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This TOP provides guidelines and procedures for helicopter vibration calibration and measurements. Guides are provided for vibration frequencies and magnitudes to be expected. Procedures are developed for transducer selection and placement, instrumentation system design, and data collection. Emphasis is placed on use of piezoelectric accelerometers for vibration measurement, and tape recorders for data storage. Step-by-step procedures are provided for accelerometer sensitivity measurement and calibration, instrumentation system adjustments and calibrations, and data collection and handling.

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Test Operations Procedure (TOP) 7-3-531
AD No.

VIBRATION TESTING OF HELICOPTER EQUIPMENT

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1. SCOPE.

This TOP is intended to cover procedures for using piezoelectric accelerometers from device selection to presentation of data. Piezoresistive devices are not recommended for helicopter vibration measurements but are briefly discussed as an alternative for very low frequency measurements. It is anticipated that this document will be amended in the future to include specific instructions for modal analysis; however, the procedures presented here will still apply for that application.

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2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

2.1.1 Vibration testing should be conducted from a fixed-base airfield with at least aviation unit maintenance level capabilities. The airfield should include a level, hard-surfaced area for ground runs that is sufficiently removed from other aircraft to be independent of their ground effects. The ground run area should, if possible be free from wind conditions in order to establish a baseline. Wind induces vibrations in the rotor systems which may or may not affect the data. The ground run area must be in an area that is reasonably free of electromagnetic interference. Hangar space must be available for installation and maintenance of instrumentation equipment with adequate heating for curing epoxy resins or other adhesives used to attach accelerometer mounts.

2.1.2 A test flight area must be locally available and suitable for flying flight profiles. An example of a typical flight profile for vibration testing is provided in Appendix C. Projects that require live-fire testing of armament systems will require special ranges and support for that purpose. Flight profiles such as referenced above and armament testing would normally be conducted on two different test areas, but both scenarios may be part of one test.

2.1.3 A suitable test-bed aircraft must be available for the duration of the vibration testing. The aircraft type/model is dictated for each test in most cases; but for some equipment testing may be required on several aircraft types. It is most desirable that aircraft selected for use in vibration testing be dedicated for that purpose. This is necessary due to the down time needed for instrumentation installation and maintenance, and because of the fragility of the instrumentation equipment and wiring.

2.1.4 Instrumentation facilities and personnel must be available for production of plans, and fabrication, installation, calibration and maintenance of the instrumentation system. A selection of accelerometers, charge amplifiers, multiplexers (MPX's), data storage equipment, wire and cable, connectors and other instrumentation hardware must be available. The completed installation of instrumentation on an aircraft must be approved by a qualified and approved airworthiness team. Following the airworthiness approval, an Electromagnetic Interference/Electromagnetic Compatibility (EMI/EMC) test flight must be flown by a qualified test pilot.

2.1.5 Data processing facilities must be available for processing the flight data. It is desirable, but not imperative, to have the data processing facilities on-site where the test is being conducted. When on-site data processing is not feasible it is very important to have a means of viewing the raw data to assure the basic quality of the recorded data.

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2.2 Instrumentation.

The instrumentation effort in this document includes those efforts required to produce a vibration measurement system, and is split into the following categories:

a. Management and planning

b. System design

c. Setup and calibration of tape recorder

d. Accelerometer calibration

e. System fabrication

f. Shop calibration.

g. System installation

h. System calibration

2.2.1 Project Management and Planning.

Project management must determine what is to be measured as a starting point. For example, is the measurement intended to check level for human comfort, environment produced by a new blower motor, or safe and reliable air bag deployment? Test directives generally determine basic goals for measurement but, in most cases, are not specific enough to determine frequencies, acceleration limits, etc. Proper planning will determine the details necessary to build an instrumentation system that will satisfy the requirements. The basic problem is to determine approximate location for each transducer (accelerometer); the principle axis or axes of interest at each location; the expected frequencies of interest; and the expected upper limit of the vibration peak amplitude. The following paragraphs are intended to help place limits on these parameters. For planning worksheet see Figure C-2, Appendix C.

2.2.1.1 Transducer locations may be given in the test directive, but in most cases will have to be determined locally from the test requirements. There should be a compelling reason for the placement of each transducer. If the waterline, buttline and fuselage station are known, they should be entered as the location; otherwise a verbal description will do for planning purposes.

2.2.1.2 Vibration frequencies and amplitudes on helicopters are divided into two major categories: Those for which the forcing functions are the rotors and blades; and those driven by gunfire. Rotor and blade frequencies for most Army helicopters are provided in Table A-1, Appendix A.

Methods for estimating peak vibration amplitudes and frequencies that are driven by the rotors and drive trains of helicopters are provided in MIL-STD-810E[1*], Method 514.4 with Change Notice 2. Harmonics of a frequency f_x are integer multiples of f_x; i.e., $2f_x$, $3f_x$, etc. Vibration from harmonics of the rotor frequencies decrease in significance as the number of blades increase (see AMCP 706-201[A], page 5-3). The first significant harmonic of the rotor frequency is equal to the number of blades, e.g., a rotor with 3 blades produces a significant 3rd harmonic and decreasing amplitudes for multiples of that harmonic. Conversely, a rotor with 2 blades may produce 10 significant harmonics of the blade frequency before decaying to insignificance. For the AH-1, OH-58A and UH-1 those harmonics are still less than 125 Hertz (Hz).

Frequencies below about 10 Hz may approach the low frequency cutoff of piezoelectric transducers and charge amplifiers. Very low frequencies that are of testing interest should be itemized in the FREQUENCY/MIN column on the planning worksheet.

Gunfire vibration characteristics differ markedly from that induced by rotor and drive mechanisms. Method 519.4 of reference 1 gives extensive help in estimating the characteristics of gunfire for various guns and aircraft, but must include Change Notice 2 to specifically address helicopters and the guns used on helicopters. The method does make the following very important points: (1) Most aircraft vibration driven by gunfire arises from the overpressure pulse at the gun muzzle, not from the kick of the weapon; (2) the primary vibration frequencies generated by gunfire are the firing rate and its harmonics, and (3) significant harmonics of the firing rate may go up to 2,000 Hz. It should be noted that Method 519.4 covers weapons with a firing rate of 100 rounds/second; 2,000 Hz is the 20th harmonic of the firing rate.

One test conducted by ATTC at Fort Rucker (IBAHRS) measured vibration on a modernized Cobra (AH-1S) during gunfire using the M197 automatic cannon. The firing rate was about 12 rounds/second. The data indicated the primary frequency at about 12 Hz, and significant (measurable) harmonics out to the 19th harmonic at about 226 Hz. Unlike rotor induced vibration, which decays rapidly with higher order harmonics, this test exhibited no decay in the harmonics until after the 17th harmonic, decaying on the 18th and 19th harmonics, and not significant on the 20th and above.

A review of rotor frequencies and the foregoing discussion indicates that seldom, if ever, should one encounter significant helicopter vibration above 500 Hz, and most would be contained below 250 Hz.

2.2.2 Engineering and Design.

The task for engineering is to select the accelerometers, charge amplifiers, multiplexers and tape recorder, and produce the drawings to

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*Superscript numbers/letters correspond to those in Appendix D, References.

fabricate a working system. In the block diagram of Figure 1, the sensitivity of the accelerometer, the gain of the charge amplifier, and the gain of the signal conditioner must all be selected to produce a useable signal at the inputs to the MPX's. Note that most systems would use only one or the other of the MPX's but not both. It would be a simple matter to select a suitable combination if the vibration was limited to a single sinusoid, but that is never the case. Helicopter vibration is always an extremely complex combination of many frequencies and amplitudes. Thus for an MPX limited to inputs ranging from 0 to 5 volts direct current (VDC), the accelerometer-charge amp combination must be selected to assure their output never exceeds that range. To achieve this, the instantaneous values of all the vibration frequencies must not exceed the maximum output voltages when they are all in phase and summed. In practice, only rarely are all frequencies in phase, and to set gains such that limiting could never occur would have gains so low that many desirable signals would be below noise. A reasonable compromise would be to assume a maximum voltage excursion of 2 or 3 times the maximum known frequency amplitude.

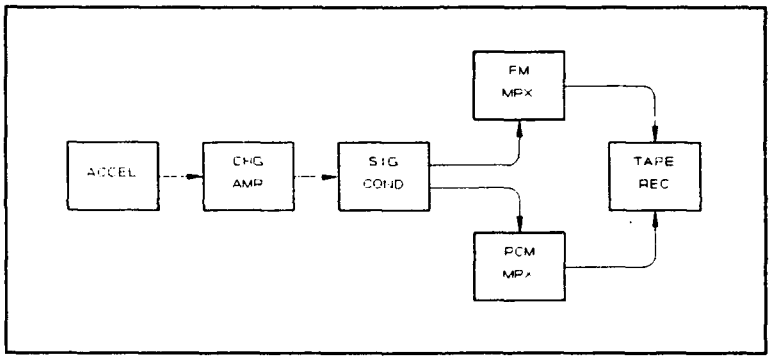


Figure 1: Vibration System Block Diagram

2.2.2.1 Instrumentation system design should start with a review of the completed Vibration Measurement Planning Worksheet (VMPW), (Figure C-2, App C). Most of the entries on the worksheet are critical to the system design. Refer to Figure 2 while working through the following procedures.

a. Using the VMPW, note any limitations for each accelerometer such as:

(1) High temperature exposure (engines);

(2) Accessibility for mounting & cable connections;

(3) Exposure to harsh elements (fuel, hydraulic fluid, etc.);

(4) Electromagnetic interference (EMI) exposure (radio/radar

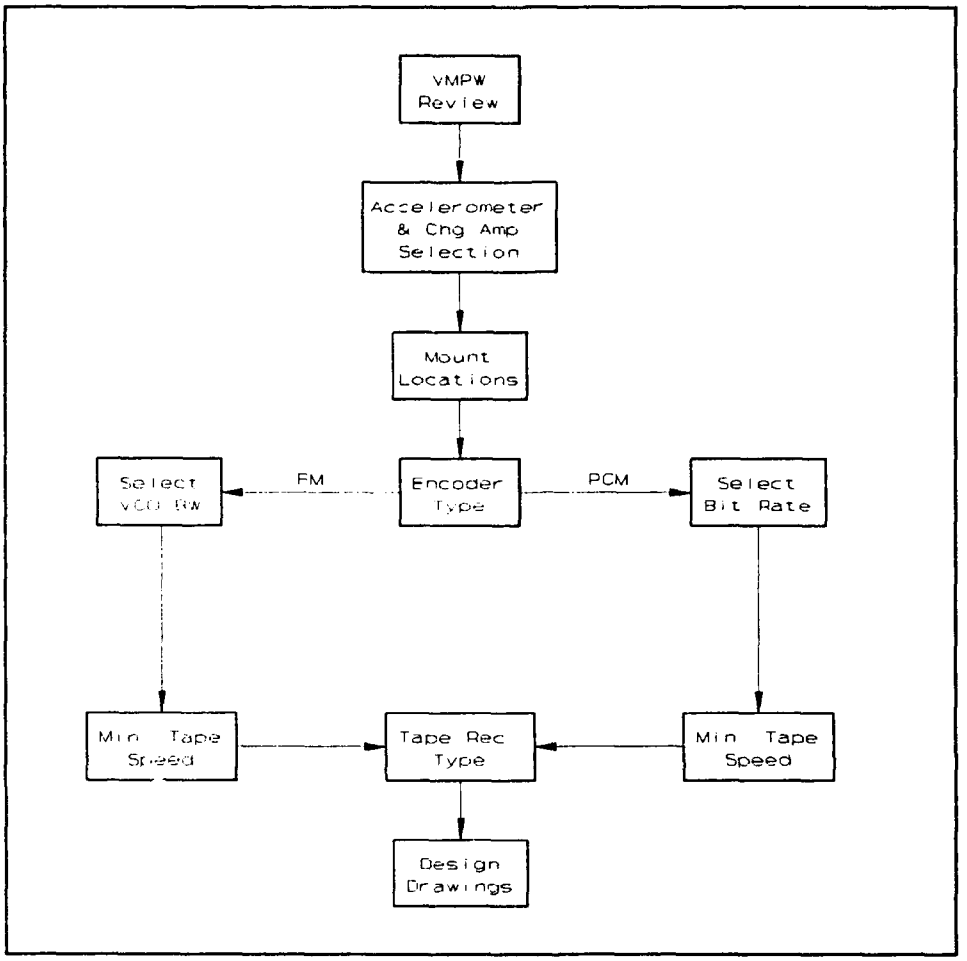


Figure 2: System Design Guide

transmitters & antennas, etc);

(5) Extreme g level requirements (gunfire, etc.)

(6) Extreme high (or low) frequency requirements.

b. Make tentative selections for accelerometer/charge amplifier pairs for each location listed on VMPW. Use manufacturer nominal specifications for accelerometer sensitivity and charge amplifier gains, along with peak g's in equation (1) below to estimate the peak-to-peak (p-p) voltage output for each position:

$$2 \times Sensitivity \times Gain \times Peak\ g's = millivolts_{p\text{-}p}\ out \qquad \textbf{Equation (1)}$$

Where: Sensitivity is in picocoulombs (pC) per g_{peak}
1 pC = 10^{-12} Coulomb;
Gain is in millivolts/pC;
Output is in millivolts p-p.

It may be necessary to provide additional gain beyond that of the charge amplifier to obtain an adequate signal. Analog signal conditioning may be added following the charge amplifiers for that purpose. Signals that require low-pass filtering must have sufficient gain to compensate for insertion loss of the filter. Low-pass filtering is recommended in all cases; but for pulse code modulation (PCM) it is required to prevent frequency aliasing.

Piezoresistive accelerometers are not recommended for vibration measurements, but may be desirable for very low frequency and direct current (DC) measurements. They use voltage amplifiers, either internal or external, rather than charge amplifiers. Vibration voltages are superimposed on a DC bias voltage that in turn is determined by gravity and g-loading from aircraft maneuvers. Therefore any DC offset from aircraft maneuvers is not available for vibration gain, and may cause voltage limiting (distortion) in the vibration signal. They do, however, provide a means of measurement for frequencies below the cutoff of piezoelectric and charge amplifier devices.

c. On the test bed aircraft determine a location for the main instrumentation rack. Determine actual mount locations and details for each accelerometer. Make notes of the following information for each accelerometer:

(1) Accelerometer identification (ID) No. and Model No;

(2) Orientation on aircraft for each axis;

(3) Dimensions to mount location from a nonmoving reference point;

(4) Mount type to be used or any machining needed for custom mount;

(5) Locations for mounting charge amplifiers.

Make note of potential locations for instrumentation control, tape recorder remote control, and remote time display panels in cockpit.

d. Select encoder type between frequency modulation (FM) and PCM. Most vibration work uses FM because of the high sample rates and bit rates required for PCM, requiring higher tape speed and less recording time for tests. PCM has the advantage of faster processing time due to the relative ease of handling digitized data directly from the test. Both options should be checked to select the most advantageous of the two.

e. Most applications use Inter-Range Instrumentation Group (IRIG) Constant Bandwidth (CBW) A or B channel Voltage Controlled Oscillators (VCO's)

for vibration measurement. Channel A VCO bandwidths are ±2 kilohertz (kHz) with nominal frequency response of 400 Hz; channel B bandwidths are ±4 kHz with nominal frequency response of 800 Hz. Since most helicopter vibration is well below 500 Hz, either A or B channel VCO's are adequate. In either case, it is normally the reference oscillator (usually 240 kHz) that determines the minimum tape speed. Table 6-1, IRIG STANDARD 106-86[2], indicates for wideband direct record the upper band edge (UBE) is 250 kHz for a tape speed of 381 mm/s (15 inches per second (ips)). See reference 2, Chapters 3 and 6 for other VCO and tape recorder configurations.

f. PCM requires more information than FM to determine minimum tape speed. Minimum tape speed is actually determined by the bit rate and PCM code used. The code is usually offered in two or more choices, NRZ-L or Biϕ-L, but NRZ-L is not recommended for recording on direct record. In any case, to determine the bit rate it is necessary to construct a data frame. The following information is necessary to construct a data frame:

(1) Number of words for frame synchronization (sync) pattern;

(2) Number of data channels (not just accelerometers);

(3) Maximum measurement frequency for each channel;

(4) Sample rate for each data channel (usually 5 times maximum frequency);

(5) Number of bits per data channel.

In its simplest form (no sub or supercommutation), the bit rate (BR) can be calculated as:

$$BR = \frac{(W_{FS} + W_D)}{FRAME} \times \frac{FRAMES}{SECOND} \times \frac{BITS}{WORD} \qquad \textbf{Equation (2)}$$

Where: W_{FS} = Number of words in frame sync pattern;
W_D = Total number of data words.

Data streams that contain both rapidly changing data such as vibration and slow changing data, e.g., airspeed or temperature, can conserve on the bit rate by using supercommutation for the fast data and subcommutation for the slow data. References 3 and 5 contain much helpful information on setting up commutation systems.

Biϕ-L is the most commonly recommended PCM code for direct record systems, but randomized NRZ-L (RNRZ-L) may also be used and may often allow a ½ reduction in tape speed. The portion of table 6-10, reference 2, that pertains to wideband direct record is reproduced in table 1 for convenience.

Table 1: Minimum Tape Speeds for PCM Codes and Bit Rates

Wideband Tape Speed		Biφ-L	RNRZ-L
mm/s	(ips)	kb/s	kb/s
1,524.0	(60)	450	750
762.0	(30)	225	375
381.0	(15)	112	187
190.5	(7½)	56	93

g. After the minimum tape speed has been determined a tape recorder type may be selected. Two commonly available airborne instrumentation tape recorders are the Ampex AR-700 and the Datatape MARS-2000. Both recorders have 14 analog tracks. Space or availability may dictate use of one over the other, but if set up properly they are equivalent in performance. The main difference between the two is reel size; the AR-700 uses a 318 mm (12½ inch) reel while the Mars 2000 uses a 267 mm (10½ inch) reel. Maximum record time for these reel sizes may be found in table 2:

Table 2: Record Time vs. Reel Size and Tape Speed

Tape Speed mm/s (ips)	Maximum Record Time (Minutes)		
	Reel Size mm (in.) - - - Nominal Tape Length m (ft)		
	267 (10½) - - - 1,400 (4,600)	318 (12½) - - - 2,200 (7,200)	356 (14) - - - 2,800 (9,200)
190.5 (7½)	123	192	245
381 (15)	61	96	123
762 (30)	31	48	61
1524 (60)	15	24	31

h. After the tape speed and recorder type have been selected, it is necessary to assign tape tracks with modulation type (FM or direct record) for each track. FM MPX's typically have high output impedance (up to 1 kiloohm (kΩ)) and cannot drive the standard 75 ohm (Ω) input impedance for the tape recorder channels; it is necessary to provide higher input impedances for tracks carrying FM MPX data. These tracks should be set up with input impedances of 1 kΩ or greater, and doubled if redundancy is used. A tradeoff occurs in that increasing input impedances decreases noise immunity. To prevent cross talk (coupling from adjacent tracks) it is desirable to carry FM multiplex tracks on alternating (all odd or all even) tracks.

Standardization of tape tracks is desirable wherever possible. Changing input impedances, record and bias levels, etc. is damaging to the equipment and costs man-hours in both the instrumentation and data reduction efforts. To keep tape recorder changes to a minimum the following track assignments are offered as a standard:

Table 3: Recommended Tape Track Assignments

Tape Track Assignments	
Track	Data Assignment
1	Intercom (voice)
2	IRIG B Time (1 kHz)
3	FM Multiplex No. 1
4	PCM No. 1
5	FM Multiplex No. 2
6	PCM No. 2
7	FM Multiplex No. 3
8	PCM No. 3
9	FM Multiplex No. 4
10	Unassigned
11	Unassigned
12	Unassigned
13	Unassigned
14	Tape Speed Reference

i. The data recorded on tape is a time record for each accelerometer axis. The data reduction process will use the time record to obtain plots of the original time record, spectrum displays, etc. To obtain consistent results, the plots must be made across the same time record. Making these plots requires a means of triggering the data reduction equipment to start and stop at the same times for numerous data playbacks. One means of providing the trigger is to record the tape recorder tachometer sync on the same multiplex with the vibration data. A circuit for doing this is provided in Figure 3. Note that after the recorder is turned on, as it approaches sync speed, all of the VCO's will go on tape as much higher in frequency than their actual frequencies, and approach their true frequencies as the recorder approaches sync. When the tape is reproduced each discriminator will see all lower frequency VCO's pass through its passband as the original recorder came up to speed. To prevent false triggering it is therefore necessary for the sync signal to be carried on the lowest frequency in each multiplex. The same reasoning may be followed to show that it is necessary for the VCO to be near the upper band edge when the recorder is not in sync, and lower band edge when

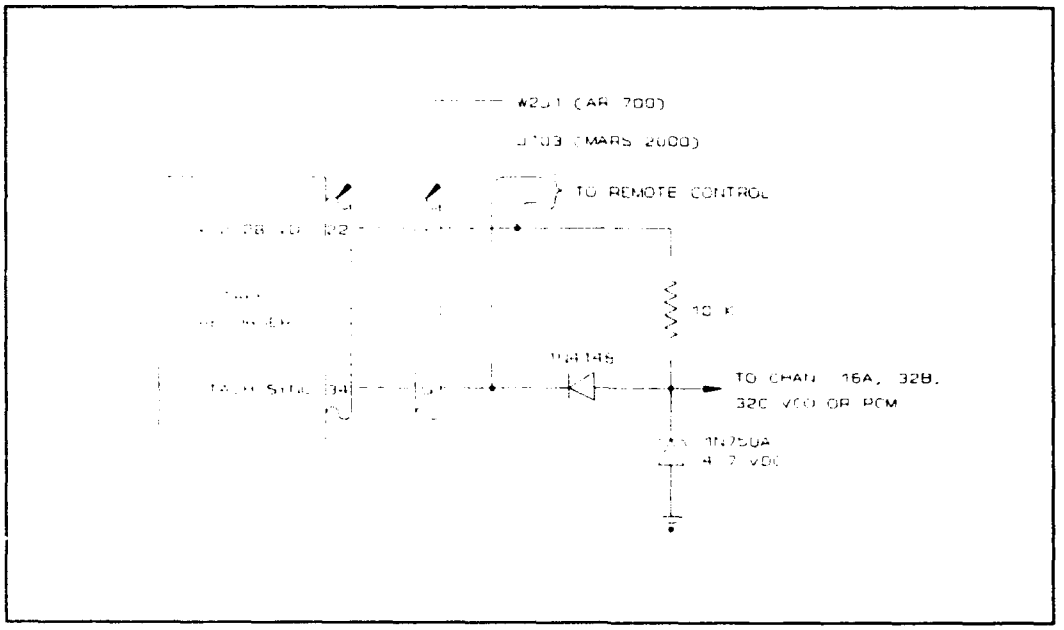


Figure 3: Recorder Tachometer Sync Circuit

it is in sync.

The preceding paragraphs enable proceeding with the following work:

(1) Completion of system design and wiring diagrams. Locate each charge amplifier as close as possible to its accelerometer. Noise suppression is best served by using long charge amplifier/encoder cables and short accelerometer cables.

(2) Order any connectors, wire and cable, or other parts not on hand;

(3) Order (or have machined) any accelerometer mounting pads not on hand. Mounting surfaces of machined pads shall be flat within ±0.025 mm (±0.001 in.) unless otherwise specified by manufacturer;

(4) Laboratory setup and calibration of tape recorder (supply calibration technician with channel allocations, input impedances and tape speed);

(5) Laboratory calibration of all accelerometers. Supply calibration technician with model number, peak g's and frequencies for each accelerometer.

2.2.3 Laboratory Setup and Calibration of Tape Recorder.

2.2.3.1 Except as noted below, the tape recorder shall be setup and calibrated in accordance with references 3 and 4. All tape recorder adjustments shall be accomplished in the laboratory as an initial setup. Field adjustments shall only be permissible on an external reproduce amplifier and never on the tape recorder.

Tape recorder adjustments such as head azimuth, timing error, etc. shall be accomplished as periodic maintenance. Adjustments for input impedance, tape speed, record bias and level shall be accomplished for each project.

2.2.3.2 All test equipment shall be in current calibration. IRIG DOCUMENT 118-79[3] calls for test equipment required for each adjustment or test but, in general, the following equipment is required:

a. Signal Generator

b. True rms Voltmeter

c. Wave Analyzer

d. Electronic Counter

e. Dual Trace Oscilloscope

f. Spectrum Analyzer.

2.2.3.3 Perform the following setups, tests and adjustments in accordance with reference 3:

a. Set each record amplifier input impedance to that requested in Para. 2.2.2.1h.

b. Check tape speed using reference 3, Volume III, Chapter 2 as a guide. Adjust as necessary using manufacturer's recommendations.

c. Adjust record bias and record level to conform to requirements of reference 3, Volume II, Chapter 4.

d. For FM multiplex channels only, after record bias and level adjustments have been made, insert a signal of standard (1 V_{rms}) level and 10 percent upper cutoff frequency. Measure the output level from the reproduce amplifier. Re-adjust the record level potentiometer to reduce the reproduce amplifier output to ½ the previous level (-6 dB). This step is in variance with reference 3, and is done to reduce the signal-to-noise ratio in accordance with Telemetry Applications Handbook[B], paragraph 3.7.6.

2.2.4 Laboratory Calibration of Accelerometers.

2.2.4.1 Regulations require periodic recalibration of accelerometers. Piezoelectric accelerometers change sensitivity slightly over time due to aging, and must be verified. Standard procedure is to maintain a laboratory calibration facility that is in calibration at all times, and use the facility to calibrate working accelerometers as they are required for a particular project.

The primary equipment for the calibration facility is a shake table, complete with its control equipment, and two calibration standard accelerometers. The first of the two calibration standard accelerometers is called the WORKING STANDARD. The working standard accelerometer is installed inside the shake table, and is never removed under ordinary circumstances. The second of the calibration standards is called the LABORATORY STANDARD. The laboratory standard is periodically sent to a calibration facility where it is certified to be in compliance with MIL-STD-45662A. This calibration procedure produces a tabulation of frequency vs. sensitivity that is traceable to the National Institute of Standards and Technology (NIST).

Following calibration, the laboratory standard is used to verify the working standard by installing the newly received laboratory standard as a device under test (DUT) on the shaker table, and comparing outputs of the two standards. This comparison should be made each time the laboratory standard is returned from calibration and at the beginning of each project calibration.

The calibration facility must have either an analog or a digital X-Y plotter, capable of plotting sensitivity vs. frequency, or plotting percent deviation from standard (100 or 160 Hz) sensitivity vs. frequency.

Systems that are not computer controlled shall be validated by the manufacturer's procedures and, at a minimum must both set zero and sensitivity of both axes for the plotter, and set zero, balance and sensitivity of both comparator amplifiers.

The following special tools are required for mounting accelerometers:

a. Torque wrench for hex (allen) head drivers, 0-50 kg-cm (0-50 lb-in.);

b. Set of hex drivers for (a);

c. Socket set for (a);

d. Special mounting sockets with connector side cutouts if required.

2.2.4.2 The following steps should be followed for calibrating project accelerometers:

Step 1: Obtain all accelerometers for one project, to be processed as a batch. Include one spare of each type if possible.

Step 2: Assure that adapter blocks or plates are on hand for mounting each accelerometer to the shake table. Hardware that is not available should be fabricated as soon as possible. Mating surfaces to the shake table and the accelerometer should be flat within ±0.025 mm (±0.001 in.) or to manufacturer specification.

Step 3: Obtain all studs, mounting screws, etc. for mounting accelerometers.

Step 4: Fabricate as necessary any accelerometer cables not on hand.

Step 5: Inspect all accelerometers carefully for any physical damage.

Step 6: Carefully clean any foreign material from each accelerometer. Never use sandpaper or other harsh abrasives for cleaning. Use appropriate hydrocarbon solvents to remove old epoxy or other adhesive.

NOTE: Hydrocarbon solvents are usually toxic and flammable. Use sparingly, with adequate ventilation; avoid skin/eye contact and heed all cautions on container.

Step 7: To avoid changing adapters and cables between runs, arrange to shake similar types in successive runs.

Step 8: Turn on coolant and power to shake table system. Allow 15 minutes warmup time for system to stabilize, or as recommended by manufacturer.

Step 9: Using adapters as necessary, mount accelerometer to shake table, using a thin film of petroleum jelly on the mounting surface. Use only mounting screws supplied by manufacturer, or machine screws of the same type.

NOTE: Manufacturers usually supply Allen head screws, which are specially tempered for high tensile strength; other machine screw types may break off in mount when torqued to specification.

Step 10: Torque all mounting screws or studs to manufacturer recommendation. If manufacturer recommendation is not available, use table 4 as a guide.

Table 4: Recommended Machine Screw Torque Guide

Machine Screw Torque Guide			
Stud Thread	kg-cm	Nm	(lb-in)
2-56	6	0.6	(5)
4-40	9	0.9	(8)
6-32	12	1.2	(10)
8-32	16	1.6	(14)
10-32	21	2.1	(18)
¼-28	28	2.8	(24)

Step 11: Setup shaker system to peak g and frequency limits as directed by instrumentation engineer; if unspecified, set for 1 g peak and 10 to 1000 Hz.

Step 12: Measure accelerometer sensitivity at reference frequency (usually 100 or 160 Hz).

Step 13: Using sensitivity measured in Step 12 and logarithmic sweep, plot log f vs. percent sensitivity deviation over frequency range (k).

Step 14: Label each plot with test date, accelerometer model and serial number, and peak g's.

Step 15: Remove accelerometer and wipe clean with tissue. Repeat steps 8 through 15 for each accelerometer.

Step 16. Turn off system and coolant.

Documentation of the calibrations allows maintaining a history of a particular device, and drastic changes from a previous calibration indicate physical internal damage, even when external damage is not evident. When an accelerometer exhibits such a change from previous calibrations, the calibration setup should be checked for bad cables, grounding problems, data entry errors or other irregularities. If none are found, rerun the calibration. If the accelerometer still indicates a large change from previous calibration, it should be disposed of through normal property book procedures.

2.2.5 System Fabrication.

2.2.5.1 Standard instrumentation practices and procedures for fabrication and wiring of aircraft instrumentation shall be used without exception. Only the

procedures unique to vibration measurements will be discussed in this TOP.

2.2.5.2 Coaxial cable runs from accelerometers to charge amplifiers must be kept very short. Such long runs are usually done to accommodate placement of the charge amplifier on the instrumentation rack, at the expense of data quality. Accelerometers requiring more than 3.7 m (12 ft) cable to connect on the instrumentation rack shall instead have a remote charge amplifier and a shorter cable.

2.2.5.3 Prefabricated accelerometer cables shall be used if available. These cables are supplied by various manufacturers in standard lengths of 457 mm (18 in.) and in multiples of 305 mm (1 ft).

2.2.5.4 Voltage amplifiers/signal conditioners, low pass filters, and FM multiplexers may all be placed on the instrumentation rack along with the tape recorder.

2.2.5.5 Programmable amplifiers, signal conditioners, filters, and PCM encoders shall be programmed before being mounted on the instrumentation rack. Instructions for programming shall be provided by system designer.

2.2.6 Shop Calibrations.

Shop calibrations are done to troubleshoot the system for defective components and wiring errors before the aircraft installation. These calibrations do not replace the system calibrations of paragraph 2.2.8, which would omit the aircraft intercom system, accelerometer cabling, etc.

Prior to system calibration a complete schematic of the system should be available for reference. A complete set of Helicopter Vibration Calibration Sheets (Figure C-3, App C) should also be on hand, with the Accelerometer, Charge Amp and VCO columns completed. The procedure will approximately follow the steps indicated in Figure 4. The following equipment, or equivalents, will be required to perform the shop calibrations:

ITEM	NOMENCLATURE	MFR/MODEL
1	Oscilloscope, Dual Trace	Tektronix/465
2	Oscilloscope	Tektronix/7623A
3	Spectrum Analyzer	Tektronix/7L5
4	Digital Voltmeter (DVM)	Hewlett Packard/3466A
5	Synthesizer/Function Generator	Hewlett Packard/3325A
6	Charge Calibrator	Kistler/563A
7	Discriminator Bank*	EMR/4150

*Requires channel selectors for FM multiplex channels to be tested.

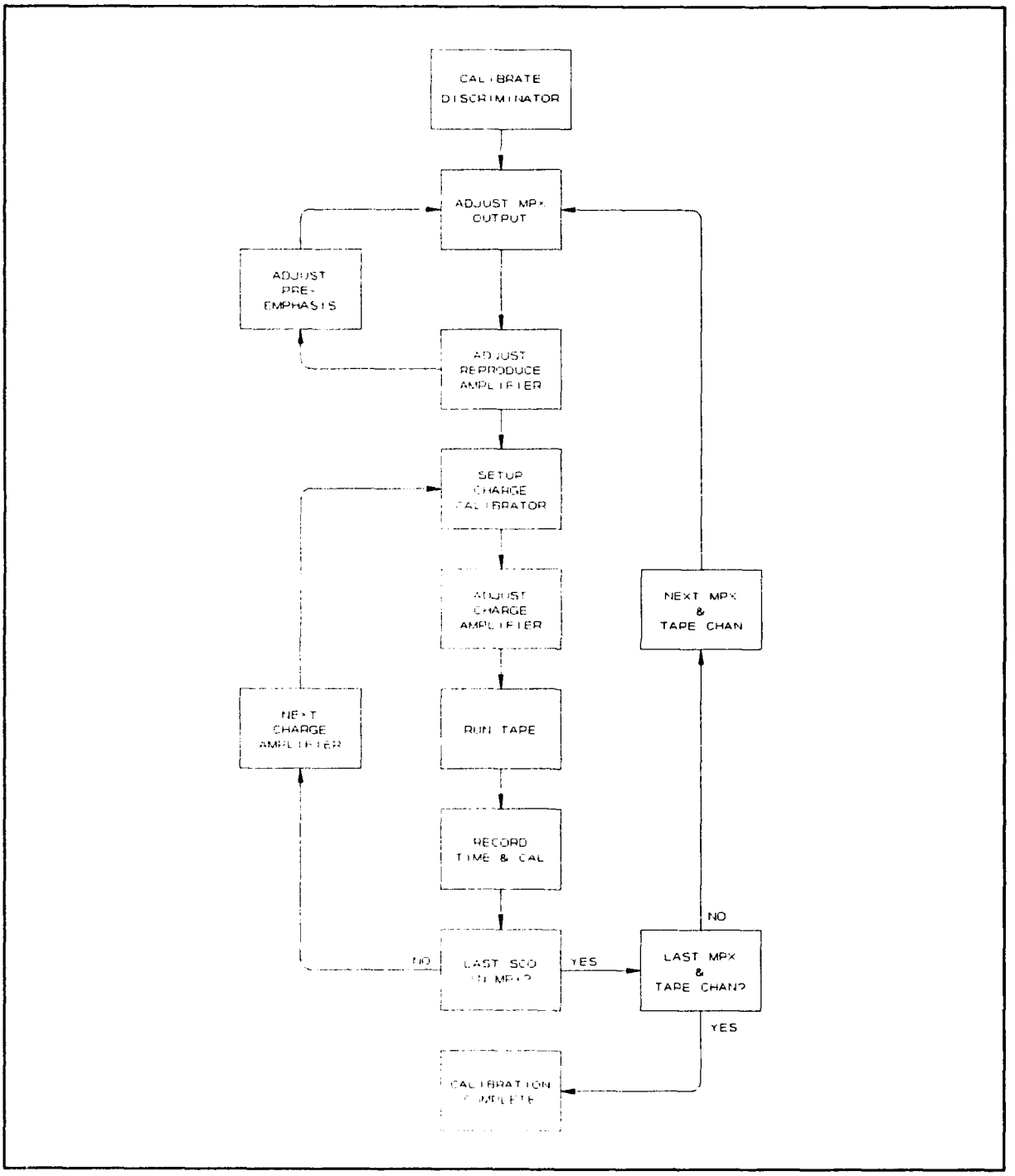


Figure 4: Shop Calibration Procedures

2.2.6.1 Discriminator Calibration.

Calibrate the discriminator before each use by performing the following steps.

Step 1: Turn on the signal generator and discriminator, and allow to warm up for 15 minutes.

Step 2: Using a 50 Ω load on the signal generator output, connect the output to the input of the discriminator bank.

Step 3: Set the signal generator output amplitude to 100 millivolts rms.

Step 4: Connect a DVM to the output of the first discriminator to be calibrated.

Step 5: Set signal generator to the center frequency of the discriminator. Refer to tables 5A and 5B for midband and bandedge frequencies.

Table 5A: Channel A Subcarrier Oscillator Center and Bandedge Frequencies

Channel A Subcarrier Oscillator Frequencies				
Original Channel Designation	New Channel Designation	Center Frequency (kHz)	Lower Bandedge (kHz)	Upper Bandedge (kHz)
1A	16A	16	14	18
2A	24A	24	22	26
3A	32A	32	30	34
4A	40A	40	38	42
5A	48A	48	46	50
6A	56A	56	54	58
7A	64A	64	62	66
8A	72A	72	70	74
9A	80A	80	78	82
10A	88A	88	86	90
11A	96A	96	94	98
12A	104A	104	102	106
13A	112A	112	110	114
14A	120A	120	118	122
15A	128A	128	126	130
16A	136A	136	134	138
17A	144A	144	142	146
18A	152A	152	150	154
19A	160A	160	158	162
20A	168A	168	166	170
21A	176A	176	174	178

Table 5B: Channel B Subcarrier Oscillator Center and Bandedge Frequencies

Channel B Subcarrier Oscillator Frequencies				
Original Channel Designation	New Channel Designation	Center Frequency (kHz)	Lower Bandedge (kHz)	Upper Bandedge (kHz)
3B	32B	32	28	36
5B	48B	48	44	52
7B	64B	64	60	68
9B	80B	80	76	84
11B	96B	96	92	100
13B	112B	112	108	116
15B	128B	128	124	132
17B	144B	144	140	148
19B	160B	160	156	164
21B	176B	176	172	180

Step 6: Using the balance adjustment, adjust the discriminator output voltage to 0.000 ±0.002 volts or to manufacturer's specification.

Step 7: Set signal generator frequency to upper bandedge (UBE).

Step 8: Using the bandedge adjustment, adjust the discriminator output voltage to +2.500 ±0.002 volts.

Step 9: Set the signal generator to lower bandedge (LBE).

Step 10: Measure the output voltage; should be -2.500 ±0.002 volts.

Step 11: Connect the voltmeter to the next discriminator channel.

Step 12: Repeat steps 5 through 12 until all channels are calibrated.

2.2.6.2 Charge Calibrator Setup.

The charge calibrator must be correctly setup with a signal generator to give the correct output. The purpose of the calibrator is to deliver the same charge, in picocoulombs, that an accelerometer would deliver at the g level of calibration. Thus for a calibration level of 2 g's peak, an accelerometer with 6.38 pC/g sensitivity must deliver (2 g)(6.38 pC/g) = 12.76 pC to the charge amplifier to represent 2 g's.

The Kistler Model 563A charge calibrator has a range switch and a vernier control. The vernier may be varied from 0.00 to 9.99 pC, and the range switch has decade choices from 0.1k to 1000k. These controls are used to set the

charge output for the sensitivity of the individual accelerometer being calibrated based on a 10-volt peak (7.071 volts rms) signal generator input. When a signal generator will not put out a 10 volt peak signal, it can be compensated with the range dial on the calibrator. Based on a 10-volt peak input signal, the picocoulomb dial is direct reading from 0 to 9.99 picocoulombs when the range switch is set to the 1k range. For a signal generator input of 1 volt peak, the vernier is direct reading when the range switch is set to 10k, for outputs of 0 to 9.99 pC. Table 6 below lists settings and signal generator inputs for various calibration levels.

Table 6: Kistler Charge Calibrator Control Settings

Calibration Level (g's)	Signal Generator Voltage		Accelerometer Charge Sensitivity (S)			
			0 to 10 pC/g		10 to 100 pC/g	
	P-P	rms	Range	Vernier	Range	Vernier
0.1	2.000	0.707	1K	S	10K	S/10
0.2	4.000	1.414	1K	S	10K	S/10
0.5	10.000	3.536	1K	S	10K	S/10
1	2.000	0.707	10K	S	100K	S/10
2	4.000	1.414	10K	S	100K	S/10
5	10.000	3.536	10K	S	100K	S/10
10	2.000	0.707	100K	S	1000K	S/10
20	4.000	1.414	100K	S	1000K	S/10
50	10.000	3.536	100K	S	1000K	S/10

2.2.6.3 FM Multiplex Output Adjustment.

It is recommended that the output of each MPX to a tape recorder be adjusted to assure each subcarrier in the MPX has adequate amplitude to produce an acceptable signal-to-noise (S/N) ratio, without overdriving the record electronics. Adjusting the output by the following steps allows a record level of approximately 300 millivolts per subcarrier to achieve that result.

Step 1: Apply power to the instrumentation system and test equipment, and allow the equipment to warm up while the test equipment is being cabled into the system.

Step 2: Obtain a degaussed test tape that is in good condition, and load it on the recorder.

Step 3: Connect a DVM between a multiplex output and the tape recorder input. The voltmeter must have a frequency response of 500 kHz or greater.

Step 4: Adjust the multiplex output to 1 V_{rms} for channel B MPX's or to 1.4 V_{rms} for channel A MPX's.

Step 5: Connect the spectrum analyzer in one of the FM multiplex lines to the tape recorder, using a tee connector.

Step 6: Use the following initial settings for the Model 7L5 spectrum analyzer:

Dot Frequency (Fine and Coarse): 240.000 kHz
Digital Storage: All Off
Resolution: 3 kHz
Frequency Span/Division: 50 kHz
Reference Level: Lin; 100 mV
Triggering: Free Run; Norm
Time/Division: 50 ms
Input Termin Z: 1 M Ω 20 pF
Input Ref: dBV.

Using the above settings it should be possible to identify each subcarrier and the reference oscillator. The amplitude of each subcarrier should be about 300 mV.

Step 7: Reconnect the spectrum analyzer to the tape recorder reproduce amplifier output for the same multiplex.

Step 8: Start the tape recorder in the record mode.

Step 9: Adjust the reproduce amplifier output to the same amplitude as on the input side of the recorder. For subcarrier oscillators with no individual adjustments, proceed to step 12.

NOTE: These multiplexers can usually be trimmed to have equal outputs by changing the internal pre-emphasis resistors as a permanent solution.

Step 10: For subcarrier oscillators with individual output amplitude adjustments, readjust the overall (summed) FM multiplex output until the least (including reference) is 300 mV.

Step 11: Adjust each subcarrier output to 300 mV, as seen at the tape reproduce output.

Step 12: Disconnect the spectrum analyzer and connect the DVM. It should read close to 1 volt rms for B channel subcarriers, or 1.4 volts rms for A channel subcarriers.

Step 13: Stop the tape recorder.

Step 14: Repeat steps (4) through (13) for each multiplex and tape

channel; it should not be necessary to readjust the reproduce amplifier for each channel.

Step 15: Remove the magnetic tape and degauss it for reuse.

2.2.6.4 Charge Amplifier Adjustments.

Obtain the system calibration sheets, the system schematics and a degaussed tape. Completion of the calibration sheets during the shop calibration is optional, but they are needed to provide the set levels for the charge calibrator and the output levels for the charge amplifiers. Care used in this shop procedure will save much time on the aircraft calibration, and will usually produce a much more organized and concise final calibration tape.

Step 1: Turn on the instrumentation system and the test equipment to allow warmup time while the tape is being loaded and the test equipment is being cabled.

Step 2: Cable the test equipment into the system as in Figure 5. Variations will occur from the figure, but should only amount to cable changes.

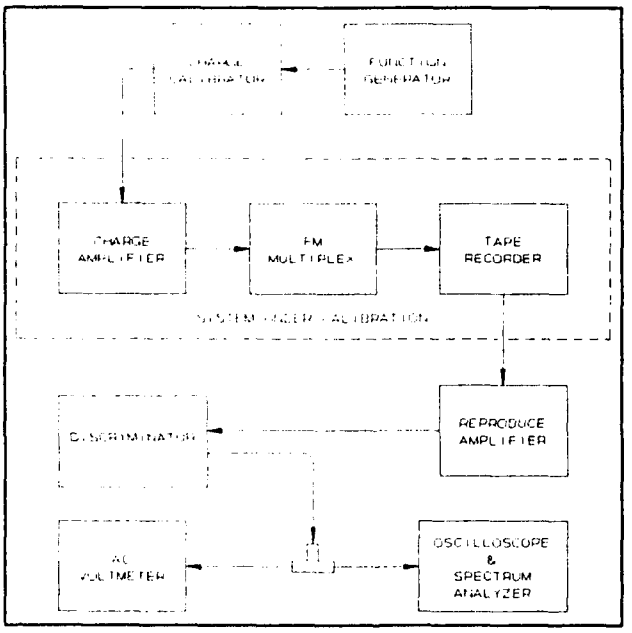


Figure 5: Calibration Cabling

Step 3: Install a degaussed tape in the tape recorder.

Step 4: Set the reproduce amp to the IRIG B tape channel and look at the output on the oscilloscope; the signal should be clean and undistorted.

Connect the output to a time code display and check that the display reads correctly.

Step 5: Use the g level from the calibration sheet and the procedure in 2.2.6.2 to set the signal generator and charge calibrator to proper levels for the first axis to be calibrated. Always work in the same order as the calibration sheet.

Step 6: Set the frequency on the signal generator to 100 Hz.

Step 7: Connect the charge calibrator output to the charge amp to be calibrated.

Step 8: Start the tape recorder and go to RECORD mode; the SYNC light should illuminate.

Step 9: Observe the signal from the tape reproduce amp on the DVM and on the oscilloscope.

Step 10: Adjust the charge amp output to obtain 1.414 volts rms on the DVM. This should be 4 volts p-p on the oscilloscope and should be a clean and undistorted sine wave, but the adjustment must always be made using the DVM.

Step 11: Turn off the tape recorder.

Step 12: Disconnect the signal input to the charge amp, and connect it to the next charge amp.

Step 13: Repeat steps 5 through 12 until all the charge amplifiers have been adjusted.

Step 14: Rewind the magnetic tape. The tape should be labeled and retained temporarily for future reference.

Step 15: Turn off the instrumentation system and test equipment; this concludes the shop calibration.

2.2.6.5 3 dB Low Frequency Cutoff Measurement.

There may be times when it is necessary to measure the -3 dB low frequency cutoff point of a system. Since AC voltmeters will not give a correct reading at low frequencies, the following method offers a means of finding the -3dB point. When used with a signal generator and charge calibrator it measures low frequency cutoff for the charge amplifier only; if used with the actual accelerometer and charge amp on a shake table, it provides the low frequency cutoff for the system. The procedure is the same in either case.

Step 1: Set up the system to provide 2.000 volts rms (2.828 volts peak) at 100 Hz output from the discriminator or charge amplifier, on a DVM.

Step 2: Monitor the same output with an oscilloscope. Set the oscilloscope for 0.5 Volts/Div sensitivity, and assure the vernier is in the calibrated detent. The oscilloscope input must be on DC coupling; it will attenuate low frequency signals if it is not.

Step 3: The trace on the oscilloscope will be over-ranged at 100 Hz. Decrease the frequency of the signal generator incrementally until the trace exactly fills the graticule of the oscilloscope, at 4 volts p-p or 2 volts peak. The reduction of a sine wave from X volts rms to X volts peak is a 3 dB drop. The frequency setting of the shake table or signal generator is the -3 dB cutoff.

2.2.7 System Installation.

The instrumentation system shall not be installed prior to scheduled aircraft maintenance; such maintenance shall be accomplished before instrumentation installation to prevent damage to instrumentation components and wiring. The interruption of testing for scheduled aircraft maintenance will usually require partial or complete recalibration of the instrumentation system.

2.2.7.1 Instrumentation system installation shall follow standard procedures for aircraft wiring with the exceptions for accelerometers and their cables as itemized below.

2.2.7.2 Accelerometer installation shall be nondestructive to the airframe and equipment without the express approval of the test director.

2.2.7.3 Accelerometer mounting pads shall be installed by maintenance personnel. All mounting pads shall be supplied to maintenance with complete instructions such as type, location and orientation.

2.2.7.4 Mounting pads shall be epoxied in place in most cases. Ciba-Geigy P/N RP 1257-0A (FSN 8030-00-891-3113) 2-part epoxy is recommended. Follow product instructions, but 24 hours minimum curing time at room temperature is recommended.

2.2.7.5 Accelerometers shall be installed by instrumentation personnel. Mounting screws shall be installed with a torque wrench to manufacturer's recommendation, or as indicated in table 4, page 15.

2.2.7.6 Accelerometer cables shall be secured with cable ties or clamps with maximum spacing of 30 cm (1 ft.) intervals.

2.2.8 System Calibration.

Prior to system calibration a complete schematic of the system shall be available for reference. A complete set of Helicopter Vibration Calibration Sheets (Figure C-3, App C) shall also be on hand, with the Accelerometer, Charge Amp and VCO columns completed. The following equipment, or equivalents, will be required to perform the system calibrations:

ITEM	NOMENCLATURE	MFR/MODEL
1	Oscilloscope, Dual Trace	Tektronix/465
2	Digital Voltmeter (DVM)	Hewlett Packard/3466A
3	Synthesizer/Function Generator	Hewlett Packard/3325A
4	Charge Calibrator	Kistler/563A
5	Discriminator Bank*	EMR/4150
6	Amplifier/Speaker	Radio Shack/277-1008
7	Intercom Headset	

*Requires channel selectors for FM multiplex channels to be tested.

2.2.8.1 Calibration Procedure.

This calibration procedure is critical and unforgiving; errors produced at this point will be carried through to data presentation. Exercise extreme care while following the calibration steps.

Step 1: Obtain a magnetic tape to record the calibration. A new tape is preferred, but a used tape known to be in good condition will suffice. Degauss both sides of the tape.

Step 2: Turn on the instrumentation system and the test equipment to allow warmup time while the tape is being loaded and the test equipment is being cabled.

Step 3: Cable the test equipment into the system as in Figure 5. Note that the discriminator must be connected to the output of the reproduce amplifier (not to the tape input) to generate a valid calibration tape.

Step 4: Install the calibration tape into the tape recorder.

Step 5: Connect the speaker/amp to the reproduce amp output, and select the tape channel for intercom/voice.

Step 6: Start the tape recorder and go to RECORD mode; the SYNC light should illuminate.

Step 7: Check for voice output on the tape, and annotate the tape as being the Cal Tape for project name and date. Annotate the tape each time that the "Tape is going off." Stop the tape.

Step 8: Set the reproduce amp to the IRIG B tape channel and look at the output on the oscilloscope; the signal should be clean and undistorted. Connect the output to a time code display and check that the display reads correctly. Stop the tape.

Step 9: Using table 6 on page 20 as a guide and the accelerometer sensitivity and calibration g level from the calibration sheet, set the signal generator output level, and the charge calibrator range and vernier for the first accelerometer axis to be calibrated. Always do each axis in the same order as the calibration sheet.

Step 10: Set the frequency on the signal generator to 100 Hz.

Step 11: Disconnect the accelerometer axis to be calibrated. Connect the charge calibrator output to the accelerometer cable at the accelerometer end.

Step 12: Connect the DVM and oscilloscope to the reproduce output. Set the tape reproduce channel to the correct tape channel for the MPX.

Step 13: Start the tape recorder, and record the start time on the calibration sheet.

Step 14: Annotate the tape for the accelerometer and axis being calibrated. Observe the signal on the DVM and on the oscilloscope*. Record the DVM reading on the cal sheet. Allow at least 30 seconds recording time before turning the tape off, and record the turnoff time on the cal sheet.

*The observed DVM reading should be as set in the shop calibration. If it is not, the circuit should be troubleshot and corrected from the record side of the system; do not record the troubleshooting on the calibration tape. Continue procedure when satisfactory.

Step 15: Reset the signal generator to sweep the frequency from 1 Hz to 1000 Hz. Set the time for LOG and 30 seconds; this will allow 10 seconds/decade.

Step 16: Start the tape. After the SYNC light appears, start the sweep. Enter the start time on the calibration sheet, and annotate the tape.

Step 17: After the sweep is completed, stop the tape.

Step 18: Disconnect the signal input to the accelerometer cable. Reconnect the cable to the accelerometer.

Step 19: Repeat steps 9 through 18 until all the accelerometers have been calibrated.

Step 20: Annotate the end of tape.

Step 21: Rewind the magnetic tape. The tape should be labeled and provided to data processing as soon as possible.

Step 22: Turn off the instrumentation system and test equipment. Return all aircraft cabling to flight configuration. This concludes the vibration system calibration.

2.2.8.2 The system should now be ready for airworthiness review and then EMI/EMC flight test.

3. REQUIRED TEST CONDITIONS.

Test conditions required for vibration testing are discussed elsewhere in this TOP or are weather related as discussed below.

3.1 Flying Weather.

Vibration testing shall not be conducted during adverse flying weather conditions unless there is a compelling reason for doing so, e.g., the weather is part of the test.

3.2 Rain/Humidity.

Rain and/or extremely high humidity may adversely affect performance of the instrumentation system, in particular magnetic tape handling and tape recorder performance. Testing in rain should be avoided if possible.

3.3 Wind.

Wind should not affect instrumentation system performance, but its effects may be present in the data.

3.4 Temperature.

Temperature should not affect instrumentation system performance, but extreme cold may require wiring system heaters for proper performance.

4. TEST PROCEDURES.

4.1 Flight Profile.

4.1.1 A Flight Profile Card/Sheet shall be prepared by the test director prior to each vibration test (example in Figure C-1, App C). The flight profile may include various combinations of the following:

(1) Engine start;
(2) Ground runup;
(3) In ground effects hover;
(4) Out of ground effects hover;
(5) Takeoff;
(6) Level flight;
(7) Normal flight maneuvers;
(8) Blade tracking;
(9) Autorotation;
(10) Landing.

Recording time is a necessary consideration for any test flight. Recording time shall be estimated for each maneuver and coordinated with the instrumentation engineer to assure all of a test can be completed on one tape.

4.2 Flight/Test Scheduling.

4.2.1 Flight/Test scheduling shall be done by the test director in coordination with flight operations, aircraft maintenance contractor, and the instrumentation engineer.

4.2.2 Instrumentation shall assign a technician to be responsible for system servicing and data handling for each scheduled test. It shall be the responsibility of the technician to secure magnetic tape for the test in a timely manner.

4.2.3 A preflight conference shall be scheduled by the test director before each test flight to rehearse the test with the flight crew, instrumentation, and data processing personnel. Any special data processing requirements should also be discussed at this time.

4.3 Preflight.

4.3.1 The instrumentation technician shall tend to the following duties at least 1 hr before flight:

a. Arrange for ground power to be available at the aircraft;

b. Label and degauss both sides of a new magnetic tape for the test.

c. Prepare to assist the aircraft preflight with the following tools/equipment:

(1) Flight tape;

(2) Tools for removing/installing tape recorder cover;

(3) Earplugs;

(4) Intercom headset.

4.3.2 The instrumentation technician shall tend to the following duties starting ½ hr before flight:

a. Apply ground power to the instrumentation system;

b. Set Julian (local) time on the time code generator;

c. Assure remote time display is working;

d. Load magnetic tape on tape recorder;

e. Run magnetic tape from remote control to assure RECORD and SYNC lights are working;

f. Maintain intercom contact with flight crew through ground power-to-aircraft power transfer and assure time does not reset during transfer;

g. Disconnect headset and leave area just before aircraft taxis.

4.4 Flight Test.

4.4.1 The pilot shall conduct the test maneuvers on the flight profile card in sequence, if possible. The instrumentation system operator shall perform the following iterations for each maneuver:

a. Start tape recorder about 30 seconds before each test maneuver;

b. Put voice annotation on tape after SYNC light comes on;

c. Annotate tape on maneuver completion, i.e., "Test complete; tape is going off."

Repeat the above steps for each test maneuver.

4.4.2 After all test maneuvers are completed or if test is aborted, stop recorder.

4.4.3 Rewind the tape. After tape stops and the READY light is on, rewind tape again. This will allow tape removal if ground power is unavailable.

4.5 Postflight.

4.5.1 The completed flight profile card shall be given to the instrumentation technician after the mission is complete.

4.5.2 The instrumentation technician shall remove the magnetic tape, replace the tape recorder cover, and secure the instrumentation system.

4.5.3 The instrumentation technician shall deliver the flight test tape and the flight profile card for data processing.

5. DATA REQUIRED.

The data required may be separated into two categories: Data required for processing (raw data) and data required for a final report.

5.1 Data Required for Processing.

a. Accelerometer identification by Model No., Serial No., location and orientation;

b. Calibration sheets;

c. Calibration tape;

d. Flight data tapes;

e. Flight profile cards.

5.2 Data Required for Final Report. As determined by project requirements, to include presentation of processed data.

6. PRESENTATION OF DATA.

Vibration data is usually presented as variations of frequency spectra vs. vibration amplitude, such as power spectral density (PSD) plots. There are several commercially available software packages that offer special zoom features, etc. These packages are installed in most data processing facilities, and data be can presented as plots of raw, averaged, or smoothed routines that best suit the needs of the customer.

APPENDIX A

VIBRATION SYMBOLS, EQUATIONS and TABLES

$$G = \text{acceleration in gravitational } (g) \text{ units} = \frac{\text{acceleration}}{g} \tag{A-1}$$

$$d_0 = \text{peak displacement} \tag{A-2}$$

$$D = 2d_0 = \text{peak-to-peak displacement} \tag{A-3}$$

$$V_0 = \text{peak velocity} \tag{A-4}$$

$$D = \frac{V_0}{2\pi f} \tag{A-5}$$

$$d = d_0 \sin(2\pi f t) \tag{A-6}$$

$$v = d_0 (2\pi f) \cos(2\pi f t) \tag{A-7}$$

$$a = -d_0 (2\pi f)^2 \sin(2\pi f t) \tag{A-8}$$

$$f_{MIN} = \sqrt{\frac{(G_{PEAK})(386.09)}{2D_{MAX}\pi^2}}, \text{ for maximum table displacement} \tag{A-9}$$

$$f_{MIN} = 5.11\sqrt{G_{PEAK}} \text{ for } D_{MAX} = 0.750 \text{ inch} \tag{A-10}$$

$$\text{For sinusoids only: rms value} = 0.707 \times \text{peak value} \tag{A-11}$$

$$\text{rms value of } n \text{ summed sinusoids} = \sum_{i=1}^{n} \frac{e_{i(rms)}}{\sqrt{n}} \tag{A-12}$$

Table A-1: Rotor Frequencies at 100 per cent revolutions per minute (RPM)

AIRCRAFT TYPE	MAIN ROTOR		TAIL ROTOR	
	PRIMARY FREQUENCY (HERTZ)	BLADE FREQUENCY (HERTZ)	PRIMARY FREQUENCY (HERTZ)	BLADE FREQUENCY (HERTZ)
AH-1G	5.40	10.80	27.50	55.00
AH-64	4.82	19.27	23.33	93.33
CH-3	3.38	16.92	20.72	103.60
CH-47C (METAL BLADE)	3.92	11.75	3.92	11.75
CH-47C (FIBERGLASS)	3.75	11.25	3.75	11.25
CH-47D (FIBERGLASS)	3.75	11.25	3.75	11.25
CH-54	3.70	18.50	14.10	56.40
OH-6A	7.98	31.90	51.30	102.60
OH-8	8.20	41.00	49.00	98.00
OH-58A	5.90	11.80	37.50	75.00
OH-58C	5.90	11.80	37.50	75.00
OH-58D	6.57	26.27	39.68	79.37
UH-1	5.40	10.80	27.50	55.00
UH-60	4.30	17.20	19.83	79.33
500MD	8.20	41.00	49.00	98.00

APPENDIX B

GROUNDING TECHNIQUES

The importance of proper grounding cannot be overemphasized in vibration measurement. Aircraft wiring is inherently an electrically noisy environment, and once noise is added to the signal from an accelerometer there is no means to distinguish between acceleration and noise. Any amplification from charge amplifiers and signal conditioners will amplify the in-band noise the same as acceleration signals. It is therefore necessary to use any means available to suppress noise throughout the system, but this is especially true before any amplification of the signal.

The circuits of Figure B-1 and B-2 on the following pages were selected to illustrate some commonly encountered grounding and shielding problems. Both circuits use identical components; only the wiring and potential spacing of components differ.

The accelerometer in the illustrations has the shield of the X-axis internally connected to the accelerometer case for electrostatic shielding; the Y and Z axes are isolated from the case. Accelerometers may or may not use the case as signal common, depending on the model. This particular connection is used here because it illustrates both configurations. Since instrumentation systems are temporary installations, it is usually undesirable to drill the test bed to mount an accelerometer, and the accelerometer is commonly mounted to a machined mounting pad and epoxied in place. The accelerometer is, therefore, usually not grounded locally regardless of internal connections.

The charge amplifiers in the illustrations use a coaxial input to a single-ended amplifier, with the coaxial shield connected to signal ground but not connected to case ground. The case is usually grounded through mounting, but may alternatively be grounded through the output connector. The case (pin E) should be connected to signal ground only if it is not in contact with aircraft ground; it should not be connected if the case is aircraft ground.

The FM multiplex has connections for chassis (case) ground and for power/signal ground on the external connector; however, they are internally connected. This is a very real situation, in that FM multiplexers in common usage are internally wired that way. Since the signals at the multiplex are relatively large signals, the internal ground connection is not necessarily a problem if care is used in the input circuit design.

Placement of accelerometers is seldom a matter of choice, due to specific parameters to be measured. Placement of an instrumentation rack of equipment is usually very limited, due to size and space requirements. These restrictions will often result in some cables being quite long and others

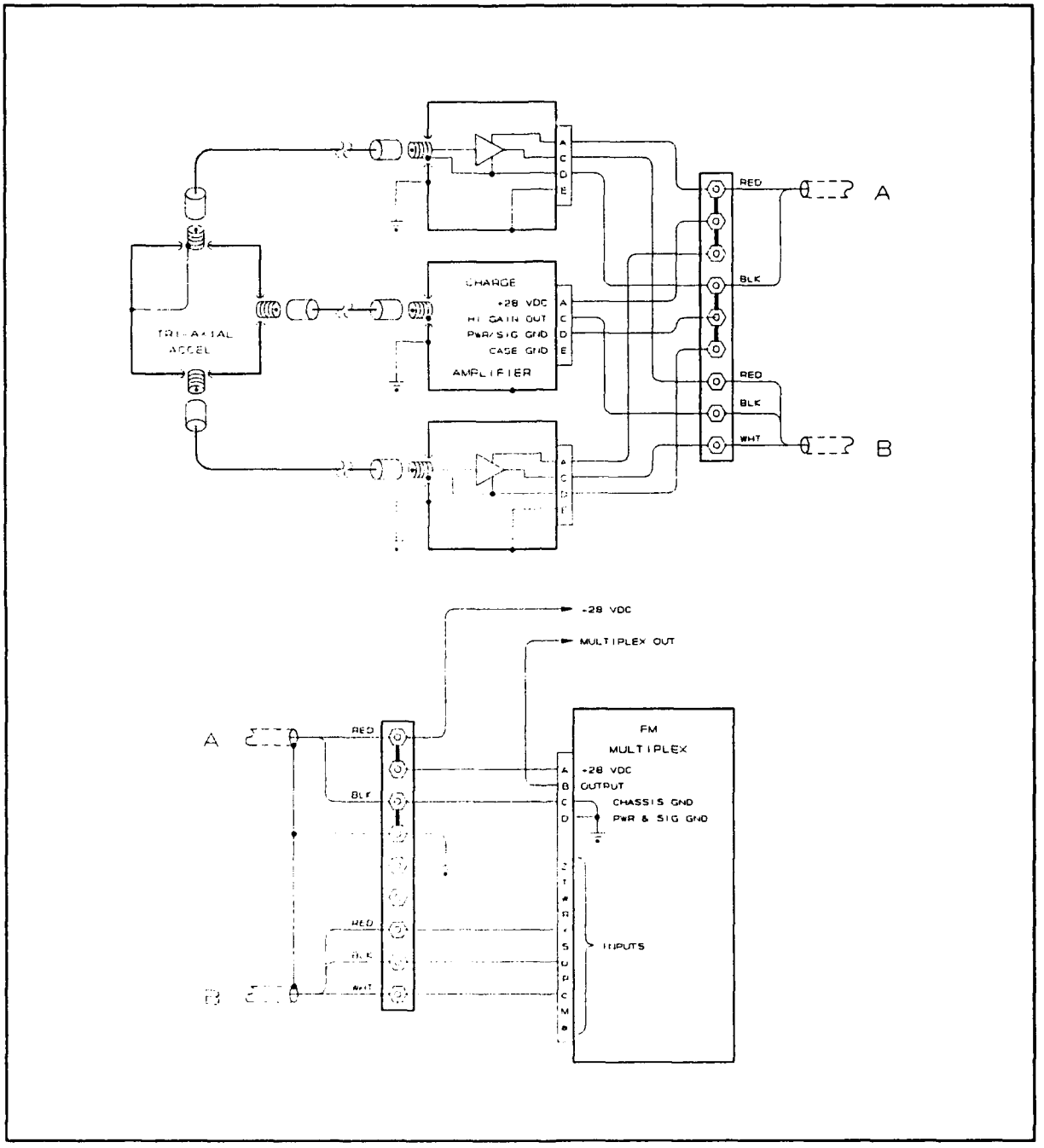


Figure B-1. Charge Amp Connections - Example 1

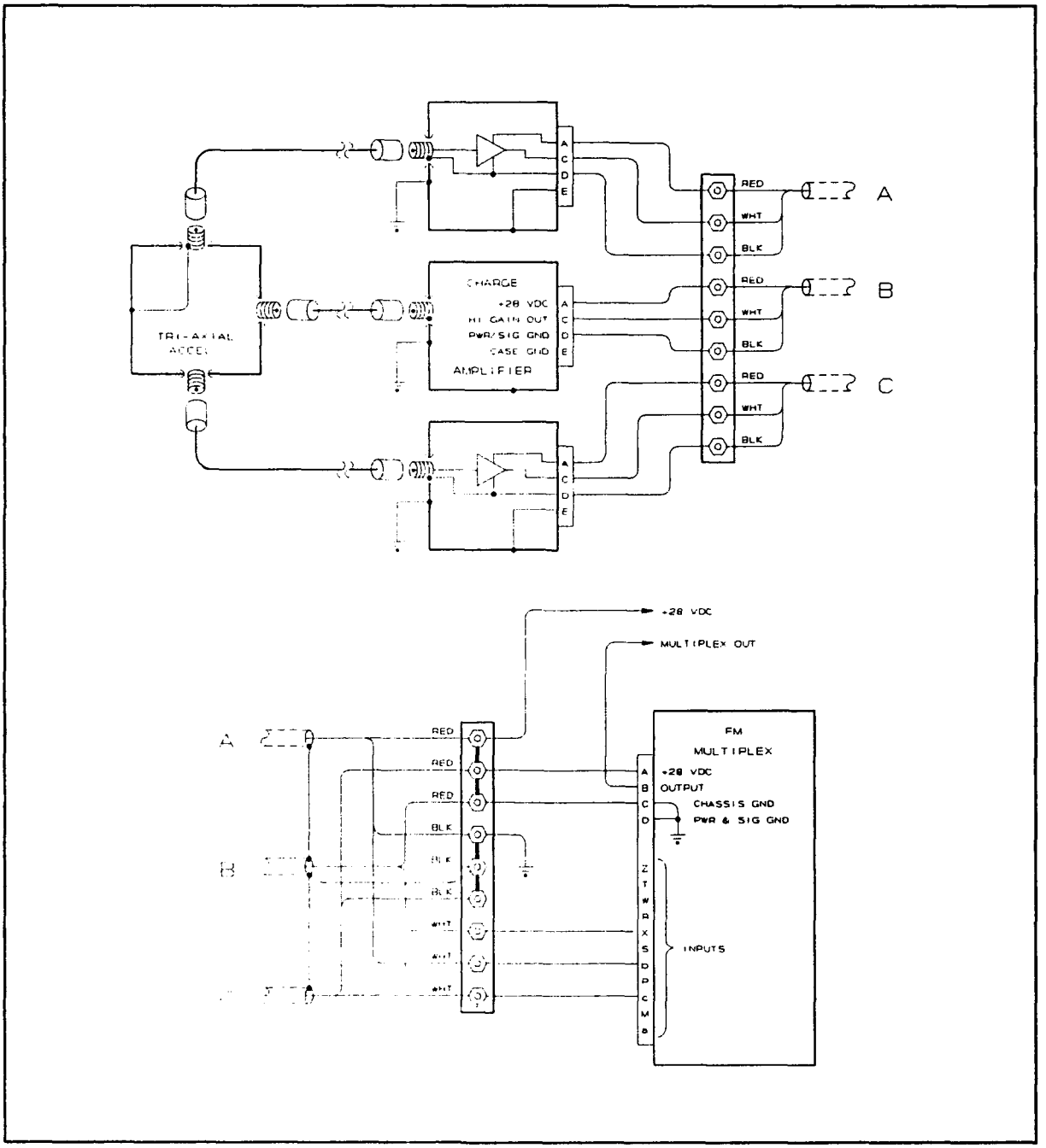


Figure B-2. Charge Amp Connections - Example 2

short. The problem is to make proper choices to keep system noise at a minimum.

The circuits of Figures B-1 and 2 are both satisfactory connections but B-1 is easier to wire and takes less aircraft cabling. The coaxial cables connecting the axes of the accelerometer to the charge amplifiers are carrying very small signals, and should be kept very short. Signal current flows in both center conductor and shield for these cables; a bad connection of a shield totally disables the axis.

The shielded pair A and triplet B of Figure B-1 and shielded triplets A, B, and C of Figure B-2 carry power, power and signal ground, and signal. These are electrically large signals and small currents, and the cables can be relatively long without seriously affecting signal quality. Both circuits refer all grounding and signals to a point near the FM multiplexer. The charge amplifiers have single-ended inputs, so it is imperative they have the same ground as the multiplexer.

APPENDIX C

DATA COLLECTION SHEETS

OH-58D FLIGHT DATA CARD
WHOLE-BODY VIBRATION TEST XO-314

Aircraft SN: _____ Date: _____
PIC: _____ Phone: _____
T/O GW: _____ OAT: _____ PA: _____

Prior to start of each flight maneuver the instrumentation recorder will be turned on. After completion of each maneuver the instrumentation recorder will be turned off.

1. VMC Takeoff
2. Climb at 500 ft/min to 800 ft AGL
3. Straight and Level 60 KIAS for 5 Min
4. Straight and Level 100 KIAS for 5 Min
5. Straight and Level Vne _____ KIAS _____ Min
6. 15 Degree Left Bank for 360 Degrees at 100 KIAS
7. 15 Degree Right Bank for 360 Degrees at 100 KIAS
8. 30 Degree Left Bank for 360 Degrees at 100 KIAS
9. 30 Degree Right Bank for 360 Degrees at 100 KIAS
10. Left Sideways Flight for Length of Runway at Highfalls
11. Right Sideways Flight for Length of Runway at Highfalls
12. Hover In-Ground Effect for 3 Min
13. Hover Out-Ground Effect for 3 Min
14. Rear Flight for Length of Runway at Highfalls
15. VMC Approach
16. NOE Flight (SP1 to RP2)

Figure C-1: Typical Flight Profile Card (Example)

VIBRATION MEASUREMENT PLANNING WORKSHEET

PROJECT_____ DATE :_____
AIRCRAFT TYPE_____ TEST DIRECTOR/ENGINEER_____

LOCATION NO.	NO. AXES	FREQUENCY		PEAK G's	LOCATION DESCRIPTION
		MIN	MAX		

Figure C-2. Planning Worksheet.

HELICOPTER VIBRATION CALIBRATION SHEET

SHEET___OF___

PROJECT NAME:_____
PROJECT No.:_____
AIRCRAFT TYPE:_____
AIRCRAFT NO.:_____

TAPE RECORDER TYPE:_____
TAPE RECORDER S/N:_____
TAPE RECORDER SPEED:_____
TAPE RECORDER TIME TRACK:_____

CALIB. TAPE NO.:_____
CALIBRATION DATE:_____
ENGINEER:_____
CALIBRATED BY:_____

ACCELEROMETER				CHARGE AMP	VCO		TAPE RECORDER								DISC OUTPUT (V_{rms})
ID NO	IDENT. & SENSI-TIVITY (pC/g)	LOCATION: BUTTLINE WATERLINE FUSELAGE STATION	AXIS ORIEN-TATION: UP,DWN, RT,LFT, FWD,AFT	SERIAL NO. ------ g's @ 100 Hz / SWEEP 1 Hz TO 1 kHz	BLK NO.	IRIG CHAN NO.	TRK NO.	START TIME HR	START TIME MIN	START TIME SEC	OUTPUT (V_{rms})	STOP TIME HR	STOP TIME MIN	STOP TIME SEC	
	MOD_____ S/N_____ AXIS_____ SENS_____	BL_____ WL_____ FS_____		S/N:_____ g's:_____ / SWEEP TIMES											
	MOD_____ S/N_____ AXIS_____ SENS_____	BL_____ WL_____ FS_____		S/N:_____ g's:_____ / SWEEP TIMES											
	MOD_____ S/N_____ AXIS_____ SENS_____	BL_____ WL_____ FS_____		S/N:_____ g's:_____ / SWEEP TIMES											
	MOD_____ S/N_____ AXIS_____ SENS_____	BL_____ WL_____ FS_____		S/N:_____ g's:_____ / SWEEP TIMES											
	MOD_____ S/N_____ AXIS_____ SENS_____	BL_____ WL_____ FS_____		S/N:_____ g's:_____ / SWEEP TIMES											

Figure C-3: Helicopter Vibration Calibration Sheet

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APPENDIX D. REFERENCES

1. MIL-STD-810E with Change Notice 2 (1 September 1993)*, Environmental Test Methods and Engineering Guidelines, 14 July 1989.

2. IRIG STANDARD 106-86, Telemetry Standards, May 1986 (Revised September 1989).

3. IRIG DOCUMENT 118-79, Test Methods for Telemetry Systems and Subsystems, Volume III, Test Methods for Recorder/Reproducer Systems and Magnetic Tape.

REFERENCES FOR INFORMATION ONLY

a. AMCP 706-201, Engineering Design Handbook, Helicopter Engineering, Part One, Preliminary Design, August 1974.

b. TP000044, Telemetry Applications Handbook, E. 1. Law and D. R. Hust, Pacific Missile Test Center, September 1987.

*Change Notice 2 has very significant changes regarding helicopters (Method 514.4) and helicopter guns (Method 519.4).

TOP 7-3-531
26 August 1994

Forward comments, recommended changes, or any pertinent data which may be of use in improving this publication to Commander, U.S. Army Test and Evaluation Command, ATTN: AMSTE-CT-T, Aberdeen Proving Ground, MD 21005-5055. Phone: (410) 278-1486, DSN: 298-1486 and EMAIL: amstectt@apg-9.apg.Army.mil. Technical information may be obtained from the preparing activity: Commander, U.S. Army Aviation Technical Test Center, ATTN: STEAT-TS-D, Fort Rucker, AL 36362-5276. Phone: (205) 255-8226, DSN 558-8226 and EMAIL: steattsd@rucker-emhl.Army.mil. Additional copies are available from the Defense Technical Information Center, Cameron Station, Alexandria, VA 22304-6145. This document is identified by the accession number (AD No.) printed on the first page.