SAE Aerospace
An SAE International Group

AEROSPACE STANDARD

SAE AS8054 REV. A

Issued	1996-05
Reaffirmed	2005-10
Cancelled	2012-05

Superseding AS8054

Airborne Engine Vibration Monitoring (EVM) System, Guidelines for Performance Standard For

RATIONALE

This AS was raised at the request of the Regulatory authorities to provide a minimum performance standard for airborne vibration monitoring systems. Since its creation, these systems have greatly advanced in technology and application and AIR1839, shortly to be re-issued as ARP1839 now contains much more extensive and up-to-date information concerning such installations. Recent survey of the regulatory authorities by E-32 showed no further interest or usage of AS8054.

E-32 therefore voted for its cancellation.

CANCELLATION NOTICE

This document has been declared "CANCELLED" as of May 2012. By this action, this document will remain listed in the Numerical Section of the Aerospace Standards Index.

Cancelled specifications are available from SAE.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: http://www.sae.org

SAE values your input. To provide feedback on this Technical Report, please visit http://www.sae.org/technical/standards/AS8054A

TABLE OF CONTENTS

1. SCOPE

This SAE Aerospace Standard (AS) provides guidelines for the functional, performance, qualification and acceptance testing, and documentation requirements for the components of an airborne engine vibration monitoring (EVM) system which is intended for use as a turbojet engine rotor unbalance indicating system, per FAR 25.1305 (D)(3) on transport category airplanes.

For the purpose of this document, this means a system which can provide real-time flight deck displays of engine vibration caused by rotor unbalance, throughout the flight envelope, which are suitable for:

a. Relating to engine vibration limits (where such limits are specified)
b. Use in ice shedding procedures
c. Helping the flight crew to determine which engine has the higher level of vibration, following an engine damage event.

As a minimum, the functional capability for such a system shall include the ability to compute and display vibration levels specifically related to the rotational speed(s) of the engine rotor(s). Systems which can produce only broadband vibration outputs have been used in the past but they are not considered suitable for the above purposes. Some EVM systems may also generate other outputs, suitable for such functions as engine vibration trend monitoring or trim balance calculation, but these are considered to be outside the scope of the requirements for a minimum system.

This document also defines some recommended, optional, functions and features which, while they are outside the scope of minimum requirements, are nevertheless considered to be highly desirable for a practical system.

It should be noted that systems incorporating capabilities such as described above are also sometimes referred to by the abbreviation AVM. However, there are, or can be, airborne measurements taken of vibrations from sources other than the engines.

For the purpose of this document the more descriptive term, engine vibration monitor (EVM), will be used.

1.1 Purpose:

The purpose of this document is to provide guidance on the requirements for airborne EVM systems for turbojet engines on transport category airplanes.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this specification and references cited herein, the text of this specification takes precedence. Nothing in this specification, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AIR1839 A Guide to Aircraft Turbine Engine Vibration Monitoring Systems

2.2 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-HDBK-217F Change Notice 1 Reliability Prediction of Electronic Equipment

2.3 FAA Publications:

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591.

FAA/AC 21-16C	RTCA Inc. Document, RTCA/DO-160C
FAA/AC 20-115B	RTCA Inc. Document, RTCA/DO-178B
FAA/AC 20-136	Protection of Aircraft Electrical/Electronic Systems Against the Effects of Lightning
FAA/AC 25-1309.1A	System Design and Analysis
FAR 21.611	Federal Aviation Regulations, Part 21.611
FAR 25.1309	Federal Aviation Regulations, Part 25.1309

2.4 ANSI Publications:

Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ANSI S2.11-1969 American Standards for the Calibration of Shock and Vibration Sensors

2.5 RTCA Publications:

Available from RTCA Inc., 1140 Connecticut Avenue, NW, Suite 1020, Washington, DC 20036.

RTCA/DO-160C Environmental Conditions and Test Procedures for Airborne Equipment (Radio Technical Commission for Aeronautics).

RTCA/DO-178B Software Considerations in Airborne Systems and Equipment Certification

2.6 Other Publications:

ISA-RP37.2	Guide for Specification and Test for Piezoelectric Acceleration Transducers for Aerospace Testing
ARINC 404A	Air Transport Equipment Cases and Racking
ARINC 600	Air Transport Avionics Equipment Interfaces

2.7 Definitions:

The following are definitions of terminology used herein:

BROADBAND FILTER: A broadband filter is one which has fixed low pass and high pass corner frequency break points. It is designed to highly attenuate input signals with frequencies above and below the range of interest and to pass, with equal and minimal attenuation, input signals with frequencies within the range of interest. The filter characteristics of primary interest are indicated in Figure 1.

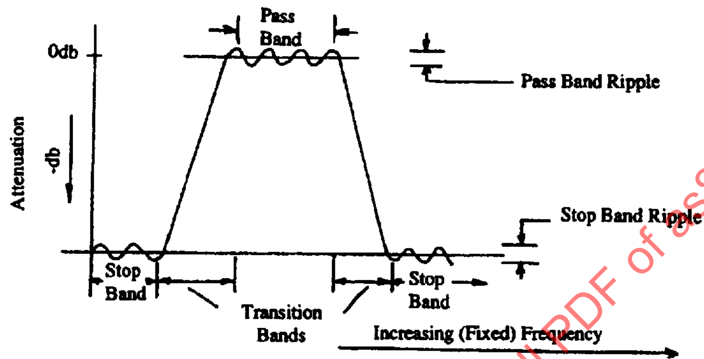


FIGURE 1 - Broadband Filter Characteristics

COMPONENT: A component is an element of a higher level unit or system. In this document the term “EVM component” specifically refers to a signal conditioner unit, a vibration sensor, a remote converter unit or a flight deck vibration display unit.

INSTALLER: The party responsible for the installation of the equipment in the aircraft and for obtaining certification for the complete system as installed.

SUPPLIER: The manufacturer and/or the manufacturer’s agent supplying or quoting on the articles specified.

TRACKING FILTER: A tracking filter is a narrow bandpass filter, the center frequency of which is controlled to follow the frequency of a varying parameter of interest (in this case, the rotational frequency of an engine rotor). It is designed to highly attenuate input signals with frequencies which are not close to the present frequency of the parameter of interest and to pass, with minimal attenuation, input signals with a frequency which is close to the present frequency of the parameter of interest.

The filter characteristics of primary interest are indicated in Figure 2.

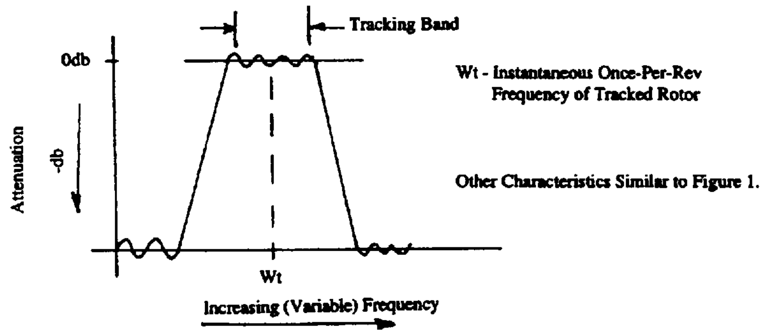


FIGURE 2 - Tracking Filter Characteristics

2.8 Abbreviations:

The following abbreviations are used herein:

AC	Alternating Current
AC	Advisory Circular
ACMS	Aircraft Condition Monitoring System
ARINC	Aeronautical Radio, Inc.
AS	Aerospace Standard
AVM	Airborne Vibration Monitor
EVM	Engine Vibration Monitor
BITE	Built-in Test-Equipment
°C	Degrees Celsius
dB	Decibels
DC	Direct Current
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
g	Acceleration Due to Gravity
Hz	Hertz
ISA	Instrument Society of America
LRU	Line Replaceable Unit
m	meters
RCU	Remote Converter Unit
RMS	Root Mean Square
RPM	Revolutions Per Minute
RTCA	Radio Technical Commission for Aeronautics
SAE	Society of Automobile/Aerospace Engineering
Torr	The pressure exerted by a column of Mercury 1 mm high under the influence of 1g (Standard Gravitational Acceleration) at 0 °C.
TSO	Technical Standard Order
SPL	Sound Pressure Level
VAC	Volts (Alternating Current)
VDC	Volts (Direct Current)

3. REQUIREMENTS:

For the purpose of this document it is assumed that an EVM system consists of the following basic components:

a. Signal conditioning unit(s) which receives inputs from engine mounted vibration sensor(s) (either directly or via a remotely mounted converter unit) and from engine tachometer(s). It processes these signals to produce outputs proportional to the level of vibration generated by engine rotor unbalance forces. The signal conditioner should be able to detect its own critical internal failure modes and provide a self-test output. An optional output for upstream system diagnosis and analysis is also recommended.

b. Vibration sensor(s), which may include some conversion electronics, mounted in a suitable location(s) on the engine, and with the appropriate orientation(s), to measure the vibration(s) due to rotor unbalance.

c. Remote converter unit(s) (RCU) are not used by all systems. When used, they are usually mounted as close to the sensor(s) as possible. An RCU is used to convert/amplify the low-level, direct output of the sensor(s) to a signal, which is less susceptible to noise and interference, for transmission to the signal conditioner. The RCU should be able to detect its own critical internal failure modes and provide a self-test output. An optional output for upstream system diagnosis and analysis is also recommended.

d. Dedicated, flight deck mounted, displays for providing engine vibration information to the flight crew (unless such information is displayed by means of multifunction displays).

NOTE: While engine tachometer(s) provide necessary input(s) to the signal conditioner, they are not considered to be a part of the EVM system unless they are dedicated to that purpose. Normally the primary purpose of an engine tachometer is to provide rotor speed signals to the engine control system and other systems and to the flight deck for display. As such they are considered to be part of the engine instrumentation package.

If the same tachometers are also used for the EVM function, their characteristics and output signal quality definition, including engine and installation effects, shall be provided so that the EVM supplier may:

a. Determine whether the tachometer characteristics are suitable for the EVM purpose and,
b. Design the signal conditioner to properly interface with the tachometer signal(s).

The cabling and connectors that interconnect the various LRUs may, or may not, be supplied with the system but, in either case, attention should be paid to their design and characteristics. Cable lengths should be minimized and, where possible, connectors eliminated to optimize the reliability of the system.

3. (Continued):

It is recognized that the configurations for specific applications will vary. The engines being monitored may have one or more rotors. The signal conditioner may be restricted to monitoring only one engine or may be required to monitor more than one engine. The system may employ remote converter units or they may be integral with the signal conditioner, as stated above. Some systems currently in production include a unit which mounts in the forward flight deck panel and incorporates the functions of the signal conditioner, (a)., and the flight deck display, (d), above. In cases such as these it is the responsibility of the supplier to select and comply with the requirements from Sections 3 and 4 as appropriate for their configuration.

It is beyond the scope of this document to cover all the possibilities, so configuration dependent requirements have been avoided except where they directly impact the required minimum performance.

The design, construction, performance, environmental capability and reliability of the EVM system and it's components shall be as specified in 3.1 through 3.5.

The performance of the components, and of the EVM System as a whole, as called out in 3.1 through 3.5, shall be demonstrated under standard conditions and over the required range of environmental conditions.

NOTE: AIR1839, covers a broader scope than this document but also contains much useful design information concerning the basic elements of a minimum system as defined herein.

Figure 3 shows a block diagram of a representative system employing signal converter/amplifiers integral with the signal conditioner unit.

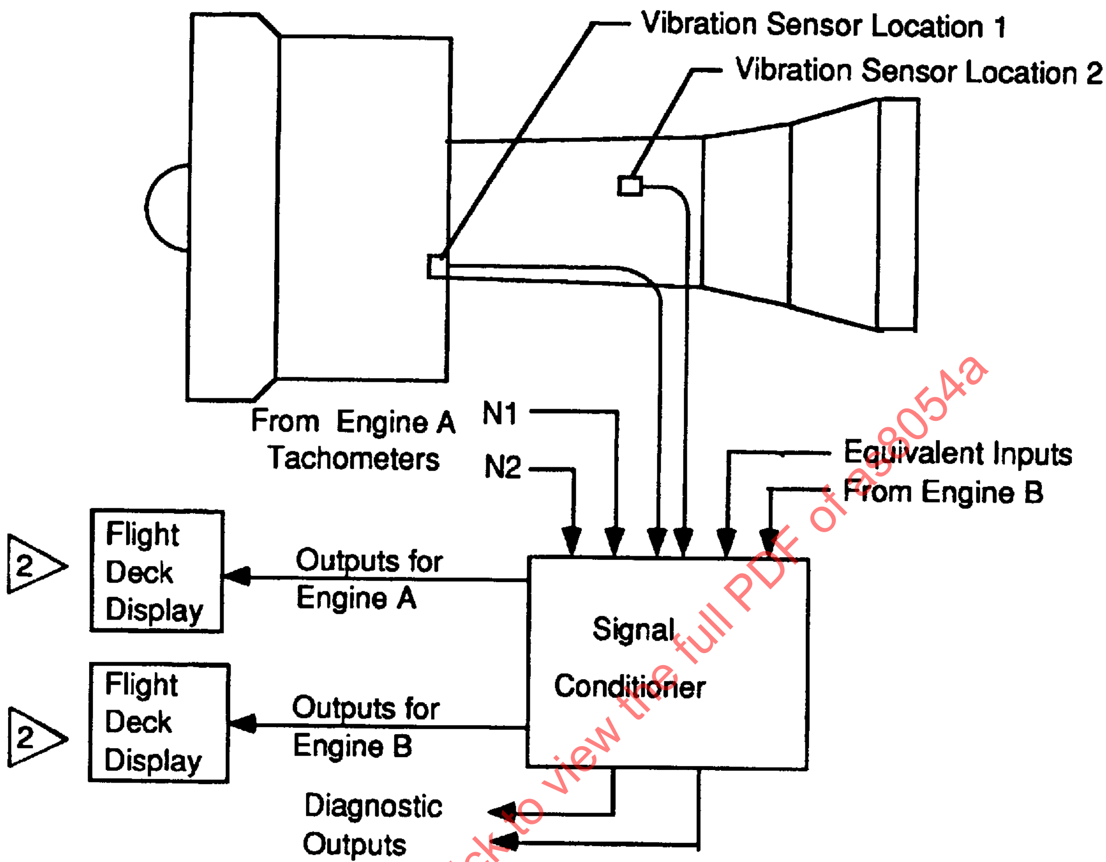
3.1 General Design Requirements:

3.1.1 Workmanship: Workmanship shall be in accordance with the best practice of high quality aircraft equipment. Proper handling of parts and equipment shall be employed to assure freedom from physical damage such as cracks, scratches, twists, fractures, etc., and the possibility of hidden damage such as that produced by flexure of leads, stressing of soldered joints, overtightening of fasteners, etc.

3.1.2 Human Factors/Personnel Safety: The equipment shall be designed to adequately protect flight and maintenance personnel from injury and to minimize incorrect maintenance.

3.1.3 Interchangeability: Components bearing the same part number shall be interchangeable and shall not require calibration or adjustment to meet system performance requirements. Components bearing the same part number and suffix shall be identical except for changes meeting the FAR 21.611 definition of a minor change.

Components bearing different part numbers shall not be interchangeable.



1 Example illustrates a single signal conditioner processing two separate vibration outputs from each of two two-spool engines.

2 Dedicated displays shown. Shared multi-function displays may also be used.

FIGURE 3 - Typical EVM System Components 1

3.1.4 Dimensions and Tolerances: Where dimensions and tolerances may affect the interchangeability, operation or performance of the assembly, they shall be held or limited accordingly. Internal and external shimming shall not be used.

3.1.5 Identification

3.1.5.1 Component and/or Nameplate Marking: For each component, the following minimum information shall be legibly and permanently marked on the component, or nameplate attached thereon, in such a manner that it cannot be readily removed:

a. Name and address (optional, included where practical) of the manufacturer
b. The name, type, part number or model designation of the article
c. The serial number or the date of manufacture of the article, or both
d. AS8054 and/or TSO designation as applicable

Other information, from the list in 3.1.5.2, may also be marked on the component, or component nameplate, at the supplier's option.

All individual parts and pertinent subassemblies (first and second level) shall be marked with vendor's part number, except for those parts which do not have, and cannot be provided with, a suitable surface for markings.

3.1.5.2 Identification in the Installation Instructions: The information in 3.1.5.1 and the information below shall be provided in the Installation Instructions for each component.

a. Country of origin
b. Federal supplier code number
c. Category of Approval per DO-178B
d. Environmental Test Categories per DO-160C, Appendix A

3.1.6 Inspection Seals: Seals, embossed with the manufacturer's identification, shall be provided at strategic locations, other than those locations which are normally disassembled during replacement of line replaceable components, to indicate if disassembly has been performed after inspection.

3.1.7 Weight: The maximum weight of each component shall be specified. The weight of each component shall be kept to the minimum, consistent with good design practices to meet the operational requirements.

3.1.8 Materials: Materials shall be of a quality which relevant experience and/or tests have shown to be suitable and dependable for airborne use.

3.1.8.1 Nonmetals: Nonmetals, unless suitably protected, shall be moisture and flame resistant and self-extinguishing. Such materials shall not be capable of supporting fungus growth and shall not be adversely affected by environmental exposure as specified herein.

3.1.8.2 Flammable Materials: Flammable materials shall not be used. The materials used shall not liberate gases which can form acid or corrosive alkali. Insulation materials shall not support combustion or form current-conducting paths when subjected to electrical arcs or explosions of vapors which may be present.

3.1.9 Processes: All manufacturing processes shall be documented and be available to the installer as confidentiality permits.

3.1.10 Electrical/Electronic Design Requirements: The design, construction and performance of the EVM system shall be consistent with the reliability requirements of 3.1.12

The EVM components shall satisfy the relevant requirements of 3.1, 3.2, 3.3, 3.4, and 3.5 over the range of environmental conditions defined in RTCA DO-160C, or otherwise specified in this document, as appropriate to the airplane type and component installation.

Care must be taken to ensure that the characteristics of the individual components are compatible so that unwanted events, e.g., saturation or false indications, do not arise from environmental conditions such as steady state acceleration, low or high frequency vibration outside the range of interest and temperature changes.

3.1.10.1 Restricted Parts: No variable parts, such as potentiometers, shall be used.

3.1.10.2 Electrical Power: The system shall be designed to accept, and operate with, the electrical power characteristics defined either by the EVM manufacturer, or as required for a specific installation, including maintaining operation and indication during and after voltage transients such as will normally occur during electrical bus switching.

The maximum load of the system shall be specified.

3.1.10.3 Electrical Bonding and Grounding: The equipment grounding system shall provide for separation of AC power, DC power, chassis ground and signal ground(s). Optionally, signal ground(s) may be "referenced" to chassis ground. Wire shields shall not be used as a signal return. Conductive equipment enclosures must be capable of being bonded to aircraft structure, which may be done by dedicated faying surface contacts, bonding jumper or by wiring through an interface connector. On nonconductive enclosures, controls or metal parts which may be touched shall be bonded to ground. Case ground shall not be used for electrical power returns. Materials, surface preparation and finishes for electrical bonding surfaces shall be compatible with preservation of adequate electrical conductivity over the life of the equipment. The maximum resistance across any bonding or grounding junction shall be 10 mΩ, as manufactured.

3.1.10.4 Insulation and Dielectric Strength: These requirements are specific to each EVM component and are provided in 3.2, 3.3 and 3.4.

3.1.10.5 Cabling and Connectors: Some types of vibration sensor (e.g., piezoelectric) have a high impedance signal output which is noise sensitive, unless the sensor also includes integral conditioning electronics. To prevent unwanted, spurious signals due to cable movement or induced EMI, the wiring from the sensor to the first stage amplifier (which may be in the signal conditioner or in a remote converter unit) must be a good quality, low-noise-treated, shielded, twisted pair.

If the sensor contains integral electronics, or a remote amplifier is used, the cable to the signal conditioner shall be a good quality, twisted shielded pair.

Cabling and connectors mounted on the engine shall be specified by the engine manufacturer. If necessary, the equipment supplier may specify the standard of other wiring to be used with the equipment.

When routing EVM signal cables, special care should be taken to route them away from electrically noisy lines to minimize the potential for interference. It is preferred that dedicated connectors be used at interfaces. If multipin connectors are shared with other systems, the pin assignments should be such that the pins carrying EVM signals are not adjacent to pins carrying signals which could adversely affect the EVM functions.

The cabling/connectors and/or their installation shall provide means to prevent cables from being cross-connected such that the data generated for one engine is transposed to the display for another engine.

3.1.11 Environmental Requirements: In most EVM systems, the various system components will be installed in significantly different environments. For the purpose of this document it is assumed that the signal conditioner will be mounted inside the fuselage and remote converters (if used) will be mounted in the engine compartment or in the strut.

Unless specifically called out in this document, the equipment categories (as defined in DO-160C) to which the EVM components are designed and tested may be selected by the equipment supplier, based on either preference or knowledge of a specific application. The selected categories for each component shall be listed in the Installation Instructions and, optionally, on the component, or component nameplate, as specified in 3.1.5.

For simplicity, the requirements which apply to the EVM system as a whole and also those which apply to individual components but which can be stated easily in tabular form are provided in 3.1.11.1 through 3.1.11.14. Other environmental requirements, which are unique to a component, are provided in 3.2, 3.3, 3.4 and 3.5.

The EVM system and its components shall continue to satisfy the performance and other requirements of 3.1, 3.2, 3.3, 3.4 and 3.5 over the range of environmental conditions defined in 3.1.11 and the relevant conditions in 3.2, 3.3, 3.4 and 3.5, or other environmental conditions provided by the installer for the specific application, whichever are the more stringent.

3.1.11.1 Aircraft Attitude: The aircraft attitude shall have no effect on system performance when the EVM components are in their normal installed positions.

3.1.11.2 Temperature and Altitude: The EVM components shall be designed to meet the requirements of this Aerospace Standard over the temperature and altitude ranges defined in Section 4.0, Table 4.1 of DO-160C for the categories defined below.

a. Signal Conditioner: Category A1
b. Vibration Signal Sensors: Category D3
c. Remote Amplifiers: Category D3
d. Flight Deck Displays: Category A1

3.1.11.3 Temperature Variation: The EVM components shall be designed to meet the requirements of this Aerospace Standard during and after exposure to the temperature variations defined in Section 5.0 of DO-160C for the categories defined below

a. Signal Conditioner: Category C
b. Vibration Sensors: Category A
c. Remote Amplifiers: Category A
d. Flight Deck Displays: Category C

3.1.11.4 Humidity: The EVM components shall be designed to meet the requirements of this document during and after exposure to the humidity environment defined in Section 6.0 of DO-160C for the categories defined below

a. Signal Conditioner: Category A
b. Vibration Sensors: Category C
c. Remote Amplifiers: Category C
d. Flight Deck Displays: Category A

3.1.11.5 Operational Shocks and Crash Safety: The EVM signal conditioner and flight deck displays shall be designed to meet the requirements of this document after being exposed to shocks experienced during normal aircraft operation per the conditions defined in Section 7.0 of DO-160C.

The EVM signal conditioner and flight deck displays shall also be designed to not detach from their mountings or separate in a manner that presents a hazard during an emergency landing.

If the EVM signal conditioner and flight deck display are designed to a known mounting orientation in the aircraft, the following minimum crash safety load factors in Table 1 shall be met.

TABLE 1 - Minimum Crash Safety Load Factors

Direction of Load (Aircraft Axis)	Load (g)
UP	3.0
DOWN	6.0
FORWARD	9.0
AFT	1.5
LATERAL	3.0

3.1.11.5 (Continued):

If the EVM signal conditioner and flight deck display are designed for an unknown orientation in the aircraft, the minimum crash safety load factors shall be 9.0 g for all directions of load.

The EVM vibration sensors shall be designed to withstand an acceleration, in any direction, of 1000 g (9810 m/s^2), half sine wave, for 1 ms without physical damage or functional impairment.

The shock capability of remote converters shall be defined in the Installation Instructions.

3.1.11.6 Vibration: The EVM components shall be designed to meet the requirements of this document during and after exposure to the vibration environments defined in Section 8.0 of DO-160C as applicable to the aircraft type and installation location.

Remote converters may be vibration isolated, if required to meet the requirements.

3.1.11.7 Explosion Proofness: The EVM signal conditioner and flight deck displays shall be designated as Category X equipment as defined in DO-160C, Section 9.0 and have no special requirements.

The equipment categories to which the EVM vibration sensors and remote converters are designed and tested shall be selected from DO-160C, Section 9.0 and based either on the supplier's preference or the installer's specification.

3.1.11.8 Waterproofness: The EVM signal conditioner and flight deck displays shall be designated as Category X equipment as defined in DO-160C, Section 10.0 and have no special requirements.

EVM vibration sensors and remote amplifiers shall be designed and tested to either Category W or Category R, DO-160C, Section 10.0, requirements. The selection shall be based on either the supplier's preference or the installer's specification.

3.1.11.9 Susceptibility to Fluids: The EVM signal conditioner and flight deck displays shall be designated as Category X equipment as defined in DO-160C, Section 11.0 and have no special requirements.

EVM vibration sensors and remote converters shall be designated as Category F equipment as defined in DO-160C, Section 11.0. The fluids, for which the units are designed and tested, to not be susceptible, shall be listed in the Installation Instructions.

3.1.11.10 Sand and Dust: EVM components installed inside the fuselage, under the engine cowling or inside the engine strut shall be designated as Category X equipment as defined in DO-160C, Section 12.0 and have no special requirements.

The requirements for components located elsewhere shall be provided by the installer.

3.1.11.11 Fungus Resistance: The EVM components shall be designed and tested to meet the requirements of Category F equipment as defined in DO-160C, Section 13.0.

3.1.11.12 Salt Spray: The EVM signal conditioner and flight deck displays shall be designated as Category X equipment as defined in DO-160C, Section 14.0 and have no special requirements.

Unless otherwise specified by the installer, EVM vibration sensors and remote converters shall be designated as Category X equipment as defined in DO-160C, Section 14.0 and have no special requirements.

3.1.11.13 Electromagnetic Compatibility (EMC): Electromagnetic compatibility requires that:

a. The EVM system perform its intended functions in the airplane electromagnetic environment. Specific requirements for operation in the presence of induced and conducted audio signals and radiated and conducted radio frequency signals are contained in 3.1.11.13.2, 3.1.11.13.3, and 3.1.11.13.4.

b. The presence or operation of the subject system shall not degrade the performance of other airplane systems. Specific requirements for magnetic effects are given in 3.1.11.13.1 and for the emission of radio frequency energy are given in 3.1.11.13.5.

3.1.11.13.1 Magnetic Effect: Any EVM component installed in, or near, the flight deck shall be designed and tested to meet the requirements of equipment Class A as defined in DO-160C, Section 15.0.

3.1.11.13.2 Audio Frequency Conducted Susceptibility - Power Inputs: Unless otherwise specified, the EVM components shall be designated as Category E equipment as defined in DO-160C, Section 18.0. The EVM components shall be designed to not be adversely affected by conducted frequency components harmonically related to the power source fundamental frequency and shall function with no false warnings, malfunctions and/or damage allowed.

3.1.11.13.3 Induced Signal Susceptibility: Unless otherwise specified, the EVM components shall be designated as Category Z equipment as defined in DO-160C, Section 19.0. The EVM System shall be designed to not be adversely affected by induced audio frequency signals and transients generated by other on-board equipment and shall function with no false warnings, malfunctions and/or damage allowed.

3.1.11.13.4 Radio Frequency Susceptibility (Radiated and Conducted): Unless otherwise specified by the installer, the EVM component supplier shall select the category to which the equipment is designed and qualified from the categories defined in DO-160C, Section 20.0.

During exposure to radiated and conducted radio frequency energy with frequencies and field strengths appropriate (per DO-160C, Section 20.0.) for the equipment category selected, the EVM system, as installed in the airplane, may deviate from the performance requirements specified herein, provided:

a. It does not suffer permanent damage
b. It does not cause damage to other systems
c. It does not produce false high readings
d. It recovers function within 4 s after cessation of the condition.

3.1.11.13.5 Emission of Radio Frequency Energy: The EVM components shall be designated as Category Z equipment as defined in DO-160C, Section 21.0.

The EVM components shall not be a source of any objectionable interference under operating conditions at any frequencies used by the airplane, either by radiation, conduction or feedback in any electronic equipment installed in the same airplane, in accordance with RTCA DO-160C.

3.1.11.14 Susceptibility to Lightning Induced Effects: Unless otherwise specified by the installer, the EVM component supplier shall select the category to which the equipment is designed and qualified from the categories defined in DO-160C, Section 22.0. The EVM system, as installed in the airplane, shall withstand lightning-induced voltage transients, resulting from the lightning environment defined in AC 20-136, with no false warnings, malfunctions and/or damage and shall automatically recover to normal operation within 4 s of cessation of the transient.

3.1.12 Reliability: Component and system reliability shall be considered as a major design factor. Based upon a best available knowledge of component reliability characteristics, the design safety factors used and the operating conditions specified herein, the equipment supplier shall calculate and document the mean-time-between-failure (MTBF) for each unit.

In addition, the probability of single failures, which could result in the types of failure conditions listed in 3.2.2.4, shall be calculated.

3.1.12 (Continued):

Guidance concerning system failure analysis and failure condition categories is contained in Advisory Circular 25-1309.1A.

NOTE: A complete failure analysis for the entire system, including wiring, connectors, power supplies, etc. and the effects of configuration, can only be conducted by the installer.

3.2 Specific Design Requirements for the EVM Signal Conditioner:

The signal conditioner unit is the central processor for the EVM system. The unit receives signals from engine-mounted vibration sensors (either directly or via remote amplifiers, depending on the system design) and from the engine tachometers. The unit generates signals, proportional to the vibration levels caused by each engine rotor unbalance, for output to flight deck displays and other airborne systems, e.g. Flight Data Recorders.

If multiple engines are serviced by the same signal conditioner, the design must include means to prevent a single, undetected failure of the system from generating misleading vibration outputs for more than one engine.

The incorporation of optional functions, which are not related to the indication of rotor unbalance to the flight crew, per FAR 25.1305, shall be accomplished in such a way that failures of these functions cannot interfere with the primary EVM function.

3.2.1 Input Requirements: All inputs shall be suitably buffered and/or isolated to prevent the failure of an individual input from affecting other inputs.

3.2.1.1 Electrical Power Input: The signal conditioner shall accept, and operate from, electrical power per the requirements of 3.1.10.2

3.2.1.2 Vibration Input: The signal conditioner shall receive vibration inputs, either directly from the sensors or from remote converter units (RCUs).

To ensure that saturation or false indications do not occur, it is necessary that the maximum input levels that may be present at DC and at frequencies below, within and above the vibration measurement range be specified.

3.2.1.2.1 Direct Input from Vibration Sensor: The unit shall be designed to accept, and accommodate, signals from one or more engine mounted sensors suitable for measuring the magnitude of vibration at each sensor location. The number, type, location and dynamic range of the sensors will depend on the specific engine and installation and shall be specified by the engine manufacturer.

3.2.1.2.1 (Continued):

Unless the vibration sensors contain integral conditioning electronics, the signal processor shall provide amplification and conversion of the low-level sensor signals to a level and form suitable for the internal signal processing required for the functions and performance defined in 3.2.2.

Care shall be taken to ensure that the signal conditioner can accommodate the maximum input signal, which could result from any possible combination of constant and/or varying accelerations at the sensor location, without saturation which could result in either the masking of the true vibration level or the generation of a false failure indication (see 3.2.2.4). Vibration sensor characteristics are defined in 3.3.

3.2.1.2.2 Input from Remote Converter Unit (RCU): If RCUs are used, the signal conditioner shall accept inputs from these units and, with the exception of providing initial amplification and signal conversion, shall meet the same requirements as specified in 3.2.1.2.1

If required, (see 3.4.3.2), the signal conditioner shall also accept a failure indication signal from the RCU and process it to meet the requirements of 3.2.4.

RCU characteristics are defined in 3.4.

3.2.1.3 Tachometer Input: Unless otherwise specified, the unit shall accept inputs from tachometers for each engine rotor.

The characteristics of these inputs shall be defined by the engine manufacturer.

In the event that the normally supplied tachometers are not suitable for providing an input to the tracking filter(s), the required characteristics shall be negotiated for the specific installation. Adequate tachometer signals must be provided to support the user specified requirements.

The signal conditioner shall be able to correctly process each required tachometer signal through the speed range specified in 3.2.2.1.1. An input shall be used only if its value is within an established range.

If the tachometer signals are shared with other systems they shall be buffered at the signal conditioner to prevent failures in the unit from affecting the signals themselves. The tachometer signals shall also be isolated from one another such that a fault at one input shall not affect any other input.

3.2.2 Signal Processing:

3.2.2.1 General:

3.2.2.1.1 Speed Range: The signal processor shall be capable of handling the complete range of input, internal and output signals which will be encountered over the speed ranges of the engine rotors from below ground idle to above red line limits. The actual limits will be determined for the specific application and shall be sufficiently wide to prevent loss of useful data at, or close to, the upper and lower limits.

3.2.2.1.2 Initializing: Where required in the system, anti-aliasing filters shall be provided such that, in the presence of any signal of significant amplitude and frequency higher than the frequency range of interest, the amplitude error from aliased signals folded back into the frequency range of interest is within an allocated portion of the accuracy specified in 3.2.2.2.4. Figure 4 illustrates this requirement.

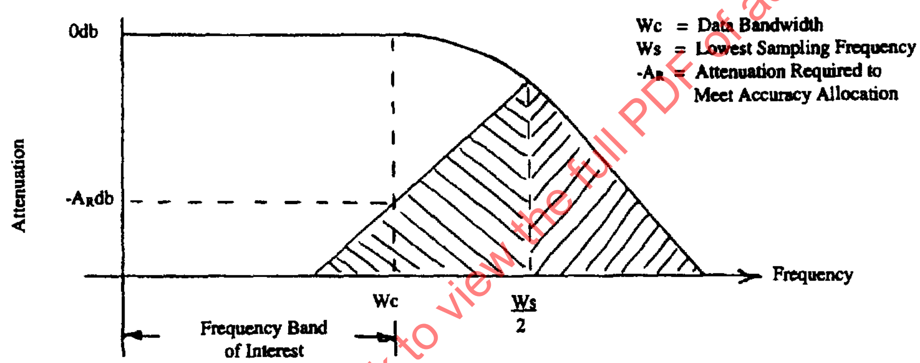


FIGURE 4 - Anti-Aliasing Requirements

3.2.2.2 Tracking Filters: Units incorporating tracking filters shall provide synchronous, narrow bandpass filtering, controlled by the tachometer signals, to measure the vibration levels which are synchronous with the rotational frequency of each engine rotor over the speed range defined in 3.2.2.1.1.

It is acknowledged that the same capability could also be achieved by the use of on-line, real-time spectral analysis and it is not the intent of this document to rule out any such usage.

3.2.2.2.1 Tracking Filter Characteristics: The tracking filter center frequency shall be slaved to the engine rotor speed.

The filter characteristics shall be determined by the specific application to meet the requirements of this standard and any other requirements specified by the installer.

3.2.2.2.1 (Continued):

Neither engine acceleration/deceleration (within the limits specified by the installer) nor random or periodic tachometer signal noise shall adversely affect tracked data accuracy beyond specified limits.

3.2.2.2.2 Tracking Rate: When a change in tachometer input occurs the tracking filter shall center and stabilize on the new frequency within 4 s.

3.2.2.2.3 Amplitude Linearity: The unit's tracked vibration amplitude shall be linear within ±2% of a best fit straight line over the speed range of the engine rotors specified in 3.2.2.1.1.

3.2.2.2.4 Amplitude Accuracy: The unit shall have a steady-state tracked vibration amplitude error of less than (±2% of reading ±1% of full scale) over the speed range of the engine rotors specified in 3.2.2.1.1

When a change in vibration input amplitude occurs the output shall stabilize to 100% of the new value within 2 s.

3.2.2.3 Broadband Filters: If, in addition to the required tracking filter outputs, a broadband output is proposed for the application, the bandpass filter corner frequencies shall be set to cover the speed range of the engine rotors specified in 3.2.2.1.1

The filter characteristics, including bandpass limit frequencies, shall be defined in the Installation Instructions. A broadband output should, preferably, be specified as true RMS or average.

3.2.2.4 Failure Detection: Using the definitions contained in AC25.1309-1A and in DO-178B, the FAA has determined the minimum classifications for certain EVM system failure conditions as follows:

a. Failure conditions which can cause interchanging of displayed vibration levels, i.e., the sensed vibration level of one engine is incorrectly identified with a different engine, are classified as hazardous/severe major

b. Failure conditions, which can cause the display to indicate normal levels of vibration when, in fact, an abnormally high level of vibration exists, are classified as “major” (hazardous/severe major for systems monitoring engines with established vibration limits).

c. Failure conditions, which can cause the display to indicate an abnormally high level of vibration when, in fact, a normal level of vibration exists, are classified as “major”

d. Failure conditions which are properly detected and annunciated are considered to be “minor”.

Failures of the signal conditioner, which could result in conditions (a), (b), or (c) above, shall be detected and, together with failure indications received from an RCU (if used, see 3.2.1.2.2), shall be processed to produce an output to the flight deck per 3.2.4.

3.2.2.4 (Continued):

The probability of occurrence and level of detection coverage for these failures shall be provided in the Installation Instructions.

3.2.3 Output Requirements: All outputs shall be suitably buffered and /or isolated to prevent the failure of an individual output from affecting other outputs.

Any limitations on maintenance cables connected to the diagnostic outputs required in order to prevent data collection from affecting the EVM operation shall be clearly stated in the Installation Instructions or the Maintenance Instructions.

3.2.3.1 Electrical Power Output: If the signal conditioner supplies power to RCUs, the required power output characteristics shall be defined.

3.2.3.2 Analog Output: If required by the application to interface with a dedicated flight deck indicator, the unit shall provide a direct current or voltage signal to drive a zero to full-scale indicator with range, sensitivity, scaling, load and other salient characteristics to be defined by the installer or the indicator supplier.

3.2.3.3 Digital Output: If a digital output data link is required by the application, the bus characteristics and data content requirements shall be defined by the installer.

3.2.3.4 Vibration Signal Diagnostic Output(s): It is recommended that the signal conditioner provide output(s) suitable for diagnosing and troubleshooting the vibration signals. These signals should represent, as closely as possible, the “raw data” from the vibration sensors and should be adequately buffered to prevent the presence of instrumentation at these outputs from interfering with the primary functions of the unit. If the system includes RCUs, the signal conditioner should contain provisions for passing such a signal from the RCU through to an output port and/or outputting the functional vibration output from the RCU, if these signals are not the same.

3.2.4 Failure Indication: The signal conditioner shall provide an output signal(s) to alert the flight crew to failures of the signal conditioner, or remote converter (if used), which could result in invalid vibration outputs per 3.2.2.4.

The specific means shall be agreed with the installer and /or the flight deck display supplier.

3.2.5 Software Requirements:

3.2.5.1 Software Level: If any of the required signal conditioner functions are implemented using digital processing, the equipment supplier shall select a specific software level from the options described in RTCA DO-178B, and shall design, test and document the software in accordance with the appropriate requirements from DO-178B. The software level shall be indicated in the Installation Instructions and, optionally, on the unit nameplate.

3.2.5.1 (Continued):

Selection of a minimum appropriate software level requires knowledge of system application details (e.g., the existence of established engine vibration limits) and knowledge of system installation details (e.g., wiring configuration, display system characteristics, etc.) Provided this information is available to the EVM component manufacturer, appropriate system reliability requirements may be determined using the methods described in FAA Advisory Circular AC25.1309-1 A.

Guidance concerning the definition of software levels, the relationship between software levels and failure conditions, and how the required software level is determined is contained in RTCA DO-178B, as authorized by FAA Advisory Circular AC20-115B.

3.2.5.2 Software Version Identification: All changes to embedded airborne software shall require, as a minimum, a new software part number modification level indicated on the outside of the host unit. Major software changes may require a new software part number suffix.

3.2.6 Electrical Characteristics:

3.2.6.1 Insulation Resistance: The unit (except for printed circuit boards) shall be designed to have an insulation resistance of not less than 40 MΩ between mutually insulated parts when measured at 500 VDC.

3.2.6.2 High Potential: The unit (except for printed circuit boards) shall be designed to withstand, without damage, a high potential test voltage of 700 VAC, 50-400 Hz for 1 min, between mutually insulated parts, without any arcing or sparking, or leakage current in excess of 1.0 mA.

3.2.7 Physical Requirements: For the most part, the physical requirements of the signal conditioner will be dependent upon the intended installation. Unless specifically stated in this document, the requirements for such characteristics as packaging, mounting, electrical interfaces, etc., will be contained in the detailed specification for the installation.

It is recommended that the dimensions and installation of the equipment should be according to either ARINC 404 or ARINC 600.

3.3 Specific Design Requirements for EVM Vibration Sensors:

The physical principle of the vibration sensor shall be defined. The sensor shall convert sensed vibration, in the direction of the sensitive axis, into electrical signals suitable for processing by the signal conditioner, either directly or via remote converter units. The sensor may contain conversion/ amplification electronics, but care must be taken to ensure that the sensor is designed and tested in a manner appropriate for the environment in which these components must operate.

3.3 (Continued):

The sensing element shall be electrically isolated from ground.

The direction of positive acceleration, i.e., towards, or away from, the mounting base shall be defined by the supplier in the Installation Manual.

3.3.1 Reference Frequency and Temperature: A permanent reference frequency of 100 Hz or 120 Hz and a permanent reference temperature of 24 °C ± 5 °C, shall be established for the vibration sensors.

3.3.2 Operating Ranges:

3.3.2.1 Measurement Range: The measurement range of the vibration sensor shall cover the speed ranges of the engine rotors, as defined in 3.2.2.1.1.

3.3.2.2 Temperature Range: The operating temperature range (continuous rating) of the vibration sensor shall be defined.

An extreme temperature range and the effect of time spent at the extreme temperature range on the expected life of the sensor shall also be defined.

3.3.2.3 Acceleration Range: The vibration sensor shall meet the following requirements for accuracy and linearity of output signal and reliability while being subjected to the full spectrum of multiaxis vibration that may be present at the sensor location. The installer and/or the engine manufacturer shall define the range of acceleration and frequency applicable to the specific installation.

3.3.3 Vibration Measurement: The output and location of the vibration sensor shall be specified by the installer in conjunction with the engine manufacturer and shall be such that adequate amplitude is obtained for further processing when the device is subject to the minimum vibration level to be measured.

3.3.3.1 Output Sensitivity: The nominal value of the output sensitivity (output units/g), over the required measurement range (see 3.3.2.1) shall be specified by the installer and/or the engine manufacturer.

At the reference temperature and reference frequency, the output sensitivity of the sensor shall be within ±5% of the specified nominal value.

3.3.3.2 Amplitude Linearity: The output signal shall be linear to within ±1% of a best fit straight line for any combination of vibration level and frequency over the required measurement range, as defined in 3.3.2.1.

3.3.3.3 Frequency Response: The relative frequency response shall be flat, to within ±2.5% of the reference frequency, over the required measurement range, as defined in 3.3.2.1.

3.3.3.4 Resonant Frequency (Mounted): When properly mounted, per 3.3.6.2, the fundamental, mounted, resonant frequency of the sensor in the sensitive axis shall be outside the frequency range from 0 to 5 times the maximum rotational frequency of the high speed rotor of the application engine.

3.3.3.5 Temperature Sensitivity: The allowable sensitivity deviation of the vibration signal, for the frequency range of interest, over the temperature range with respect to the reference temperature shall be ±10%, typical.

Note that temperature shock may cause certain types of sensor to generate a transient DC or low frequency output, which can be of significant magnitude relative to normal signal levels. The maximum amplitude and frequency spectrum of such outputs, for the proposed sensor location, shall be specified.

3.3.3.6 Transverse Sensitivity: The maximum output that may be obtained when the sensor is vibrated in any direction orthogonal to the sensitive axis shall be less than 5% of the output that is obtained when vibrated in the sensitive axis, over the frequency range from zero up to the maximum rotational frequency of the high speed rotor of the application engine.

3.3.4 Electrical Characteristics:

3.3.4.1 Insulation Resistance: Minimum values of the electrical insulation resistance from each ungrounded electrical pin to case ground and between each pin shall be specified.

3.3.4.2 Electrical Capacitance: The electrical capacitance from each ungrounded electrical pin to case ground shall be nominally equal and specified. The electrical capacitance of the sensing element shall also be specified.

3.3.4.3 High Potential: The vibration sensor shall withstand the specified AC voltage and frequency from each connector pin to ground for 30 s without breakdown or fluctuation in current flow.

3.3.4.4 Connectors: The class and type of connectors used for the vibration sensors shall be specified by the engine manufacturer.

3.3.4.5 Leads: Depending upon the configuration, there may be an integral lead between the vibration sensor body and the connector. Such a lead must be capable of being formed to a radius of 2.0 in (5 cm) and pulled with a static load of 55 lb (25 kg) without damage to the sensor or degradation of the signal.

3.3.5 Environmental Requirements:

3.3.5.1 Constant Acceleration: The output of the vibration sensor in the presence of constant acceleration in the direction of the sensitive axis shall be defined.

3.3.5.2 Temperature Shock: The vibration sensor shall withstand a temperature change from the minimum operational to the maximum operational, or vice versa, within 5 min without physical damage

3.3.5.3 Acoustic Noise: The output of the vibration sensor, as the result of acoustic noise of 150 dB SPL from 10 to 10 000 Hz, shall be no greater than 0.02 g equivalent.

3.3.6 Physical Requirements:

3.3.6.1 Metals: Only metals accepted by the engine manufacturer may be used.

3.3.6.2 Mounting: Mounting requirements shall be agreed between the supplier and the engine manufacturer.

3.4 Specific Design Requirements for Remote Converter Unit (RCU):

Remote converter units shall receive the direct outputs of the vibration sensors and amplify and convert them to signals which are suitable for transmission from the RCU location to the signal conditioner without requiring special protection beyond that normally provided for wiring between the engines and the fuselage.

3.4.1 Input Requirements:

3.4.1.1 Electrical Power Input: The RCU may be powered from the signal conditioner, or from power supplied by the aircraft, depending on the specific installation. In either case, the electrical power characteristics shall be agreed upon by the RCU supplier and the installer and/or the signal conditioner supplier, to meet the requirements of 3.1.10.2.

3.4.1.2 Vibration Input: The RCU shall accept signals from one or more engine mounted vibration sensors suitable for measuring the magnitude of vibration at the sensor location. The number, type and dynamic range of the vibration sensors will depend on the specific engine and installation and shall be specified. Care shall be taken to ensure that the RCU can accommodate the maximum input signal which could result from any possible combination of constant and/or varying accelerations at the sensor location without saturation which could result in either the masking of the true vibration level or the generation of a false indication. Vibration sensor characteristics are defined in 3.3.

As with the signal conditioner, care shall be taken to ensure that high levels of vibration do not cause saturation such that either the vibration level indicated is limited, or a false failure indication is produced (see 3.2.2.4).

Vibration sensor characteristics are defined in 3.3.

3.4.2 Signal Processing:

3.4.2.1 Amplification and Conversion: The RCU shall convert and amplify the direct vibration inputs into output signals for transmission to the signal conditioner.

The linearity and accuracy of the RCU outputs shall be consistent with the output requirements for the signal conditioner, per 3.2.2.2.3 and 3.2.2.2.4 and shall be stated by the supplier.

3.4.2.2 Failure Detection: A failure of the RCU, which could result in failure conditions 1, 2 or 3 of 3.2.2.4 shall be detected and result in an output to the signal conditioner per 3.4.3.2.

3.4.3 Output Requirements:

3.4.3.1 Vibration Output: The RCU shall output a converted, amplified signal consistent with, and suitable for, the functional and performance requirements of the signal conditioner specified in Section 3.

3.4.3.2 Failure Indication: The RCU shall provide, to the signal conditioner, an output which discloses any failures detected per 3.4.2.2. This output may be a separate signal, or discrete, or a unique value of the normal vibration output signal, as agreed with the EVM signal conditioner supplier.

3.4.3.3 Vibration Signal Diagnostic Output(s): It is recommended that the RCU shall provide output(s) suitable for diagnosing and troubleshooting the vibration signals. These signals should represent, as closely as possible, the “raw data” from the vibration sensors and should be adequately buffered to prevent the presence of instrumentation at these outputs from interfering with the primary functions of the unit. This signal(s) may be transmitted to the signal conditioner for monitoring at its output port(s) per 3.2.3.4.

3.4.4 Electrical Characteristics:

3.4.4.1 Insulation Resistance: The unit (except for printed circuit boards) shall be designed to have an insulation resistance of not less than 40 MΩ between mutually insulated parts when measured at 500 VDC at the reference temperature, per 3.3.1.

3.4.4.2 High Potential: The unit (except for printed circuit boards) shall be designed to withstand, without damage, a high potential test voltage of 700 VAC, 50 to 400 Hz, between mutually insulated parts for 1 min without any arcing or sparking or leakage current in excess of 1.0 mA.

3.5 Specific Design Requirements for EVM Displays:

The Signal Conditioner may interface with a dedicated flight deck instrument(s) or with a multifunction display, depending upon the specific installation. The signal transmission medium for these interfaces may be analog or digital, again depending upon the installation.

The requirements and standards for multifunction displays are beyond the scope of this document and are considered to be the responsibility of the system installer.

The following material represents the requirements and standards for flight deck instruments dedicated to indicating engine vibration level.

3.5.1 Indicating Methods: Either a digital display, a rotating pointer or a simulated rotating pointer (such as could be produced by an LED or LCD display) may be used. Clockwise pointer motion shall represent increasing vibration level.

3.5.2 Instrument Markings:

3.5.2.1 Finish: Unless otherwise specified by the installer, white matte material shall be used for major graduations, numerals and pointers.

Nonfunctional surfaces shall be a durable dull black.

3.5.2.2 Numerals: Sufficient numerals shall be marked to positively and quickly identify all graduations. Numerals shall distinctly indicate the graduations to which each applies.

3.5.2.3 Graduations: Major graduations shall be used at intervals not to exceed 10% of full-scale value.

Minor graduations shall be clearly visible and easily distinguishable from major graduations.

3.5.2.4 Digital (Counter Type) Displays: If a digital display is used, it shall indicate increments no larger than 5% of full-scale value.

3.5.2.5 Visibility: All fixed and moving functional markings shall be visible from any point within the frustum of a cone whose side makes an angle of not less than 30° with a line perpendicular to, and passing through the center of, the instrument face, and whose small diameter is the aperture of the instrument case. In the case of nonround instruments, the equivalent subtended viewing angle shall be used.

The distance between the instrument face and the cover glass shall be the practical minimum and shall not exceed 0.25 in.

3.5.3 Performance:

3.5.3.1 Instrument Error:

a. Scale error: Instrument calibration data shall be provided with the installation instructions. The error at each major graduation shall not exceed 5% of full-scale reading.

b. Position error: The difference in indicator reading, when the indicator is rotated from the normal position to any other position, shall not exceed 3% of full-scale reading.

3.5.3.2 Display Response: Needles, symbols, and other indicators shall move smoothly and without sudden jumps, unless such movement is in response to a change in the input signal.

3.5.3.3 Surface temperature: The surface temperature of displays installed in the flight deck shall not exceed 49° C.

3.5.4 Environmental Requirements: Environmental requirements for dedicated EVM displays are listed in 3.1.11. Unless otherwise specified, all tests shall be conducted with the instrument in its normal operating position.

4. UNIT QUALIFICATION AND ACCEPTANCE:

Each type of component shall be analyzed, inspected and tested, as specified in 4.1 through 4.5.2.12, to demonstrate compliance with the performance and other requirements of this document.

In addition, each Qualification Unit and each Production Unit shall be subjected to an acceptance test per 4.6. The qualification test and acceptance test procedures and pass/fail criteria shall be documented per 4.7.1.

4.1 Performance Measurement and Display:

The ability of the EVM system to sense, process and display the level of vibration caused by engine rotor unbalance shall be established by appropriate tests, analyses and inspections covering representative operational configurations and conditions.

In most EVM systems, the various components will be installed in significantly different environments. It is therefore necessary to demonstrate the performance of each component individually in its appropriate environments and also the performance of the system as a whole under the specified conditions.

The equipment category for each component, as defined in the various Sections of DO-160C, shall be as stated herein, unless otherwise defined by the installer to be consistent with a specific application.

In either case, the applicable categories to which the equipment is qualified shall be clearly stated in the installation instructions and, where practical, on the unit or unit nameplate.

The manufacturer of each component shall be responsible for performing all required tests, analyses and inspections specified herein to verify the performance requirements specified under 3.1 and 3.2, 3.3, 3.4 or 3.5, as appropriate.

The installer shall be responsible for ensuring that the system as a whole, as installed, meets all the performance and other requirements.

4.2 Test Samples:

The qualification tests shall be conducted on a sample of the equipment that is in full conformity with production specifications. If the tested item incorporates features that are still experimental or in the development stage, any tests involving the nonproduction features shall be repeated later on a production unit or evidence presented to substantiate that the test results are valid for a production unit.

4.3 Failure During Test:

The qualification test samples shall complete all tests under Section 4 without maintenance and without necessity to re-calibrate the equipment. If a unit fails under test, the circumstances shall be documented (per 4.7.1 (c)) and the test repeated.

4.4 Hazard Analysis:

Analyses shall be conducted to show that hazards resulting from system failures, including crew error, as reasonably anticipated as possible, have been considered and preventive action taken accordingly.

4.5 Qualification Test Procedures:

All qualification units shall be first subjected to the acceptance tests of 4.6. Units which pass shall then be subjected to tests by the equipment manufacturer, under standard and environmental conditions, to demonstrate compliance with the requirements of this document. As a minimum, the tests called out in 4.5.1 through 4.5.2.12 shall be conducted.

4.5.1 Electrical Tests:

4.5.1.1 Electrical Power: Tests shall be performed to demonstrate that the EVM components can accept, and operate as specified, when supplied with electrical power of the type and quality chosen by the EVM supplier, or as otherwise specified by the installer, including maximum, minimum and transient values.

4.5.1.1.1 Power Input: The EVM components shall, where appropriate, be tested in accordance with Section 16 of DO-160C for the equipment category selected by the EVM supplier or otherwise specified by the installer.

4.5.1.1.2 Voltage Spike: The EVM components shall, where appropriate, be tested in accordance with the requirements for category A equipment from Section 17 of DO-160C.

4.5.1.2 Insulation Resistance: The insulation resistance shall be measured for 5 s between all electrical circuits and the metallic case. Insulation resistance measurements shall not be made on circuits where the potential will appear across elements such as windings, resistors, capacitors, etc., since this measurement is intended only to determine adequacy of the insulation.

4.5.1.3 High Potential: For this test, the potential shall be a sinusoidal voltage of a commercial frequency with an rms value of five times the maximum circuit voltage. Hermetically sealed instruments shall be tested at five times the maximum circuit voltage up to a maximum of 1000 V rms. The potential shall start from zero and be increased at a uniform rate to its test value. It shall be maintained at this value for 5 s and then reduced at a uniform rate to zero.

The EVM equipment shall not be damaged by the application of this test voltage between electrical circuits, or between electrical circuits and a conductive case. Since these tests are intended to assure proper electrical insulation of the circuit components in question, the test voltage shall not be applied to circuits where the potential will appear across elements such as windings, resistors, capacitors, etc.

4.5.2 Environmental Tests: The EVM components shall be tested to demonstrate compliance with the performance requirements under the environmental conditions and for the categories specified in 3.1.11, 3.2, 3.3, 3.4, and 3.5 or to more stringent requirements if selected by the supplier or specified by the equipment installer.

4.5.2.1 Temperature and Altitude: Testing shall be conducted in accordance with the procedures of Section 4.0 of DO-160C.

In addition, Flight Deck mounted equipment shall be operated in an environment which is thermally equivalent to the production installation for 30 min or until the surface temperature stabilizes. The maximum surface temperature shall be recorded.

4.5.2.2 Temperature Variation: Testing shall be conducted in accordance with the procedures of Section 5.0 of DO-160C.

4.5.2.3 Humidity: Hermetically sealed components shall be tested for leaks by means of a mass spectrometer type of helium leak detector or equivalent. The leak rate shall not exceed 10^{-9} torr liters per second at a pressure differential of one atmosphere.

Other components shall be tested in accordance with the procedures of Section 6.0 of DO-160C.

4.5.2.4 Operational Shock and Crash Safety: Testing shall be conducted in accordance with the procedures of Section 7.0 of DO-160C.

4.5.2.5 Vibration: Testing shall be conducted in accordance with the procedures of Section 8.0 of DO-160C.

4.5.2.6 Explosion Proofness: Testing shall be conducted in accordance with the procedures of Section 9.0 of DO-160C.

4.5.2.7 Waterproofness: Testing shall be conducted in accordance with the procedures of Section 10.0 of DO-160C.

4.5.2.8 Susceptibility to Fluids: Testing shall be conducted in accordance with the procedures of Section 11.0 of DO-160C.

4.5.2.9 Fungus Resistance: Testing shall be conducted in accordance with the procedures of Section 13.0 of DO-160C.

4.5.2.10 Electromagnetic Compatibility: The EVM components shall be tested for susceptibility to electromagnetic interference in accordance with Sections 17, 18, 19 and 20 of D0-160C.

The EVM components shall be tested for excess electromagnetic emissions in accordance with the requirements for category Z equipment from Section 21 of D0-160C.