INCH-POUND

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ENCODERS, SHAFT ANGLE TO DIGITAL, GENERAL SPECIFICATION FOR

This military standard is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers the requirements for all types of analog shaft angle input to digital output encoders. It is not complete in itself, but should be used in conjunction with MIL-S-81963 which will form an integral part of this specification.

1.2 Classification.

1.2.1 Nomenclature. The nomenclature consists of the item name, followed by a type designation which includes a modification letter and a part identifying number. All encoders having the same design nomenclature are physically, mechanically and electrically interchangeable for all military applications. The type designation is indicated by digits and letters which indicate in code form the principal physical and electrical characteristics affecting interchangeability (see Table I). Throughout the designation, a "W" will indicate a special case to be defined by the applicable specification sheet.

1.2.1.1 Item name. In all cases, the item name will be "Encoder, Shaft Angle to Digital".

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to Commanding Officer, Naval Air Warfare Center Aircraft Division, Code SR3, Lakehurst, NJ 08733-5100 by using the self-addressed Standardization Document Improvement Proposal (DD FORM 1426) appearing at the end of this document or by letter.

AMSC - N/A FSC 5990

1.2.1.2 Size. The first two digits of the type designation will indicate the maximum diameter of the encoder in tenths of an inch. If the maximum diameter is not a whole number of tenths, the next higher tenth will be used.

1.2.1.3 Type. The type, or operating principle employed, will be designated by a single letter according to the following schedule:

Capacitive	-	C	Optical (Lamp)	-	L
Contact	-	K	Optical (LED)	-	S
Eddy Current	-	E	Other	-	W
Magnetic	-	M			

1.2.1.4 Code and scan. The output code and scanning method will be designated by a single letter according to the following schedule:

Natural Binary, Line-Scan	-	A
Natural Binary, U-Scan	-	B
Natural Binary, V-Scan	-	C
Natural Binary, M-Scan	-	N
Reflected (Cyclic) Binary (Gray Code) Line-Scan	-	D
Reflected (Cyclic) Binary (Gray Code) Lead-Lag	-	P
Binary Coded Decimal, Line-Scan	-	E
Binary Coded Decimal, U-Scan	-	F
Binary Coded Decimal, V-Scan	-	G
Binary Coded Decimal, M-Scan	-	M
Decimal, Line-Scan	-	H
Incremental (With Zero Reference)	-	J
Incremental (Without Zero Reference)	-	K
Altitude reporting (ICAO)	-	U
Other	-	W

1.2.1.5 Readout. Whether the sensor selection is accomplished internally or externally, and whether the readout is parallel or serial will be designated by a letter according to the following schedule:

External Logic, Parallel	-	J
External Logic, Serial	-	K
Internal Logic, Parallel	-	L
Internal Logic, Serial	-	M

1.2.1.6 Capacity. The capacity of the encoder, with reference to the code, will be designated by a two-digit number equal to the highest power of two or ten, contained in the total count. If the number is less than 10, it should be preceded by a zero. Incremental will be listed as the closest power of two. The resolution will occasionally be listed directly instead of exponentially. Consult the applicable specification sheet to avoid confusion.

1.2.1.7 Function. The digital output of the encoder is a mathematical function of the shaft position. This function will be designated by a letter according to the following:

Linear	-	R
Sine-Cosine	-	S
Tangent	-	T
Exponential	-	X
Logarithmic	-	Z
Other	-	W

1.2.1.8 Resolution. The resolution of the encoder will be designated by a number equal to the highest power of two or ten, with reference to the code, counted by one revolution of the input shaft. If the number is less than 10, it should be preceded by a zero. Incremental units will be listed as the nearest power of two. The resolution will occasionally be listed directly instead of exponentially. Consult the applicable specification sheet to avoid confusion.

1.2.1.9 Design modification. The upper case letter "A" following the resolution designation indicates the original or basic issue of an encoder type. Subsequent modifications which affect interchangeability are designated by succeeding letters in the alphabet, with the exception of "I", "L", "O", and "Q", which are prohibited.

1.2.1.10 Input voltage. The input voltage required for proper operation will be specified on the applicable specification sheet.

1.3 Illustration. An encoder bearing the type designation 18KCJ13R07B, illustrated in Table I, has the following characteristics:

Size	-	Diameter greater than 1.7 but not more than 1.8 inches	(18)
Type	-	Contact	(K)
Code and Scan	-	Natural Binary; V-Scan	(C)
Readout	-	External Logic; Parallel	(J)
Capacity	-	2^{13} counts	(13)
Function	-	Linear	(R)
Resolution	-	7 Bit	(07)
Modification	-	First Modification	(B)

1.4 Part identifying number (PIN). The part identifying number consists of the letter "M", the basic number of the specification sheet (not including the revision letter), an assigned dash number and a suffix letter designating the latest modification letter in the type designation, as shown in Table II.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications and standards. The following specifications and standards form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

MILITARY

MIL-C-5541	-	Chemical Conversion Coatings of Aluminum and Aluminum Alloys
MIL-W-16878/4	-	Wire, Electrical, Polytetrafluoroethylene (PTFE), Insulated, 200°C, 600 Volts, Extruded Insulation
MIL-S-19500	-	Semiconductor Device, General Specification for
MIL-M-38510	-	Microcircuit, General Specification for
MIL-B-81744	-	Barrier Coating Solution, Lubricant Migration Deterring
MIL-B-81793	-	Bearing, Ball, Precision, for Instruments and Rotating Components
MIL-L-81846	-	Lubricating Oil, Instrument, Ball Bearings, High Flash Point
MIL-S-81963	-	Servocomponents, Precision Instrument, Rotation, Common Requirements and Tests

STANDARDS

MILITARY

MIL-STD-105	-	Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-198	-	Capacitor, Selection and Use of
MIL-STD-199	-	Resistor, Selection and Use of
MIL-STD-202	-	Test Methods for Electronic and Electrical Components
MIL-STD-810	-	Environmental Test Methods
MIL-STD-883	-	Test Methods and Procedures for Microelectronics
MIL-STD-1334	-	Process for Barrier Coating of Anti-Friction Bearings

(Unless otherwise specified, copies of federal and military specifications, standards and handbooks are available from the Standardization Documents Order Desk, Bldg. 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

2.2 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, (except for associated detailed specifications, specification sheets or MS standards), the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Specification sheets. The individual item requirements shall be as specified herein, in MIL-S-81963, and in accordance with the applicable specification sheets. In the event of any conflict between requirements of *MIL-S-81963, this specification and the specification sheet*, the latter shall govern.

3.2 Qualification. Encoders furnished under this specification shall be products which are authorized by the qualifying activity for listing on the applicable qualified products list at the time set for opening of bids (see 4.4 and 6.4).

3.3 First article. When specified in the contract or purchase order (see 6.2), a sample shall be subjected to first article inspection (see 4.5).

3.4 Design and construction. Encoders shall be of the design, construction and physical dimensions specified (see 3.1).

3.4.1 Physical characteristics. The physical characteristics of the encoder shall be as specified in the applicable specification sheet. In addition, the encoder shall be designed and constructed to perform with no reduction in accuracy, repeatability, or service life requirements after undergoing the environmental conditions of 4.8.

3.4.2 Termination identification. When screw and solder pin terminals are designated, the terminals shall conform to the specifications of MIL-S-81963. Unless otherwise specified on the applicable specification sheet, the wire for wire leads shall be in accordance with MIL-W-16878/4, E-26, and shall be a minimum of 18 inches long. Wire leads shall be capable of being pulled, bent, and twisted as required in MIL-S-81963. Terminal and lead wire identification marking for terminal screw, solder pin, or wire lead type shall be in accordance with the applicable specification sheet.

3.4.3 Direction of shaft rotation. Unless otherwise specified on the applicable specification sheet, counterclockwise rotation of the shaft shall produce an increasing count. The standard (positive) direction of rotation of the shaft is counterclockwise when the encoder is viewed from the shaft extension end.

3.4.4 Stops. The encoder shall contain no mechanical stops. The input shaft shall be capable of continuous rotation in either direction.

3.4.5 Dimensions. Outline drawings for the standard encoder sizes are included on Figures 1 through 5. Lettered dimensions shown on the outline drawings are provided in Table III.

3.4.6 Operating speed. The operating speed of encoders shall be as specified in the applicable specification sheet.

3.4.7 Operating life. The operating life of encoders furnished under this specification shall be as specified in the applicable specification sheet.

3.4.8 External power supply. Power to the electronics portion of an encoder may, if necessary, be supplied by an external power supply as specified in 3.4.8.1 and 3.4.8.2. This external power supply shall be considered as part of the encoder and must meet all environmental requirements of the encoder. If no external power supply is required for operation of the encoder, the encoder shall operate with equivalent input voltages.

3.4.8.1 External power supply configuration. The configuration of the external power supply, if used, shall be as specified in Figure 6.

3.4.8.2 Input power requirements. The power supply input voltages shall meet the requirements of the applicable specification sheet.

3.4.9 Electrical characteristics. The electrical characteristics of the encoder shall be as specified in the applicable specification sheet.

3.4.10 Diode isolation (contact type). Isolation diodes shall be provided as an integral part of the encoder package. The maximum voltage drop across each isolation diode shall not exceed 1 volt. The isolation diodes shall be wired to prevent the flow of current if the high side of a DC voltage source is connected to the encoder common lead and the low side is connected to any other encoder lead.

3.5 Parts, materials and processes. Whenever possible, encoders shall be constructed from parts and materials in accordance with MIL-S-81963.

3.5.1 Commercial parts. Commercial parts having equivalent properties to military parts may be used when, on the date of invitation for bids, there are no suitable military standard parts. Commercial hardware such as nuts, bolts, and washers having suitable properties may be used, provided they can be replaced by military standard parts without alteration to parts or equipment.

3.5.2 Bearings. Corrosion-resisting ball bearings ABEC Class 5 or better, of the radial thrust type, shall be used in the construction of encoders (except that higher precision bearings shall be used in applications where bearing runout will cause a shift of one-half count or greater on the least significant digit). This latter requirement shall be the maximum permissible bearing error. Bearings shall meet the requirements of MIL-B-81793.

3.5.3 Lubricants. All bearings used in the fabrication of encoders shall be processed and barrier coated in accordance with MIL-STD-1334, using the barrier coating solution of MIL-B-81744. The bearings shall be lubricated with the lubricant specified in MIL-L-81846.

3.5.4 Metals. Metals shall conform to the requirements of MIL-S-81963.

3.5.4.1 Rotor shaft and housing. Rotor shaft and housing shall meet the requirements of MIL-S-81963.

3.5.4.2 Electrical contacts. Under storage and use environments, electrical contact surfaces shall not form chemical combinations resulting in films of higher electrical resistivity than the parent material.

3.5.4.3 Aluminum. Where practicable, aluminum alloy parts shall be anodized in accordance with MIL-S-81963. Aluminum alloys which do not anodize satisfactorily shall be coated with a chemical film in accordance with MIL-C-5541.

3.6 Electronic components.

3.6.1 Resistors. All discrete resistors used in the fabrication of encoders shall be selected from MIL-STD-199.

3.6.2 Capacitors. All discrete capacitors used in the fabrication of encoders shall be selected from MIL-STD-198.

3.6.3 Semi-conductors. Silicon semiconductors conforming to MIL-S-19500 JAN TX shall be used throughout an encoder requiring semiconductor devices. The reverse bias impedance of isolating diodes, when used, shall not be less than one megohm throughout the range of operating temperatures.

3.6.4 Integrated circuits. All integrated circuits used in the fabrication of encoders shall conform to MIL-M-38510 Class B and MIL-STD-883 Class B.

3.6.5 Hybrid electronic packages. All hybrid electronic packages shall conform to MIL-M-38510 Class B and MIL-STD-883 Class B.

3.7 Performance requirements.

3.7.1 Visual and mechanical inspection. Visual and mechanical inspection shall be performed in accordance with 4.7.1 and shall meet the requirements of MIL-S-81963. Any evidence of inferior workmanship or disagreement with the specification shall be cause for rejection.

3.7.2 Weight. The weight of the encoder shall not exceed the value listed on the applicable specification sheet by more than one percent of the listed value.

3.7.3 Moment of inertia. When calculated in accordance with 4.7.3, the moment of inertia shall be no greater than that specified in the applicable specification sheet.

3.7.4 Shaft radial play. When measured in accordance with 4.7.4, the shaft radial play shall not exceed the value specified in the applicable specification sheet.

3.7.5 Total shaft runout. When measured in accordance with 4.7.5, the runout of the shaft diameter shall not exceed the value specified in the applicable specification sheet.

3.7.6 Shaft end play. When measured in accordance with 4.7.6, the shaft end play shall not exceed the value specified in the applicable specification sheet.

3.7.7 Shaft perpendicularity. When measured in accordance with 4.7.7, the perpendicularity of the shaft shall not exceed the value specified in the applicable specification sheet.

3.7.8 Mounting boss concentricity. When measured in accordance with 4.7.8, the concentricity of the shaft shall not exceed the value specified in the applicable specification sheet.

3.7.9 Torque.

3.7.9.1 Breakaway torque, mechanical. When tested in accordance with 4.7.9.1, the starting torque shall not exceed the value specified in the applicable specification sheet.

3.7.9.2 Running torque. When tested in accordance with 4.7.9.2, the running torque shall not exceed the value specified on the applicable specification sheet.

3.7.10 Dielectric withstanding. Encoders shall display no evidence of internal arcing or flashover or insulation breakdown when tested in accordance with MIL-S-81963 and 4.7.10.

3.7.11 Insulation resistance. When tested in accordance with 4.7.11, the insulation resistance shall meet the requirements of MIL-S-81963. The resistance between any lead wire and the encoder case shall not be less than 10 megohms.

3.7.12 Code and scan. When tested in accordance with 4.7.12, the encoder shall meet the requirements for output code, scanning, resolution, direction of operation for increasing count, mode of operation (parallel or serial) and capacity as specified in the applicable specification sheet.

3.7.13 Electrical noise.

3.7.13.1 Electrical noise in contact-type encoders. Unless specified otherwise in the applicable specification sheet, the maximum value for edge noise shall not exceed 10 percent of the quantum duration and surface noise shall not exceed 10 percent of the nominal "On" voltage level. Tests shall be performed in accordance with 4.7.13.1.

3.7.13.2 Electrical noise in non-contact type encoders. When required by the specification sheet, the maximum values for the duration of ringing and the maximum amplitude and duration of the bit drop shall not exceed the value specified in the applicable specification sheet. Tests shall be performed in accordance with 4.7.13.2.

3.7.14 Transition accuracy. When the encoder is tested in accordance with 4.7.14, each increment of shaft rotation between output count transitions shall be within the limits specified in the applicable specification sheet. Each output count transition shall occur at its appropriate angle within the same limits (tolerances not cumulative).

3.7.14.1 Zero position. Transition error tests shall be referenced to the zero position of 4.7.14.1.

3.7.14.2 Transition gradient . When tested in accordance with 4.7.14.2, the current may be determined by measuring the voltage drop across the series resistor. The transition gradient or sharpness of switching shall not exceed 55 percent of the allowable transition error limit for the current carried by each individual bit to change from 20 to 80 percent of its full conducting value.

3.7.15 Sensor alignment. The encoder shall be tested in accordance with the multichannel strip-chart recorder method of 4.7.15 or any other method which would (1) reveal the absence of one or more quanta, and (2) reveal errors of track-to-track quantum alignment.

3.7.16 Temperature rise. When tested in accordance with 4.7.16, the maximum temperature measured shall not exceed the value specified in the applicable specification sheet.

3.7.17 Electromagnetic interference. When tested in accordance with 4.7.17, the encoder shall meet the requirements of MIL-S-81963 and 4.7.17 herein.

3.7.18 Dynamic accuracy.

3.7.18.1 Dynamic accuracy (contact type). When tested in accordance with 4.7.18.1, the maximum number of errors shall not exceed:

$$F_{int} \times 3600 \div 10{,}000 \text{ (max) for each direction}$$

3.7.18.2 Dynamic accuracy (non-contacting type). When the encoder is tested in accordance with 4.7.18.2, no errors shall be allowed.

3.7.18.3 Count methods.

3.7.18.3.1 Comparison method - (absolute (true and complement)). When tested in accordance with 4.7.18.3.1, the circuit shall be such that it operates at the discriminating level specified in the applicable specification sheet.

3.7.18.3.2 Counter method - (incremental type). When tested in accordance with 4.7.18.3.2, the readout of the encoder shall be equal to the total number of the discrete outputs of the encoder.

3.7.18.3.3 Count sequence method - (absolute (true output only)). When tested in accordance with 4.7.18.3.3, a change in count which is greater than one and less than full count shall be considered an error.

3.7.19 Variation of brush contact resistance (contact types only). When tested in accordance with 4.7.19, the resistance value measured through any lead shall not exceed the value specified on the applicable specification sheet.

3.7.20 Position sensitivity. Unless specified otherwise, when tested in accordance with 4.7.20, the encoder shall be capable of operation in any attitude or inclination with no reduction in accuracy or service life requirements. The maximum rate of inclination shall be as specified in the applicable specification sheet.

3.7.21 Interrogation current.

3.7.21.1 Peak - (for encoders using DC or pulsed interrogation). When tested in accordance with 4.7.21.1, the peak interrogation current shall be as specified in the applicable specification sheet.

3.7.21.2 RMS - (for encoders using sine wave interrogation). When tested in accordance with 4.7.21.2, the RMS interrogation current shall be as specified in the applicable specification sheet.

3.7.22 Interrogation input impedance. When tested in accordance with 4.7.22, the calculated value of the interrogation input impedance shall be as specified in the applicable specification sheet as a function of shaft position.

3.7.23 Power. When tested in accordance with 4.7.23 and MIL-S-81963, the total power shall be as specified in the applicable specification sheet.

3.7.24 Logical "1" and logical "0" output levels. When tested in accordance with 4.7.24, the output and input from each track shall be within the limits specified on the applicable specification sheet.

3.7.25 Electrical capacity (contact type only). When tested in accordance with 4.7.25, the capacitance value obtained shall not exceed the value stated on the applicable specification sheet.

3.7.26 Conversion and recovery times.

3.7.26.1 Conversion time. When tested in accordance with 4.7.26.1, conversion time shall not exceed the value specified in the applicable specification sheet.

3.7.26.2 Recovery time. When tested in accordance with 4.7.26.2, recovery time shall not exceed the value specified in the applicable specification sheet.

3.7.27 Reverse bias impedance test (contact encoders incorporating internal isolating diodes). The encoder shall be tested in accordance with 4.7.27. The reverse bias impedance of all isolating diodes shall not be less than one megohm.

3.7.28 Maximum bit rate.

3.7.28.1 Maximum bit rate (parallel readout encoder). When tested in accordance with 4.7.28.1, the maximum bit rate shall be as specified in the applicable specification sheet.

3.7.28.2 Maximum bit rate (serial readout encoder). When tested in accordance with 4.7.28.2, the maximum bit rate shall be as specified in the applicable specification sheet.

3.7.29 Output impedance. When tested in accordance with 4.7.29, the calculated value shall not exceed the value specified in the applicable specification sheet.

3.7.30 Isolation. When required by the applicable specification sheet, the encoder shall be tested in accordance with 4.7.30 and shall meet the specified requirements therein.

3.7.31 Security of terminals or wire leads. The security of each screw type or solder pin type of terminal or of each wire lead, as applicable to the particular type of encoder, shall be tested in accordance with 4.7.31, and shall meet the requirements of MIL-S-81963.

3.7.32 Mission readiness test (contact only). When tested in accordance with 4.7.32, a dynamic accuracy test shall be performed. No run-in shall be allowed.

3.8 Environmental tests.

3.8.1 Altitude.

3.8.1.1 Altitude, low temperature. When tested in accordance with 4.8.1.1, the encoder shall meet the requirements of Table IV.

3.8.1.2 Altitude, high temperature. When tested in accordance with 4.8.1.2, the encoder shall meet the requirements of Table IV.

3.8.2 Vibration. When tested in accordance with 4.8.2, the encoder shall meet the requirements of MIL-S-81963 and Table IV.

3.8.3 Mechanical shock. Unless specified otherwise in the applicable specification sheet, the encoder shall be tested in accordance with 4.8.3. The encoder shall then meet the requirements of MIL-S-81963 and Table IV.

3.8.4 Acceleration. Encoders shall be capable of withstanding structural deterioration caused by acceleration. After testing in accordance with 4.8.4, the encoder shall meet the requirements specified in the applicable specification sheet.

3.8.5 Humidity. Encoders shall be capable of operation in an atmosphere of relative humidity. After testing in accordance with 4.8.5, the encoder shall meet the requirements of Table IV and shall conform to the electrical characteristics specified on the applicable specification sheet. There shall be no evidence of corrosion or deterioration of the encoder as the result of these tests.

3.8.6 Salt atmosphere. When required by the specification sheet, the encoders shall be tested in accordance with 4.8.6 and shall then meet the requirements of 4.7.1 and Table IV.

3.8.7 Fungus. Encoders shall be capable of operation after exposure to fungi without evidence of deterioration. After testing in accordance with 4.8.7, the encoder shall be tested in accordance with 4.7.9, 4.7.13, 4.7.14, and 4.7.24 and shall meet the requirements therein.

3.8.8 Sand and dust. Encoders shall be capable of operation in a sand and dust laden atmosphere without evidence of deterioration. After testing in accordance with 4.8.8, the encoder shall meet the requirements specified in the applicable specification sheet.

3.8.9 Temperature shock. Encoders shall be capable of withstanding the sudden change in temperature of the surrounding atmosphere without deterioration. After testing in accordance with 4.8.9, the encoder shall meet the requirements specified in the applicable specification sheet.

3.9 Life test. The encoders shall be tested in accordance with 4.9 and shall meet the requirements of Table IV.

3.10 Maintainability. The design of the encoder shall facilitate maintenance repairs to the maximum practical extent. No special tools shall be required for disassembly. Parts shall be suitably marked where necessary to ease the operation of reassembly.

3.11 Reliability. When specified by the contracting activity, a reliability test plan shall be submitted, the tests performed, corrective action for any failures implemented, and the results reported (see 6.5).

3.12 Identification. Encoders shall be identified by markings conforming to Figure 7. If an external power supply is used, it shall be identically marked to the encoder it supplies.

3.13 Workmanship. Encoders shall be manufactured and finished at that level of workmanship associated with high quality electrical instruments and shall meet the requirements of MIL-S-81963.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. The responsibility for performance of all inspection requirements shall be in accordance with MIL-S-81963.

4.1.1 Responsibility for compliance. The responsibility for compliance with all requirements of sections 3 and 5 shall be in accordance with MIL-S-81963.

4.1.2 Test equipment and test facilities. The accuracy of test equipment in inspection facilities shall conform to MIL-S-81963.

4.1.3 Alternate test methods. Alternate test methods shall conform to MIL-S-81963.

4.2 Test conditions.

4.2.1 Standard test conditions. Unless otherwise specified herein or in the applicable specification sheet, all temperature, atmospheric pressure, and relative humidity tests on the encoder shall be performed under room ambient conditions. The encoder shall be mounted in the applicable mounting fixture in accordance with MIL-S-81963. Mounting hardware shall conform to the requirements of Table V.

4.2.2 Standard test input. Unless otherwise specified herein or in the applicable specification sheet, the encoder output shall terminate in the load specified in the applicable specification sheet during electrical operating tests.

4.3 Classification of tests. The methods of sampling, inspection, and tests conducted on encoders shall be as follows:

a. Qualification (4.4)

b. First Article (4.5)

c. Quality Conformance (4.6)

4.4 Qualification inspection. Qualification inspection shall be performed at a laboratory approved by the Naval Air Systems Command and shall be performed in accordance with MIL-S-81963 and Table IV herein.

4.4.1 Qualification sample. The qualification sample shall be as specified in MIL-S-81963.

4.4.2 Qualification inspection routine. The qualification inspection routine shall be performed in accordance with MIL-S-81963 and Table IV herein.

4.4.3 Assessment of qualification inspection tests.

4.4.3.1 Qualification sample failure. Qualification sample failure shall be as specified in MIL-S-81963.

4.4.3.2 Degradation of performance. No minor degradations or relaxations will be permitted during qualification inspection tests for encoders.

4.4.4 Disposition of qualification sample. Disposition of the qualification sample shall be as specified in MIL-S-81963.

4.4.5 Requalification. The frequency of qualification inspection in order to retain qualification approval shall be as specified in MIL-S-81963.

4.4.6 Changes to encoders. After samples have been submitted for qualification, no change shall be made in the materials, design, or manufacturing processes without prior approval by the qualifying activity.

4.5 First article sample inspection. When specified by the contracting activity, first article testing shall be conducted as specified in MIL-S-81963 and a test report filed (see 6.5).

4.5.1 First article sample failure. Action following first article sample failure shall be as specified in MIL-S-81963.

4.6 Quality conformance inspection. Quality conformance inspection shall be as specified in MIL-S-81963 and Table IV herein.

4.6.1 Quality conformance inspection sampling. Statistical sampling and inspection shall be as specified in MIL-S-81963. When MIL-STD-105 specifies an action taken by the Government, it shall, at the option of the Government, be performed either by the Government or by the contractor under the supervision of the Government.

4.6.2 Quality conformance inspection routine. The minimum of inspection to be verified by the Government Inspector may substitute 100 percent inspection for all or part of the sampling procedure.

4.6.3 Quality conformance sample failure. Action following quality conformance sample failure shall be as specified in MIL-S-81963.

4.7 Test methods and examinations. All operating tests shall be performed with no warm-up or run-in time allowed.

4.7.1 Visual and mechanical inspection. The encoder shall be examined in accordance with MIL-S-81963 and shall meet the requirements of 3.7.1. Particular attention shall be given to soldered connections, finish, and general appearance. The inspection shall include an examination of the identification and connector to assure conformance to the specification.

4.7.2 Weight. The encoder, including cable and connectors, shall be weighed on a balance scale of sufficient accuracy to obtain a value within one percent of the true weight. Weight shall meet the requirements of 3.7.2.

4.7.3 Moment of inertia. The moment of inertia of the disc containing the least significant digit shall be calculated using the following equation and shall meet the requirements of 3.7.3.

$$I = (1/2)\ (M_1 r_1^2)\ +\ (1/2)\ (M_2 r_2^2)$$

M_1 = mass of disk M_2 = mass of shaft

r_1 = radius of disk r_2 = radius of shaft

4.7.4 Shaft radial play. The shaft radial play of the encoder shall be measured in accordance with MIL-S-81963 and shall conform to the requirements of 3.7.4 herein.

4.7.5 Total shaft runout. The total shaft runout of the encoder shall be measured in accordance with MIL-S-81963. The encoder shall meet the requirements of 3.7.5 herein.

4.7.6 Shaft end play. The encoder end play shall be measured in accordance with MIL-S-81963 and shall conform to the requirements of 3.7.6 herein.

4.7.7 Shaft perpendicularity. The encoder perpendicularity shall be measured in accordance with MIL-S-81963 and shall conform to the requirements of 3.7.7 herein.

4.7.8 Mounting boss concentricity. The encoder concentricity shall be measured in accordance with MIL-S-81963 and shall conform to the requirements of 3.7.8 herein.

4.7.9 Torque. Torque tests shall not be performed on a complete encoder assembly in operating condition. The measured torque shall include the torque required to overcome the friction in bearings, contacts and, if used, internal gear train; and the inertia of all rotating parts.

4.7.9.1 Breakaway torque, mechanical. The torque required to start the encoder from rest shall be measured in the clockwise and counter-clockwise directions. The encoder shall conform to the requirements of 3.7.9.1 herein.

4.7.9.2 Running torque. The torque required to drive the encoder at maximum operating speed for at least three revolutions in the clockwise and counterclockwise directions shall be measured. The encoder shall conform to the requirements of paragraph 3.7.9.2.

4.7.10 Dielectric withstanding voltage. When tested in accordance with MIL-S-81963, a maximum test potential of 250 volts, 50 to 60 hz shall be applied between all terminals (except the case ground terminal) tied together and the encoder case. Subsequent tests shall be performed at 80 percent of the initial voltage (maximum of 200 volts). Care must be taken to avoid the application of test potential across internal logic circuits. Dielectric withstanding voltage shall meet the requirements of 3.7.10 herein.

4.7.11 Insulation resistance. The voltage for insulation resistance test shall be 250V ± 10 percent instead of the voltage specified in MIL-S-81963. Care must be taken to avoid the application of test potential across components other than insulation. Measurements shall be made between the mutually insulated points. Insulation resistance shall be measured in accordance with the requirements of 3.7.11 herein.

4.7.12 Code and scan. The encoder shall be connected to simulate operating conditions with a circuit providing the proper interrogation voltage, current and waveform as specified in the applicable detail specification sheet, and the output logic circuit, if required. The output shall be wired to a lamp bank capable of representing the digital output. The encoder shall be rotated by hand and interrogated at sufficient intervals. The encoder shall conform to the requirements specified in 3.7.12.

4.7.13 Electrical noise.

4.7.13.1 Electrical noise in contact-type encoders. Connect the encoder as shown in Figure 8. Rotate the encoder shaft at its maximum operating speed and observe the output from all tracks. Electrical noise, as defined by this specification, is caused by variations in the steady state resistance of the contact-type encoders. Figure 10A depicts the two types of noise associated with contact-type encoders; that is, edge noise which occurs at the transition points, and surface noise (or amplitude noise) caused by the variation of brush contact resistance of the code disc. The encoder shall meet the requirements of 3.7.13.1.

4.7.13.2 Electrical noise in non-contact type encoders. Connect the encoder as shown in Figure 8. Rotate the encoder shaft at its maximum

operating speed and observe the outputs from all tracks. Electrical noise, as defined by this specification, is caused by ringing in the output switching circuits, and bit dropout (spurious signal) caused by uneven (non-homogeneous) disposition of the code pattern on the code disc. Figure 10B depicts both types of electrical noise. The encoder shall meet the requirements of 3.7.13.2.

4.7.14 Transition accuracy. The encoder shall be mounted in an angular test fixture provided with means for measuring the angular position of the encoder shaft. The measuring means shall be capable of measuring an angle one tenth the size of the tolerance on the angle to be measured. The encoder shall be zeroed as specified in 4.7.14.1, and the angle measured as each successive count transition occurs, in both the clockwise and counterclockwise directions, for one revolution of the input shaft. On multiple disc encoders, this procedure shall be repeated at all transition points of the least significant digit on succeeding discs until total count is reached. Calculate the theoretical angle between transitions using the following formula:

$$\text{angle} = \frac{360 \text{ degrees}}{\text{number of counts/turns}}$$

The error in accuracy is equal to the difference of the measured transition point and the theoretical transition point.

$$\text{Error} = \text{Measured} - \text{theoretical}$$

(If the measured transition point is less than the theoretical transition point, the error will be negative; and if the measured transition point is greater, the error will be positive.) Transition accuracy shall meet the requirements of 3.7.14.

4.7.14.1 Zero position. The zero position is defined as the mean of four angular position measurements at which the output transitions occur. In the case of an absolute encoder, it is determined from the following angular measurements:

a. From the greatest to the least number represented by the code; for example, 1...11 to 000...00.

b. From the least to the next greater number (000...00 to 000...01).

c. When returning from the next greater number to the least (000...01 to 000...00).

d. From the least number to the greatest; for example, 000...00 to 111...11.

In the case of an incremental encoder, any chosen zero position is determined from the corresponding angular measurement.

4.7.14.2 Transition gradient test. A current meter (with less than 10 ohms internal series resistance) shall be placed between the encoder's bit output and the bit's load (as an alternative, a series resistor equal to or less than 10 ohms may be placed in series between the encoder's output bit and load). The current reading may be obtained by measuring the voltage drop across the series resistor. The encoder shall be tested in accordance with the requirements of 3.7.14.2 herein.

$$I_{calculated} = \frac{V\ measured}{R\ series}$$

4.7.15 Sensor alignment. Each output signal shall be recorded simultaneously by means of a multichannel strip-chart recorder with the encoder shaft rotating for at least two complete revolutions in each direction. Where it is not possible to record all channels simultaneously (such as a multi-turn unit), two or more recordings may be made; but the second and subsequent recordings shall include a record of the next most significant or least significant digit output contained on the previous recording. The speed of rotation shall be the maximum operating speed or that given by the following equation:

$$n = \frac{2\ fm}{R}\ x\ 60\ (rev/m)$$

where:

n is less than the operating speed

fm (Hz) = the maximum response frequency of the recording, which shall not be less than 5 kHz, and

R (1/rev) = count per one revolution of the input shaft.

The recording shall be such that the amplitude of each trace shall not be less than 0.5 inch, and the chart speed shall be sufficient to ensure that one On-Off cycle of the least significant digit shall be readable. The tracks shall be examined to check that each quantum is recorded and that each sensor is so aligned to avoid the possibility of an ambiguous output occurring. In a V-scan example, the transitions from one quantum to the next in each track shall occur in the center 70 percent region between the transitions of the next most significant tracks.

4.7.16 Temperature rise. While the encoder is unenergized and at standard test conditions of 4.2.1, connect thermocouples to the outer case of the encoder. Energize the encoder as specified in the applicable specification sheet. Monitor all of the thermocouples. The encoders shall meet the requirements of 3.7.16.

4.7.17 Electromagnetic interference. Encoders shall be so constructed that radiated and conducted radio noise will not jeopardize the effective use of communication or navigation equipment, nor shall the encoder be susceptible to radiated or conducted radio noise generated by other equipment. The encoder shall meet the requirements of 3.7.17 herein.

4.7.18 Dynamic accuracy.

4.7.18.1 Dynamic accuracy (contact type). The encoder shall be mounted with the shaft in a horizontal position and continuously interrogated with the interrogation voltage and brush current specified in the applicable specification sheet. The encoder shall be driven at its maximum operating speed for one hour in both the clockwise and counterclockwise directions. The accuracy of count shall be determined using one of the methods of 4.7.18.3. The encoder shall conform to the requirements of 3.7.18.1.

4.7.18.2 Dynamic accuracy (non-contacting type). The encoder shall be mounted with the shaft in a horizontal position and continuously interrogated with the interrogation voltage and waveform specified in the applicable specification sheet. The encoder shall be driven at its maximum operating speed for one hour in both the clockwise and counterclockwise directions. The encoder shall conform to the requirements of 3.7.18.2 herein.

4.7.18.3 Count methods.

4.7.18.3.1 Comparison method - (absolute (true and complement)). Encoders which produce the complement of the principal readout by means other than conversion may be tested by the following method. A circuit shall be set up to compare each binary digit of the output, excepting the least significant digit, with its complement; if each digit is not different from its complement, an error indicating device shall be actuated. The encoder shall conform to the requirements of 3.7.18.3.1.

4.7.18.3.2 Counter method - (incremental type). Starting with the encoder at its zero position, rotate the shaft through the required number of turns for full count of the encoder. The encoder shall be meet the requirements of 3.7.18.3.2.

4.7.18.3.3 Count sequence method - (absolute (true output only)). With encoder shaft rotating at specified rpm and the required interrogation rate applied, a circuit shall be connected which, upon command of the interrogation voltage, shall sample the output state of the encoder and store this information. Upon command of the second interrogation voltage, a second sample shall be taken and compared to the previous sample. The encoder shall meet the requirements of 3.7.18.3.3.

4.7.19 Variation of brush contact resistance (contact type only). The resistance from the interrogation lead, through the disc circuit and brush

contact, to each brush lead shall be measured throughout one revolution of each disc. The encoder shall meet the requirements of 3.7.19 herein.

4.7.20 Position sensitivity. The encoder shall be placed in a fixture capable of driving the input shaft at its rated operating speed. The fixture shall be mounted securely on a scorsby table in a manner which will insure that the encoder shaft is parallel to one of the three mutually perpendicular axes. The scorsby table shall be capable of inclining the encoder at the rate specified in the applicable specification sheet. The output of the encoder shall be monitored during the test by the test circuit shown in Figure 8. The encoder shall be placed in a fixture capable of driving the input shaft at its rated operating speed. The encoder shall meet the requirements of 3.7.20 and Table IV.

4.7.21 Interrogation current.

4.7.21.1 Peak - (for encoders using DC or pulsed interrogation). Supply the encoder interrogation waveform specified in the applicable specification sheet and measure the peak interrogation current using an oscilloscope with a current probe. The encoder shall meet the requirements of 3.7.21.1.

4.7.21.2 RMS - (for encoders using sine wave interrogation). Supply the encoder with the interrogation waveform specified in the applicable specification sheet. Insert an ammeter in series with the interrogation input, and measure the RMS current. The encoder shall meet the requirements of 3.7.21.2.

4.7.22 Interrogation input impedance. Calculate the encoder's interrogation input impedance from the interrogation voltage and interrogation current measured in 4.7.21.1 and 4.7.21.2. The encoder shall meet the requirements of 3.7.22.

4.7.23 Power. Supply the encoder under maximum rated load conditions with the input voltage(s) specified in the applicable specification sheet. Measure the source current(s) with (an) appropriate ammeter(s). From the supply voltage(s) and current(s), calculate the total power drawn by the encoder. The encoder shall meet the requirements of 3.7.23.

4.7.24 Logical "1" and logical "0" output levels. Connect the encoder as shown in Figure 8. Rotate the encoder shaft at its maximum operating speed, and measure the "1" output voltage and current levels on all tracks. The output from each shall be within the limits specified in the applicable specification sheet. Rotate the encoder shaft at its maximum operating speed and measure the "0" output levels on all tracks. Repeat the foregoing test with the inputs, including interrogation waveform, at the high and low tolerances specified in the applicable specification sheet. The encoder shall meet the requirements of 3.7.24.

4.7.25 Electrical capacity (contact type only). Using a capacitance bridge, measure the value of capacitance (at 400 Hz) between the encoder disc and case. The encoder shall meet the requirements of 3.7.25 herein.

4.7.26 Conversion and recovery times.

4.7.26.1 Conversion time. Connect the encoder as shown in Figure 10. Rotate the encoder shaft at its maximum operating speed, and interrogate the encoder at its maximum interrogation rate. Observe the conversion time, which is the time between the start of interrogation and the time at which the first digit (in the case of serial output or the entire word in the case of parallel output) transitions from 10 to 90 percent of its steady value. The encoder shall meet the requirements of 3.7.26.1.

4.7.26.2 Recovery time. Under the same conditions as specified for the conversion time test (4.7.26.1), observe the recovery time. The recovery time is the time required for the output to decline from 90 percent of its nominal value following the removal of the interrogation voltage. The encoder shall then meet the requirements of 3.7.26.2.

4.7.27 Reverse bias impedance test (contact encoders incorporating internal isolating diodes). Reverse the polarity of the current source and the leads and repeat the test of 4.7.19. The encoder shall meet the requirements of 3.7.27 herein.

4.7.28 Maximum bit rate.

4.7.28.1 Maximum bit rate (parallel readout encoder). Connect the encoder as shown in Figure 8. Rotate the encoder shaft at its maximum operating speed and observe the least significant digit on an oscilloscope. Measure the frequency of one complete "zero-one" cycle; the bit rate is equal to twice this frequency. The encoder shall meet the requirements of 3.7.28.1.

4.7.28.2 Maximum bit rate (serial readout encoder). Connect the encoder as shown in Figure 8. The encoder shaft may be rotating or stationary. Interrogate the encoder at its maximum interrogation rate. Measure the duration of one bit of output. The frequency corresponding to this period is the maximum bit rate. The encoder shall meet the requirements of 3.7.28.2.

4.7.29 Output impedance. Using a current probe, measure the output current of each encoder bit when connected shorted to ground. Calculate the output impedance using these values and the voltage levels obtained from 4.7.19. The encoder shall meet the requirements of 3.7.29.

4.7.30 Isolation. The encoder shall be supplied with all of its specified operating inputs except the interrogation signal. The encoder shaft shall be positioned to that angle which would produce a logical "0"

signal on each output line upon interrogation. The outputs shall be connected to a lamp type readout. Disconnect one lead at a time and apply a logic signal to that lead. Observe that a logic "1" does not appear on any of the other outputs. Reconnect the lead and move to the next one and repeat the test. When the foregoing has been completed, turn the encoder shaft to the angle which, when the encoder is interrogated, will produce a logic "1" on all outputs. Repeat the procedure of applying a logic "1" to each line as described above. The encoder shall be tested in accordance with 3.7.30.

4.7.31 Security of terminals or wire leads. The security of each screw-type or solder-type terminal or of each wire lead shall be tested in accordance with MIL-S-81963 and shall meet the requirements of 3.7.31.

4.7.32 Mission readiness test (contact type only). The encoder shaft shall remain stationary relative to the case for a period of not less than seven days. At the end of this time, the dynamic accuracy test (4.7.18) shall be performed. The accuracy test shall commence at the start of the first revolution of the encoder shaft, after the inactive period. The encoder shall meet the requirements of 3.7.32 herein.

4.8 Environmental.

4.8.1 Altitude.

4.8.1.1 Altitude, low temperature. The encoder shall be placed in a suitable test chamber and shall be electrically and mechanically connected as described in 4.7.11. The encoder shall be zeroed in accordance with 4.7.11.1, and the chamber temperature shall then be reduced to the low temperature specified in the applicable specification sheet. After the temperature has been stabilized for two hours and while still at the low temperature, the pressure of the chamber shall be reduced to the equivalent of 100,000 feet of altitude. While at this pressure and temperature, the encoder shall be subjected to and shall meet the requirements of 4.7.11. While maintaining the low temperature, the pressure of the chamber shall be returned to ambient pressure. The encoder shall then be subjected to and shall meet the requirements of 3.8.1.1 and Table IV.

4.8.1.2 Altitude, high temperature. Repeat the test of 4.8.1.1, except the temperature shall be increased to the high temperature specified in the applicable specification sheet. The encoder shall then be subjected to and shall meet the requirements of paragraph 3.8.1.2 and Table IV.

4.8.2 Vibration. Unless otherwise specified in the applicable specification sheet, encoders shall be tested in accordance with MIL-S-81963. Encoders larger than size 23 shall be tested in accordance with Test Condition A; encoders size 23 and smaller shall be tested in accordance with Test Condition B. The encoder shall be rigidly mounted on a test fixture, utilizing standard mounting surfaces, with the shaft free

to rotate. The test of 4.7.17 shall be performed once in each of the three mutually perpendicular orientations during the vibration test. The encoder shall meet the requirements of 3.8.2 and Table IV.

4.8.3 Mechanical shock. Unless otherwise specified by the applicable specification sheet, the encoder shall be subjected to the low shock (specified pulse) test of MIL-S-81963 with the shaft free to rotate while mechanically loaded. The encoder shall be securely attached to a rigid test fixture, and the test fixture securely mounted to the shock test device. The encoder shall meet the requirements of 3.8.3 and Table IV.

4.8.4 Acceleration. The encoder shall be subjected to the acceleration indicated in MIL-STD-202, Method 212. After conclusion of this test, the encoders shall meet the requirements of 3.8.4 and Table IV.

4.8.5 Humidity. Unless otherwise specified by the applicable specification sheet, the encoder shall be subjected to the humidity test of MIL-STD-202, Method 103, Condition B. The tests of Table IV shall be conducted after conditioning at high humidity and after the drying period. The encoder shall meet the requirements of 3.8.5 herein.

4.8.6 Salt atmosphere resistance. When required by the applicable specification sheet, the encoder shall be subjected to the salt atmosphere test in accordance with MIL-S-81963. After completion of the test, the encoder shall meet the requirements of 3.8.6 and Table IV.

4.8.7 Fungus. The encoder shall be subjected to the fungus test of MIL-STD-810, Method 508. The encoder shall be disassembled at the conclusion of this test and inspected for evidence of fungus growth. The encoder shall then meet the requirements of 3.8.7.

4.8.8 Sand and dust. The encoder shall be subjected to the sand and dust test of MIL-STD-202, Test Method 110, Steps 1 through 4. The encoder shall then meet the requirements of 3.8.8 and Table IV.

4.8.9 Temperature shock. The encoder shall be subjected to the temperature shock test of two separate chambers, one maintaining a temperature of -55°C and the other at +85°C. Place the encoder in the low temperature chamber for a period of one hour. After the completion of this period, transfer the unit to the high temperature chamber with a total maximum transfer time of five minutes at room ambient temperature. After a high temperature period of one hour, repeat the cycle with a transfer time not to exceed five minutes. A total of five cycles shall be performed. At the conclusion of this test, the encoders shall be subjected to and shall meet the requirements of 3.8.9 and Table IV.

4.9 Life. Unless otherwise specified in the applicable specification sheet, the encoder shall be operated at maximum operating speed in the clockwise direction for one hour. At the end of this period, the encoder

shall be operated at maximum slew speed, in the same direction, throughout at least one full count cycle. The direction of rotation shall then be reversed and the encoder shall be operated at maximum operating speed in the counterclockwise direction for one hour. At the end of this period, the encoders shall be operated at maximum slew speed, in the counter-clockwise direction throughout at least one full count cycle. The foregoing shall be repeated until the encoder has been run for the total number of revolutions or hours specified in the applicable specification sheet. The encoder shall be subjected to and shall meet the requirements of the tests indicated in Table IV when the test is approximately 25, 50, 75 and 100 percent complete.

4.10 *Inspection of packaging*. Sample packages and packs shall be selected and inspected in accordance with MIL-S-81963.

5. PACKAGING

5.1 Preservation and packaging. The requirements for preservation and packaging shall be in accordance with MIL-S-81963.

6. NOTES

(This section contains information of a general explanatory nature that may be helpful, but not mandatory.)

6.1 Intended use. The intended use for encoders covered by this specification must be in accordance with MIL-S-81963.

6.2 Acquisition requirements. Procurement documents should contain the information specified in MIL-S-81963.

6.3 First article inspection. Information pertaining to first article inspection of encoders should be as specified in MIL-S-81963.

6.4 Qualification. With respect to products requiring qualification, awards will be made in accordance with MIL-S-81963. The activity responsible for the Qualified Products List is the Naval Air Warfare Center Aircraft Division Lakehurst, Systems Requirements Department (Code SR3), Lakehurst, NJ 08733-5100; however, information pertaining to qualification of products may be obtained from Commanding Officer, Crane Division, (Code 7065), Naval Surface Warfare Center, Crane, IN 47522-5070.

6.5 Consideration of data requirements. The following data requirements should be considered when this specification is applied on a contract. The applicable Data Item Descriptions (DID'S) should be reviewed in conjunction with the specific acquisition to ensure that only the essential data is requested/provided and that the DID's are tailored to reflect the requirements of the specific acquisition. To ensure correct contractual application of the data requirements, a Contract Data

Requirements List (DD Form 1423) must be prepared to obtain the data, except where DOD FAR Supplement 27.475-1 exempts the requirement for a DD Form 1432.

Reference Paragraph	DID Number	DID Title	Suggested Tailoring
3.11	DI-RELI-80250	Reliability Test Plan	Contractor format
3.11	DI-RELI-80251	Reliability Test Procedures	----------
3.11	DI-RELI-80252	Reliability Test Reports	----------
3.11	DI-RELI-80253	Failed Item Analysis Report	----------
3.11	DI-RELI-80254	Corrective Action Plan	----------
3.11	DI-RELI-80255	Failure Summary and Analysis Report	----------
4.5	DI-NDTI-80809A	Test/Inspection Report	----------

The above DID'S were those cleared as of the date of this specification. The current issue of DOD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL), must be researched to ensure that only current, cleared DID'S are cited on the DD Form 1432.

6.6 Definitions.

6.6.1 Accuracy. The maximum angular difference between the shaft angle input to an encoder and an indicated shaft angle as read from the code output. Accuracy includes both transition error and quantizing error, and is the quantitative statement of the maximum of all errors.

6.6.2 Analog. Pertaining to data in the form of smoothly variable physical quantities.

6.6.3 Binary. The term referring to the number 2 or to the number system with a radix of 2.

6.6.4 Binary code. The definition of a series of binary numbers relative to the corresponding number system represented.

6.6.5 Binary coded decimal (BCD code). A decimal notation in which the individual decimal digits are each represented by a group of binary bits. Usually associated with codes of four or more bits used to define the Arabic numbers 0 through 9.

6.6.6 Binary number. A mathematical system in which only two digits are used (1 and 0).

6.6.7 Bit. An abbreviation for BInary digiT and has the value of either true (1) or false (0), on or off; the basic unit of the binary system.

6.6.8 Bit and complement. The insertion of parity bits such that for each binary 1, there is a binary 0.

6.6.9 Capacity (total count). The total number of digital values or counts available from the encoder.

6.6.9.1 Single-turn encoder. In single-turn encoders, the capacity is reached by one revolution of the shaft.

6.6.9.2 Multi-turn encoder. In multi-turn encoders, the amount of turns necessary for full scale is the capacity divided by the resolution.

6.6.10 Code. A number of binary digits uniquely arranged to define each position in a given number system.

6.6.11 Complement. The process, act, or result of inverting a logic function or number to the opposite binary state (180 degrees out of phase).

6.6.12 Count error. An omission or mistake in coded output.

6.6.13 Data. Any representations such as characters or analog quantities to which meaning is assigned.

6.6.14 Encoder. Shaft position analog-to-digital encoders are electromechanical devices that convert input analog data in the form of contact closures or voltage levels.

6.6.14.1 Absolute. An absolute encoder is an electromechanical device which provides a unique binary word output for each increment of resolution.

6.6.14.2 Incremental. An incremental encoder is an electromechanical device which provides alternate logic "0" and logic "1" bits for each successive increment of resolution.

6.6.15 Gray code. A unit distance code obtained by a reflection of each bit in the natural binary code. Also called the reflected binary code.

6.6.16 Incremental code. A two bit binary code used to increment or deincrement an external accumulator.

6.6.17 Line or pulse count. The number of lines comprising the complete circle of radial lines on an encoder disc. Defines the number of pulse periods per complete revolution of the input shaft.

6.6.18 Multi-turn encoder. Multi-turn encoders contain two or more code discs which are internally geared to increase the capacity in a particular

encoder frame size. The ratio of each gearing stage corresponds to the total count of the following disc.

6.6.19 Natural binary code. A binary number system in which the bits are weighted as powers of two; that is, 1, 2, 4, 8, 16, 32, and so on.

6.6.20 Noise. Any momentary variation in the steady state resistance of the encoder contact. Usually measured as a momentary fluctuation of the voltage across a load supplied through an encoder contact.

6.6.21 Radix. The number of digit symbols in a number system; the numerical base of the number system.

6.6.22 Resolution. The total number of code positions per 360 degrees of encoder shaft rotation (expressed as counts per turn in incremental encoders).

6.6.23 Scanning methods.

6.6.23.1 V-Scan. In V-scan, the sensors are positioned in the form of an inverted V. A single sensor, at the apex of the V, is placed on the least significant track. Two sensors are placed on each succeeding track with an interval equal to the size of the bit preceding it.

6.6.23.2 M-Scan. M-scan is a variation of V-scan with the lead tracks or sensors in complemented form relative to their lag track counterparts.

6.6.23.3 U-scan. In U-scan the sensors are positioned in the form of an inverted U. The sensor at the apex of the U is placed on the least significant track. On the other tracks, two sensors are placed by pairs with an interval equal to the size of the least significant bit on the track of interest. As in V-scan and M-scan, an external switching network is required for sensor selection.

6.6.24 Shaft angle. The angular position of the encoder shaft measured from the zero reference point in a positive direction.

6.6.25 Slew speed. The maximum angular velocity to which an encoder may be accelerated and still retain full accuracy when slowed below the maximum rotation speed.

6.6.26 Temperature rise. The temperature rise of an encoder is the increase of the internal temperature of the encoder above the ambient temperature due to the dissipation of energization power.

6.6.27 Transition accuracy. The maximum difference in angle between the actual and the true positions of a transition between one code position and an adjacent code position.

6.6.28 Transition error. The difference between the shaft angle at which a code position change should occur (theoretical transition point) and the angle at which it actually does occur (measured transition point), and is usually a measure of the sum of manufacturing tolerances and wear.

6.6.29 Units of measurement. Unless otherwise specified, units of measurement are as follows:

a. Angles - degrees and minutes
b. Potential - volts rms
c. Impedance - ohms
d. Current - amperes rms
e. Temperature - degrees Centigrade
f. Time Phase - degrees
g. Torque - ounce-inches
h. Time - seconds
i. Angular velocity - revolutions per minute (rpm)

6.7 Subject term (key) word listing.

Bit rate
Breakaway torque
Capacity (total count)
Code
Conversion time
Dynamic accuracy
Electrical noise
First article
Interrogation current
Life test
Mission readiness
Moment of inertia
Position sensitivity
Quality conformance
Readout
Recovery time
Resolution
Reverse bias impedance
Running torque
Scan
Shock, mechanical
Shock, temperature
Slew speed
Transition accuracy
Transition gradient
Zero position

6.8 Changes from previous issue. Asterisks are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

6.9 International standardization agreements. Certain provisions of this specification are subject of international standardization agreements reached by the NATO Working Group on Analog and Digital Servocomponents (AC/301(SG/A)(WG/5)). When amendment, revision, or cancellation of this specification is proposed which affects or violates the international agreement concerned, the preparing activity will take appropriate reconciliation action through international channels, including departmental standardization offices, to change the agreement or make other appropriate accommodations.

6.10 Applicable international documentation. NATO documents applicable to this specification are Allied Standard Publication (AStanP)-3, Volume 5990 Chapter 7, NATO Electronic/Electrical Preferred Parts List, Encoders, Shaft Angle to Digital; AStanP-4, Volume 5990 Chapter 10, NATO Electronic/Electrical Technical Recommendation, Encoders, Shaft Angle to Digital; and AStanP-5, Volume 5990 Chapter 10, NATO Quality Assessment Recommendation for Electronic/Electrical Parts, Encoders, Shaft Angle to Digital.

TABLE I. Nomenclature.

ENCODER, SHAFT ANGLE TO DIGITAL	18	K	C	J	13	R	07	B
Item name	Size	Type	Code & Scan	Readout	Capacity	Function	Resolu-tion	Design Modifi cation
1.2.1.1	1.2.1.2	1.2.1.3	1.2.1.4	1.2.1.5	1.2.1.6	1.2.1.7	1.2.1.8	1.2.1.9

TABLE II. Example of part identifying number.

M	85082/1	-01	A
Military Designation	Specification Sheet No.	Dash No.	Latest Modification Letter

TABLE III. Standard dimensions for encoders, shaft angle to digital.

For location of lettered dimensions, see:

FIGURE	1	2	3	4	5	6
ENCODER SIZE	8-11	15-18	23	31	35	40

(Dimensions are in inches unless otherwise specified)

DIMENSIONS	A	B	C	D	E	G	H
ENCODER SIZE	AS LISTED ON SPECIFICATION SHEET TABLE II		Maximum 1/	+0.0000 -0.0005	AS LISTED ON SPECIFICATION SHEET TABLE II		±0.003
08			0.753	0.5000			0.040 2/
11			1.062	1.0000			0.062 2/
15			1.437	1.3120			0.040
18			1.750	1.5620			0.040
23			2.250	2.0000			0.062
31			3.062 3/	----			0.132
35			3.500 4/	3.1250 5/			0.160 6/
40			4.000 7/	2.562 5/			0.310 8/

NOTES:

1/ Unless stated otherwise on applicable specification sheet.

2/ Tolerance is maximum.

3/ Tolerance is +0.000/-0.005.

4/ Tolerance is +0.003/-0.010.

5/ Tolerance is +0.000/-0.001.

6/ Tolerance is ±0.004.

7/ Tolerance is ±0.005.

8/ Tolerance is ±0.010.

TABLE III. Standard dimensions for encoders, shaft angle to digital - (Continued).

DIMENSIONS	I	J	K	L	P	U
ENCODER SIZE	±0.003 1/	±0.003	Maximum 1/	Maximum	Maximum	
08	----	0.062 7/	0.049	0.670	----	AS SPECIFIED ON SPECIFICATION SHEET TABLE II
11	0.062	0.093 1/	0.050	0.975	1.062	
15	0.132	0.093	0.078	1.312	1.500	
18	0.132	0.093	0.078	1.625	1.750	
23	0.200	0.125	0.095	2.062 9/	2.300	
31	0.093	0.078	----	2.937	----	
35	0.125 6/	0.100 6/	0.100 6/	3.290 10/	----	
40	----	0.125 7/	0.150 7/	3.760	4.000 11/	

NOTES:

9/ Tolerance is ±0.003.

10/ Tolerance is ±0.006.

11/ Tolerance is ±0.016.

TABLE IV. Qualification and quality conformance inspection tests.

Test Number	Requirement	Test	Test Method for Examination	Inspection	
				Qualification Sample Number	Quality Conformance
1	3.7.1	4.7.1	Visual and mechanical inspection	1, 2, 3, 4	X
2	3.7.2	4.7.2	Weight	1, 2, 3, 4	-
3	3.7.3	4.7.3	Moment of inertia 1/	1, 2, 3, 4	-
4	3.7.4	4.7.4	Shaft radial play	1, 2, 3, 4	X
5	3.7.5	4.7.5	Total shaft runout	1, 2, 3, 4	X
6	3.7.6	4.7.6	Shaft end play	1, 2, 3, 4	X
7	3.7.7	4.7.7	Perpendicularity, shaft	1, 2, 3, 4	X
8	3.7.8	4.7.8	Mounting boss concentricity	1, 2, 3, 4	X
9	3.7.9.1	4.7.9.1	Mechanical breakaway torque	1, 2, 3, 4	X
10	3.7.9.2	4.7.9.2	Running torque	1, 2, 3, 4	X
11	3.7.10	4.7.10	Dielectric withstanding voltage	1, 2, 3, 4	X
12	3.7.11	4.7.11	Insulation resistance	1, 2, 3, 4	X
13	3.7.12	4.7.12	Code and scan	1, 2, 3, 4	X
14	3.7.13	4.7.13	Electrical noise	1, 2, 3, 4	X
15	3.7.14	4.7.14	Transition accuracy	1, 2, 3, 4	X

TABLE IV. Qualification and quality conformance inspection tests - Continued.

Test Number	Requirement	Test	Test Method for Examination	Inspection	
				Qualification Sample Number	Quality Conformance
16	3.7.15	4.7.15	Sensor alignment	1, 2, 3, 4	-
17	3.7.16	4.7.16	Temperature rise	1, 2, 3, 4	-
18	3.7.17	4.8.17	Electromagnetic interference	1, 2, 3, 4	-
19	3.7.18	4.7.18	Dynamic accuracy	1, 2, 3, 4	X
20	3.7.19	4.7.19	Variation in contact resistance 3/	1, 2, 3, 4	X
21	3.7.20	4.7.20	Position sensitivity, during test nos. 14, 16, 22, and 27	1, 2, 3, 4	-
22	3.7.21	4.7.21	Interrogation current	1, 2, 3, 4	-
23	3.7.22	4.7.22	Interrogation input impedance	1, 2, 3, 4	-
24	3.7.23	4.7.23	Power	1, 2, 3, 4	-
25	3.7.24	4.7.24	Logical "1" and logical "0" output	1, 2, 3, 4	X
26	3.7.25	4.7.25	Electrical capacity (contact) 3/	1, 2, 3, 4	-
27	3.7.26	4.7.26	Conversion and recovery	1, 2, 3, 4	-
28	3.7.27	4.7.27	Reverse bias impedance (contact) 3/	1, 2, 3, 4	X
29	3.7.28	4.7.28	Maximum bit rate	1, 2, 3, 4	-

TABLE IV. Qualification and quality conformance inspection tests - Continued.

Test Number	Requirement	Test	Test Method for Examination	Inspection	
				Qualification Sample Number	Quality Conformance
30	3.7.29	4.7.29	Output impedance	1, 2, 3, 4	-
31	3.7.31	4.7.31	Security of terminals or wire leads	1, 2, 3, 4	-
32	3.8.1.1	4.8.1.1	Altitude, low temperature, during test nos. 12 and 19	1, 2	X
33	3.8.1.2	4.8.1.2	Altitude, high temperature, during test nos. 12 and 19	1, 2	X
34	3.8.2	4.8.2	Vibration, during test no. 19	1, 2, 3, 4	X
35	3.8.3	4.8.3	Mechanical low shock, followed by test no. 19	1, 2, 3, 4	X
36	3.7.30	4.7.30	Isolation 2/	3, 4	-
37	3.8.4	4.8.4	Acceleration, followed by test no. 19	3, 4	-
38	3.8.5	4.8.5	Humidity, followed by test nos. 11, 12, and 19	3, 4	-
39	3.8.6	4.8.6	Salt atmosphere, followed by test nos. 1, 9, 10, 11, 19, and 36 2/ and 4/	1, 2, 3, 4	-
40	3.8.7	4.8.7	Fungus, followed by test nos. 9, 10, 14, 15, and 25	1, 2	-

TABLE IV. Qualification and quality conformance inspection tests - Continued.

Test Number	Requirement	Test	Test Method for Examination	Inspection	
				Qualification Sample Number	Quality Conformance
41	3.8.8	4.8.8	Sand and dust, followed by test nos. 9, 10, and 19	1, 2	-
42	3.9	4.9	Life, during which test nos. 9, 10, and 19 performed at 25, 50, 75, and 100%	1, 2	X
43	3.8.9	4.8.9	Temperature shock, followed by test no. 19	1, 2, 3, 4	X
44	3.7.32	4.7.32	Mission readiness, followed by test no. 19 3/	1, 2, 3, 4	X

1/Calculated from design data; required only once per design.

2/Test Nos. 36 and 39 shall be performed only when required by the applicable specification sheet.

3/Test Nos. 20, 26, 28, and 43 are required for contact encoders only.

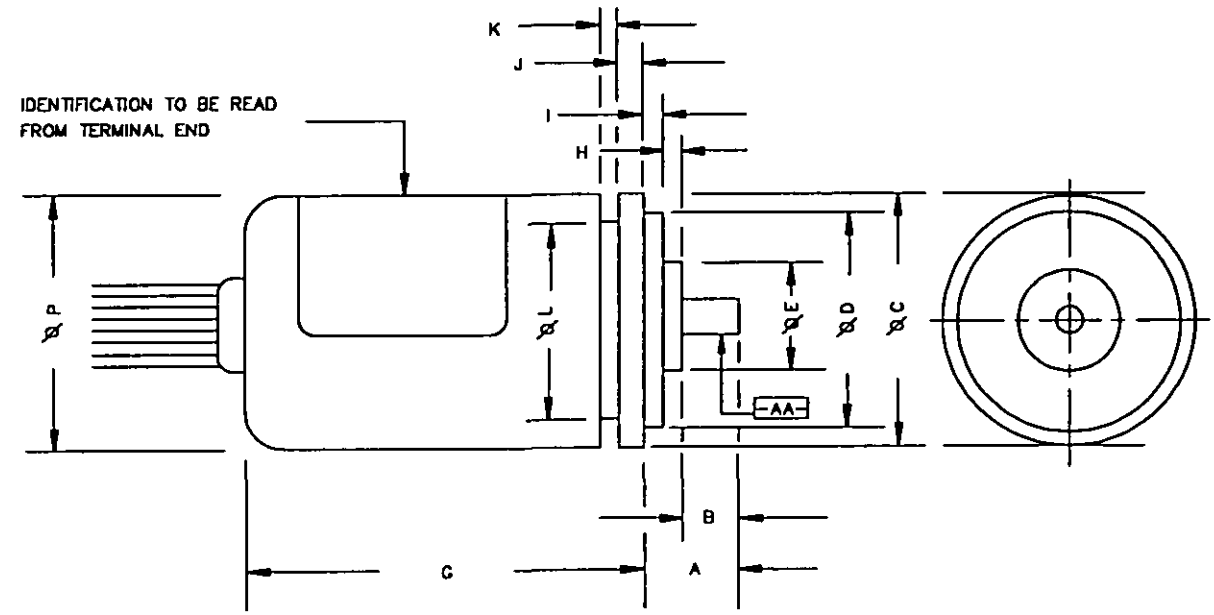
4/ After test no. 39, test no. 19 (dynamic accuracy) shall be performed on half the samples only.

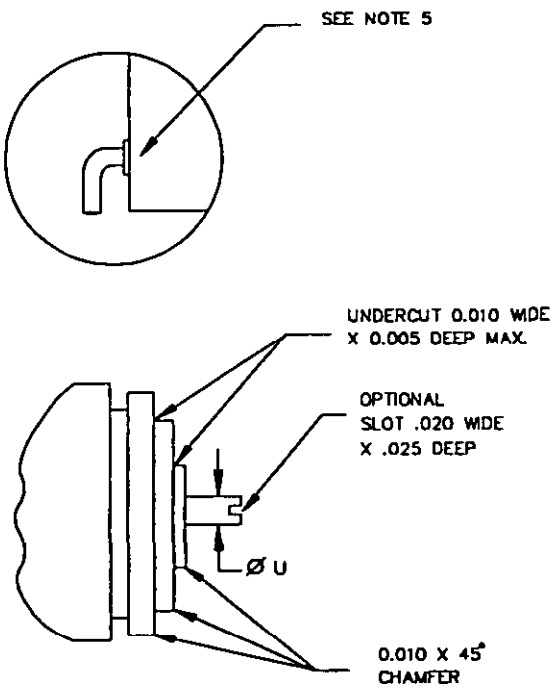
TABLE V. Terminal hardware.

Military Hardware	Number Required	Military Standard	Size
Machine Screw	5 EA	MS-35276-203	11
		MS-35275-213	15,18,23
		MS-35275-227	31
Lock Washer	5 EA	MS-35338-134	11
		MS-35338-135	15,18,23
		MS-35338-136	31
Drive Washer	1 EA	MS-17186-6	11,15,18,23
		MS-17186-8	31
Nut	1 EA	MS-17187-2	11,15,18,23
		MS-17187-3	31

NOTE:

1. The above hardware is for synchro mount type encoders.

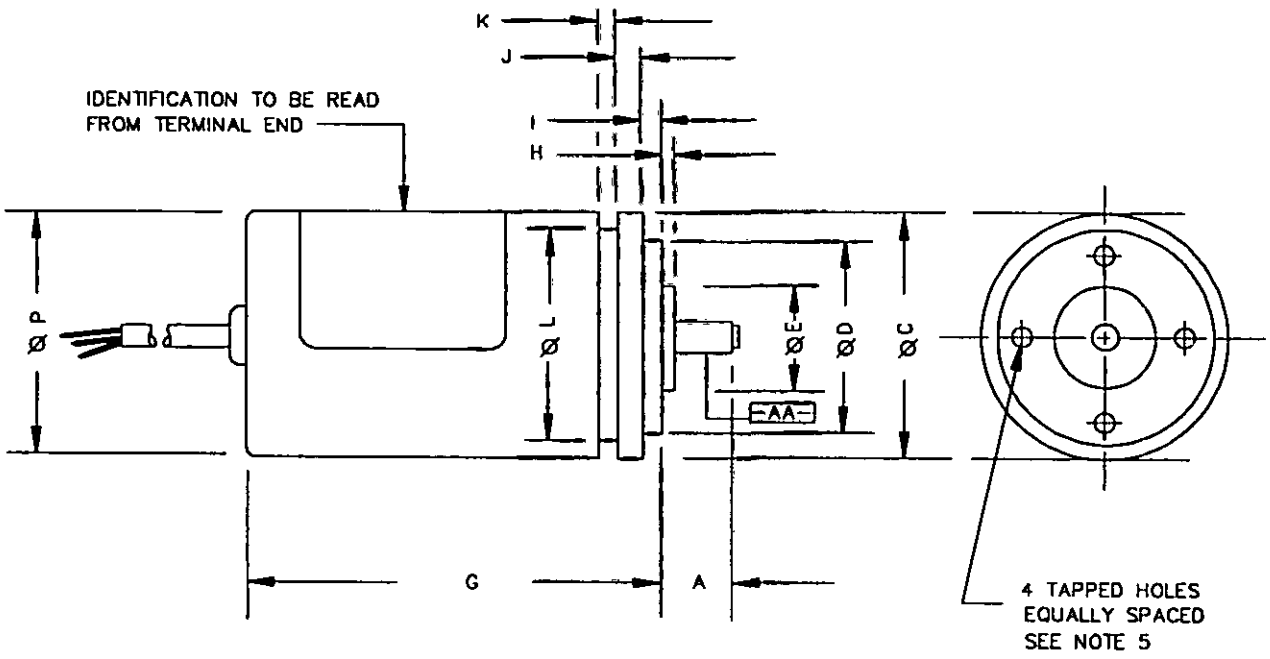


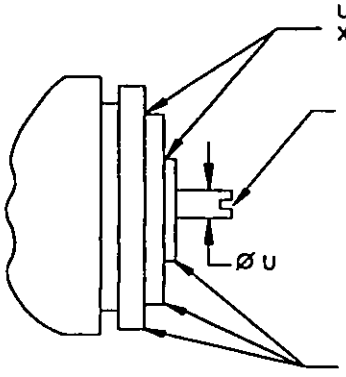


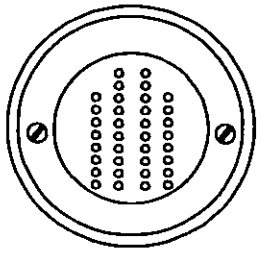
NOTES:

1. UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES.
2. UNLESS OTHERWISE SPECIFIED, TOLERANCES ON DECIMALS SHALL BE ±.005 AND ON ANGLES ±2°.
3. END PLAY AND RADIAL PLAY SHALL BE MEASURED DURING REVERSAL OF THE FOLLOWING LOADS:
   END PLAY – 1 POUND
   RADIAL PLAY – 0.5 POUND.
4. MINOR VARIATIONS OF UNIT CONFIGURATION ARE PERMITTED FOR UNDIMENSIONED DESIGN DETAIL.
5. LEADS MAY EXTEND FROM THE TERMINAL END OF THE ENCODER IN ANY ACCEPTABLE MANNER.
6. LETTERED DIMENSIONS ARE SHOWN IN TABLE III.

FIGURE 1. Outline drawing for sizes 08 and 11 shaft angle to digital encoders (synchro mount).







OPTIONAL TERMINAL END
FOR SIZE 18

NOTES:

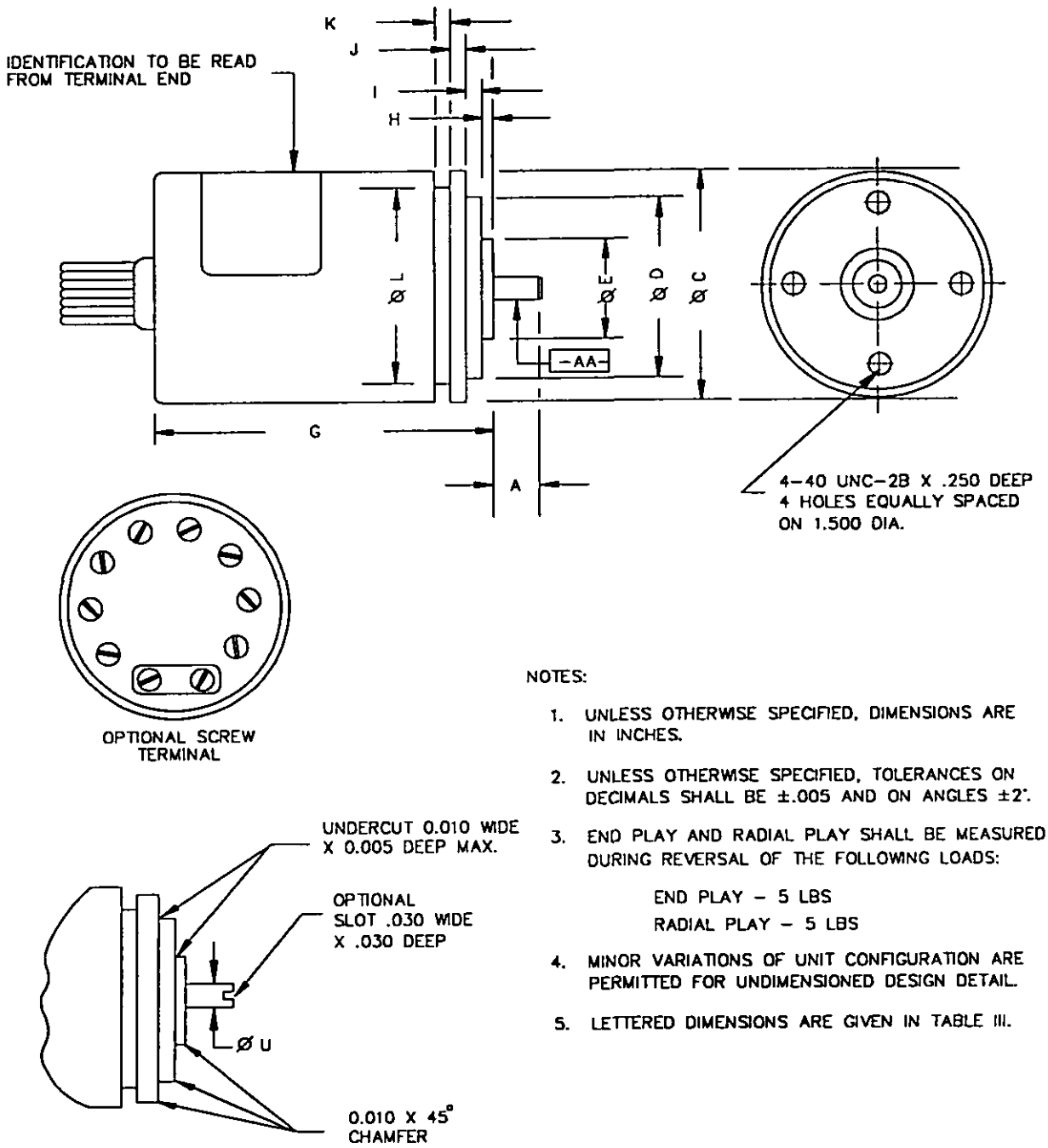
1. UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES.
2. UNLESS OTHERWISE SPECIFIED, TOLERANCES ON DECIMALS SHALL BE ±.005 AND ON ANGLES ±2°.
3. END PLAY AND RADIAL PLAY SHALL BE MEASURED DURING REVERSAL OF THE FOLLOWING LOADS:

   END PLAY – 2.5 LBS

   RADIAL PLAY – 2.5 LBS
4. MINOR VARIATIONS OF UNIT CONFIGURATION ARE PERMITTED FOR UNDIMENSIONED DESIGN DETAIL.
5. TAPPED HOLES FOR SIZE 15 SHALL BE 4–40 UNC–2B, 0.25 DEEP ON 1.100 DIAMETER.

   TAPPED HOLES FOR SIZE 18 SHALL BE 4–40 UNC–2B, 0.125 DEEP ON 1.250 DIAMETER.
6. LETTERED DIMENSIONS ARE GIVEN IN TABLE III.

FIGURE 2. Outline drawing for sizes 15 and 18 shaft angle to digital encoders (synchro mount).

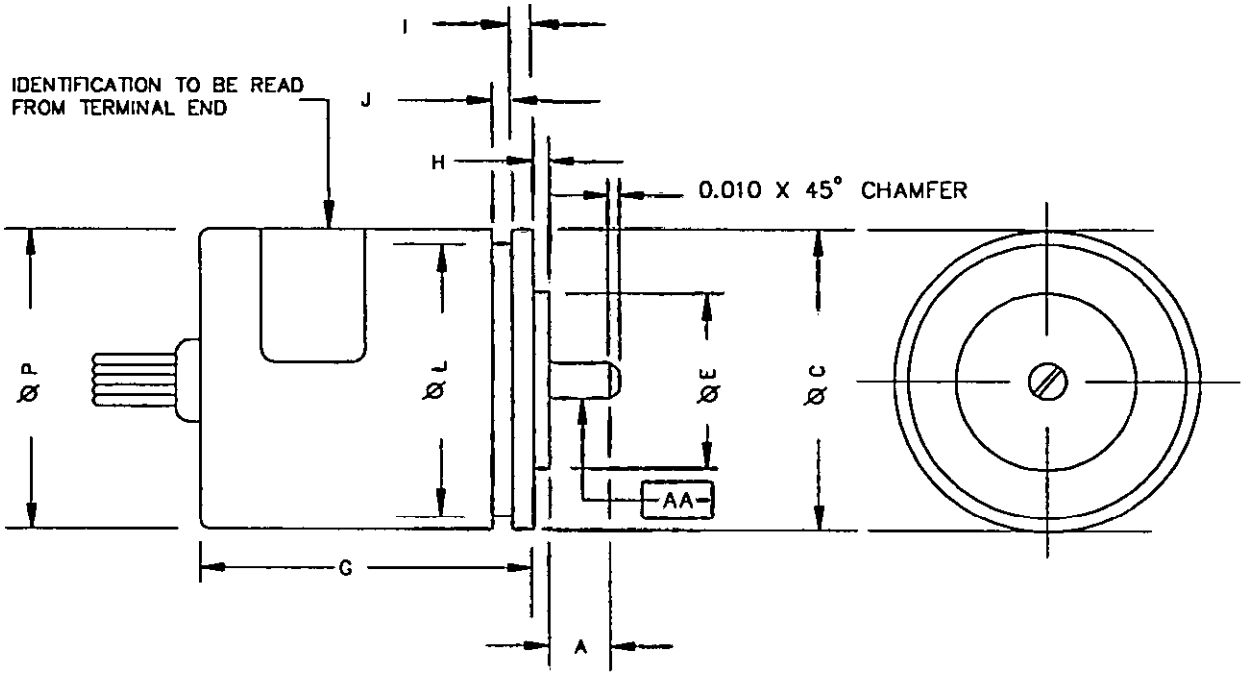


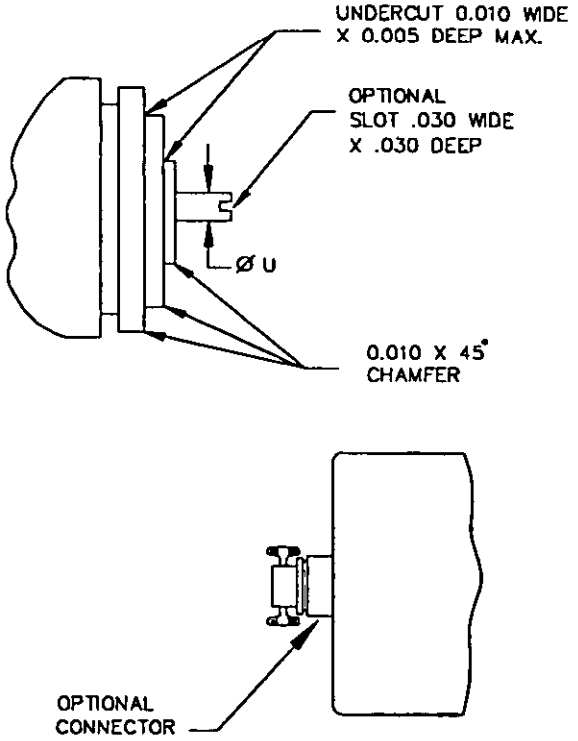
NOTES:

1. UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES.
2. UNLESS OTHERWISE SPECIFIED, TOLERANCES ON DECIMALS SHALL BE ±.005 AND ON ANGLES ±2°.
3. END PLAY AND RADIAL PLAY SHALL BE MEASURED DURING REVERSAL OF THE FOLLOWING LOADS:

   END PLAY – 5 LBS
   RADIAL PLAY – 5 LBS
4. MINOR VARIATIONS OF UNIT CONFIGURATION ARE PERMITTED FOR UNDIMENSIONED DESIGN DETAIL.
5. LETTERED DIMENSIONS ARE GIVEN IN TABLE III.

FIGURE 3. Outline drawing for size 23 shaft angle to digital encoders (synchro mount).





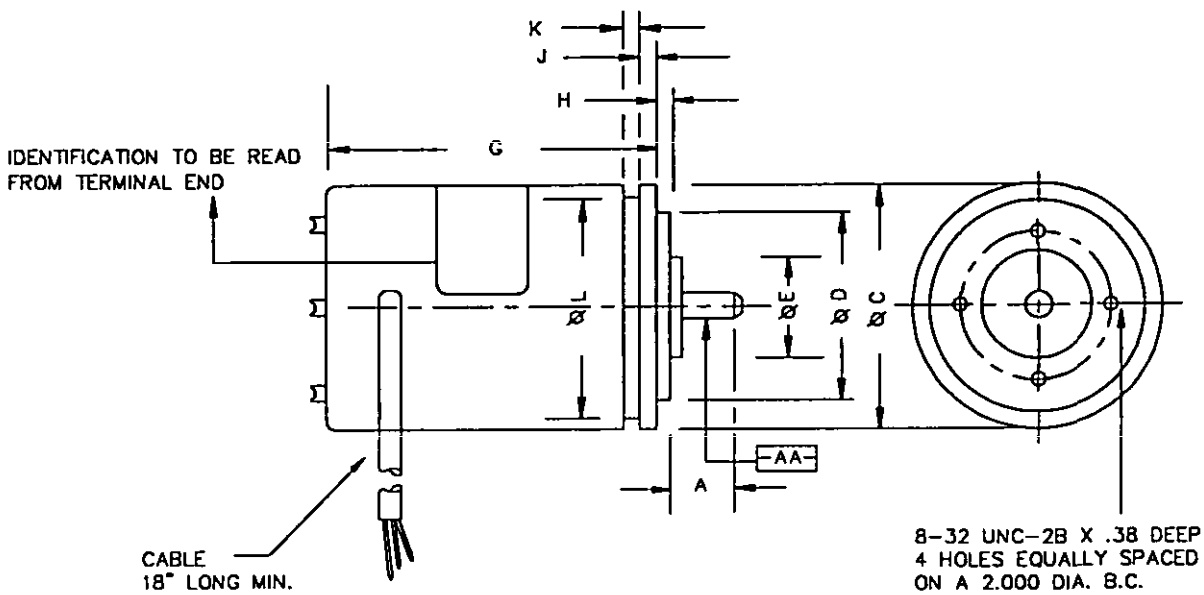
NOTES:

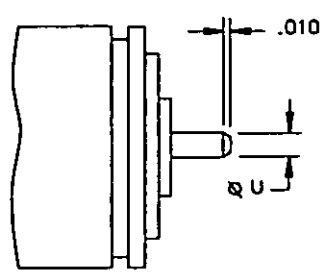
1. UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES.
2. UNLESS OTHERWISE SPECIFIED, TOLERANCES ON DECIMALS SHALL BE ±.005 AND ON ANGLES ±2°.
3. END PLAY AND RADIAL PLAY SHALL BE MEASURED DURING REVERSAL OF THE FOLLOWING LOADS:

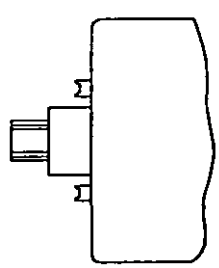
   END PLAY – 5 LBS
   RADIAL PLAY – 5 LBS

4. MINOR VARIATIONS OF UNIT CONFIGURATION ARE PERMITTED FOR UNDIMENSIONED DESIGN DETAIL.
5. LETTERED DIMENSIONS ARE GIVEN IN TABLE III.

FIGURE 4. Outline drawing for size 31 shaft angle to digital encoders (synchro mount).







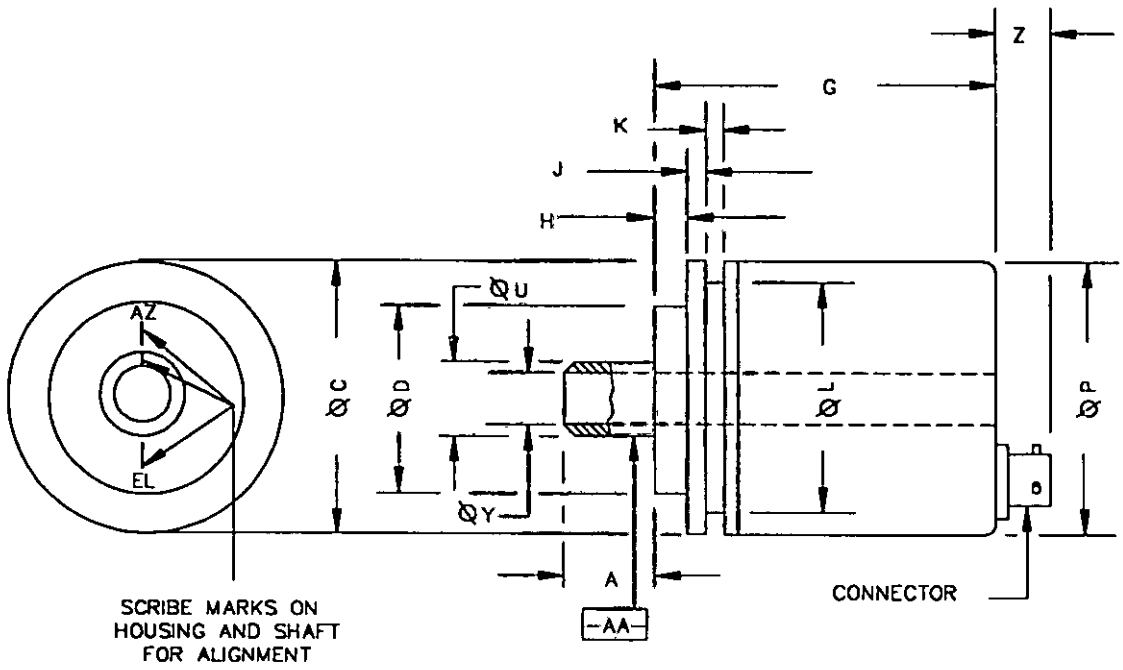
NOTES:

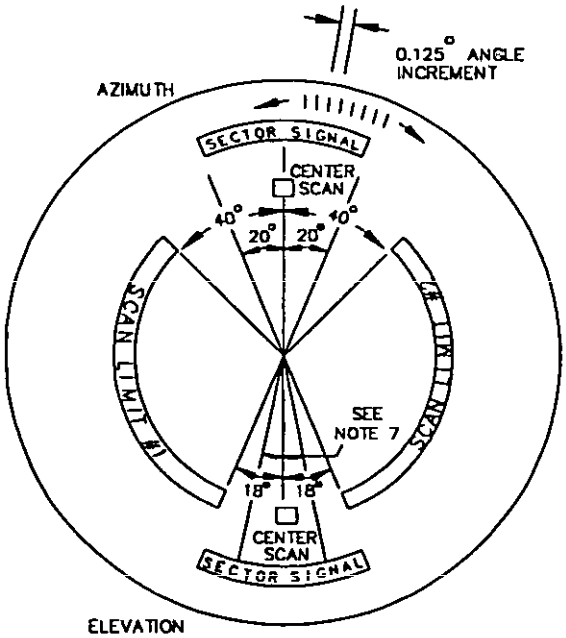
1. UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES.
2. UNLESS OTHERWISE SPECIFIED, TOLERANCES ON DECIMALS SHALL BE ±.005 AND ON ANGLES ±2°.
3. END PLAY AND RADIAL PLAY SHALL BE MEASURED DURING REVERSAL OF THE FOLLOWING LOADS:

   END PLAY – 5 LBS
   RADIAL PLAY – 5 LBS

4. MINOR VARIATIONS OF UNIT CONFIGURATION ARE PERMITTED FOR UNDIMENSIONED DESIGN DETAIL.
5. LETTERED DIMENSIONS ARE GIVEN IN TABLE III.

FIGURE 5. Outline drawing for size 35 shaft angle to digital encoders (synchro mount).





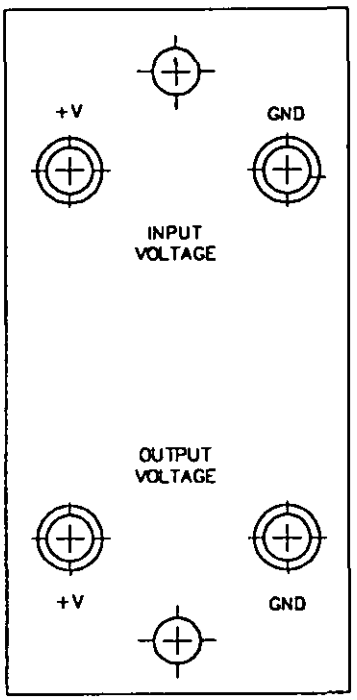
NOTES:

1. UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES.
2. UNLESS OTHERWISE SPECIFIED, TOLERANCES ON DECIMALS SHALL BE ±.005 AND ON ANGLES ±2°.
3. END PLAY AND RADIAL PLAY SHALL BE MEASURED DURING REVERSAL OF THE FOLLOWING LOADS:

   END PLAY – 5 LBS

   RADIAL PLAY – 5 LBS
4. TOTAL RUNOUT OF MAJOR DIAMETER OF FEATURE -AA- SHALL NOT EXCEED .0030 FIM.
5. MINOR VARIATIONS OF UNIT CONFIGURATION ARE PERMITTED FOR UNDIMENSIONED DESIGN DETAIL.
6. CONCENTRICITY AND PERPENDICULARITY SHALL BE MEASURED WITH THE UNIT IN A VERTICAL POSITION, SUPPORTED BY THE SHAFT, WHILE ROTATING THE HOUSING.
7. THE ELEVATION SCAN SECTOR SIGNAL SHALL BE SPECIFIED ON THE SPECIFICATION SHEET.
8. LETTERED DIMENSIONS ARE GIVEN IN TABLE III.

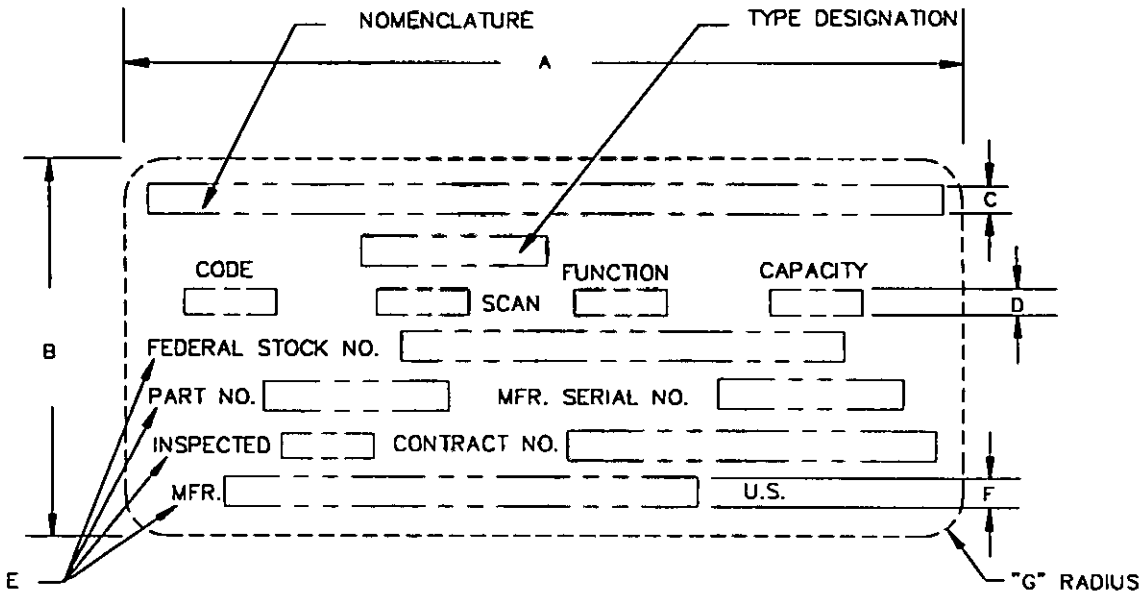
FIGURE 6. Outline drawing of size 40 hollow shaft shaft angle to digital encoder.



NOTES:

1. ALL DIMENSIONS SHALL BE SPECIFIED IN THE CONTRACT OR PURCHASE ORDER. SHAPE IS NOT NECESSARILY AS INDICATED IN THIS DRAWING.
2. TERMINALS SHALL BE POSITIVELY IDENTIFIED ON THE CASE AS INDICATED, STATING THE ACTUAL VOLTAGE VALUE.
3. POWER SUPPLY SHALL BE MARKED IDENTICALLY TO THE ENCODER IT SUPPLIES.

FIGURE 7. External power supply configuration.



TABULATION OF LETTERED DIMENSIONS (INCHES, MAX.)

ENCODER SIZE	A	B	C	D	E	F	G
	INCH	INCH	INCH	INCH	INCH	INCH	INCH
05	1.500	0.625	.0469	.0469	.0469	.0469	.1250
08	2.250	0.625	.0469	.0469	.0469	.0469	.1250
11, 12, 15, 16	3.000	0.075	.1094	.0781	.0469	.0625	.1250
18, 19, 23, 30, 31, 37 1/	3.625	1.000	.1094	.0937	.0469	.0625	.0250

1/ ALL SIZES LARGER THAN SIZE 37 SHALL USE THIS SIZE LETTERING.

NOTES:

1. LEGEND SHALL BE CENTRALLY LOCATED HORIZONTALLY AND VERTICALLY.
2. ALL CHARACTERS SHALL BE GOTHIC OR FUTURA TYPE CAPITALS WITHOUT SERIFS.
3. IDENTIFICATION MARKING INFORMATION SHALL BE AS SPECIFIED IN THE APPLICABLE SPECIFICATION SHEET.
4. THE MANUFACTURER'S PART NUMBER SHALL BE IDENTICAL WITH THE MANUFACTURER'S PRODUCTION DRAWING NUMBER, INCLUDING APPLICABLE DASH NUMBERS. CHANGES IN THE MANUFACTURER'S PART NUMBERS SHALL BE GOVERNED BY THE REQUIREMENTS OF MIL-D-1000 REGARDING DRAWING NUMBERS.
5. SEQUENTIAL SERIAL NUMBERS SHALL BE REQUESTED FROM THE PROCURING AGENCY.
6. "INSPECTED" BLOCK REQUIRES GOVERNMENT INSPECTOR'S ACCEPTANCE STAMP.
7. GOVERNMENT CONTRACT NUMBER OR INDUSTRY PURCHASE ORDER NUMBER SHALL BE APPLIED.

FIGURE 8. Identification marking.

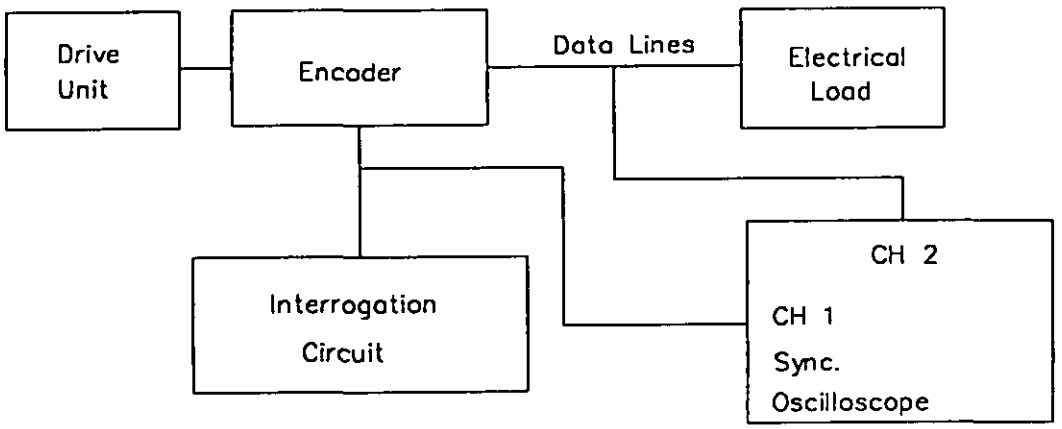
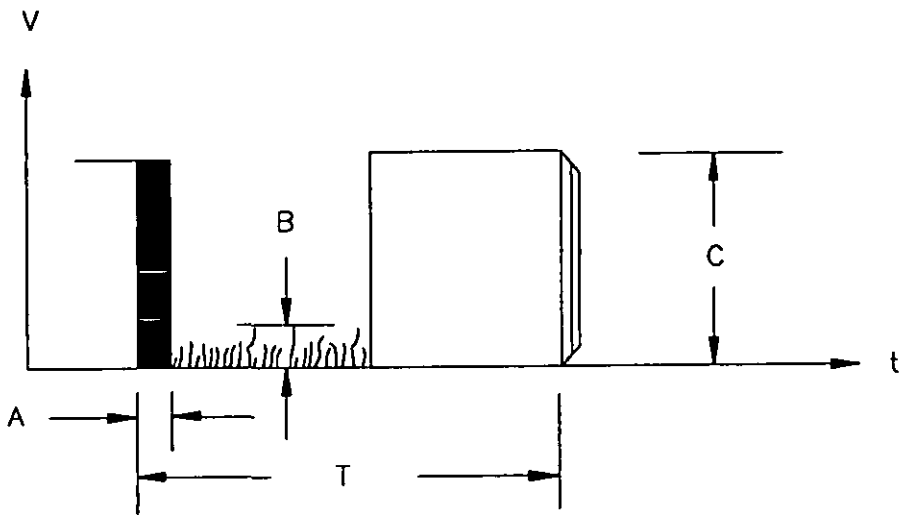


FIGURE 9. Encoder test setup.



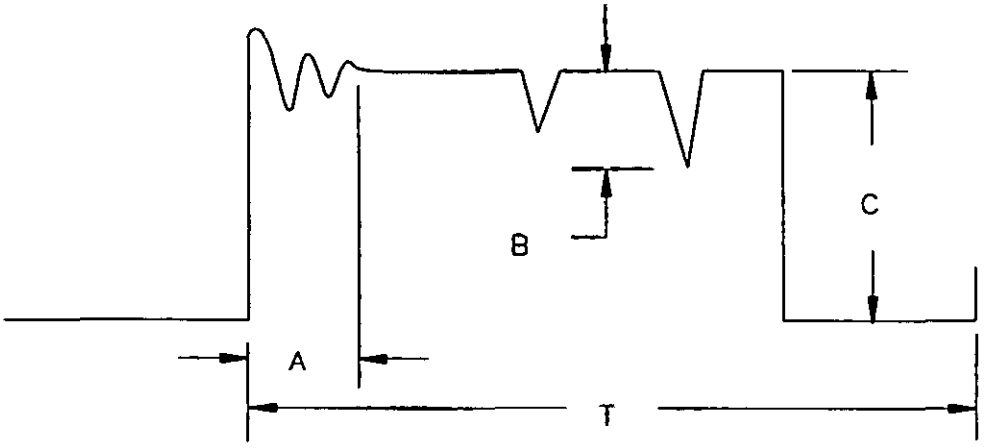
A = Edge Noise (Given in % of Duration T)

B = Surface Noise (Given in % of Amplitude C)

V = Voltage

t = Time

FIGURE 10A. Electrical noise for contact encoders.



A = Ringing (Given in % of Duration T)

B = Bit Dropout (Given in % of Duration T)

FIGURE 10B. Electrical noise for non-contact encoders.

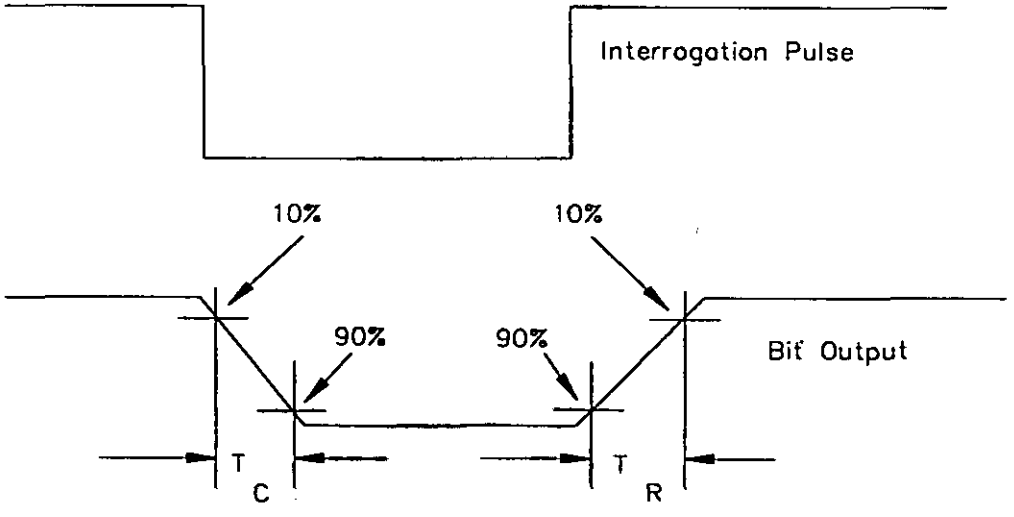


FIGURE 11. Conversion recovery time test setup.

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(Project 5990-0405)

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
3. The preparing activity must provide a reply within 30 days from receipt of the form.

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4. NATURE OF CHANGE (Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME (Last, First, Middle Initial)	b. ORGANIZATION	
c. ADDRESS (Include Zip Code)	d. TELEPHONE (Include Area Code) (1) Commercial (2) AUTOVON (If applicable)	7. DATE SUBMITTED (YYMMDD)

8. PREPARING ACTIVITY

a. NAME COMMANDING OFFICER, NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION LAKEHURST SYSTEMS REQUIREMENTS DEPARTMENT	b. TELEPHONE (Include Area Code) (1) Commercial: (908) 323-7488 (2) AUTOVON: 624-7488
c. ADDRESS (Include Zip Code) CODE SR3 LAKEHURST, NJ 08733-5100	IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT: Defense Quality and Standardization Office 5203 Leesburg Pike, Suite 1403, Falls Church, VA 22041-3466 Telephone (703) 756-2340 AUTOVON 289-2340

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