is normally used to hold large components against the board and thus protect them from the effects of vibration. The removal of such strapping is accomplished by the careful use of a thermal parting tool for this especially tough material and is very difficult to remove. Refer to paragraph 6-2.4.4 for details. In addition to utilizing trained personnel and the use of proven techniques, the latest available equipment sould be employed.

6-3.1.1 Repair of Damaged Holes in Multilayer PCBS

1. Clean surface to be repaired, using a stiff bristle brush dampened in perchloroethylene. Rinse with isopropyl alcohol.

2. Special care must be taken to keep rework area localized. Mask and/or plug adjacent holes to prevent the possibility of filling.

3. Select the proper bonding materials (resin and catalyst) and mix as recommended by manufacturer.

4. Mixinfiberglass #128 and stir until all fibers are wet.

5. Cure as recommended by manufacturer, then abrade flush.

6. Small plates coated with release agent may be clamped on the filled area to minimize amount of abrading required to flush.

7. Redrill hole per applicable drawing.

6-3.1.2 Repair of Internal Shorts

6-3.1 .2.1 Non Connector Area

1. Make a series of resistance readings and/or continuity checks. Record the data. Determine, if possible, the exact location of short or shorted holes before attempting any drilling.

2. Drill-out barrel of suspected hole or holes, slightly larger than the barrel O.D.

3. Examine hole carefully (using magnifier viewer) to be sure the entire barrel has been completely removed.

4. Repeat resistance and/or continuity checks to verify removal of short.

5. Clean hole or holes with isopropyl alcohol and mask area around hole.

6. Fill hole with epoxy and cure.

7. Abrade flush to surface of board and clean with alcohol.

8. Hard-wire, externally, all circuits removed by drilling and solder with rosin core solder. Care must be taken in routing external strappings to prevent "Cross Talk. "

9. Remove all flux residue, using cotton-tipped applicator and alcohol.

10. Install conformal coat over external wires.

11. Cement all external wiring to board surface (if required) or if board is not conformal coated.

NOTE

Tack external wiring down with cement in one-inch increment, each tack being approximately 1/4" in length.

6-3.1 .2.2 Connector Area

NOTE

It is assumed that the board in question has been tested and a record made of the shorted pins.

CAUTION

Make certain of the amount of current board will stand.

1. Connect power supply and digital voltmeter leads in parallel with the power supply set at 1 Vdc and with the current limited to 5A.

2. Probe shorted pins to ground circuit until the pin with the greatest voltage drop (least indicated voltage reading) is located.

3. Using the drill press and trepanning tool, remove all board material from around shorted pin. Good workmanship practice must be used to prevent tool from becoming plugged and thereby damaging connector/pin, After material has been removed, check as in step 2 to ascertain that short has been removed.

4. Install insulating sleeve over connector pin, not to extend above the bored surface. Fill board with epoxy and cure.

5. Using acceptable soldering procedure and continuity chart, replace the internal circuit by hard-wiring on the board surface. Epoxy the wire to the board surface as required. Check electrical circuit for proper routing and design specifications. Retest board for shorta. If the short occurs at a hole where no pin is installed, use drill-bit just large enough to remove the plated barrel from the hole. (It is advisable to check the artwork to see what internal circuitry is being removed by drilling, if any.) Fill hole with epoxy and cure. Hard-wire externally all circuits removed by drilling. Follow same procedure outlined in paragraph 6-3.1.2, steps 8 through 11.

6 4 REPLATING

6-4.1 INTRODUCTION

The technician will need to replate a printed circuit board whenever it has become impaired due to physical damage or neglect. Uneven, thin, scratched or blistered gold plating on contact bars may be replated if the scratches do not reduce the bar cross-section by more than 20% or by less than 20% of the contact area. When replating, potentially dangerous chemicals must be used, therefore, only a qualified micro-repair technician should attempt to do the work. The following safety precautions are to be observed in addition to applicable standard safety precautions:

1. Rubber gloves should be worn to avoid possible skin irritation and prevent circuit board contamination.

2. Wash gloved hands thoroughly in mild soap and water prior to removing the gloves.

4. Before putting on rubber gloves, check carefully for holes or other defects that may permit toxic chemicals to come in contact with the skin.

5. When repairing boards with installed components, be sure that the plating current will not pass through any of the component. Mask any adjacent circuits or conductors to ensure against inadvertent contact.

6-4.2 SPOT PLATING (TYPICAL)

NOTE

Use manufacturer's recommended solutions and procedures.

STEP I

1. Prepare the stylus in accordance with the directions. Prior to use, the stylus shall be soaked in the gold solution.

STEP II

1. Use abrader on the area until the surface is smooth and all defective gold plating is removed.

2. Rinse area with deionized water.

3. Brush on a solution of Anionic surface active agent for 10-30 seconds to clean the exposed copper.

4. Rince with deionized water for 30-60 seconds. A suitable clean surface can be identified by the absence of "water breaks."

5. Dry the board, using dry gas or air.

STEP III

1. Mask areas only where necessary to prevent component damage.

2. Mount board in a suitable holder. Tilt to prevent the plating solution from running onto the board.

3. Position return probe to the contact bar at joint near the area to be plated. Take care not to damage board or components with sharp point of probe.

4. Plate at approximately five (5) volts for 20-30 seconds at between 40 to 80 Ma. If the area to be plated is large, plate each small area for 20-30 seconds. The stylus must be kept moving to prevent "burning" the gold.

5. The stylus shall be dipped into the gold solution before plating each contact bar.

6. Rinse the plated board in deionized water.

7. Dry board, using dry gas or air.

8. Buff contact area lightly until similar in luster to others.

STEP IV

Perform tape test per IPC Acceptability Guide Lines (A-600-A) as follows:

1. Place a strip of cellophane tape 3/8-inch wide (approximately) over contact bars that have been repaired. Tape shall conform to Type 1, Class A of Federal Specification L-T-90. Use tape that has been manufactured within the previous 6 months.

2. Apply uniform pressure to the tape.

3. Rapidly pull the tape off perpendicular to the board.

4. Examine the tape and the board for evidence of removed plating.

5. If there is evidence of removed plating, repeat the cleaning and plating operations.

6. Remove tape residue using isopropyl alcohol, or equivalent.

6-4.3 ALTERNATIVE PLATING REPAIR PROCEDURES

6-4.3.1 Solder on Gold Plating

1. Remove excess solder by vacuuming or by wicking with fluxed end of braided wire. Apply heat only so long as required to melt and remove the solder.

2. Remove any remaining solder with an electric eraser or similar abrader.

3. Clean with alcohol.

4. Replace in accordance with spot plating procedure.

6-4.3.2 Thin or Missing Gold Plating

1. Remove all gold using an abrader.

2. Clean with isopropyl alcohol.

3. Replace in accordance with spot plating procedure.

6-5 MAINTENANCE OF MI CROSTATION

The microelectronic repair technician usually has access to some of the most sophisticated tools an electronic oriented technician could want, consequently the proper maintenance of the station will greatly enhance its capabilities. The micro-electronic technician should maintain his work station and equipment as outlined in Section 5 of this publication.

SECTION 7

DIGITAL TROUBLESHOOTING TECHNIQUES

7-1 DIGITAL TESTING TECHNIQUES

In order to accurately test today's advanced digital equipment, the technician must learn how to use some very unusual technical troubleshooting aids. These aids will make the technician's job easier, faster and more accurate. The technician who learns to use the logic clip, logic probe, logic pulser and current tracer will acquire a good understanding of digital testing techniques.

7-1.1 LOGIC CLIP

The logic clip is designed for logic level determination only on TTL and DTL logic conventions. The clip can test flip-flops, gates, counters, buffers, adders, shift registers, etc. It will not test ICS with non-standard input levels or expandable gates. By means of the logic clip the logic levels at all pins of a dual inline IC will be continuously displayed. All input pins are buffered to minimize circuit loading. The clip uses Light-Emitting Diodes (LEDs) to display "high" and "low" levels. The clip automatically locates the logic chip V_{cc} and ground pins of the chip, thereby eliminating any external power supply requirements. To use the logic clip the technician squeezes the thick end of the clip to spread the contacts, and then places the clip on the IC to be tested. The LEDs on top of the clip will indicate the logic levels at each connected IC pin (the clip may be turned either way). There are no operating controls on the logic clip.

7-1.1.1 Theory of Operation of Logic Clip

The following refers to the logic clip block diagram (Figure 7-l). Each pin of the logic clip is internally connected to a decision gate network, a threshold detector, and a driver amplifier connected to an LED. The decision gate network finds the IC V_{cc} pin (power voltage) and connects it to the clip power voltage bus, activating an LED. The network finds all logic High pins and activates corresponding LEDs. All open circuits are found and corresponding LEDs are activated. Finally, the clip finds the IC ground pin and connects it to the clip ground bus, blanking the corresponding LED. The decision gate network uses the following flow diagram (Figure 7-2). The threshold detector (refer to Figure 7-1) measures the input voltage. If the voltage exceeds the threshold voltage ($\approx$ +2 VDC), the LED is activated. If the voltage is less than the threshold voltage ($\approx$ +.8 VDC), the LED is not activated. An amplifier at the output of the threshold detector drives the LED. If the operation of the logic clip is suspected to be faulty, the operation of each pin network should be tested with relation to the others. For correct operation the logic clip must have at least one V_{cc} pin and a ground pin. Logic clip pins not connected to any circuit will indicate a high. A five-volt battery can be used to check each logic clip pin network for correct operation. Connect five volts across two pins; the remaining 14 LEDs and the + V_{cc} LED should then glow. Ground each pin one at a time (except the V_{cc}); each LED that has a ground should not glow. Use an adjustable low voltage power supply to check the threshold of each log clip pin.

7-1.2 LOGIC PROBE

The standard logic probe will detect and indicate valid logic levels. It will also indicate the presence and polarity of single pulses of IO-nanoseconds or greater in duration. In addition, it will detect "bad" logic levels, such as an open input on a TTL gate, and open circuits, such as an open collector output, without pull-up resistors. The input loading characteristics are similar to a low power TTL gate input: is therefore compatible with almost all TTL and DTL circuitry. The logic level indicator lamp will give the technician an immediate indication of the logic states, both static and dynamic, which exist in the circuit under test. Figure 7-3 shows how the logic level indicator lamp responds to voltage levels and pulses. The lamp has three possible states: off, dim and bright. The lamp is normally in its dim state and must be driven to one of its other two states by voltage levels at the probe tip. The lamp is bright for input levels above the logic one threshold, and goes off for inputs below the logic zero thershold. The lamp is dim for voltage levels between the logic one and zero thresholds and for open circuits. The indicator will flash on and off at about ten times per second for pulse train inputs larger than 10 Hz. Typical logic probe specifications are listed in Table 7-1.

7-1.2.1 Logic Probe Theory of Operation

The Logic Probe Schematic Diagram shown in Figure 7-4 is used for the following Theory of Operation explanation. At the probe input, R1 and CR "A" and CR "B" protect the probe from input overloads. At the power input connector, CR 1 and CR 3 protect the probe from reversed power connections. All input signals are applied to the two

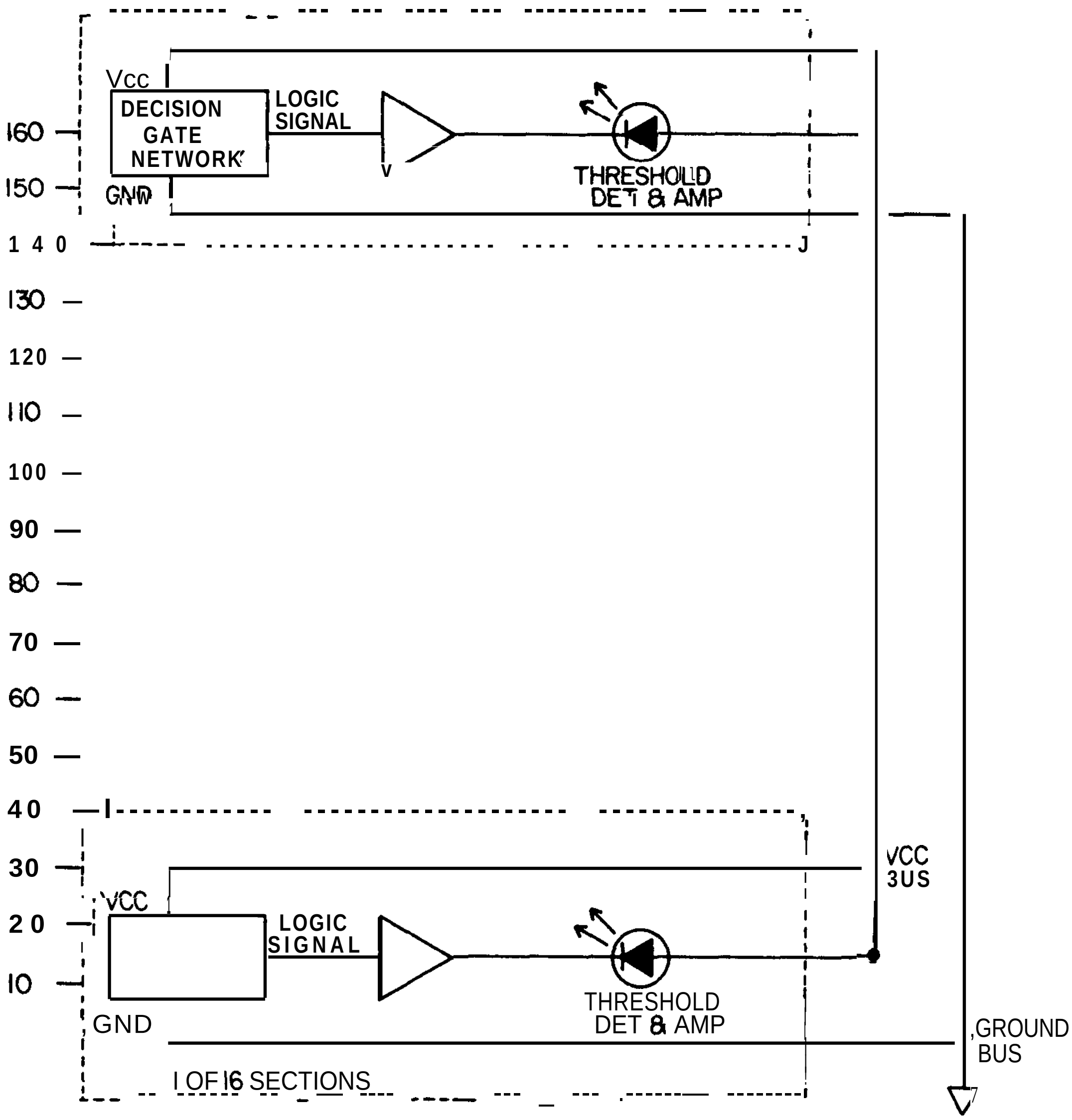


Figure 7-1. Logic Clip Block Diagram

parallel detectors. Both detectors compare the input signal to internal reference voltages. If the probe's input signal is more positive than the reference voltage of the logic One threshold detector, the detector's output will go High. Some hysteresis is injected to prevent instability, should the input voltage be equal to the reference voltage. The output of gate A is normally high (whereas gate G output is normally low). The resultant low from gate B sets the SR flip-flop thereby placing a high on the output of gate C. Coincident with this event, two things take place: 1) QA lights the logic level indicator lamp; and 2) the high outputs from gate C and the One delay causes the output of gate E to go low. This disables gate F and prevents the indicator lamp from turning off, should the input signal drop to zero during this pulse-stretching time. This cross-coupled disabling characteristic is responsible for the lamp's 10 Hz flash rate when the input is a high-frequency pulse train. Once the high from gate C propagates through the One delay (≈ 50 ins), a low on the R input of gate D attempts to reset the flip-flop. The flip-flop, however, will reset only if the input

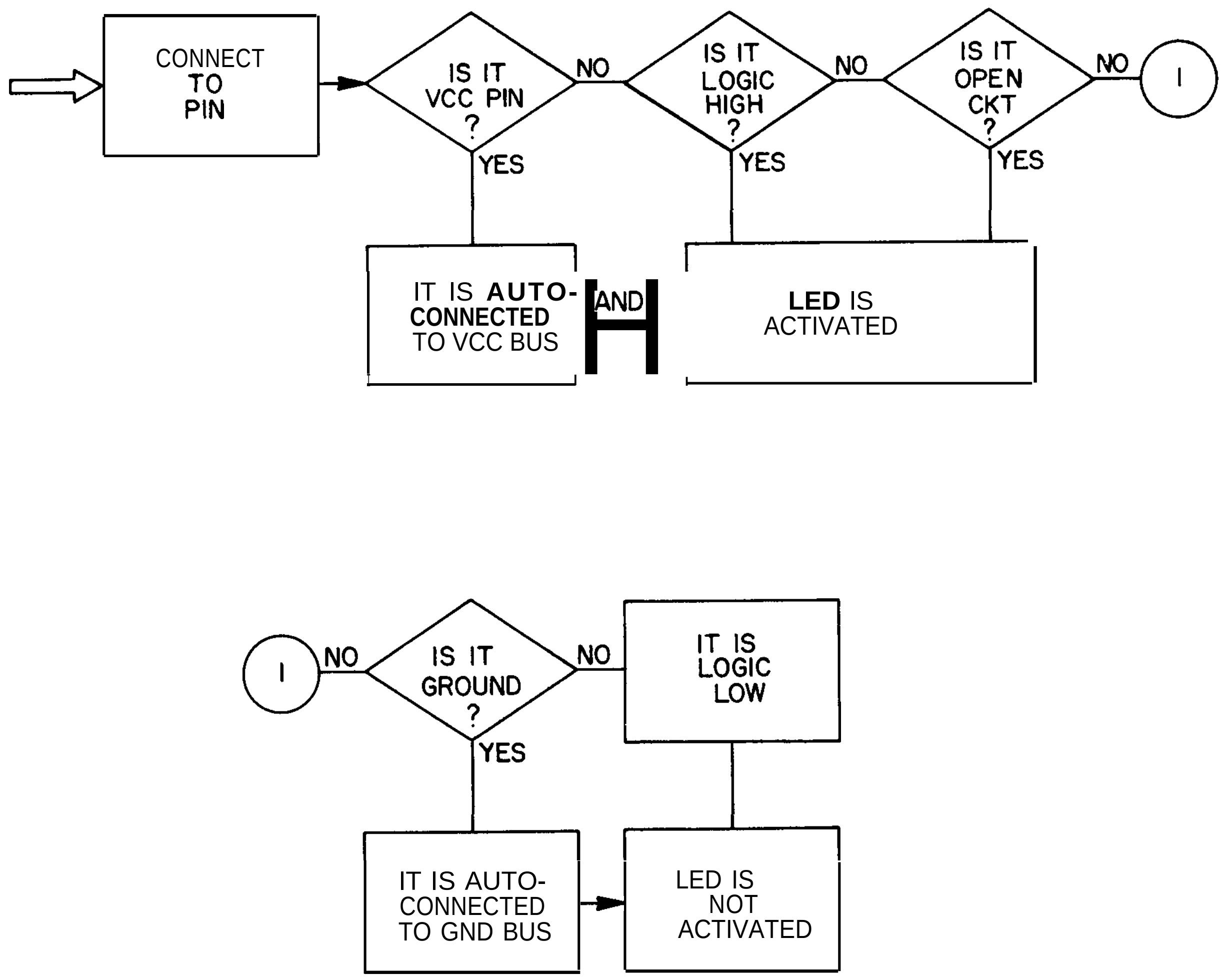


Figure 7-2. Decision Gate Network Flow Diagram

voltage drops below the logic threshold level. The indicator lamp turns on to full brilliance when gate C output goes high. This occurs when the probe's input level reaches the "l" threshold. When the probe's voltage is below the "O" threshold, the SR flip-flop in the zero channel is set high and thus prevents gate J from lighting the indicator lamp. The high from the flip-flop and the high from the Zero delay prevent the One flip-flop from setting. When the probe voltage is not positive enough to activate the One channel or low enough to activate the Zero channel, both flip-flops are low. Both low outputs become connected to gate J, which turns QB and the lamp ON. Diode CR "C" provides an added diode voltage drop in the emitter circuit and causes the lamp to glow at only half its brightness. If the probe input is continuously High the One channel flip-flop output and the logic lamp will be High (the lamp will be ON) continuously. A single fast positive pulse, 5-10 nanoseconds or slower, will actuate the ONE channel flip-flop to produce a 50-millisecond bright logic lamp flash. The delay circuit stretches the pulse. A positive pulsating signal with a frequency even slightly greater than 59 MHz will cause the lamp to flash on for about 50 milliseconds at a rate of 10 times per second. The delay circuit stretches the pulses. Negative levels or pulses will cause the lamp to switch off for about 50 milliseconds.

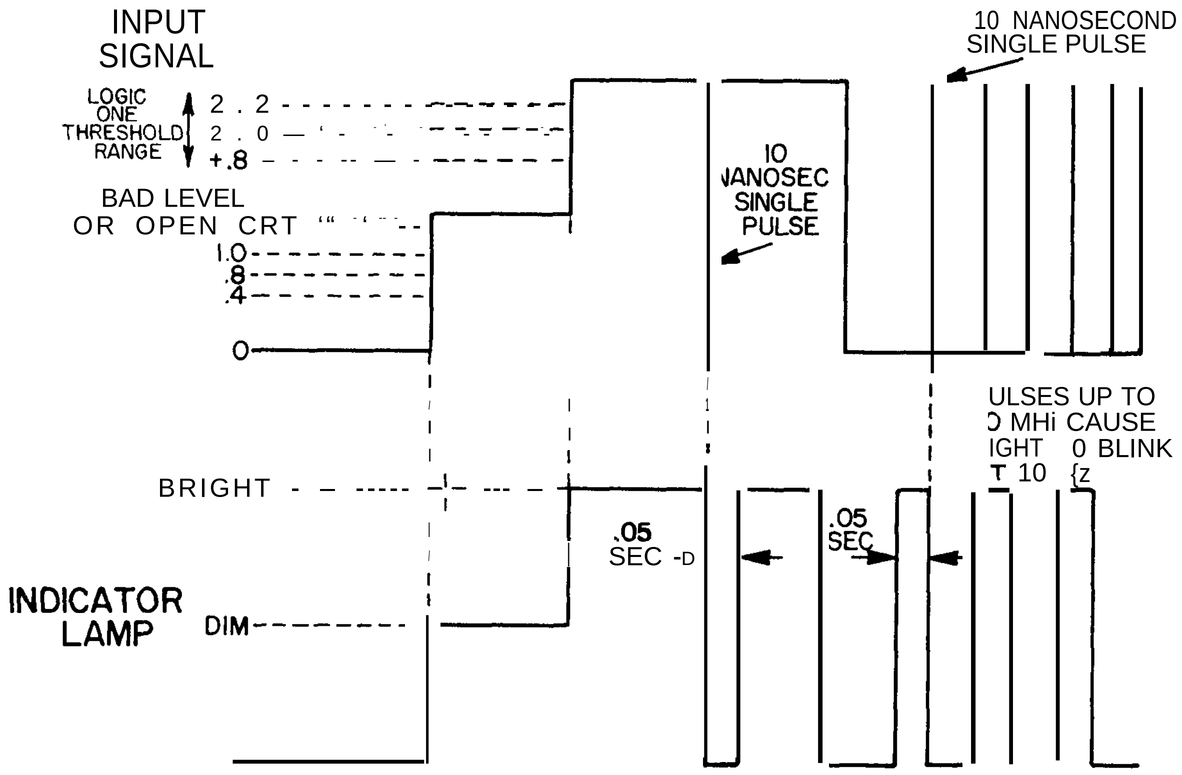


Figure 7-3. Logic Level Lamp Indication with Probe Input Voltage Levels

7-1.2.2 Operational Checks

No adjustments or preventive maintenance procedures are required for the logic probe. However, operational checks can be made to ensure the probe is operating correctly. With the logic level test setup shown in Figure 7-5, the technician should set power supply B to +5 V ±10% and power supply A to give a probe voltage of +1.5V. The probe lamp should now glow dimly. Adjust power supply A until lamp glows at full brilliance/probe tip voltage should now be 2.0 V ±.2V. Adjust power supply A downward until lamp glow is extinguished; probe tip voltage should now be .8V ±.2- .4V. If the probe power supply is not +5 V, the logic thresholds will change. The change is approximately .3 volt-threshold increase per volt of power supply increase. When using the positive pulse test setup (Figure 7-6), set power supply B to +5V. Set pulse generator to give a positive-going 10 nanosecond pulse. Set the repetition rate to about one pulse per second. The probe lamp should flash at a once-per-second rate. With the negative pulse test set (Figure 7-7), set power supply B to +5V and power supply A to 10V. Set pulse generator output polarity to negative. Adjust the pulse geneator to give waveform at the probe tip as shown in Figure 7-7. With a repetition rate of one pulse per second, the probe lamp should flash off once per second. Table 7-2 shows the recommended test equipment for performing these tests.

7-1.2.3 Troubleshooting with a Logic Probe

When using the logic probe, a DC supply can be obtained from either the circuit under test or from a separate +5 VDC supply. If a seperate supply is used, the circuit under test and the power supply grounds must be connected together. A ground clip is provided to improve pulse width sensitivity and noise immunity. The ground clip's use is optional. The logic probe is ideal for detecting short duration pulses and low repetition rate pulses that would otherwise be very difficult to observe on an oscilloscope. Positive pulses to 10 nanoseconds or greater in width trigger the lamp on for **50** milliseconds or longer. Negative pulses cause the lamp to momentarily go off. Several logic circuit

Table 7-1. Typical Probe Specifications

Positive Logic Threshold Voltages	
	Logic "l": 2.0 ± .2 volts
	Logic "O": .8 ± .2 -.4 volts
[nput Impedance	
	Greater than 25,000 ohms
Pulse Width Sensitivity	
	10 Nanoseconds
MAX PRF	
	Greater than 50 MHz
Input Overload Protection	
	± 70 VDC Continuous
	± 200 VDC Transient
	120 VAC for 30 seconds
Power Requirements	
	+ 5VDC @ 60 milliamps
	-15 VDC
Operating Environment	
	0 °C - 55"c

analysis techniques lend themselves for use with logic probes. One technique is to run the circuit under test at its normal clock rate while monitoring for various circuit control signals, such as reset, start, stop, shift, transfer, or clock signals. Questions such as "Is the counter working?" are easily resolved by noting if the probe indicator is flashing on and off, which indicates that pulse train activity is present. Another useful technique is to replace the normal clock signal with a very slow clock signal for a pulse generator, or to single-step the clock input with a logic pulser (the pulser will be discussed later). The changes in logic signals should now occur at a rate slow enough that they can be observed on a real time basis. This real time analysis technique, coupled with the ability to inject logic level pulses anywhere in the circuit with the logic pulser and the ability to detect logic state changes with the logic probe, contribute to rapid trouble-shooting and accurate fault tracing in digital circuits.

7-1.2.4 Logic Test Probe

All modern electronic equipment involves the use of some digitrd circuits to perform various functions. It is therefore necessary to devise a method of easy troubleshooting for locating faulty integrated circuits or logic output cards. A simple and quite reliable method employs the logic test probe. Since the output of a digital circuit employs either a 1 or O (zero) condition, the logic test probe can, at a glance, indicate the circuit's present state. The input(s) can then be verified by the same method, and a study of the circuit under test can determine if the correct output is present. (Refer to the digital troubleshooting methods section of this publication for a more detailed procedure for determining the proper output state of a logic circuit. Various logic test probes are available through the Naval Supply System and in the commercial market. Considerations must be observed when selecting a probe for a specific intended use. These considerations are:

1. Frequency Response
2. Minimum Pulse Width Response
3. Circuit Loading
4. Power Versatility

7-1.2.4.1 Frequency Response

The frequency response of the probe must be greater than that of the circuit under test. This allows the logic probe time to correctly identify the circuit's output condition and then reset for the next output indication while continuously monitor-ing a particular logic train. The probe divides this logic train down to a rate in which the LED can be notice-ably gated on and off, and not appear to be constantly "on" for a high frequency series of one-state-logic pulses. Probe response frequencies will range from 2 MHz to 100 MHz, depending on the one selected. Typical high quality probes are of the 50 MHz variety, with 10 MHz being quite acceptable.

7-1.2.4.2 Minimum Pulse Width Characteristics

Puke width characteristics are a prime consideration when dealing with high-speed logic circuits. Many logic probes employ protection circuits to prevent them from being falsely triggered by noise or by power source variations. Selecting a probe that will identify pulse durations in the nanosecond range is mandatory for testing modern logic equipment. Typical quality probes range from 10 to 100 nano-seconds.

7-1.2.4.3 Circuit Loading

As with any electronic test equipment, the amount of additional load that the test equipment provides to the driving circuit must be considered in order to avoid possible fake indications. The additional load of a logic probe on an integrated circuit may, in some cases, prevent a logic circuit from changing its

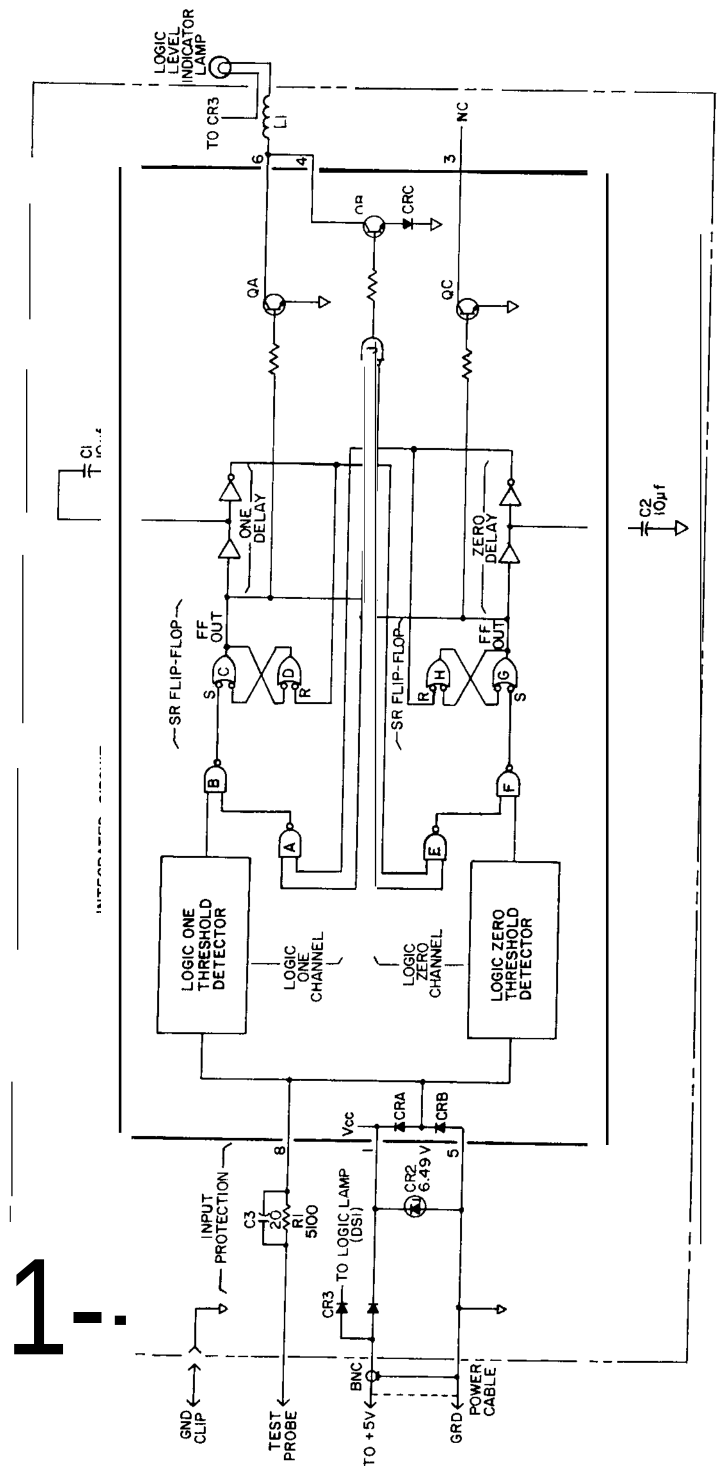


Figure 7-4. Logic Probe Schematic Diagram

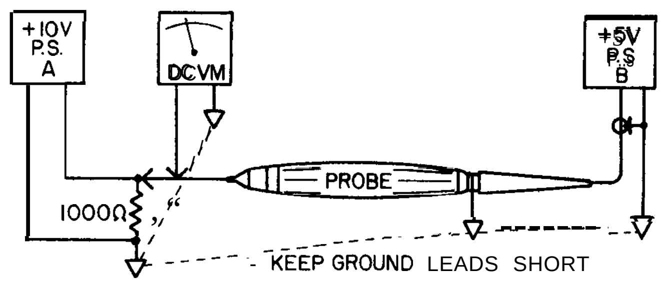


Figure 7-5. Logic Level Test Setup

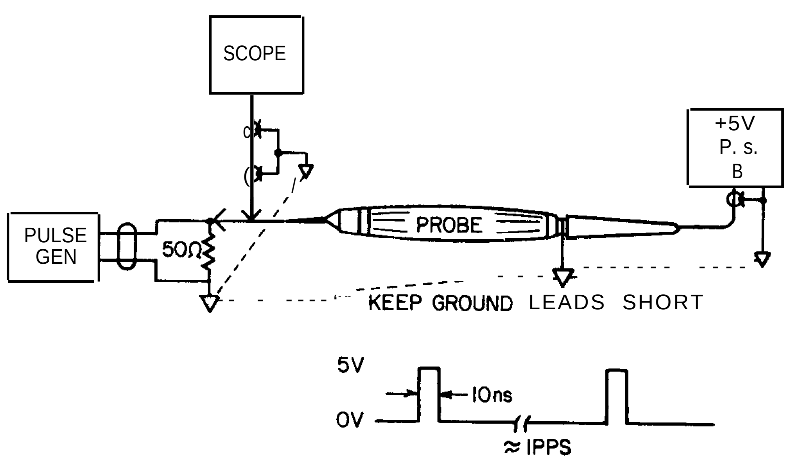


Figure 7-6. Positive Pulse Test Setup

state. A "grey area" exists in logic equipment which allows for additional errors. This is known as the "Indeterminate Region." In the "Indeterminate Region," the exact response of a logic circuit cannot be predicted. Safeguards have been included in circuit designs to ensure correct input and output levels of integrated circuits and that these levels will always lie outside the "grey region" for either state. Figure 7-8 shows that during time frame "A" a constant "l" state of logic exists. A logic test probe would show a l-state lamp illumination. Time frame "B" shows a O (zero) logic state, and the logic test probe would show the "l-state" lamp being extinguished and, if provided, an "O-state" lamp illuminated. Time frame "C" in the figure indicates two pulses of tbe l-logic state. The logic prohe lamp would now flash twice. If an "O-state" lamp is provided, it would not be illuminated because the negative excursions of the pulses did not cross the O-state threshold. Time frame "D" indicates two pulses of O-state logic, therefore the O-state lamp would light up for two flashes. However, the l-state lamp would not have illuminated because the positive excursions did not cross the l-logic threshold. Time frame "E" indicates an alternating "O" and "l" state. The leading

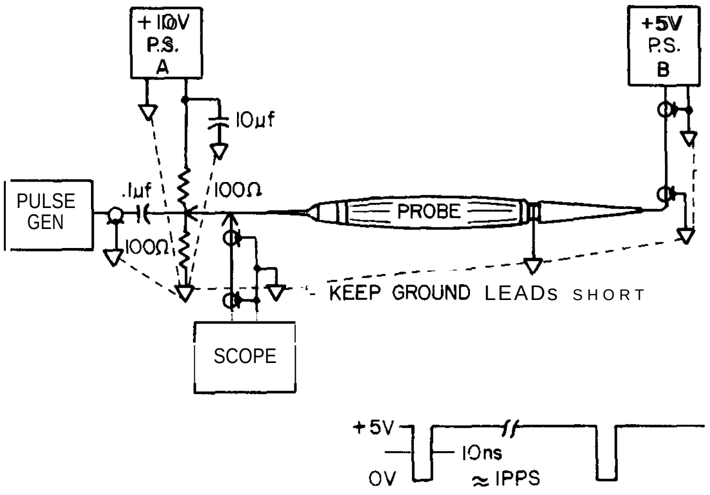


Figure 7-7. Negative Pulse Test Setup

Table 7-2. Recommended Test Equipment

1.	0-20 V O-1A power supply
2.	0-10 V O-1A power supply
3.	DC VOM ammeter 1% accuracy
4.	Pulse generator 0-1 ms pulse width
5.	Oscilloscope .3 Hz -10 MHz repartition rate 250 MHz bandwidth 10 mv/div sensitivity, vertical 1 ns/div sweep, time base 500 MHz active probe
6.	2- 100Ω resistors
7.	1 -.1 µF capacitor
8.	2-10 #F capacitors
9.	1-1 kΩ resistor

and trailing edges of the pulses are seen as clearly crossing the thresholds of both the O and the 1 states. This would cause an alternating flash between the O and 1 lamps on the logic test probe. The logic threshold exists at roughly $\geq$ 1.3 volts and $\leq$ 1.9 volts. Many logic probes have a wider threshold area ($\geq$ .7 volts and $\leq$ 2.15 volts). Within these areas the proper operation of the circuit under test and/or the logic test probe will be questionable. This problem is common when using a probe not properly designed for CMOS integrated circuits. The application of the logic probe tip to a circuit test point loads the circuit to a point where the signal present falls within the grey area. This causes the circuit to malfunction by imposing an excessive load on the driving circuit, leading to possible failure of that particular driving circuit. A malfunction may afso be due to simply loading the signal to within the grey area, causing the following circuit not to respond. Impedance of logic test probes range from 5K Ω to over one half megohm.

7-1.2.4.4 Power Versatility

Most logic test probes operate from a positive or negative five volt power source with a ten percent tolerance. Logic probes can have accessories which allow the probe to operate from sources to ± 30 volts and protect the probe from damage from voltage sources. Input signal levels to the probe tip are normally on the order of ± 5 volts, although some logic circuits use a high-level logic of ± 15 volts. Input signal levels from a failed chip may reach the applied source voltage of that chip. A logic probe may therefore be damaged if the probe design does not allow for overvoltage protection at the probe tip. This protection is usually achieved by inserting a subminiature fuse in the tip circuit.

7-1.2.4.5 Construction of a Simple Logic Probe

A simple functioned logic probe can be fabricated using materials commonly stocked throughout the fleet. Three such probes will be shown, and all are acceptable for TTL, DTL and RTL circuits. Good workmanship is as essential in probe fabrication as in all projects requiring precision. Figure 7-9 shows a probe constructed from common parts normally available and is the simplest of designs. This probe

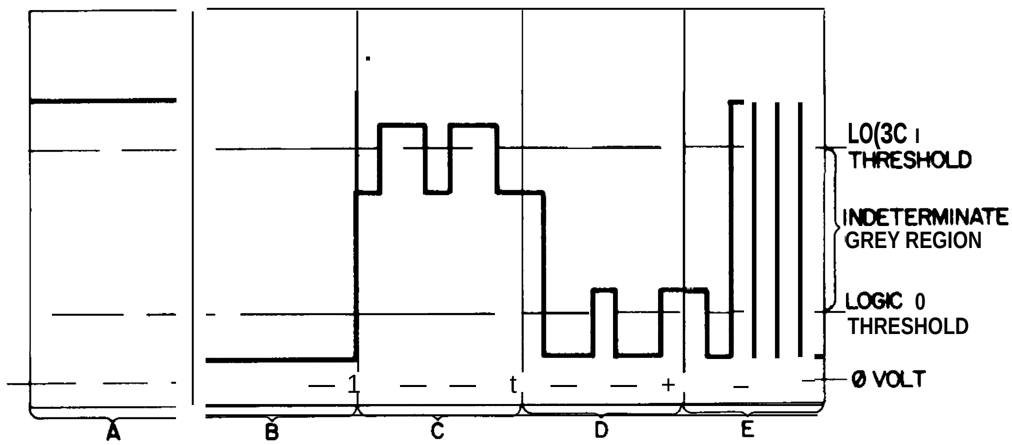


Figure 7-8. Logic Threshold and Pulse Conditions

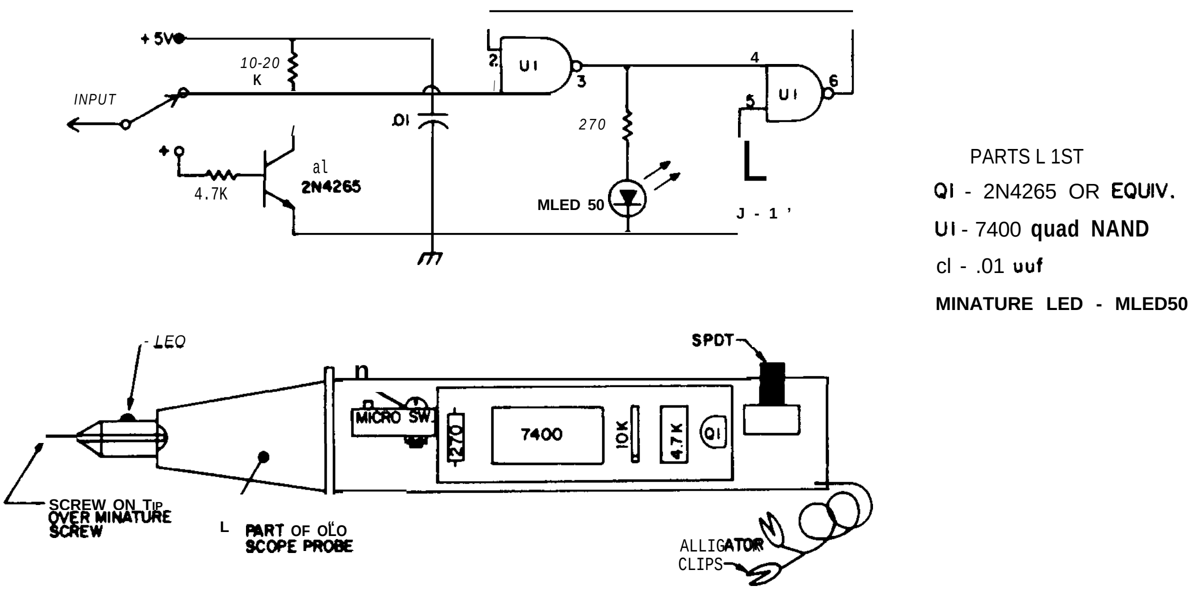
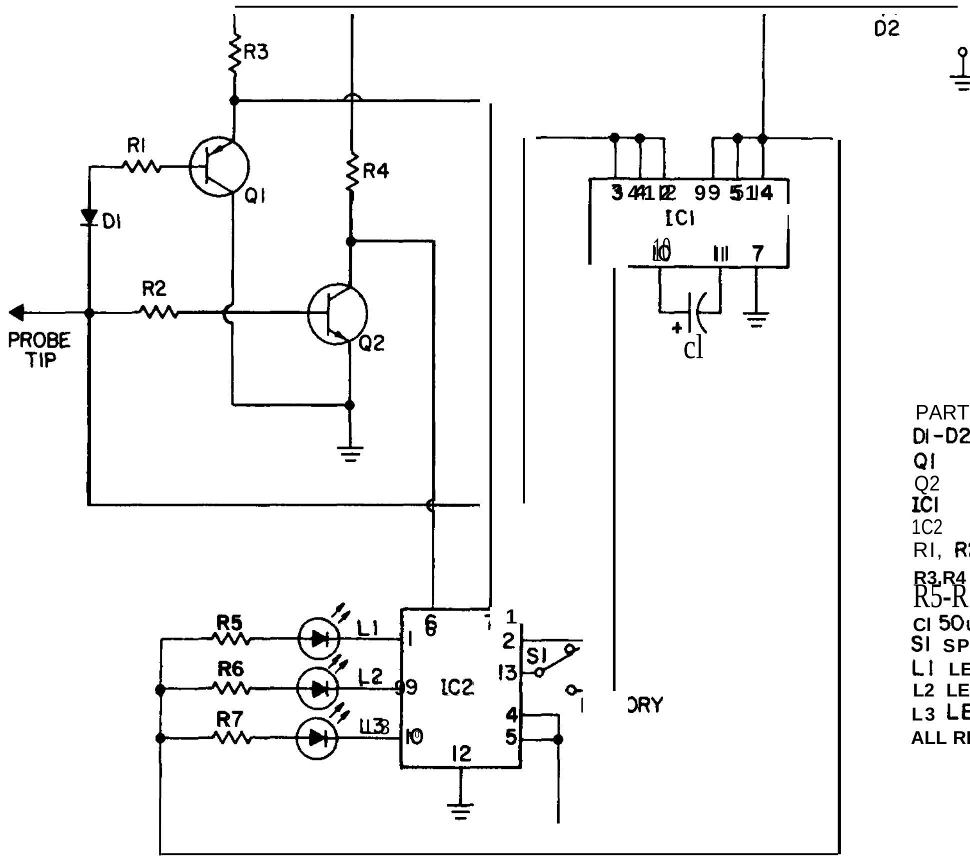


Figure 7-9. Construction of a Simple Logic Probe

has a memory for detecting a pulse that occurs only occasionally over a period of time, and a single flash of the LED might be missed by the observing technician. If such a pulse occurs, the LED will light and stay lit until the memory disable switch has been cycled. Another feature of this design is the presence of a polarity switch for working with either negative or positive logic. The limitation of this probe is that it is primarily designed for troubleshooting circuits whose states are not constantly changing. A single pulse will cause the LED to light and stay lit while holding the memory disable switch in its “on” position. A train of pulses will cause the LED to light, but only at half brilliance. The second of three probes (Figure 7-10), features a very versatile design which is the superior of the three designs presented here. Construction time by a technician is approximately three hours. This logic test probe will detect pulse



PARTS LIST
D1-D2 IN914
Q1 2N404
Q2 2N706
IC1 74121
IC2 7475
R1, R2 10KΩ
R3,R4 1 KΩ
R5-R7 150Ω
C1 50uf (ldv.) 10VDC
S1 SPST
L1 LED(PULSE)
L2 LED(LOW)
L3 LED(HIGH)
ALL RESISTORS ARE 1/4 WATT, 5%

Figure 7-10. Logic Probe Circuit

widths of 50 nanoseconds and has a frequency response in excess of 10 MHz. In operation, LED L1 flashes to show that the input is changing and is of a sufficient level to cause the test probe to show either a 1 or a O (zero) state. This is known as a pulse "Stretcher/Detector" operation. The LED L2 lighta for a logic O state, whereas LED L3 lights for a logic 1 state. The probe can be mounted in a coin collector tube or in a suitable plastic pill container obtained from the medical supply system. A toothbrush case of soft plastic is best for rough conditions where probe breakage may otherwise occur. The IC chips are mounted back-to-back for compactness. The probe tip is the shaft of a miniature screwdriver cut to length. Insulate all but the shaft tip with heat shrinkable tubing. A miniature SPST toggle switch, such as found in many AIMS/IFF equipment, can serve as the memory switch. Eighteen-inch-long leads of stranded wire with covered alligator clips were used for connecting the probe to a power source. The third logic probe design (Figure 7-11) provides for a readout of logic state, and is also a pulse stretcher/detector that cycles itself off after 300 milliseconds. The case into which it is mounted is a 5/8 inch O.D. x 3-3/4-inch plastic tube.

7-1.3 LOGIC PULSER

A "logic pulser" stimulates TTL and D1'L logic circuitry. Table 7-3 lists typical logic pulser specifications. The pulser requires +5 VDC to operate.

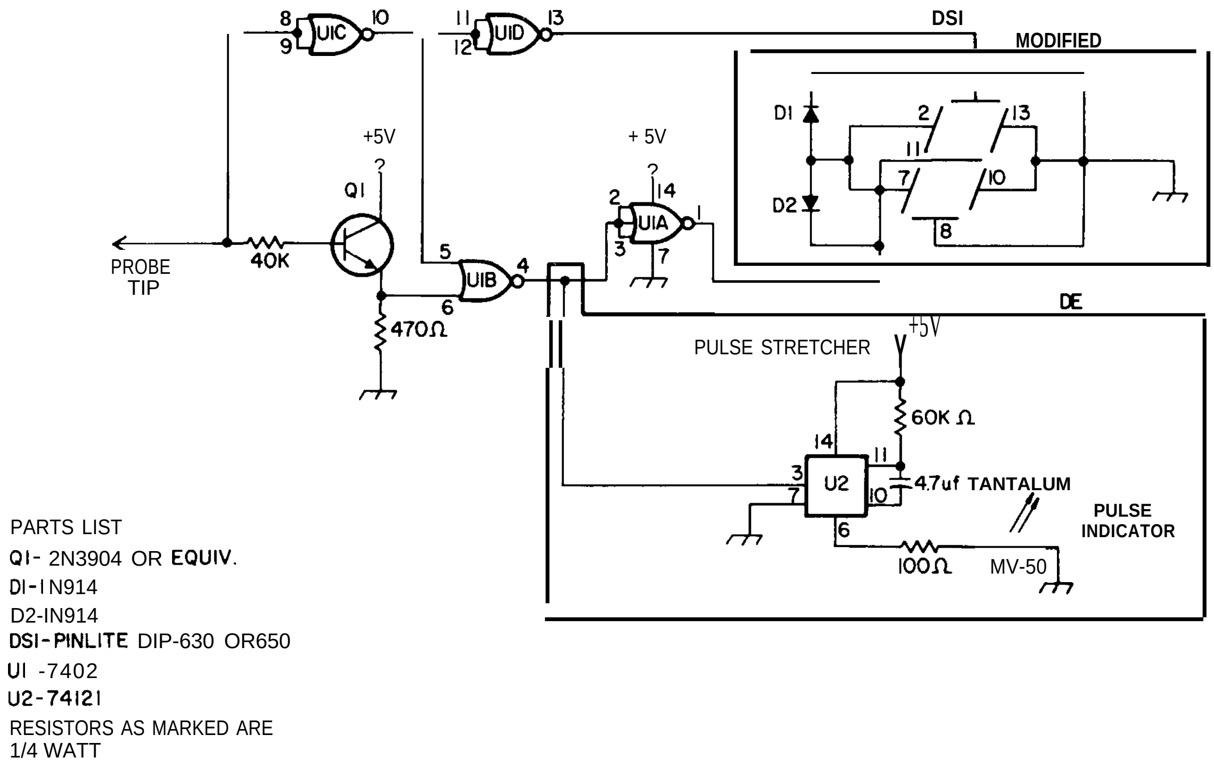


Figure 7-11. Modified Logic Probe

The input power should normally be taken from the circuit under test. If it is not possible to thus use the test circuit, then a separate +5 VDC supply may be used for power. However, in the latter case, the power supply common return must be connected to the instrument under test. The purpose of the logic pulser is to generate one Low and one High pulse each time the associated probe is triggered. Triggering is accomplished by depressing a micro-switch located on the probe body. The state of the test node is of no concern to the technician due to the fact that the logic under test will be driven either from a high to a low, or from a low to a high. The high source and sink current capability of the pulser can override IC circuit output points, originally in either High or Low states. The output pulse width of 0.3 μs limits the amount of energy delivered to the device under test, thereby eliminating the possibility of destruction. The pulser has a tri-state output. In its "OFF" state the probe's high output impedance ensures that circuit operation is unaffected by probing until the pulse switch is pressed. Pulses can be injected while the circuit is operating and no disconnections are needed.

7-1.3.1 Theory of Operation of Logic Pulser

When the pulser switch is activated (refer to Figures 7-12 and 7-13), the timing sequence starts by resetting the R-S flip-flop. The F-F "out" terminal (pin 8) goes Low from High (when the pulse switch is released, the flip-flop sets, and pin 8 goes High). Before the pulse button is pressed, UIB (Pin 3) is normally at 2.9 volts (a logic High). The Low pulse from UIB (pin 9) is differentiated by C3, R2, and R_8. The output of UIB (pin 2 goes High when the input goes Low. When the input voltage at UIB (pin 3) uses the switching threshold, the output of UIB switches back to Low. The UIB positive output pulse time is approximately 0.3 microseconds. This time is controlled by C3, R_2, R9 and the switching threshold of UIB. The positive pulse from UIB (pin 2) is applied to both the High pulse output channel and the Low pulse output channel. The positive pulse at the input

Table 7-3. Typical Logic Pulser Specifications

Sensitivity:	1 ma to 1 A
Frequency response:	light indicates single step current transitions; single pulses ≥ 50 ms in width; pulse trains to 10 MHZ
Rise time:	≤ 200 ns @ 1 ma
Power Supply Requirements:	
voltage:	4.5 to 18 VDC
input current:	≤ 75 ma
max ripple:	± 500 mv above 5 VOC
overvoltage protection:	± 25 VDC for one minute

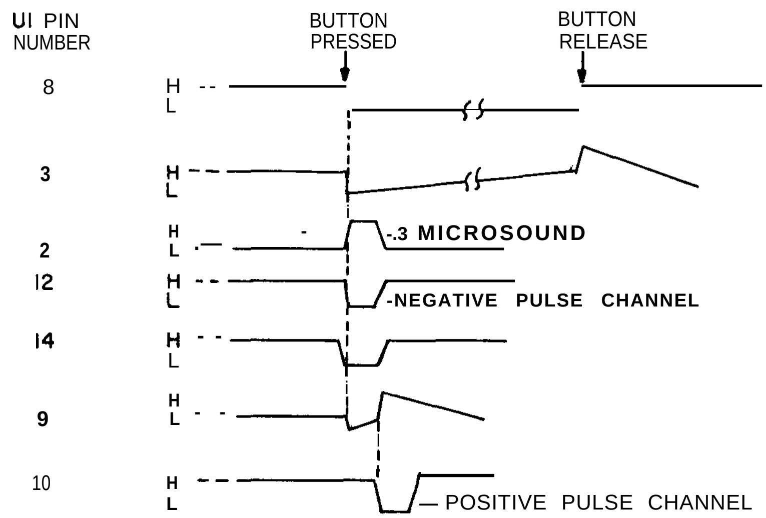


Figure 7-12. Logic Pulser Timing Diagram

of the logic low pulse output channel (UIF) is inverted at the output (pin 12). The pulse is amplified and inverted to a positive pulse by Q2. This pulse is applied to the base of Q4 and drives the transistor into saturation. The collector is clamped to the common return for the duration of the pulse. The logic High pulse output channel (UIA) inverts positive pulse from U1 pin 2. The negative puke at U1 (pin 14) is differentiated by C_2 and R_1. The positive going differentiated puke at pin 9 (Figure 7-13) is inverted by by UIE and a delayed, negative pulse is produced at the output of UIE (pin 10). This pulse starts then the original UI (pin 2) pulse stops. The negative pulse from UI (pin 10) switches Q1 on for the pulse time, producing a positive pulse at the collector. The positive pulse from the collector of Q_1 switches Q_3 on thus producing the positive output pulse. Capacitor C5 supplies current for the High pukes. Capacitor C_6 provides a low impedance path for the output pulse and protects the pulser from any DC voltages that may be inadvertantly applied to the pulsers' output probe tip. Resistance R_8 supplies a discharge path for C_6. The prohe is protected by CR1, DS1, and C_1 from overvoltage being applied to the power supply leads. Reverse polarity protection is provided by CR1, and DS1. Capacitor C_1 filters power supply spikes and

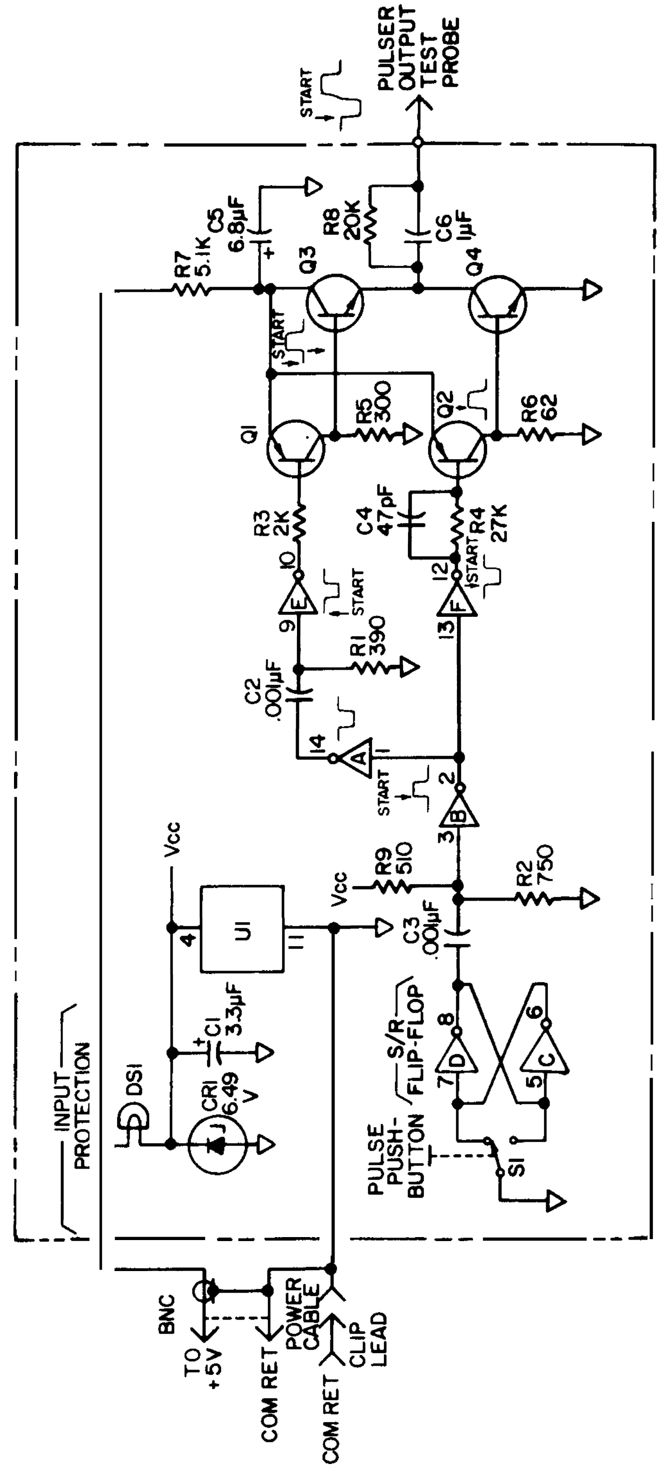


Figure 7-13. Logic Pulser Schematic Diagram

R_7 protects the output channels from damage due to overvoltage or from reversed power supply connections.

7-1.3.2 Troubleshooting with a Logic Pulser

The technician can use the logic pulser, logic probe and logic clip jointly to throughly test a logic gate. For example, a logic gate may be tested by pulsing the gate's input while monitoring the output with the logic probe (refer to Figure 7-14). The logic pulser generates a pulse opposite to the state of the input line and thus can change the output's state. This ensures that the output of the gate is not clamped in its state by another input; for example, a High on the other input of an OR gate. If the pulse is not detected at the output, pulse the output line (refer to Figure 7-15). If the output is not shorted to V_{cc} or the common return, the logic probe should now indicate a pulse. If not, check for external shorts before removing the IC. The logic pulser may also be used in conjunction with a logic probe to verify the operation of inverter-amplifiers. By pulsing the input to the inverter-amplifier (refer to Figure 7-16) and placing the logic probe on the output the technician should observe a pulse on the output line. If no puke is detected the output line should be checked for shorts as described above (refer to Figure 7-15) prior to replacing integrated circuits. When testing counters, flip-flops and shift registers, the following procedures may be used. These devices typically have several output pins where data must be monitored when testing. The logic pulser, when used as a manually-controlled clock, allows the logic clip to simultaneously examine all output data at rates convenient for viewing. When the logic clip is placed on an IC, the LEDs on the clip indicate the logic state of each pin. As the pulser clocks the input, the indications on the clip can be compared to a "truth" table.

7-1.4 CURRENT TRACER

One of the more recent state of the arts took designed for use by digital technician is called a "Current Tracer." The device is a hand-held probe which enables the precise localization of low-impedance faults in digital systems. Basically, the probe senses the magnetic field generated by a pulsating current internal to the circuit or by current pulses supplied by an external stimulus, such as a logic pulser. The technician will receive a visual indication of the presence of current pulses by the excitation of an indicator lamp located near the probe's tip. Adjustments of the probe's sensitivity over its working range (1 milliamp to 1 amp) is accomplished by a sensitivity control located near the indicator.

7-1.4.1 Theory of Operation of Current Tracer

For the theory of tracer operation, refer to the probe schematic, Figure 7-17. The current step sensor comprises a pickup core and winding and

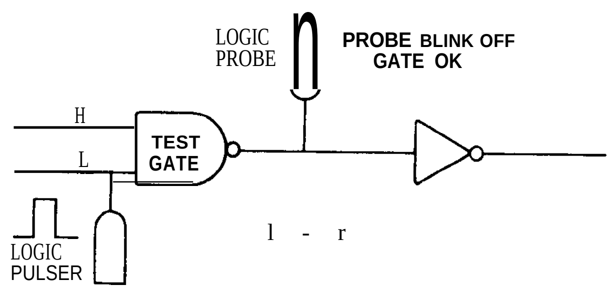


Figure 7-14. Logic Gate Testing

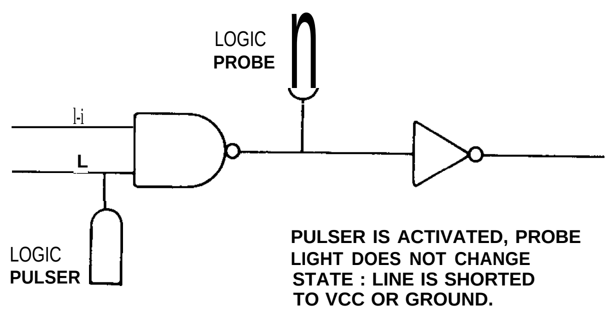


Figure 7-15. Testing for Shorts

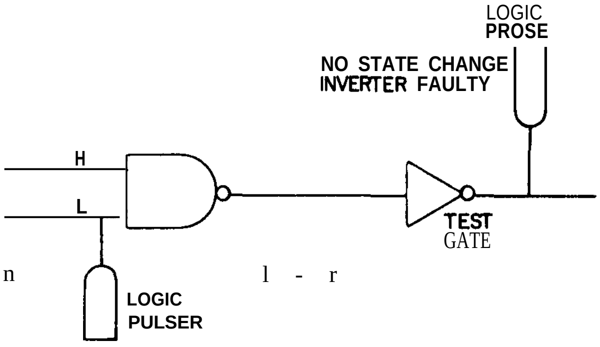


Figure 7-16. Verifying Operation of Inverter-Amplifiers

an eddy-current shield. The signal to be traced is sensed by the pickup winding and core. The variable-gain preamp consists of Q1 and peripheral components. The signal from the current-step sensor is fed directly to the base of Q1 and the output of **Q1** is taken direct to U1. The gain of the variable-gain preamp is controlled by an ac-coupling of the emitter and collector of **Q1** (via capacitors C4 and C5) to the current-controlled variable resistance presented by diode pairs CR4-CR6 and CR5-CR7. Each end of each diode pair is returned to signal ground or one of the ac-grounds formed by capacitors C6, C7, and C8. Diodes CR1, CR2 and CR3 determine the value of control current for the diode pairs. The gain control network adjusta the gain of the variable-gain preamp from -40 dB to +20 dB with an essentially constant high bandwidth. **U1** serves to increase the output of the variable-gain preamp. Interstate ac-coupling of **U1** is effected via R12 and C1O. The output of the fixed gain amplifier is **ac-coupled** through C12 to amplifier U2, which provides additional gain. The output of amplifier is internally coupled to a bipolar peak detector **(part** of U2) where a pulse of either polarity results in rapid charging of capacitor C14. This charging signal, a positive stretched version of the input, with an amplitude proportional to the input, discharges through R20. The output of the bipolar peak-detector is fed into another peak-detector consisting of an operational amplifier (P/O U3), with an additional stage in the feedback loop (P/O U2). When the signal imposed on C14 is positive, C15 becomes rapidly charged by U2 until the inputs to the operational-amplifier become equalized. The charge on C15 then slowly discharges through R18, stretching the input pulse for sufficient time to light the indicator lamp DS1. (Refer to Figure 7-17.) The signal at C15 is de-coupled to the dc amplifier, which consists of an operational-amplifier (P/O U3) and series-pass transistor Q3. The gain is set by R25 and R27; C19 is provided to suppress oscillations.

7-1.4.2 Troubleshooting with a Current Tracer

Tbe current tracer operates on the principle that whatever is driving a low impedance fault mode must also be delivering the most of the current. Tracing the path of this current thus leads directly to the fault. Problems that are compatible with this diagnostic method are:

1. Shorted inputs of ICS.
2. Solder - bridges on PCs.
3. Shorted conductors in cables.
4. Shorts in voltage distribution networks. (V_{cc} - to grid - shorts)
5. Stuck logic data bus.
6. Stuck wire - AND structure.

The desirability of current tracer use is usually indicated when conventional troubleshooting reveals a low-impedance fault. The technician then aligns the mark on the probe tip along the length of the printed circuit trace at the driving end and adjusts the sensitivity control until the indicator load barely lights. The probe is then moved slowly along the trace or placed directly on the terminal points of the nodes (or IC pins), while observing for brightness of the indicator light. This method of following the path of the current leads directly to the fault responsible for the abnormal current flow. If the driving point does not provide pulse stimulation, then the node may be driven **externally** by using a logic **pulser** at the driving point. One of the most difficult problems encountered in troubleshooting **ICs** is imposed by a stuck wire - AND node. Typically one of the open-collector gates may continue sinking current even after it has been turned off. Refernng to Figure 7-18, the technician should place the current tracer on the gate side of the pull-up resistor. He must then align the mark on the probe tip along the length of the printed-circuit trace, and adjust the prohe's sensitivity control until the indicator is just fully lighted. If the indicator will not light, then he must use a logic pulser to excite the line. When the tracer tip is placed on the output pin of each gate only the faulty gate will cause the indicator bulb to light. When a low-impedance fault exists between two gates, the current tracer and logic pulser, when used in combination quickly pinpoint the defect. In Figure 7-19, gate A output is shown shorted to ground. Place the pulser midway between the two gates and place the current tracer tip on the pulser pin. Pulse the line and adjust the current tracer sensitivity control until the indicator bulb just lights. First place the current tracer tip next to gate A and then to gate B, while

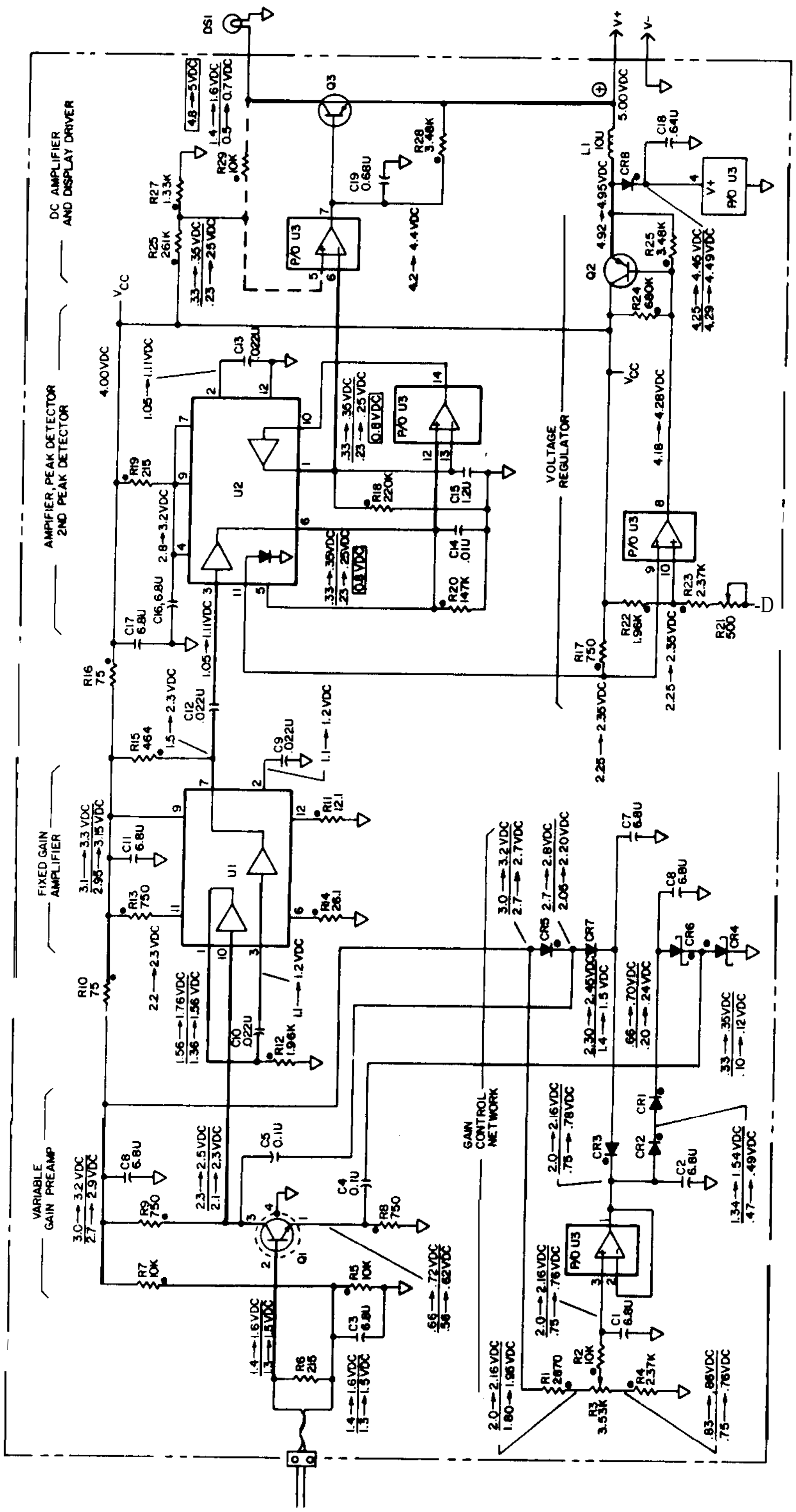


Figure 7-17. Current Tracer Schematic Diagram

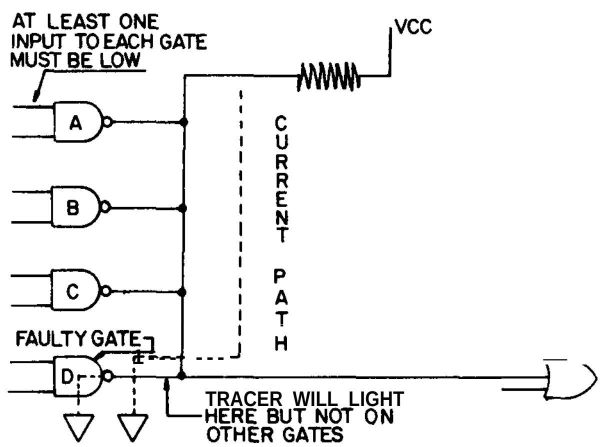


Figure 7-18. Wire AND-node Fault

continuing to excite the trace. The tracer will light only on the gate A side, since gate A (the defect) is sinking most of the current. When checking printed circuit traces which may be shorted by solder-bridges or by other means, start the current tracer at the driver and follow the trace. Figure 7-20 shows an example of an incorrect current path due to a solder bridge. As the tracer probe follows the trace from gate A toward gate B, the indicator bulb remains lighted until the tracer passes the bridge. This is an indication that the current has found some path other than the trace. Visually inspect this area for solder splashes, etc. These techniques also apply when troubleshooting shorted cable assemblies. Another type of IC model structure is the one-output, multiple-input configuration. Figure 7-21 shows this type of circuit being pulsed by a signal on gate A's input. In this case, place the current tracer's tip on the output pin of gate A then adjust the sensitivity control until the indicator light just comes on. Then check the input pins of gates B through E. If one of the input pins is shorted, that pin will be the

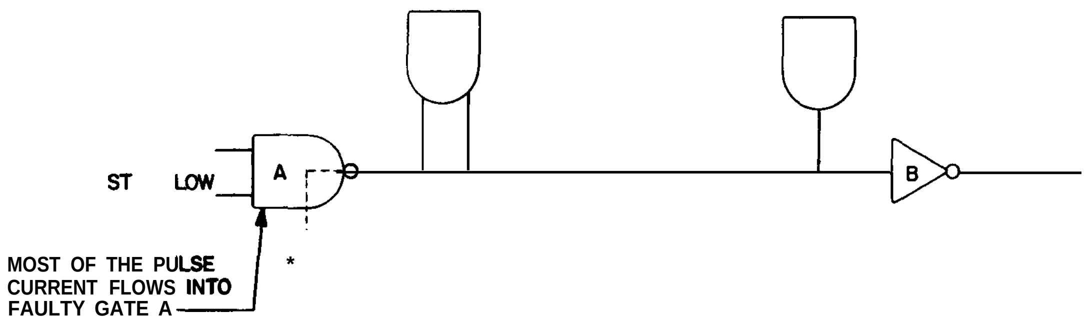


Figure 7-19. Gate-to-Gate Fault

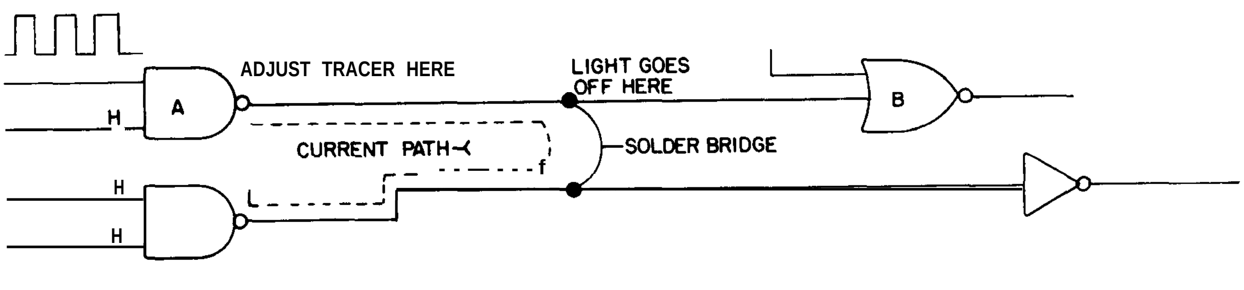


Figure 7-20. Solder Bridge in Printed Circuit

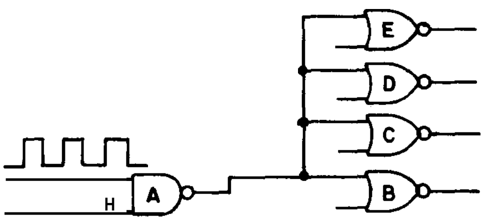


Figure 7-21. Multiple Gate Inputs

only one to light the indicator. Should the indicator fail to light when placed next to gate A's output, it is a valid indication that gate A constitutes the problem. Troubleshooting CMOS and ECL circuits is performed in the same manner as for TTL circuits; the only difference being in the voltages availabe for the current tracer's power supply connections. Table 7-4 shows the voltage range from each.

Table 7-4. Typical Voltage Ranges for CMOS, ECL, TTL Logic

CIRCUIT	TYPICAL RANGE
CMOS	3 VDC to 15 VDC
ECL	-5.2 VDC to O VDC
TTL	O VDC to 5 VDC

7-1.5 LOGIC COMPARATOR

Another device that merits consideration is known as a "logic comparator." The comparator is an IC troubleshooting tool that electrically compares a reference IC to an IC under test. The reference IC shares the power and input signals with the test IC. When comparing the output of the two ICS, any level difference existing for 0.2 μs or more will light an LED on the comparator, thereby indicating a fault exists. The logic pulser allows incircuit stimulation, so that test pulses may be introduced at circuit nodes. Thus, reset or synchronizing pulses may be injected to reset the comparator IC to the same initial state as that of the test IC. This allows both the reference and test ICS to start at the same initial reference point.

7-1.6 LOGIC ANALYZERS

Minicomputer system users can benefit from a better knowledge of debugging and troubleshooting procedures which use logic analyzers. The best way to obtain an overview of what a logic analyzer is and how it is used with minicomputers is to examine some of the common uses. The following techniques are also applicable to microprocessors and larger computers.

7-1.6.1 Software Diagnostic Techniques

Problem solving in a minicomputer is usually a complex task. A typical system can consist of a computer and many peripheral units. One or more of these peripheral units can also be considered "intelligent" with respect to the minicomputer. As various systems have been developed, sets of troubleshooting programs have been developed which are called "program (software) diagnostics." Software diagnostics are used to troubleshoot the Central Processing Unit (CPU) and units on memory and input/output (1/0) buses. A well-designed software diagnostic can usually identify a specific faulty module, but cannot always identify the cause of malfunction. Software diagnostics have several major limitations when solely used for troubleshooting, namely:

1. To use the diagnostic effectively, the system must be running at a minimal level.
2. A dead system or hung-up bus cannot be troubleshot with software.
3. Intermittent problems are difficult to find using diagnostics.
4. Diagnostics will normally not identify software problems.

For a full set of troubleshooting tools, software diagnostics must be joined with instruments which monitor system lines, activity, and timing in terms of real time. For troubleshooting minicomputer systems effectively the real-time analytical capabilities of a logic analyzer are needed.

7-1.6.2 Limitations

Microprocessor-controlled logic analyzers provide a powerful measurement tool capable of testing complex minicomputer systems. To be useful in troubleshooting, the logic analyzer must be able to collect, store and display information, perform functional measurements, and interface with other measurement devices.

7-1.6.3 Data Acquisition

Logic analyzers monitor minicomputer systems when running at their normal speeds. Two questions arise because of this: 1) how is the data acquired; and 2) what does this data represent?

7-1.6,3.1 Data Channels

A typicaf minicomputer has 16 or 18 bits of address; some may have as many as 32. This article primarily addresses a 16-bit unit for data, plus two control lines (18 total). Consequently, even early models of logic analyzers accommodate a minimum of 16 input channels plus two or more inputs for control lines or external signals. Units having 32 inputs can employ four or more auxiliary input channels.

7-1.6.3.2 Trace Specification

The data collected by a logic analyzer and shown on the display is called a "trace, " just like that on an oscilloscope. This trace provides a "window" on the data flow state of the minicomputer. The process of determining where to place the window is called "trace specification." The simplest trace specification is a single pattern trigger. For simple in-line program flow, a particular state is set on the analyzer. When that state appears for the first time, it acts as a trigger for the logic analyzer memory, and the subsequent states are stored. Programs in minicomputer systems, however, are rarely simple, therefore a more sophisticated trace specification is needed. Consider now a program with many complex branching networks (Figure 7-22). A sequential trigger, such as shown in Figure 7-22 permits a trace to be obtained for a unique program path selected from several different paths. Sequential triggering can also be used to pick up parameters entered early in program flow for use in subsequent subroutines. The logic anafyzer then displays these parameters first, just ahead of the trace listing of the subroutine.

7-1.6.4 Multiple-Occurence Trigger

A multiple-occurent trigger provides a valuable trace specification for unraveling nested loops in program flow. For example, a program may sample many peripheral units sequentially (major loop), receive data from each peripheral unit (minor loop), and then format data from each transmission (subminor loop). The combination of a sequential trigger and a multiple occurrence trigger could focus the analyzer window such that it views only the sixth data format of the third data transmission from peripheral unit three. Two trace specifications which help to monitor the clock and control lines are: the ORed trigger and the ANDed trigger. one anafyzer (HP Model 1615A) has a glitch trigger which initiates a trace if interference of a specified magnitude occurs on a designated signal line. These trace specifications provide quicker and more effective analysis of minicomputer systems. They allow the technician to check only state flow that is pertinent to the problem, and focus more quickfy on hardware of software that may be malfunctioning.

7-1.6.5 Data Storage

Trace specification is a selective trace, hence only the states of interest are stored in the logic analyzer. Data thus stored for analysis can be restricted to a particular operation, specific activities, or to a certain range of addresses. To capture every state activity would require excessive memory capacity, and would tax the technician's time by forcing him to study large amounts of output data in order to locate single malfunctions. A selective trace provides the data needed, and omits activities that are of no importance to the situation under investigation.

7-1.6.6 Data Display

After the desired data has been stored, it must be displayed in a meaningful format for analysis. Logic analyzers offer a variety of formats, which fall into three general categories: 1) list displays, 2) timing diagrams, and 3) overall system overviews.

7-1.6.6.1 List Display

The most frequently used format is a list display (Table 7-5) which is a convenient format for detailed analysis of software execution. Freedom to specify the format will vary with the particular logic analyzer used. The two logic analyzers used for examples here will be the HP 161OA and the HP 1615 A. The technician can choose clock slopes, logic polarity, numerical bases, and group inputs under different labels.

7-1.6.6.2 Timing Diagrams

The model HP 1615A Logic Analyzer provides an 8-channel timing diagram (Figure 7-23). Figure 7-23 timing display shows activity on control lines for a typical bus data transaction as a display mode. Timing diagrams show the actuaf time relation between control lines; these diagrams facilitate investigation of "handshake" and control state problems. The HP 1615A can display timing phenomena that occur prior to a trigger point, make single-shot multichannel measurements, and detect and trigger or glitches.

7-1.6.6.3 System Overview

The graph mode (Figure 7-24) provides a convenient display feature which is available on the HP 1610 Logic Analyzer. A selected parameter, i.e., address, is plotted with magnitude on the Y-axis, and the sequence of its occurrence is plotted on the X-axis (Figure 7-24). With this form of display, the technician can quickly identify irregularities and breaks in program flow. Figure 7-24 graph shows the overall system activity during a program loop.

7-1.6.7 Functional Measurements

Common functional measurements include elapsed time of program execution for two systems; elapsed time of execution for two programs on the same machine; and an event-count for a particular routine. These and similar measurements provide quantitative information as to the comparative

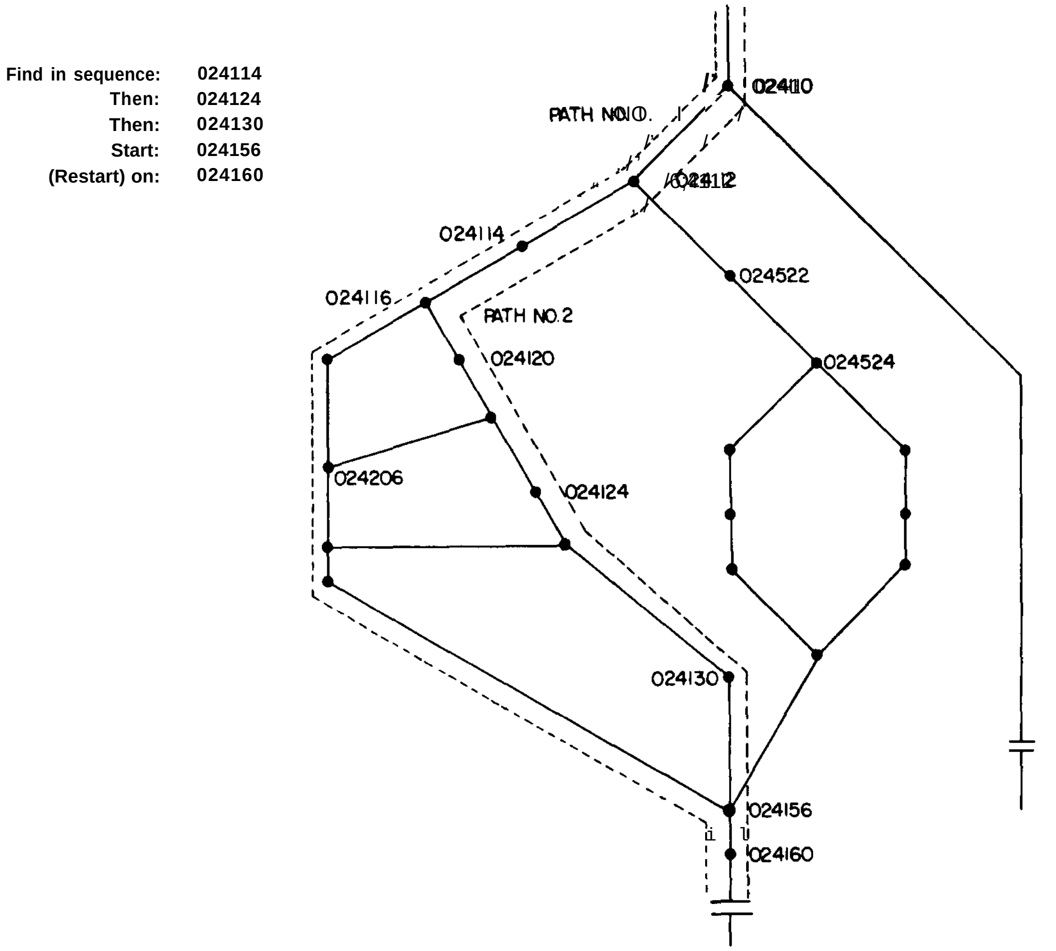


Figure 7-22. A Complex Program With Branching Network

merit of instruments, efficiency of a software code and likely sites of malfunction.

7-1.6.8 Interaction **with Other Instruments**

When troubleshooting it is usually convenient to use analog measurement tools in conjunction with the logic analyzer. Many logic analyzers provide some form of trigger output based on a defined state of timing condition. The trigger output is also useful for gating clocks, interrupting the system activity, triggering circuits, or halting the system at breakpoints to permit static debugging. A common troubleshooting technique is to pinpoint a faulty piece of hardware through state flow analyses and then use the trigger capabilities of the log analyzer to trigger an oscilloscope to study the waveform at that particular point.

7-1.7 MINICOMPUTERS

Minicomputers basically fall into two groups by virtue of operation: asynchronous and synchronous. Asynchronous operation transmits signals under control interlocked "handshake'-' (interrupt) signals. In synchronous operation, sequence of transmissions is controlled by equally spaced clock signals.

7-1.7.1 Asynchronous Operation

Typical of asynchronous systems is a DEC PDP-11 which uses a single 56-line unibus for communication between the CPU, memory, and any peripheral devices. Communication between devices is defined by the sequence of states on a set of interlocked unibus lines, termed the "handshake" (interrupt) sequences. A priority of "handshake" (interrupt) sequence sets the master-slave relationship at any given time and specifies what type of information is being passed, and where. Another asynchronous system is the DEC LSI-11. While the PDP-11 unibus has separate address lines, the DEC LSI-11-Q-BUS multiplexes address and data on the same lines. Figure 7-25 is a typical example of a system which operates asynchronously.

Table 7-5. List Display Data Format

.---TRACE------------LIST-----------------------------------TRACE----------C OMPLETE --------------------------

LABEL BASE	A OCT	D OCT	F BIN	TIME DEC	
-09	01010	177777	1	.3	u s
-08	01004	027003	0	1.3	u s
-07	01002	037001	0	1.9	u s
-06	01010	177777	1	1.0	us
-05	01010	000000	0	.4	u s
-04	01004	103501	0	1.5	us
-03	00000	000000	0	2.3	us
-02	01007	001300	0	1.0	us
-01	01006	027000	0	2.9	us
CENTER	01000	103601	1	2.6	us
+01	00000	000020	0	1.3	u s
+02	01000	063010	0	1.3	us
+03	01010	100000	0	1.0	us
+04	01002	073011	1	.9	us
+05	01010	100000	0	1.1	us
+06	01002	037011	0	1.2	us
+07	01010	100000	1	1.0	u s
+08	01010	100001	1	.4	us
+09	01004	027003	0	1.2	us
+10	01002	037011	0	2.0	u s

7-1.7.2 Synchronous Operation

Systems that operate synchronously employ a system-timing generator. These usually consist of two buses: a higher speed memory bus, and a slower speed INPUT/OUTPUT bus for peripherrd equipment. An example of a synchronous system (the HP 21 MX) is shown in Figure 7-26. As with asynchronous systems, signal path is determined by the sequence of states on the control lines, but the time of data transmission is set by defined cycles of time.

7-1.8 SETTING UP THE LOGIC ANALYZER

The first step in viewing activity on a minicomputer equipped with a logic analyzer is connecting the system to the analyzer. The technician has the option of connecting 24 to 36 individual leads, but this procedure ‘is time-consuming and is prone to error. A much more convenient way to connect the system and the analyzer is to use a dedicated interface. Most companies offer interfaces for the more popular minicomputers, such as the PDP-11. Some companies also offer a general purpose probe interface, such as the HP 10277. The probe interfaces include interchangeable wire-wrapped boards that allow the technician to choose the address, data and/or control lines he wishes to monitor. It is desirable, and sometime necessary, to process signals to the logic analyzer. The PDP-11 unibus, for example, does not have a distinct clock-signal associated with address or data lines, therefore it operates asynchronously using “handshake” (interrupt) signals. A dedicated interface, the HP 10275A PDP-11 unibus interface derives a logic analyzer clock with decoding circuits or interrupt signals. Some signal preprocessing is accomplished directly on the interfaces.

7-1.9 STATE FLOW ANALYSIS

State flow measurements illustrate techniques for monitoring a complex program execution in terms of rerd time. For the examples that follow, the measurement analyzer combines a HP 161OA Logic Analyzer with the DEC PDP-11 Minicomputer connected with two interfaces: the HP 10275A unibus interface and the HP 10277A Opt 001 General Purpose Probe Interface.

7-1.9.1 Basic State Flow Measurement

The simplest measurement involves collecting and displaying an in-line code during program execution. The analyzer display is called a “trace list.” A line-by-line comparison of a HP 161OA trace

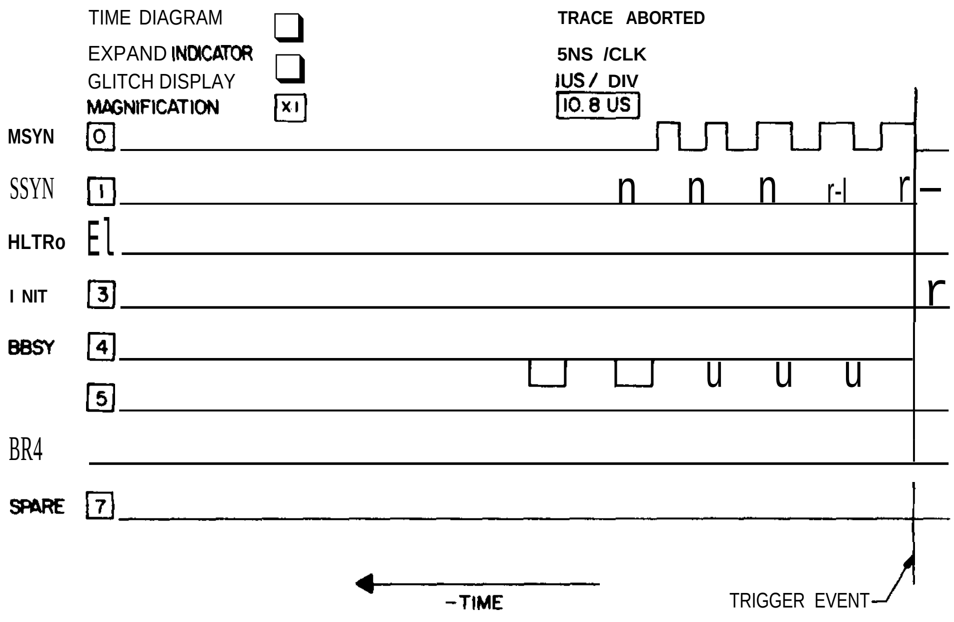


Figure 7-23. Timing Diagram

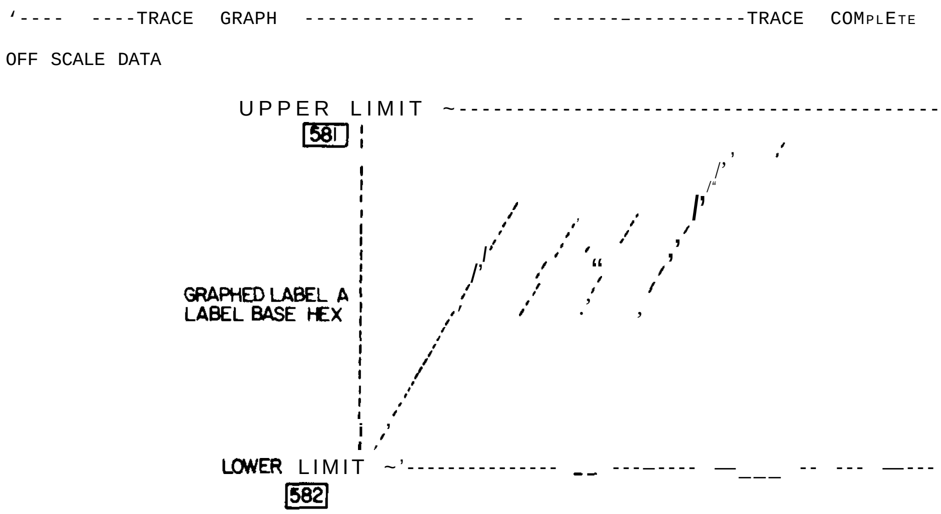


Figure 7-24. Graph Mode Display

list and the program assembler listing will show anything inconsistent between what is expected and what actually occurs. The appropriate variables are set in the Format and Trace Specification menus (Figures 7-27 and 7-28) to produce a simple trace list, beginning at the start of the start-up routine of Figure 7-29. The resultant trace list (shown in Table 7-6) begins with the initial address 2000_8, and contains the next 63 states in program execution. Twenty lines of state flow are shown on the analyzer at a time; the roll keys are used to view the other states of the trace list that are contained in the logic analyzer memory. A comparison of the trace list and the program listing will confirm that the program is executing properly. HP 161OA Logic AnaIyzer Format Specifications selected for monitor the PDP-11/04 sets 16 channels for address and 16 channels for data, all in octal base (Figure 5-27). Figure 7-28 is the Trace

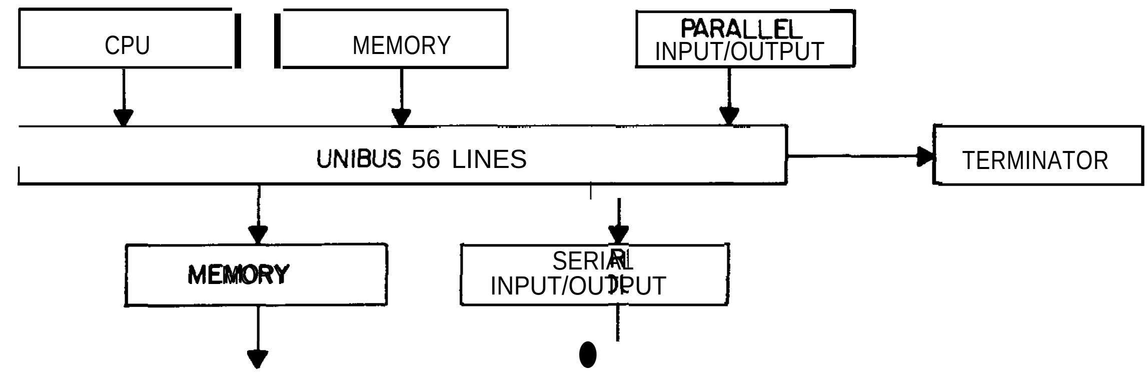


Figure 7-25. Example of an Asynchronous System

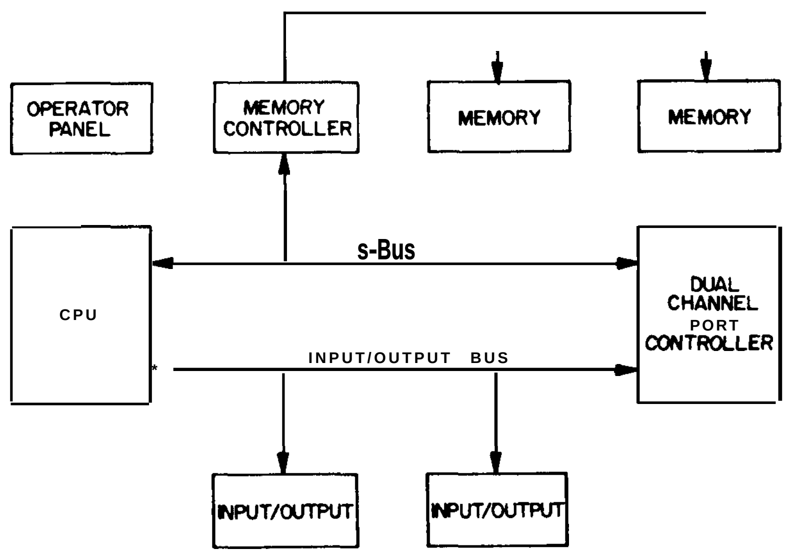


Figure 7-26. Example of a Synchronous System

Specification for making a simple trace beginning at address 002000_8, and listing 64 sequential states. Using the trace specification shown in Figure 7-28 for the start-up routine of Table 7-6 results in a simple, in-line trace list of the program execution.

7-1.9.2 **Graph Overview**

Another method of viewing program execution on the HP1610A Logic Analyzer is the graphic display. Figure 7-29 is the graphic display of the first 64 addresses of the startup routine (Table 7.6). Each point of the graph represents one of the sixty-four addresses (label a). Notice that the limits of the graph have been set at 2000_8 and 3000_8, the limits of the addresses used in the routine which makes viewing and interpreting easier. The points corresponding to the twenty states shown in Table 7-7 are intensified in the graphic display mode. Figure 7-29 is an example of the HP 1610A in graphic display mode when used with the startup routine defined by Table 7-6. Reading from left to the first twenty points correspond to twenty states displayed in Table 7-7 and these points are intensified. In actual practice it is not always possible to specify in advance the sixty-four consecutive states that contain a subtle fault that causes a program to fail or get lost, a larger overview is needed. This can be done by viewing a sample of every single, every second, every fifteenth state or any state selected. As an example, Figure 7-30 is

—- --- -FORMAT SPECIFICATION---- - _TRACE ABORTED..... —. . — — .

CLOCK SLOPE [–]
(+ –)

POD PROBE	POD 4	POD 3	POD 2	POD I
	7- - - - - 0	7 - - - - - - 0	7- - - - - - 0	7- - - - - - 0
LABLE ASSIGNMENT (A, B, C, D,E,F, X)	AAAAAAAA	AAAAAAAA	DDDDDDDD	DDDDDDDD

ACTIVE CHANNELS

LABLE	A	D
LOGIC POLARITY (+ –)	+	+
NUMERICAL BASE (BIN, OCT, DEC, HEX)	OCT	OCT

Figure 7-27. Format Specification Menu

-------TRACE SPECIFICATION ------------------ ---- TRACE ABORTED ------------------- --------

		A	D	OCCUR
	BASE	OCT	OCT	DEC
START	TRACE	002000	XXXXXX	00001

TRACE
ALL STATES

COUNT OFF

Figure 7-28. Trace Specification Menu

a graph of every fifth state of the same program, giving the technician an overview of activity across 320 states (5 x 64). The upper limit has been changed to 5100_8, thus showing the jump to an output routine at address 5000_8. By changing the occurance count on the trace specifications the technician can compress the graph by one ratio from 1:1 to 65,536:1, fo, a graph of program activity in sixty-four states to over four million states. Figure 7-30 shows an example of an expanded graph showing a discontinuity as the

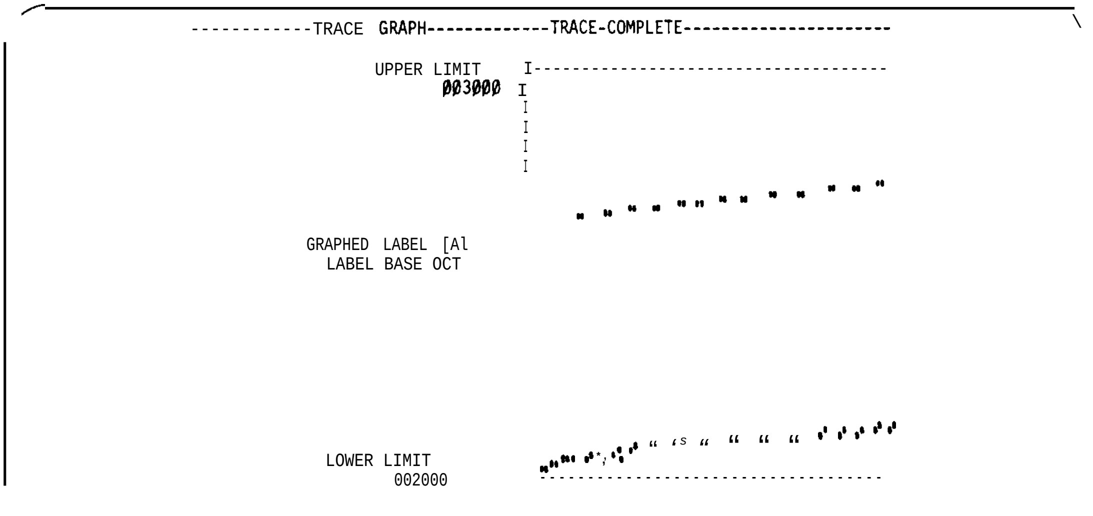


Figure 7-29. Graphic Display of First64 Addresses ofStartup Routine

program jumps tothe output routine ataddress 5000_8. Every fifth state of 320 states is shown as a point on the graph.

7-1.9.3 Measurements From aGraph Mode

The twenty intensified pointa depicted in Figure 7-30 correspond to the twenty states of Table 7-8. By centering these points areound the apparent discontinuity of Figure 7-30 and then switching to the trace list of Table 7-8 a jump will take place after address ()()21268, line 16. Because the graph was of every fifth state, the trace specification is changed to trace all states begining the trace before the suspect address and ending it after it. Thus centering the trace around the suspect address. An example of this can be seen in Table 7-9. This gives a detailed list centering around the discontinuity. By using a few simple steps the technician can locate a gross error and quickly narrow the field to a small area around the discontinuity. Using the above described technique,, the technician can rapidly find very difficult problems.

7-1.9.4 Measurements on Selected Types of Information

When only one type of information is to be collected analysis is greatly simplified. The operator may have indicators that one 1/0 is malfunctioning, as a subroutine is suspect. Tracking only one kind of information is achieved by display qualifications. The technician selects for viewing only the transactions that pertain to what he is looking for, which makes your troubleshooting more efficient and reduces the required size of analyzer memory. One type of measurement requiring display qualification is the verification of data stored in the transmit buffer on the serial 1/0. Continuing use of Table 7-6 compares the message transferred beginning at address 2500_8 to the display shown in Table 7-7 as a check of the operation of the serial 1/0 channel. Changing the trace specification to track only state address in the $0025XX_8$ field and setting the analyzer interface switch to write produces the trace list of Table 7-10 which is comprised totally of write commands to the transmit buffer. Comparing this to the terminal display provides a check on data transmission to that buffer. A second example of display qualification is that of checking the execution of a single routine in this case set the trace specification menu to trace. Only states 1775668, which is the address of the transmit buffer register on the 1/0 port. Then set the qualifier switch on the analyzer interface to WRITE. The printout (Table 7-11) from the analyzer memory, (including translation of data bits to Alphanumeric characters and the display shown in Figure 7-31) should agree. If these agree, then it can be safely assumed that the 1/0 channel is working correctly.

Table 7-6. Program Listing Sample Startup Routine

WED, JUL 18, 1979, 10:30 AM

002000	010706			BEGN	MOVR7,R6	REFERENCE R6TOTHEPC
002002	062706	005776			ADD #n,R6	SETTHESTACKPOINTER (7776)
002006	010705				MOVR7,R5	REFERENCE P5TOTHEPC
002010	062705	000470			ADD#h,R5	POINTTOISTADD. IN INTR. MESS. (2500)
002014	010504				MOVR5,R4	REFERENCEINTERRUPTMESSAGEISTADDRESS
002016	012725	004015			Mov#nJR5)+	MOVE LF,CRTOINTERRUPT BLOCK
002022	012725	051120			Mov#nJR5)+	MOVE R,PTOINTERRUPTBLOCK
002026	012725	051505			MOV #n,(R5)+	MOVES,E TOINTERRUPTBLOCK
002032	012725	020123			MOV #n,(R5)+	MOVE SB,S TO INTERRUPT BLOCK
002036	012725	047101			MOV #n,(R5)+	MOVE N,A TO INTERRUPT BLOCK
002042	012725	020131			MOV #n,(R5)+	MOVE SB,Y TO INTERRUPT BLOCK
002046	012725	042513			MOV #n,(R5)+	MOVE E,K TO INTERRUPT BLOCK
002052	012725	020131			MOV #n,(R5)+	MOVE SB,Y TO INTERRUPT BLOCK
002056	012725	047524			MOV #n,(R5)+	MOVE O,T TO INTERRUPT BLOCK
002062	012725	044440			MOV #n,(R5)+	MOVE L,SB TO INTERRUPT BLOCK
002066	012725	052116			MOV #n'(R5)+	MOVE T,N TO INTERRUPT BLOCK
002072	012725	051105			MOV #n,(R5)+	MOVE P,E TO INTERRUPT BLOCK
002076	012725	052522			MOV #n,(R5)+	MOVE U,R TO INTERRUPT BLOCK
002102	012725	052120			MOV #n,(R5)+	MOVE T,P TO INTERRUPT BLOCK
002106	012725	046440			Mov#nJR5)+	MOVE M,SB TO INTERRUPT BLOCK
002112	012725	020105			MOV #n,(R5)+	MOVE SB,F TO INTERRUPT BLOCK
002115	005205				INCR5	ADD ONE TO BLOCK
002120	010403			OVER	MOVR4,R3	SET R3 - INTERRUPT MESSAGE ADDRESS
002122	112300			MESS	MOVB(R3)+R0	MOVE DTA BYTE TO XFER REG.
002124	004267	002650			JSRA OUTT	OUTPUT DATA BYTE TO TERMINAL (5000)
002130	020305				CMPR3,R5	ALL BYTES OUT?
002132	001373				BNE MESS	NO, GET NEXT BYTE
002134	000005				REST	RESET THE UNIBUS
002136	012737	002600	000060		MOV #n,@#A	LOAD INTR TRAP CELL WITH ADDRESS
002144	012737	000340	000062		MOV #n,@#A	LOAD NEXT CELL WI PRIORITY
002152	012737	000140	177776		MOV #n,@#A	SET PROCESSOR PRIORITY
002160	012737	000100	177560		MOV #n,@#A	TURN INTERRUPT ON
002166	000001				WAIT	WAIT FOR INTERRUPT
002170	00167	177724			JMPA OVER	START OVER (2120)

7-1.9.5 Complex State Measurements Using Sequential Triggers

The HP1610 Analyzer allowstheentry of up to seven words which must be formed in a sequence prior to the initiation of the trace. Eachof these seven words may be further qualified by specifying the number of times that word is to appear (up to 65,536 times) before a search begins for the next sequence term, or the trace is begun. Asequence restart state may be used to restart the search for the trigger works if the desired sequence does not occur before this reset condition is met. These two techniques are most commonly used when tracing multipath programsor nested loops.

7-1..9.5.1 Tracing Multipath Programs

It is a rare minicomputer program that doesn't include at least one branching network. In Figure 7-32, the beginning address of the output routine for an interrupt 2128_8 can be reached by three paths. Suppose the technician is only interested in this routine when it occurs after address 27148. With sequential triggers this can be done simply by listing address 2714 and 2120 as the only two terms to be found in sequence. The trace specification menu for this condition is illustrated in Figure 7-33 and simply lists the two addresses, each occuring once. The trace list will show the two sequential terms and list the subsequent states. Should the technician

Table 7-7. Trace List of First Twenty States of Program

------------TRACE LIST------------TRACE-COMPLETE--------		
LABEL	A	D
BASE	OCT	OCT
START	002000	010706
+01	002002	062706
+02	002004	005776
+03	002006	010705
+04	002010	062705
+05	002012	000470
+06	002014	010504
+07	002016	012725
+08	002020	005015
+09	002500	005015
+10	002500	
+11	002022	012725
+12	002024	051120
+13	002502	051120
+14	002502	051120
+15	002026	012725
+16	002030	051505
+17	002504	051505
+18	002504	051505
+19	002032	012725

wish to review the states occuring between the two sequential terms, change the trace specification menu from Start mode to Center mode. In the trace list shown in Table 7-12 only four states occured between the two terms. It is obvious with the option of up to 7 trigger words it is easy to specify only the branch of interest.

7-1.9.5.2 **Tracing Nested Loops**

The capability for sequential triggers is also a convenient feature when analysis of information contained in nested loops is desired. An example of this can be found in the Figure 7-34. One routine writes a space and all 94 printable ASC11 characters to the terminal as shown in (Table 7-13). Every time the major loop is executed once (J), the minor loop (K) is executed 94 times. For an exercise consider how best to trace program execution following the 36th occurrence of the K loop during the 5th pass of the J loop. Most logic analyzers have a trigger delay, therefore the number of states to be skipped follow the occurance of a triggered word. Then using a little arithmetic one can trace the desired portion of program execution by using a trigger address of 200628, and a trigger delay of 412 states [(4 x 94) +36], this is only valid assuming the loops are of equal length. A better way exists to use sequential triggers, as is shown in Figure 7-35. The logic analyzer being used will begin ita search at address 200001_8, outside the

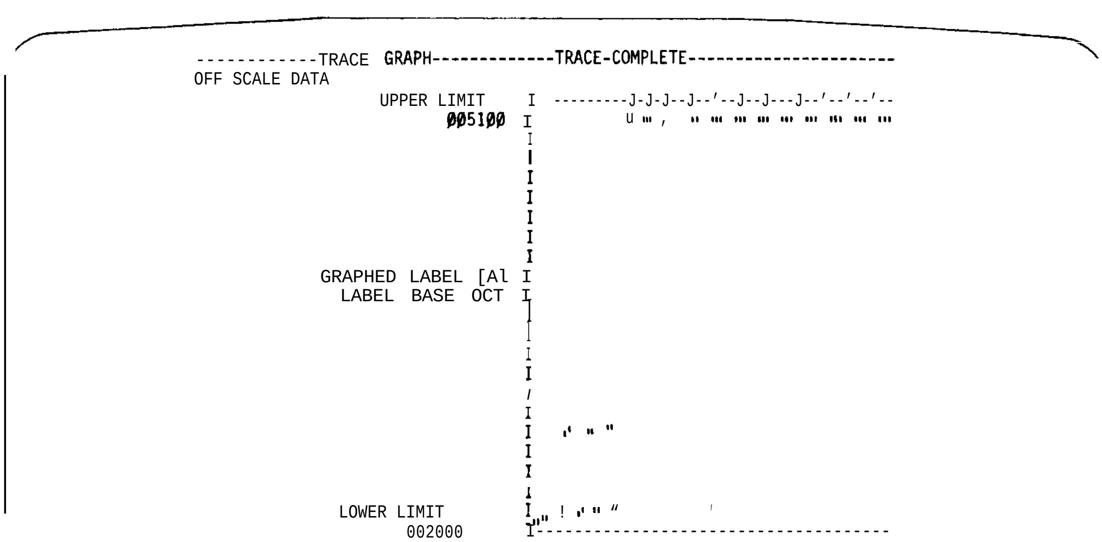


Figure 7-30. Graphic Display of Startup Routine Displaying Discontinuity at Jump

Table 7-8. Trace List Display Discontinuity in Program Execution

.----------TRACE LIST-----------TRACE-COMPLETE--------

LABEL BASE	A OCT	D OCT
+07	002046	012725
+08	002054	020131
+09	002520	047524
+10	002522	044440
+11	002072	012725
+12	002100	052522
+13	002532	052120
+14	002534	046440
+15	002116	005205
+16	002126	002650
+17	177566	000015
+18	005004	10573'Z
+19	005006	177564
+20	177564	000000
+21	005010	100375
+22	005004	105737
+23	005006	177564
+24	177564	000000
+25	005010	100375
+26	002122	112300

Table 7-9. Trace List Center Around Discontinuity

-----------TRACE LIST------------TRACE-COMPLETE-------

LABEL BASE	A OCT	D OCT
-09	002112	012725
-08	002114	020105
-07	002536	020105
-06	002536	020105
-05	002116	005205
-04	002120	010403
-03	002122	112300
-02	002500	005015
-01	002124	004267
CENTER	002126	002650
+01	007776	165054
+02	005000	110037
+03	005002	177566
+04	177566	000000
+05	177566	000015
+06	005004	105737
+07	005006	177564
+08	177564	000000
+09	005010	108375
+10	005004	105737

Table 7-10. Trace List Containing Only Write Instructions

----------TRACE LIST----------TRACE-IN PROCESS ----------

WARNING-SLOW CLOCK

LABEL BASE	A OCT	D OCT
START	177566	000015
+01	002500	005015
+02	002502	051120
+03	002504	051505
+04	002506	020123
+05	002510	047101
+06	002512	020131
+07	002514	042513
+08	002516	020131
+09	002520	047524
+10	002522	044440
+11	002524	052116
+12	002526	051105
+13	002530	052522
+14	002532	052120
+15	002534	046440
+16	002536	020105
+17		
+18		
+19		

loops, passing the initial address of the major loop 5 times and then traces the program execution after the address of the minor loop is passed 36 times. Note that in this case occurances of the address of the minor loop are counted. The resulting trace (Table 7-13) shows the count of occurances of address 20062 in the right hand column. The first count, 376 (4 x 94), shows that four complete passes of the major loop occurred before the 36 passes of the minor loop was counted. Sequential triggers make it simple to trace information deep in the nested loops of fixed or variable length without the bother and potential errors of using trigger delay and "simple" arithmetic.

7-1.9.6 Measuring Execution Time

The count time measure is especially useful for benchmark tests to check for program efficiency. As an example, the 1/0 service routine shown in Figure 7-36 can be evaluated using time measures available on a 1610 logic state analyzer. This routine moves a 12 character string to a buffer, then moves the characters one by one to a terminal, with 150ns between each transmission. The trace specification menus (Figure 7-37) is set to count time, and the time count is set to relative on the associated trace list (7-14). Relative time counts are listed for each state, and each time is measured between the state and the preceding listed state. Table 7-15

Table 7-11. Trace List of all Write Instructions to Output Buffer with Translation of Data to Alpha Numeric Code

.-------------------TRACE LIST--------PRINT-IN PROCESS--

.ABEL ;ASE	A OCT	D OCT	
;TART . . .	177566.	000114 . . .	L
+01	177566	000040	SP
+02	177566	000062	2
+03	177566	000060	0
+04 . . .	177566	..000060..	0
+05	177566	000060	0
+06	177566	000015	CR
+07	177566	000015	CR
+08 . . .	177566	..000012..	LF
+09	177566	000044	$
+10	177566	000000	NUL
+11	177566	000123	s
+12 . . .	177566.	.000015..	CR
+13	177566	000015	CR
+14	177566	000012	LF
+15	177566	000120	P
+16 . . .	177566	..000122..	R
+17	177566	000105	E
+18	177566	000123	s
+19	177566	000123	s
+20 . . .	177566	..000040..	SP
+21	177566	000101	A
+22	177566	000116	N
+23	177566	000131	Y
+24 . . .	177566	..000040..	Sp
+25	177566	000113	K
+26	177566	000105	E
+27	177566	000131	Y
+28 . . .	177566	..000040..	SP
+29	177566	000124	T
+30	177566	000117	0
+31	177566	000040	SP
+32 . . .	177566	..000111..	I
+33	177566	000116	N
+34	177566	000124	T
+35	177566	000105	E
+36 . . .	177566.	.000122..	R
+37	177566	000122	R
+38	177566	000125	u
+39	177566	000120	P
+40 . . .	177566	..000124..	T
+41	177566	000040	SP
+42	177566	000115	M
+43	177566	000105	E
+44 . . .	177566	..000040..	SP
+45	177566	177640	
+46			
+47			
+48			

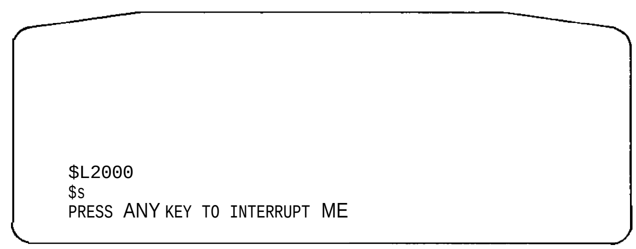


Figure 7-31. Display ofOutput Routine

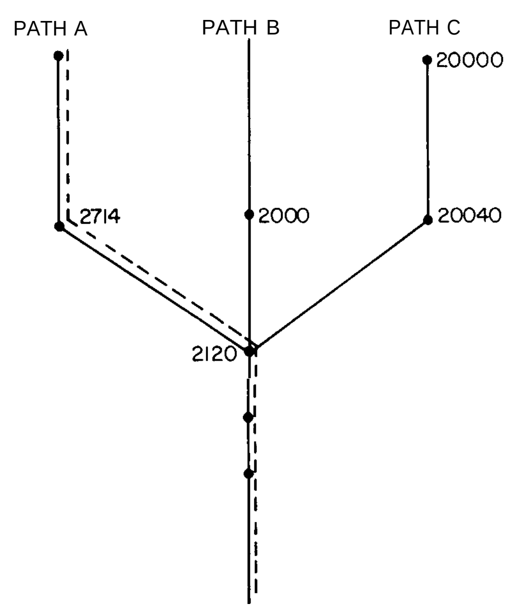


Figure 7-32. Example of **Multipath**

```
--------TRACE SPECIFICATION---------TRACE-COMPLETE----------------------

             LABEL        A        D       OCCUR
             BASE        OCT      OCT      DEC

FIND IN SEQUENCE ØØ2714   XXXXXX   ØØØØ1
[START] TRACE     ØØ212Ø  XXXXXX   ØØØØ1

SEQ RESTART [OFF]



TRACE
  [ALL STATES]



COUNT [ OFF ]
```

Figure 7-33. Trace Specification ofPath "A"

Table 7-12. Trace Listas Specified by Figure 7-33

-----------TRACE LIST------------TRACE-COMPLETE--------		
LABEL BASE	A OCT	D OCT
-09		
-08		
-07		
-06		
SEQUENCE	002714	000002
-04	007774	002170
-03	007776	000140
-02	002170	000164
-01	002172	177724
CENTER	002120	010403
+01	002122	112300
+02	002500	005015
+03	002124	004267
+04	002126	002650
+05	007776	165054
+06	005000	110037
+07	005002	177566
+08	177566	000000
+09	177566	000015
+10	005004	105737

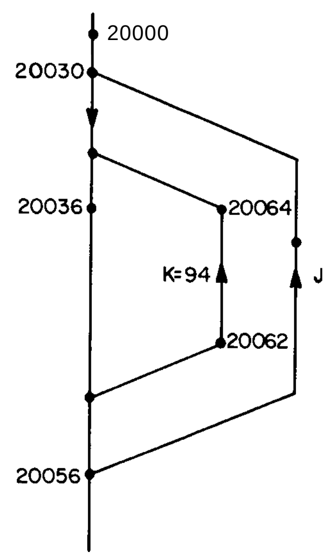


Figure 7-34. Example ofa Nested Loop

Table 7-13. Trace List of a Nested Loop

-----------TRACE LIST------------TRACE-COMPLETE--------

LABEL BASE	A OCT	D OCT	STATE COUNT DEC [REL]
EQUENCE	020000	012737	
EQUENCE	020030	005000	376
START	020062	005200	36
+01	020064	00764	0
+02	020036	110037	0
+03	020040	177566	0
+04	177566	000000	0
+05	177566	000104	0
+06	020042	105737	0
+07	020044	177564	0
+08	177564	000000	0
+09	020046	100375	0
+10	020042	105737	0
+11	020044	177564	0
+12	177564	000000	0
+13	020046	100375	0
+14	020042	105737	0
+15	020044	177564	0
+16	177564	000000	0
+17	020046	100375	0

shows the same trace list with an absolute (ABS) time measure, and **all** times are measured from zero at the trace point.

7-1.9.7 Locating Intermittent Errors

Most experienced technicians realize that the intermittent problem is the most difficult of all to find. Results from the error could show up far downstream from the error, and the original problem may be missed. The HP 1610 analyzer has a trace compare mode which can be applied in situations where an error condition occurs sporadically. First the likely location of the error is defined, and a trace is made of a program segment which is known to be executing properly (Table 7-16). The correct trace is stored in the analyzer memory. The 3 choices for subsequent traces, are OFF, STOP=, or STOP#. Using the "stop if not equal" (STOP#) operation, so long as a new trace is the same as the stored trace, the display shows zeros (Table 7-17). If the new traces does not compare to the stored one Table 7-16; the analyzer halts and the display of Table 7-18, will contain non-zero numbers. These numbers, when converted to binary numbers specify which binary bits are nonmatching. For example in Table 7-18, line 10 is 348. Converted to binary, 0000348 = 0000000000011100, and bits 2, 3, 4 of line 10 of the new trace do not match the corresponding bits of line 10 of the stored trace list.

```
--------TRACE SPECIFICATION---------TRACE-COMPLETE----------------------

          LABEL         A        D       OCCUR
          BASE         OCT      OCT       DEC

FIND IN S; QUENCE Ø2ØØØØ XXXXXX ØØØØ1
           HEN    Ø2ØØ3Ø XXXXXX ØØØØ5
[START] TRACE     Ø2ØØ62 XXXXXX ØØØ36

SEQ RESTART [OFF]



TRACE
 [ALL STATESI



COUNT [STATE]     Ø2ØØ62 XXXXXX
```

Figure 7-35. Trace Specification of Loop K

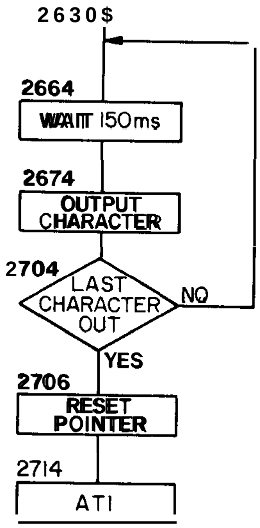


Figure 7-36. Example of Input/Output Service Routine

7-1-1o TIMING ANALYZERS

Most problems in a digital system can be located with state flow analysis techniques. However, there are problems that are best found through analysis of the timing of the various signals. Timing is often the most crucial factor in difficulties related to interface and control, glitches, clocks, phasing and similar problems. To illustrate the use of a logic analyzer in timing analysis, three examples of common measurement are given. For measurements on control lines and glitch detection a HP 1615A is used.

7-1.10.1 Analysis of Timing Relationships of Control Lines

A system crash always demands immediate attention and resolution. In this example, each time a program is started at address 600008, the processor halts and the run light extinguishes. Anafysis of both address and control lines is required. The first step to be taken is to connect the analyzer to the minicomputer in question. This may be accomplished many ways, but for this example we will be using an interface adapter. Pods 2 and 3 will be used for the 16 bits of address and pod 1 will be used for control lines. Pod 1 will be labeled in accordance with Table 7-19. For this example the format specification menu and the trace specification menu are shown in

```
-------TRACE SPECIFICATION---------TRACE-COMPLETE ---------------------

        LABEL      A       D      OCCUR
        BASE      OCT     OCT      DEC

FIND IN SEQUENCE  ØØ263Ø  XXXXXX  ØØØØ1
          THEN    002664  XXXXXX  00001
          THEN    ØØ2674  XXXXXX  ØØØØ1
          THEN    1302704 XXXXXX  00001
[START]   TRACE   002706  XXXXXX  ØØØØ1

SEO RESTART [OFF]


TRACE
 [ALL STATES]


COUNT [TIME]
```

Figure 7-37. Trace Specification Menu for Figure 7-34

Table 7-14. Trace List of Figure 7-44 with Elapsed Time Displayed

---------TRACE LIST------------TRACE-COMPLETE----------

LABEL BASE	A OCT	D OCT	TIME DEC [REL]	
SEQUENCE	002630	010503		
SEQUENCE	002664	012701	40.9	us
SEQUENCE	002674	112300	146.6	MS
SEQUENCE	002704	001367	86.8	us
START	002706	005005	1.614	S
+01	02710	062705	2.5	US
+02	002712	002542	1.4	US
+03	002714	000002	2.8	US
+04	007764	002170	1.5	us
+05	007766	000140	1.6	US
+06	002170	000167	2.1	US
+07	002172	177724	1.4	us
+08	002120	010403	2.3	US
+09	002122	112300	2.8	US
+10	002500	005015	1.5	us
+11	002124	004267	2.5	US
+12	002126	002650	1.4	US
+13	007766	165054	1.9	us
+14	005000	110037	2.8	US
+15	005002	177566	1.9	US

Table 7-15. Trace List of Figure 7-44 with Absolute Time Displayed

----------TRACE LIST------------TRACE-COMPLETE----------

LABEL BASE	A OCT	D OCT	TIME DEC [ABS]	
SEQUENCE	002630	010503	- 1.760	S
SEQUENCE	002664	012701	- 1.760	S
SEQUENCE	002674	112300	- 1.614	S
SEQUENCE	002704	001367	- 1.614	S
START	002706	005005	0	us
+01	002710	062705	+ 2.5	US
+02	002712	002542	+ 3.9	US
+03	002714	000002	+ 6.7	US
+04	007764	002170	+ 8.2	US
+05	007766	000140	+ 9.8	US
+06	002170	000167	+11.9	US
+07	002172	177724	+13.3	US
+08	002120	010403	+15.6	US
+09	002122	112300	+18.4	US
+10	002500	005015	+19.9	US
+11	002124	004267	+22.4	US
+12	002126	002650	+23.8	US
+13	007766	165054	+25.7	US
+14	005000	110037	+28.5	US
+15	005002	177566	+30.4	US

Table 7-16. Trace List of Reference

--------TRACE LIST-------------STORE-COMPLETE-----------

LABEL BASE	A OCT
START	002600
+01	002602
+02	177560
+03	177560
+04	002604
+05	002606
+06	177562
+07	002610
+08	002612
+09	002614
+10	002622
+11	002624
+12	002626
+13	002630
+14	002632
+15	002634
+16	002400
+17	002400
+18	002636
+19	002640

Table 7-17. Trace List of Good Compare

-----TRACE COMPARE----------COMPARED TRACE ------

LABEL BASE	A OCT	COMPARED TRACE MODE [STOP #]
START	000000	
+01	000000	
+02	000000	
+03	000000	
+04	000000	
+05	000000	
+06	000000	
+07	000000	
+08	000000	
+09	000000	
+10	000000	
+11	000000	
+12	000000	
+13	000000	
+14	000000	
+15	000000	
+16	000000	
+17	000000	
+18	000000	
+19	000000	

Table 7-18. Trace List of Bad Compare

-----TRACE COMPARE--------	COMPARED TRACE -------	
LABEL BASE	A OCT	COMPARED TRACE MODE [STOP #]
START	000000	
+01	000000	
+02	000000	
+03	000000	
+04	000000	
+05	000000	
+06	000000	
+07	000000	
+08	000000	
+09	000000	
+10	000034	
+11	000004	
+12	022626	
+13	022632	
+14	022636	
+15	002654	
+16	002460	
+17	022406	
+18	022626	
+19	022652	

Table 7-19. Contents of Pod-1

Bit O	—	MSYN
Bit 1	—	SSYN
Bit 2	—	HLTRQ
Bit 3	—	INIT
Bit 4	—	BBSY
Bit 5	—	NPR
Bit 6	—	BR4
Bit 7	—	Spare

Figures 7-38 and 7-39, respectively. If the program were executed properly the sequence of control events would be as shown in Table 7-20. As shown by Figure 7-39, the trace list is generated so it is evident that the trigger address 060000 is never reached. While still in this post crash state, it may be worthwhile to look at the control lines. This is accomplished by changing the mode of the analyzer to timing and using any event labeled (Figure 7-38) as a trigger. This results in a display as shown in Figure 7-40. Examining Figure 7-40, we can see that line 2, HALTREQUES (HLTRQ) is a HI, which of course halts the program. The next problem is why did the HLTRQ go HI. Choosing "END MODE" and triggering a HLTRQ will display the events that took place prior to HLTRQ going HI. When the test is run again, the

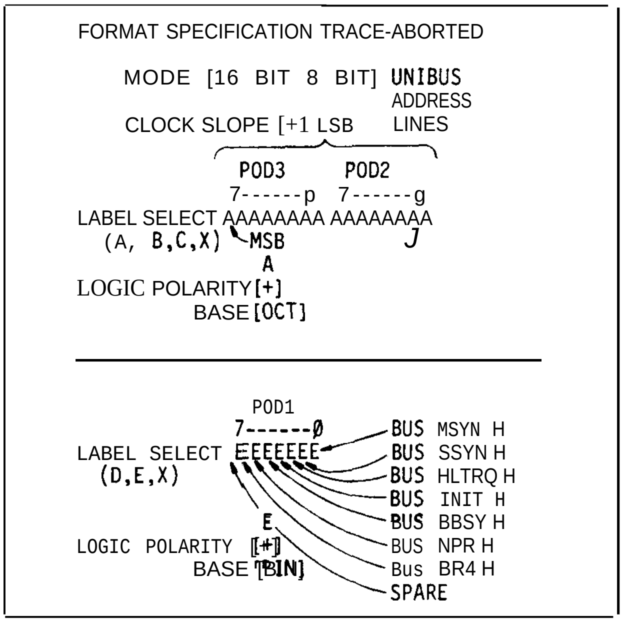


Figure 7-38. Format Specification Layout

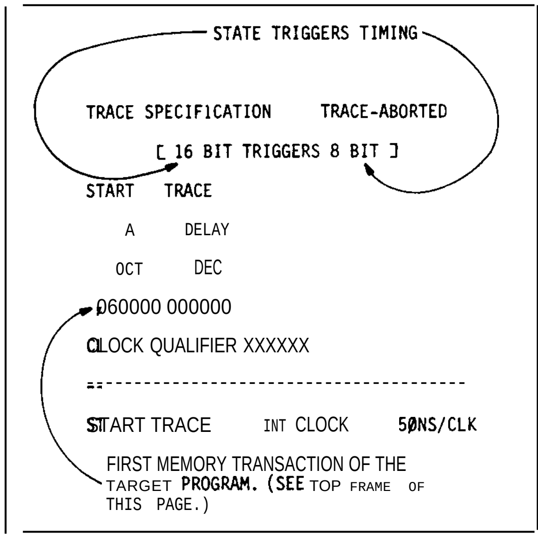


Figure 7-39. Trace Specification Menu to Initiate at 06000_8

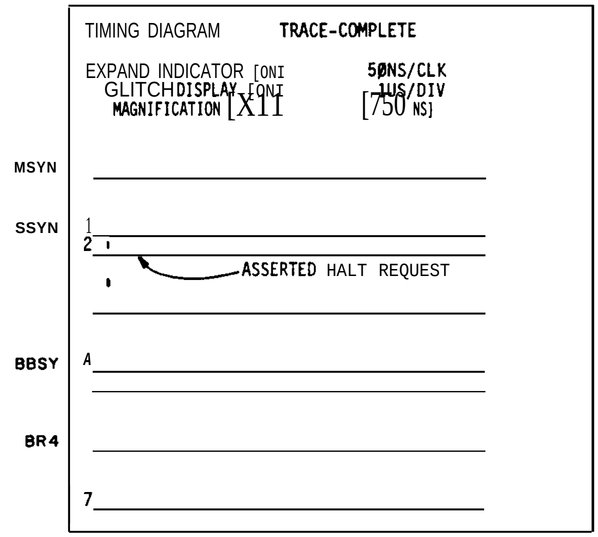


Figure 7-40. Timing Diagram of Control Lines After Program Failure

Table 7-20. Sequence of Program Execution

1. -060000 is brought up on the ADDBUJ
2. MSYN Flag is set by CPU
3. Data is put on the BUS
4. SSYN Flag is set by ROM
5. CPU reads data
6. MSYN Flag is cleared by CPU
7. SSYN Flag is cleared by ROM

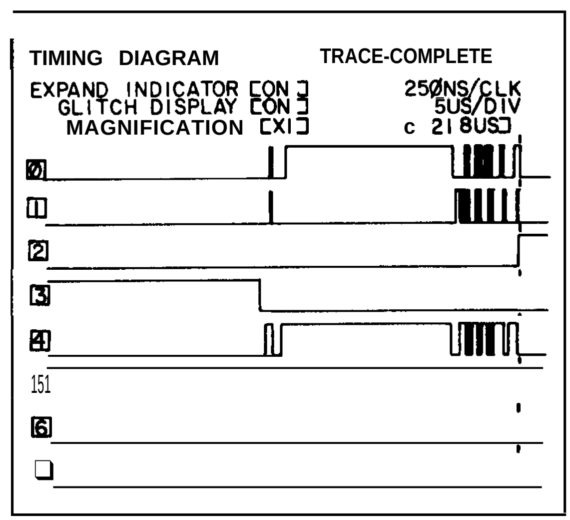


Figure 7-41. Timing Diagram of Control Lines Before Program Failure

the timing display shown in Figure 7-41 indicates that line 2(HLTRQ) is a HI. Notice lines 0(MSYN) and 1(SSYN); line MSYN was set by the CPU but no response comes from ROM(SSYN). The minicomputer used as the example will declare a timing fault and halt if tbe SSYN flag is not set within 20 microseconds of the MSYN flag being set. In the minicomputer ued as an example the ROM circuit has a special clock control circuit to compensate for its long memory access time. This circuit consists of an adjustable one shot. By connecting the spare line (line 2) to the output of the one shot, and repeating the test it gives the display shown in Figure 7-42. Then the time of the oneshot can be measured using the cursor on the analyzer. In this example the output of the one shot is shown to be 21.8 microseconds; this exceeds the 20 microseconds allowed and therefore the CPU declares a timing fault and sets halt request. By adjusting the one shot to 20 microseconds solves the problem, and only four steps were required to find the problem.

7-1.10.2 Glitch Detection

A Glitch is defined as a transient signal that if it is of sufficient amplitude and duration will

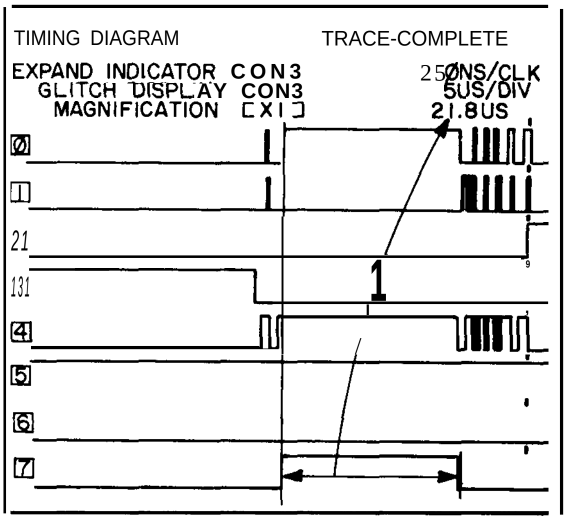


Figure 7-42. Timing Diagram of Control Line with Cursor

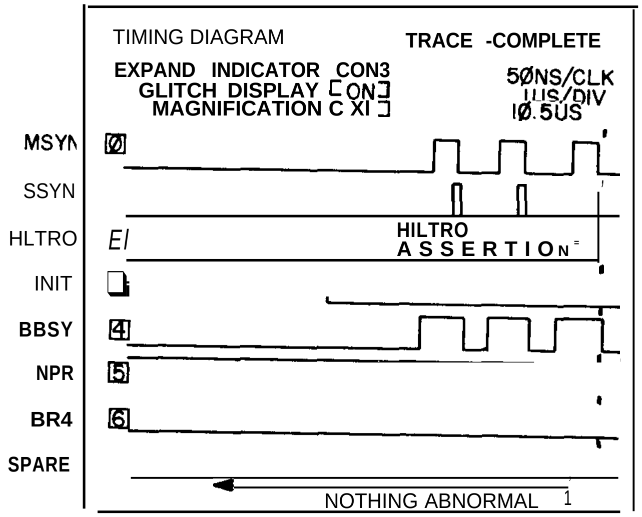


Figure 743. Timing Diagram of Control Lines Triggering on HLTRQ Line

cause the system to malfunction. Using the previous example, an analysis will be made of a different problem. In this example a terminal rewire routine is interrupt driven and is entered by pressing any key on the keyboard. The problem in this example is that every time a key is pressed the program halts. To troubleshoot this problem the setup and procedures of the preceding problem are used, and as before a display of the quiescent states of the control lines following the halt shows tht the HLTRQ flag has been set. This time triggering on the HLTRQ line one viewing the preceding activity on the control lines reveals no abnormal conditions (Figure 7-43). A capability for both state and timing analysis is a particular advantage for troubleshooting problems like this. The sequence of events suggests that a glitch could be involved, but an error in software should not be overlooked. The HP 1665A Logic analyzer defines a glitch as multiple transitions accross the threshold between sampling periods. If a glitch occurs it appears as a vertical bar, brighter and wider than the timing marks, and can be easily distinguished even if it occurs at a timing transition. For this analysis, the next step is to check the activity on control and address lines before HLTRQ is set. An example of this is given in Figure 7-44 using trace specification of Figure 7-45 format specification of Figure 7-46. The timing measure triggers the state measure, and the activity preceding the trigger

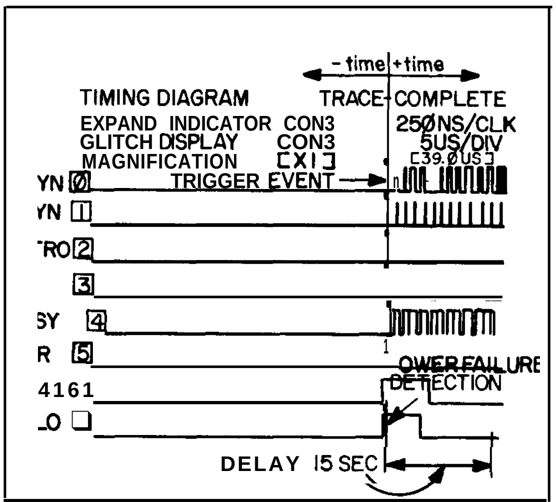


Figure 7-44. Timing Diagram Displaying Assertion of AC-LO Flag

is to be displayed. The timing diagram shows no abnormal activity on control lines monitored, but the trace list (Table 7-21) shows the address of power **fail** trap **cells,** 0000248 and 000026_8, on line 252 and 253. In normal operation whenever the power

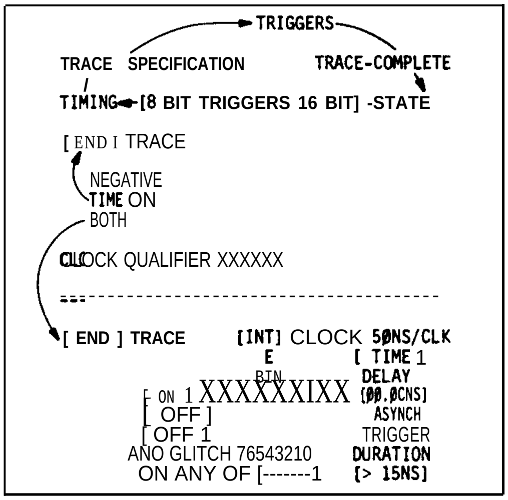


Figure 7-45. Trace Specification Menu Triggered on End of Trace

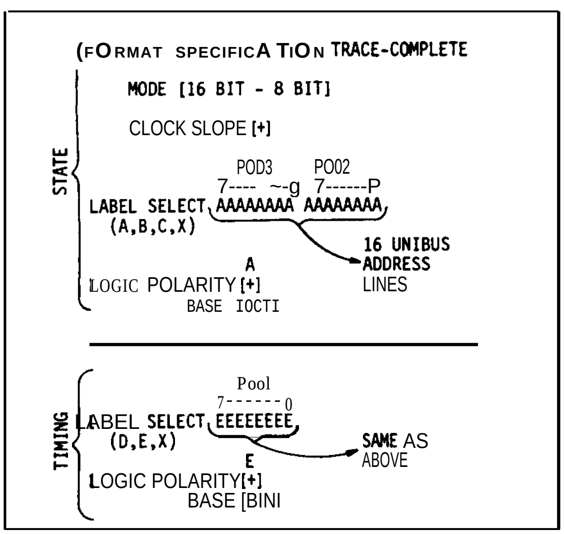


Figure 7-46. Format Specification Menu for Both State and Timing

drops below a specified level, either the AC LO or DC LO signals (generated by one shots) are set and the CPU automatically goes to a power failure routine at location 0000248 to isolate the reason for the entry to the power failure routine we will

Table 7-21. Trace List Display of Power Fail Trap Cells

TRACE LIST [16 IT] LINE NO	TRACE-COMPLETE A OCT
241	
242	
243	
244	000000
245	000000
246	002276
247	002274
248	000060
249	000062
250	002272
251	002270
252	000024
253	000026
254	000000
255	000024

attach the AC LO line to the spare input of the analyzer. The trace specification menu is altered to set a time delay of 15 microseconds to display activity before and after the trigger on the setting of HLTRQ flag. Resuming the test and viewing the timing diagram (Figure 7-46) shows that a power fail signal does occur on the AC LO line. This signal only occurs after the interrupt from the terminal and coincides with the bus request for interrupt on the BR-4(line6). The two signals are of unequal duration, which suggest that they are related, but not tied together. Two likely causes are 1) a wiring glitch on the input to the ACLO one shot. Figure 7-47 shows this being done and also shows a glitch on the input line to the one shot which occurs at the same time as interrupt from the terminal on line 6. A more detailed view (Figure 7-48) is gained by expanding the sweep with the time ten (x 10) magnifier, confining the concurrence of the glitch and the interrupt. In this example the glitch was caused by capacitive coupling between the two lines crossing the halt. The problem can be corrected by reducing the capacitance between the two lines. The interactive use of time and state traces reduces a complex problem through a short series of logical steps, each more narrowily defining the range of likely problem areas.

7-1.10.3 Asynchronous Measurement with a Logic State Analyzer

The first two examples of timing analysis used the HP 1615A which perform both

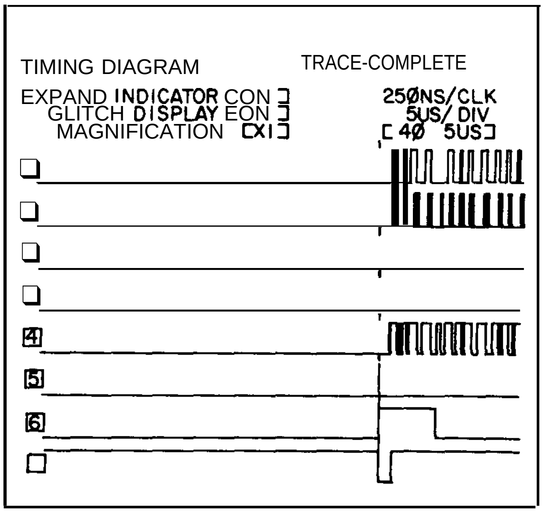


Figure 7-47. Timing Diagram Displaying a Glitch on Line 5

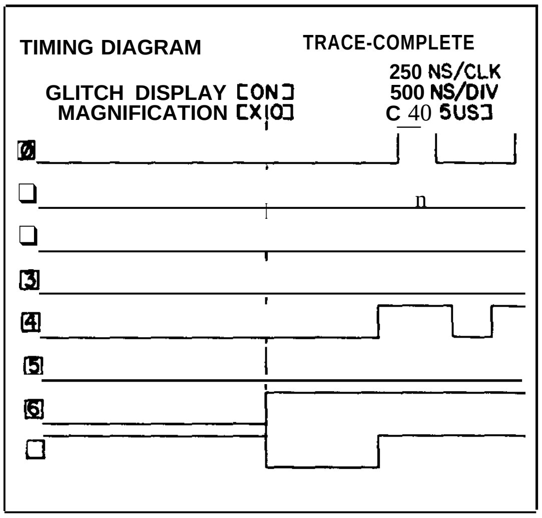


Figure 7-48. 10x Magnification of Figure 7-47

state and timing traces. The first problem, a time out problem, could also have been resolved using state flow with the HP 1610 Analyzer. The 10 MHz output of the 1610 is used to clock data into the analyzer and the Format Specification of Figure 7-49 is set. Variables to be traced include the address (in base eight) under label A, and seven control lines (in base two) as shown in Table 7-22. The trace specification menu (Figure 7-50) is set to follow the sequence that should occur beginning with address $60000_{(8)}$ on the address bus,

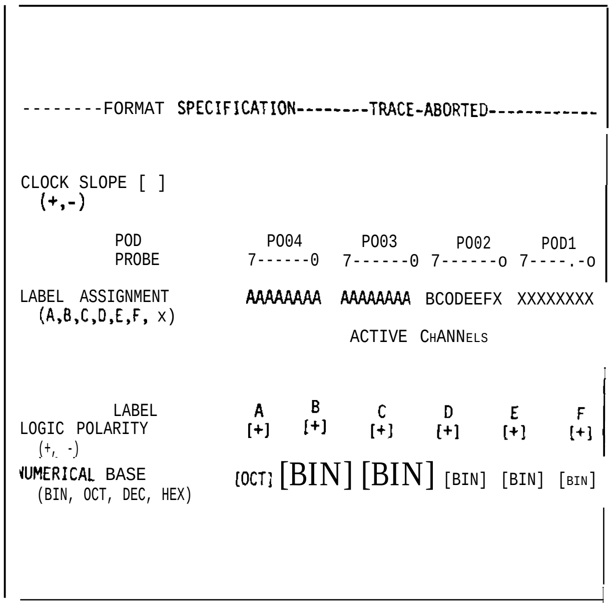


Figure 7-49. Format Specification to Assign Labels

Table 7-22. Controlling Labels

MYSN (label B)	HLTRQ (label E)
SSYN (label C)	ACLO (label E)
BR4 (label D)	BBSY (label F)
INTR (label D)	

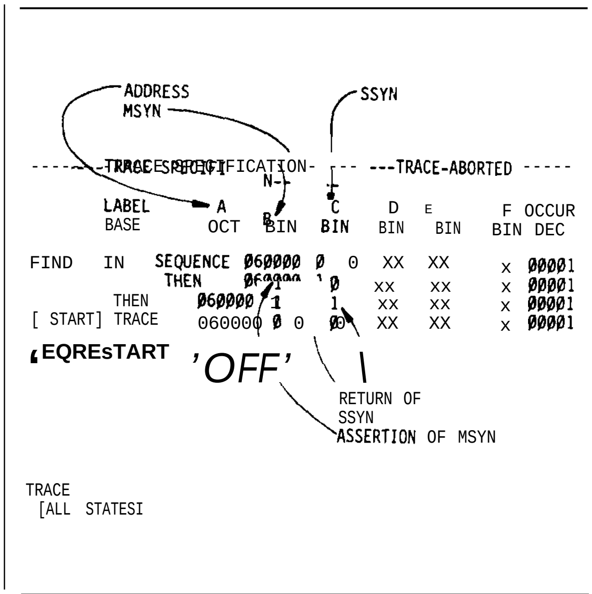


Figure 7-50. Trace Specification giving example of Activity at $60000_{(8)}$

but when MSYN flag is set, the correct response on the SSYN line does not occur, and the third term of the sequence of triggers is not satisfied, changing the trace specifications, and placing an x, (ignore) in the sequence where SSYN originally appeared, and using time count, produces the trace shown in Table 7-23. On the third line of the trace, the last of the sequence times, the relative time count is 21.3 microseconds. But this exceeds the 20 microseconds limit of the bus, and using the same logic that was used above again leads to the deduction that the one shot is too long.

7-1.11 SUMMARY

The real time anrdysis capabilities of logic analyzers make them excellent tools for troubleshooting minicomputers. Analysis is even further simplified by adding the appropriate interfaces for easier connections and preprocessed signals. Logic analyzers can be used with syneronous or asyneronous minicomputer architecture. Examples show the advantages of logic analyzers in troubleshooting both state and timing problems in minicomputer systems.

Table 7-23. Trace List Displaying Time Measurements

---TRACE LIST--TRACE-COMPLETE--

LABEL BASE	A OCT	B BIN	C BIN	D BIN	E BIN	F BIN	TIME DEC [R L]	
SEQUENCE	060000	0	0	00	00	1		
SEQUENCE	060000	1	0	00	00	1	.3	us
START	060000	0	0	00	00	1	21.3	us
+01	060000	0	0	00	00	1	.1	us
+02	000000	0	0	00	00	0	.1	us
+03	000000	0	0	00	00	0	.1	us
+04	000000	0	0	00	00	0	.1	us
+05	000000	0	1	00	00	0	.1	us
+06	000000	0	1	00	00	0	.1	us
+07	000000	0	1	00	00	0	.1	us
+08	000000	0	1	00	00	0	.1	us
+09	000000	0	1	00	00	0	.1	us
+10	000000	0	1	00	00	0	.1	us
+11	000000	0	0	00	00	0	.1	us
+12	000000	0	0	00	00	0	.1	us
+13	002240	0	0	00	00	1	.1	us
+14	002240	0	0	00	00	1	.1	us
+15	002240	1	0	00	00	1	.1	us
+16	002240	1	0	00	00	1	.1	us
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