11 March 1968

Materiel Test Procedure 5-2-532
White Sands Missile Range

U. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

COMPUTERS (ELECTRONIC)

1. OBJECTIVE

The objective of this MTP is to describe the procedures required to provide a basis for analyzing the computer characteristics which in turn will determine the applicability of the equipment to the intended usage.

2. BACKGROUND

Advances in the electronics industry have resulted in many varied applications of missileborn electronic computing equipment. Computer units may consist of simple, resistor type mixing circuits or may include a complex analog system with associated timers, limiters, demodulators, and other devices.

Although the computing equipment will vary in physical size, structure and complexity, it is the intent of this Materiel Test Procedure to provide the necessary information which will serve as a guide for performing a laboratory evaluation.

The material contained in this MTP is the result of engineering knowledge and experience gained by previous evaluations of computer equipment at the WSMR Guidance and Control Laboratory.

Final acceptance of the equipment will depend on its ability to function in accordance with predetermined specifications.

3. REQUIRED EQUIPMENT

a. Function Generator (capable of delivering triangular, size, and squarewave forms variable from 0.01 to 100 cps)
b. Sweep Drive Unit
c. X-Y Plotter
d. Direct Writing Recorder (dual-channel input and capable of a flat response from direct current to 100 cps)
e. Vacuum Tube Voltmeters (equipped with output terminals and capable of metering alternating and direct current voltages)
f. Frequency Meter (with output terminals)
g. Phase Meter (with output terminals)
h. Time Interval Counter (to include power source capable of providing start and stop signals)
i. Triggering Device (electrical and mechanical)
j. Dual Trace Oscilloscope
k. Signal Generators
l. Wave Analyzer
m. Distortion Analyzer

n. Phase Shift Network
o. Power Supplies, AC and DC
p. Components (two-position switch, single-pole double-throw switch, decade box, potentiometer)

4. REFERENCES

A. Murray, Francis J., Analog Devices, Mathematical Machines, Volume II, Columbia University Press, New York, 1961
B. Kitov, A. I., and Krinitskii, N. A., Electronic Computers, International Series of Monographs on Electronics and Instrumentation, Vol. 13, The McMillan Company, New York, 1962.
C. Korn, Granino, A., Ph.D. and Korn, Theresa, M., M. S., Electronic Analog Computers (D-C Analog Computers), Second Edition, McGraw-Hill Book Company, Inc., New York, 1956.
D. Ivall, T. E., Electronic Computers, Principles and Applications, New York, Philosophical Library, 1957.

5. SCOPE

5.1 SUMMARY

This MTP describes the procedures required to determine the applicability of missileborne electronic computers to the intended usage.

The tests shall be performed in a laboratory under normal room ambient conditions unless applicable specifications direct otherwise. In the case where testing under other environmental conditions is required, it will be necessary to obtain those MTP's or military documents (MIL-E-5272 or MIL-STD-810, USAF) that include the specifications for the subject requirements.

The specific tests to be made, plus a brief description of the circuit characteristics, are listed below:

a. Composite Tests - Composite tests provide for an analysis of an analog computer system. The system characteristics that will be determined are linearity, response time (amplitude, phase, and transient) stability, etc.
b. Limiter Tests - Limiter circuits are tested to determine the limiter slope and limiting voltage. Tests to determine the limiting action and repeatability accuracy are included.
c. Timer Tests - Time delay devices are tested to assure accurate time interval control. Reset capability tests are included for timers that are required to perform consecutive functions.
d. Integrator Tests - Integrators are tested to permit an analysis of the circuit sensitivity, frequency response, linearity and response time, and stability characteristics.
e. Differentiator Tests - Differentiators are tested to permit an analysis of the circuit sensitivity, frequency response, linearity and response time, and stability characteristics.

f. Control Amplifier Tests - Control amplifier tests provide for an analysis of the circuit sensitivity and gain, frequency response, stability, and harmonic distortion characteristics. A separate test is included for magnetic amplifiers.

g. Comparator Tests - Comparators are tested to provide for an analysis of the circuit sensitivity and linearity, output versus frequency, output versus phase, and stability and null characteristics.

h. Mixer Tests - Mixer circuits are tested to provide for an analysis of the circuit amplitude, harmonic distortion, intermodulation distortion, and phase characteristics.

5.2 LIMITATIONS

The tests described in this MTP are limited to missileborne analog computers. The extent of coverage is limited to tests that are required for a laboratory evaluation where simulated circuit input signals and loads will be used.

6. PROCEUDRES

6.1 PREPARATION FOR TEST

a. Select test equipment having an accuracy of at least 10 times greater than that of the function to be tested.

b. Record the following information:

1) Nomemclature, serial number(s), and manufacturer's name of test item(s)
2) Nomenclature, serial number, accuracy tolerances, calibration requirements, and last date calibrated of the electronic test equipment selected for the tests

c. Ensure that all test personnel are familiar with the required technical and operational characteristics of the item under test, such as stipulated in Qualitative Materiel Requirements (QMR), Small Development Requirements (SDR), and Technical Characteristics (TC).

d. Review all instructional material issued with the test item by the manufacturer, contractor, or government, as well as reports of previous tests conducted on the same types of equipment, and familiarize all test personnel with the contents of such documents. These documents shall be kept readily available for reference.

e. Thoroughly inspect the test item for obvious physical and electrical defects such as cracked or broken parts, loose connections, bare or broken wires, loose assemblies, bent relay and switch springs, and corroded plugs and jacks. All defects shall be noted and corrected before proceeding with the test. Ensure that the test item conforms to the specified size and weight requirements.

f. Subject all circuits of the test item to a continuity test to determine that circuit inpedances are as intended and that no damage will result when power is applied. Malfunctions shall be noted and corrected.

g. Prepare record froms for systematic entry of data, chronology of test, and analysis in final evaluation.

h. Assure that qualified safety personnel maintain a continuous observation of the test item through the entire test period to include unsafe conditions or practices related to the use of the test item.

i. After power is applied, adjust the supply for correct voltage and allow sufficient warmup time for stable operation.

6.2 TEST CONDUCT

6.2.1 Composite Tests

NOTE: The tests required to perform an analysis of the various channels of a computer are often identical (such as the tests for yaw, roll, and pitch channels). The tests described here-in will apply to a single channel. Repeat the tests, as necessary when more than one channel is involved.

6.2.1.1 Linearity Test

a. Connect a function generator, a sweep drive unit, a power supply, an X-Y plotter, a direct writing recorder, and a switch to the computer under test as shown in Figure 1.

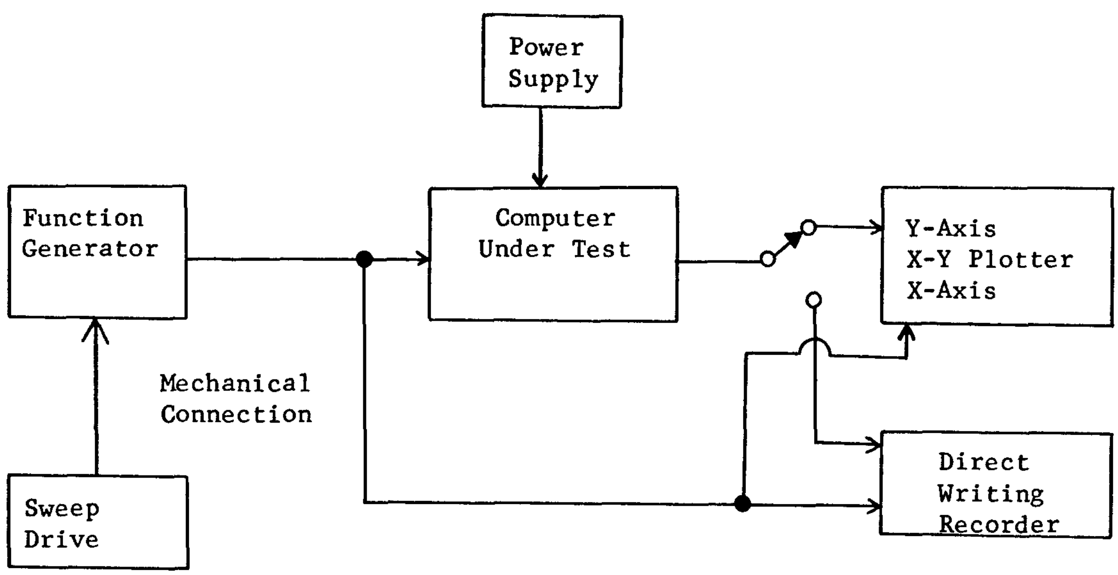


Figure 1. Typical Linearity Test Configuration

b. Apply equipment power and adjust the function generator for a triangular wave output capable of driving the unit under test from cutoff to saturation, or limiting, at a frequency of 0.01 cps.

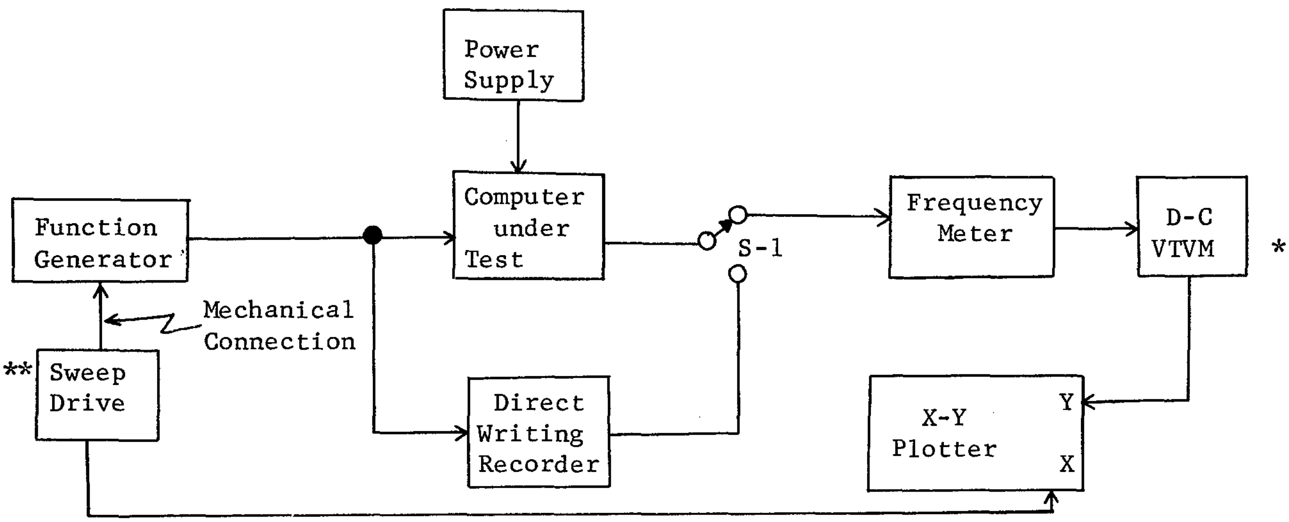
CAUTION: Do not overdrive the circuit, since damage could result

c. Adjust the plotter for a satisfactory display. Indicate the zero volt position on both the X-and Y-axis and record a sufficient amount of the output signal to permit determination of the unit linearity, limiting action, and balance with zero input (refer to the applicable specifications, if necessary).

d. If difficulties are encountered (e.g. adequate coverage of the frequency range, etc.), switch the output to the direct writing recorder and repeat the test.

6.2.1.2 Frequency Response, Amplitude Test

a. Connect a function generator, a sweep drive unit, a power supply, a direct writing recorder, a switch, a frequency meter, an X-Y plotter, and a vacuum tube voltmeter to the computer under test as shown in Figure 2.



* Used to smooth ripple
** Check for slippage

Figure 2. Typical Frequency Response, Amplitude Test Configuration

b. Apply equipment power and adjust the function generator for a sine wave output at a level just below the limiting point of the unit under test.

c. While the sweep drive and function generator are varied to provide a sweep frequency from 0.008 to 10 cps, adjust the recorder for an adequate display and record the output of the test unit. The recording must be of sufficient quality to permit determination of the unit frequency response.

d. Switch the output to the X-Y plotter. Vary the sweep drive and function generator to provide a sine wave frequency from 8 to 100 cps.

e. Adjust the X-Y plotter for an adequate display and record the output.

6.2.1.3 Frequency Response, Phase Test

a. Connect a function generator, a sweep drive unit, a power supply, a phase meter, a vacuum tube voltmeter, and an X-Y plotter to the computer under test as shown in Figure 3.

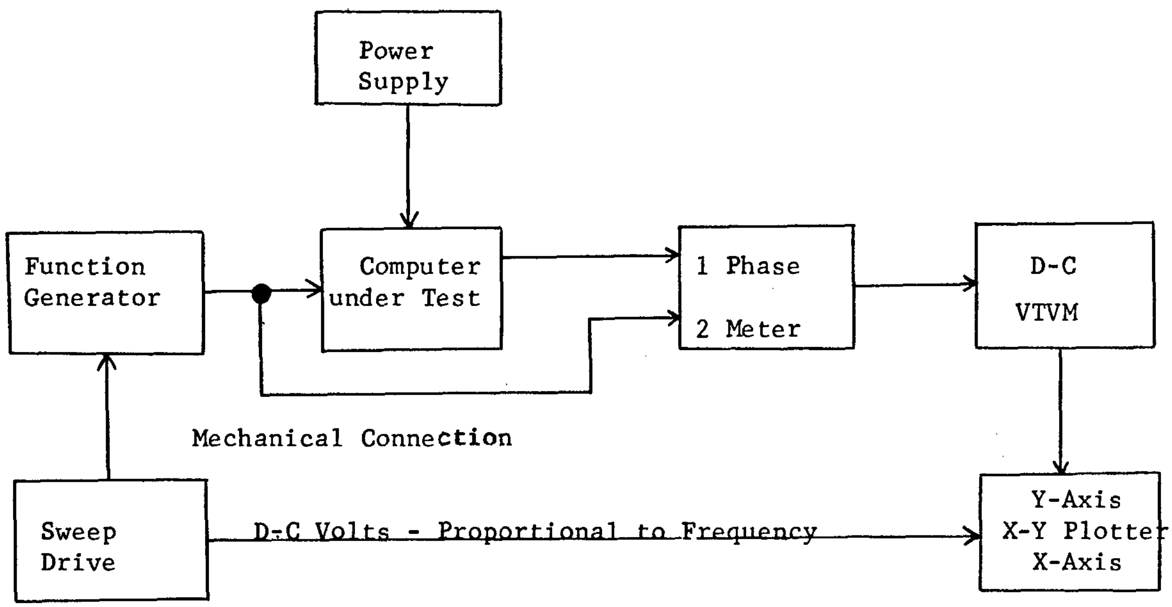


Figure 3. Typical Frequency Response, Phase Test Configuration

b. Apply equipment power and adjust the fjunction generator and sweep drive unit for a sine wave sweep frequency from 7 to 100 cps at a level sufficient to operate the unit under test without overdriving.

c. Adjust the X-axis of the plotter for an adequate display with the d-c output from the sweep drive unit applied. Adjust the X-axis for an adequate display with an input phase shift from zero to 180 degrees.

d. Record the output of the unit under test while applying an input sine wave sweep frequency from 7 to 100 cps.

6.2.1.4 Transient Response Test

a. Connect a function generator, a power supply, and a direct writing recorder to the computer under test as shown in Figure 4.

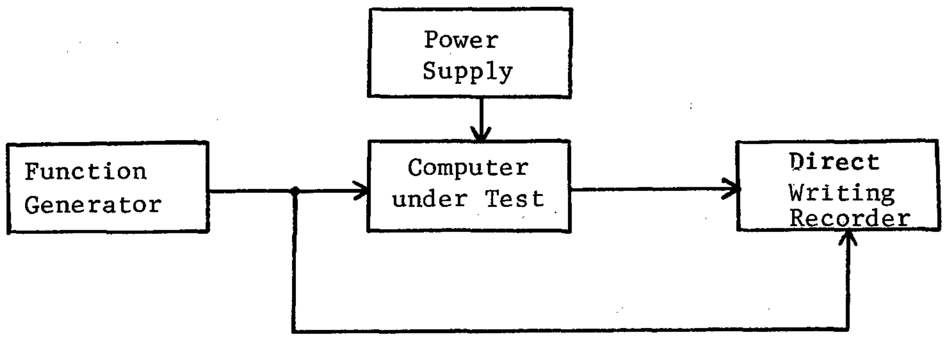


Figure 4. Typical Transient Response Test Configuration

b. Apply equipment power and adjust the function generator for a square wave output frequency of 0.5 cps at a level sufficient to operate the unit under test without overdriving.

c. Adjust the recorder to obtain equal deflection on both channels and record the input and output signals of the unit under test. The recording should be of sufficient quality to show the unit response time, stability, and gain characteristics.

6.2.2 Limiter Tests

NOTE: All of the described tests for limiters can be performed with the equipment connected in a manner similar to that shown in Figure 5.

6.2.2.1 Limiting Action Test

a. Connect a function generator and an X-Y plotter to the limiter under test as shown in Figure 5.

b. Apply equipment power (when required) and adjust the function generator for a triangular wave output frequency of 0.1 cps at a level 10 percent above that of the limiter threshold voltage.

CAUTION: Do not exceed the limiting voltage by more than 10 percent since circuit damage could result.

c. Adjust the plotter for adequate display. The Y-axis of the plotter should be calibrated in volts per division. The zero output level, of the unit under test, should be located at the center of the Y-axis range.

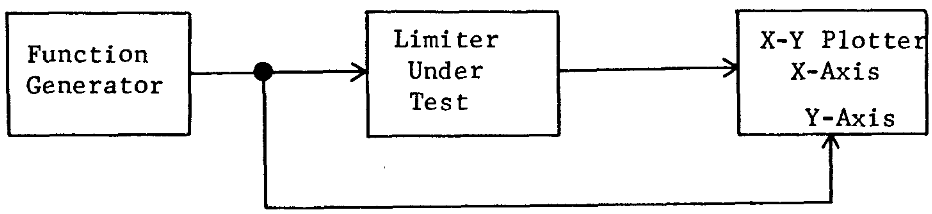


Figure 5. Typical Limiter Test Configuration

d. Record one cycle of the circuit operation. The recording should be of sufficient quality to show linearity and limiting characteristics. Ideal limiter characteristics are shown in Figure 6.

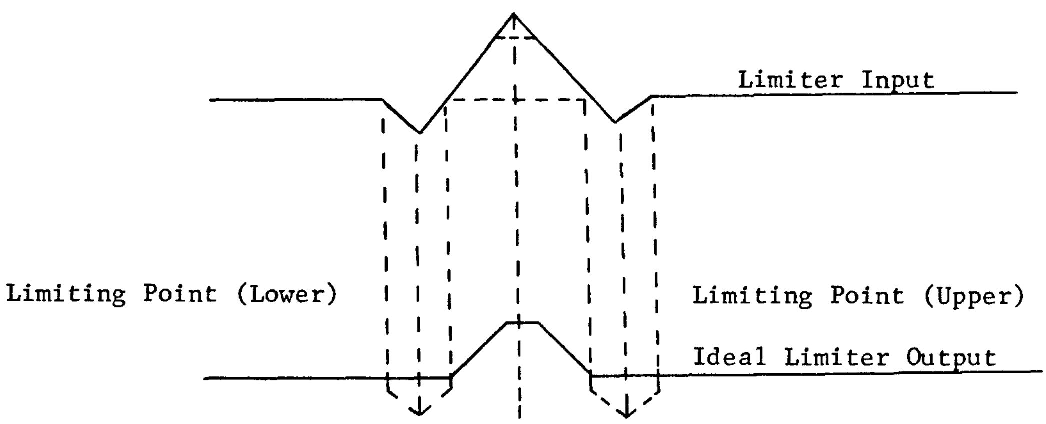


Figure 6. Ideal Limiter Waveform Characteristics

6.2.2.2 Repeatability Test

a. Leave the equipment connected as in Figure 5, and the X-Y plotter settings remaining as in step (c) of paragraph 6.2.2.1, above and increase the function generator output frequency to 0.5 cps.

b. Record five consecutive cycles of the limiter output signal (preferably, one on top of the other).

6.2.3 Timer Tests

NOTE: All of the described tests for timers will be performed with equipment connected as shown in Figure 7.

6.2.3.1 Time Interval Accuracy and Repeatability Test

a. Connect a triggering device, a switch, a power supply, and a time interval counter to the timer under test as shown in Figure 7.

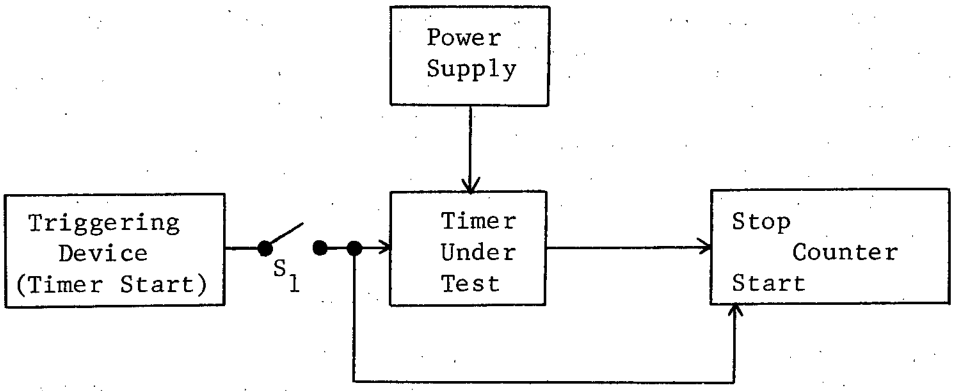


Figure 7. Typical Time Interval Accuracy and Repeatability Test Configuration

b. Apply equipment power and adjust the counter for proper operation.

(NOTE: A requirement for this test is that the start and stop pulses must be applied at precisely the same time that the timer starts and stops. If the timer energizing source does not supply start pulses capable of activating the interval counter, it may be necessary to replace S-1 with a double-pole, single-throw switch through which a separate timer start pulse can be supplied. It may also be necessary to supply a voltage to the timer contacts to produce a stop pulse capable of activating the interval counter). When the timer stops, record the time interval on a suitable data form.

c. Repeat the timer's operating cycle until a minimum of ten interval recordings are obtained. Calculate and record the average time interval on a suitable data form.

6.2.3.2 Reset Time Interval Test

NOTE: This test is only required for timers that are automatically reset. The start pulse to the counter must occur when the timer contacts close at the end of a time interval. The stop pulse to the counter must occur when the timer contacts open to signify that the timer has reset.

a. Connect the timer as shown in Figure 7, apply equipment power, and adjust the timer for proper operation.

b. Allow the timer to complete one cycle (the end of the cycle is considered to be the time when the contacts reopen). Record the time indicated on the interval counter on a suitable data form.

c. Repeat the operating cycle until a minimum of ten reset intervals are recorded. Calculate and record the average time interval on a suitable data form.

6.2.3.3 Accuracy Versus Input Voltage Variation Test

NOTE: This test is only required when the timer uses on electrical power source. The power source will be varied, in one-percent increments, five percent above and five percent below the specified levels.

a. Connect the timer, and its power source, as shown in Figure 7. Apply power and adjust the timer for proper operation.

b. Repeat the test described in paragraph 6.2.3.1 (and when applicable, 6.2.3.2) a minimum of ten times varying the timer power source five percent above and five percent below its specified voltage level, in increments of one-percent for each test run.

c. Obtain a separate recording for each run of 6.2.3.1 and/or 6.2.3.2. The recordings should show the percent average deviation and the percent maximum deviation versus the percent change in power level.

6.2.4 Integrator Tests

NOTE: All tests required to evaluate integrator circuits shall be performed with the equipment connected as shown in Figure 8.

6.2.4.1 Sensitivity Test

a. Connect a power supply, a function generator, a direct writing recorder, and a dual-beam oscilloscope to the integrator under test as shown in Figure 8.

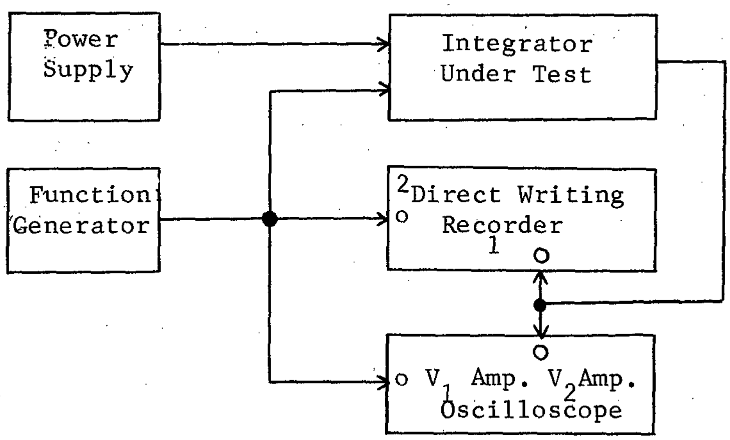


Figure 8. Typical Integrator Test Configuration

b. Determine the frequency and amplitude range of the integrator under test from the manufacturer's specifications. Apply equipment power and adjust the function generator to produce a square wave output at a frequency which is within the range of the integrator.

c. Adjust the recorder for a satisfactory display of the integrator input and output signals.

d. Starting with the square wave input at zero, slowly increase the amplitude of the function generator until a triangular output with linear sides is recorded. Determine the minimum input signal that will produce a linear output.

e. Measure the input signal level with the oscilloscope and record this value as the integrator sensitivity on a suitable data form.

6.2.4.2 Frequency Response Test

a. With the integrator connected as shown in Figure 8, apply equipment power and adjust the function generator to produce a sine wave output of the proper amplitude to serve as the input to the integrator. (It is important that this amplitude remain constant throughout the test performance).

CAUTION: Do not overdrive the integrator circuit.

b. Adjust the sensivity of the recorder to produce a full scale deflect through the entire frequency range.

c. Decrease the function generator frequency to the lower cut-off frequency of the integrator and record, at slow speed, a brief period of the integrator input and output signals.

d. Increase the function generator frequency to the higher cut-off frequency of the integrator and record as in step (c) above.

e. Connect a sweep drive unit to the function generator and adjust the sweep drive so that the integrator frequency range is slightly over-lapped at both limits.

f. Record the output. (A sine wave input to the integrator should produce a cosine wave output of constant amplitude within the specified frequency tolerances).

g. Disconnect the sweep drive unit from the function generator.

6.2.4.3 Linearity and Response Time Test

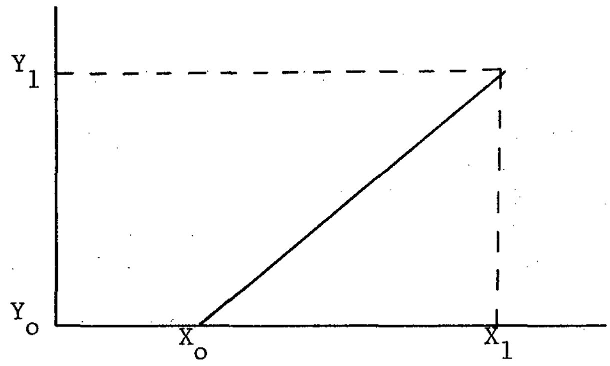
a. With the integrator connected as shown in Figure 8, apply equipment power and adjust the function generator for a square wave output at the mid-frequency range (as determined in 6.2.4.2). Adjust the amplitude of this frequency to one-third of maximum.

b. Adjust the recorder for one-third of full scale deflection and record at high speed, at least four cycles of the integrator input and output signals.

c. Adjust the frequency amplitude and the recorder for two-thirds of maximum input and record as in step (b) above.

d. Adjust the frequency amplitude for maximum input and the recorder for full scale deflection and record as in step (b) above.

e. Determine integrator linearity by noting the amount the output deviates from a straight line and record on a suitable data form. The slope of the output, as shown in Figure 9, should be directly proportional to the input amplitude.



$$\text{Slope} = \frac{Y_1 - Y_o}{X_1 - X_o}$$

$$\frac{\text{Amplitude Volts}}{\text{Time (seconds)}}$$

Figure 9. Integrator Linearity Characteristics

6.2.4.4 Stability Test

a. With the integrator connected as shown in Figure 8, apply equipment power and adjust the function generator for a square wave output at the mid-frequency range of the integrator. The amplitude should be 50 percent of the specified maximum.

b. Adjust the recorder for full scale deflection and record the input and output waveforms of the integrator.

c. Adjust the recorder so that it is operating at low speed and remove the input from the integrator.

d. Continue to record until the integrator output begins to drift or until the drift stability, or memory specification requirements have been exceeded.

6.2.4.5 Amplifier Integrator

NOTE: This test applies only to amplifier integrator circuits.

a. With the integrator connected as shown in Figure 8, apply equipment power and with the required B-plus voltage applied, adjust the function generator as directed in paragraph 6.2.4.3(a).

b. Vary the B-plus voltage in increments of one-percent to limits of ± 10 percent while recording the output, to show the percent change of B-plus voltage versus percent change of the output rate (slope).

c. Determine the slope as shown in Figure 9, and record on a suitable data form.

6.2.5 Differentiator Tests

NOTE: All tests required to evaluate differentiator circuits shall be performed with the equipment configuration similar to that shown in Figure 10.

6.2.5.1 Frequency Response Test

a. Connect a function generator, a sweep drive unit, a power supply, dual-beam oscilloscope, and a direct writing recorder to the differentiator under test as shown in Figure 10.

b. Apply equipment power and adjust the function generator for a sine wave output. Select an amplitude which does not overdrive the differentiator. Obtain the specified frequency range by consulting the manufacturer's specification or by sweeping different frequency ranges while observing the output on the oscilloscope.

c. While operating within the specified frequency range, adjust the recorder sensitivity to obtain full scale deflection at the maximum differentiator output.

d. Sweep the frequency range of the differentiator and record the input and output signals at a slow speed. The amplitude of the input must remain constant through the frequency range. With a sine wave input applied, the differentiator should produce a cosine wave output of constant amplitude over the entire frequency range.

6.2.5.2 Sensitivity Test

a. With the differentiator connected as shown in Figure 10, apply equipment power and adjust the function generator to produce a triangular waveform. Adjust the frequency to the mid-point of the differentiator frequency range and adjust the amplitude to zero.

b. Adjust the recorder for high sensitivity and slow speed, increase the amplitude of the differentiator input, and record the ouput until a symmetrical square wave of constant amplitude is present.

c. Determine the minimum input amplitude and the rate at which the output was obtained.

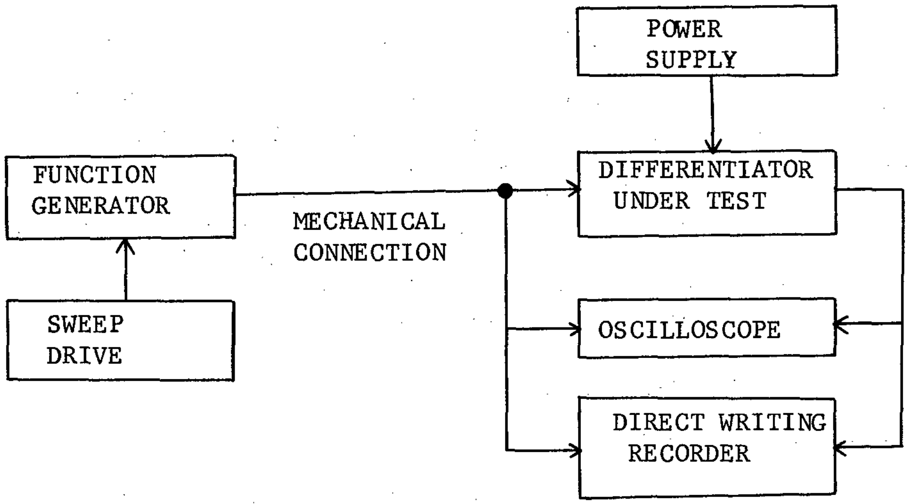


Figure 10. Typical Differentiator Frequency Response Time Test Configuration

6.2.5.3 Linearity and Response Time Test

a. With the differentiator connected as shown in Figure 10, apply equipment power and adjust the function generator for a triangular output waveform. Adjust the frequency to a value near the lower cut-off frequency of the differentiator and the amplitude to slightly less than 1/3 of maximum.

b. Adjust the recorder to 1/3 of full scale deflection and record at least four complete cycles of the differentiator input and output waveforms at a recorder speed which permits accurate time measurements.

c. Adjust the differentiator input amplitude to 2/3 of maximum and repeat the recording procedure as specified in Step (b) above.

d. Adjust the differentiator input amplitude to maximum and again repeat the recording procedure.

6.2.5.4 Stability and Zero Return Time Test

a. With the differentiator connected as shown in Figure 10, apply equipment power and adjust the function generator to produce a low frequency square wave output at 50 percent of maximum amplitude.

b. Adjust the recorder sensitivity for full scale deflection and operate at slow speed.

c. Record five cycles of the differentiator output signal with the input signal applied, then remove the input signal and record an additional five cycles of the output.

6.2.5.5. Amplifier Differentiator Test

NOTE: This test applies only to amplifier differentiator circuits.

a. With the differentiator connected as shown in Figure 10, apply equipment power and adjust the function generator to produce a triangular output waveform at a frequency midway between the frequency limits of the differentiator. The amplitude should be 50 percent of maximum.

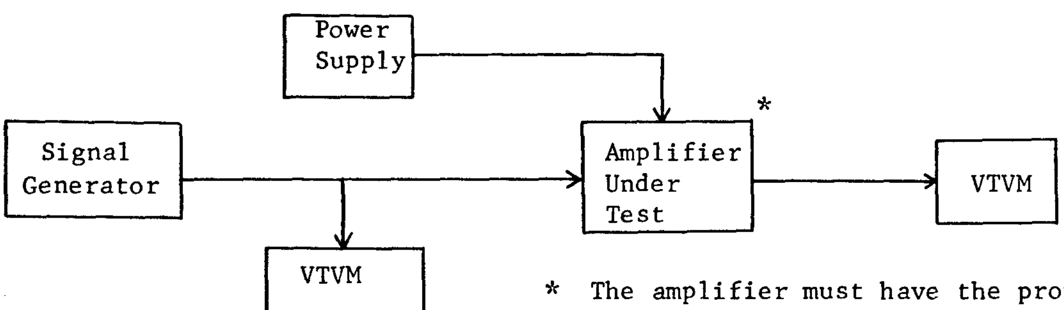
b. Apply normal B-plus voltage to the differentiator, and adjust the sensitivity of the recorder to obtain 75 percent of full scale deflection.

c. Vary the B-plus voltage in increments of one-percent to a value plus or minus 10 percent of normal, while recording at slow speed.

6.2.6 Control Amplifier Tests

6.2.6.1 Sensitivity and Gain Test

a. Connect a signal generator, two vacuum tube voltmeters, and a power supply to the amplifier under test as shown in Figure 11.



* The amplifier must have the proper load; use noninductive resistors for this purpose.

Figure 11. Typical Power Amplifier, Sensitivity, Gain and Frequency Response Test Configuration

b. Apply equipment power and adjust the signal generator for a sine wave output waveform at the mid-point of the amplifier frequency range. Adjust the signal generator initially for an output of zero amplitude.

c. Slowly increase the signal generator amplitude until the maximum signal level is obtained that will produce the desired amplifier output. The amplifier output level will be indicated on the VTVM.

NOTE: If the input frequency is low, it may be necessary to switch the VTVM to the d-c volts position.

d. Record the input and output signal levels on a suitable data form, and designate the input level as the amplifier sensitivity.

6.2.6.2 Frequency Response Time

a. With the amplifier connected as shown in Figure 11, apply equipment power and adjust the signal generator for a sine wave output waveform at the lower cut-off frequency of the amplifier.

b. Record the amplifier output at each frequency increment on a suitable data form while varying the input frequency, in at least 10 increments, until the entire frequency range of the amplifier has been covered.

6.2.6.3 Stability Test

a. Connect a signal generator, a power supply, and a direct writing recorder to the amplifier under test as shown in Figure 12.

b. Adjust the signal generator to produce an output at the mid point of the amplifier frequency range.

c. Adjust the recorder sensitivity for 75 percent of full scale deflection and record the input and output of the amplifier at a slow speed for a period of 5 minutes.

NOTE: With an input of constant amplitude, the amplifier should produce an output of constant amplitude. Any variation in the output under this condition indicates amplifier drift.

6.2.6.4 Harmonic Distortion Test

a. Connect a signal generator, a power supply, a wave analyzer, a sweep drive unit, and an X-Y plotter to the amplifier under test as shown in Figure 13.

b. Adjust the signal generator to produce an output at the midpoint of the amplifier frequency.

c. With the sweep drive d-c voltage output as the input to the X-axis of the X-Y plotter, calibrate the X-axis to include the entire range of the amplifier.

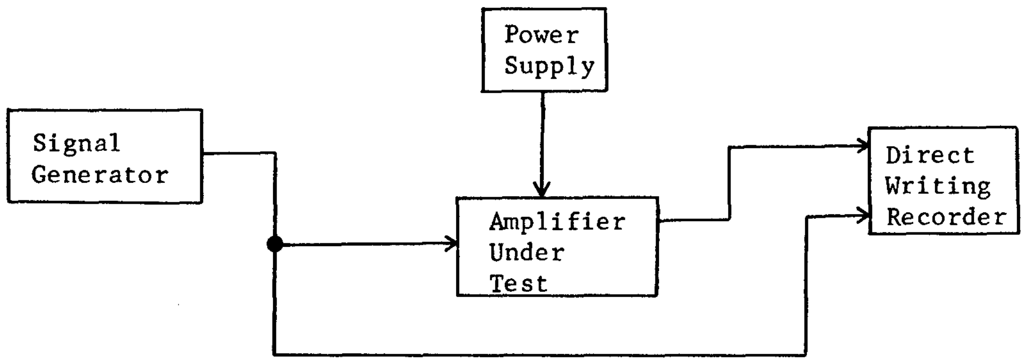


Figure 12. Typical Power Amplifier Stability Test Configuration

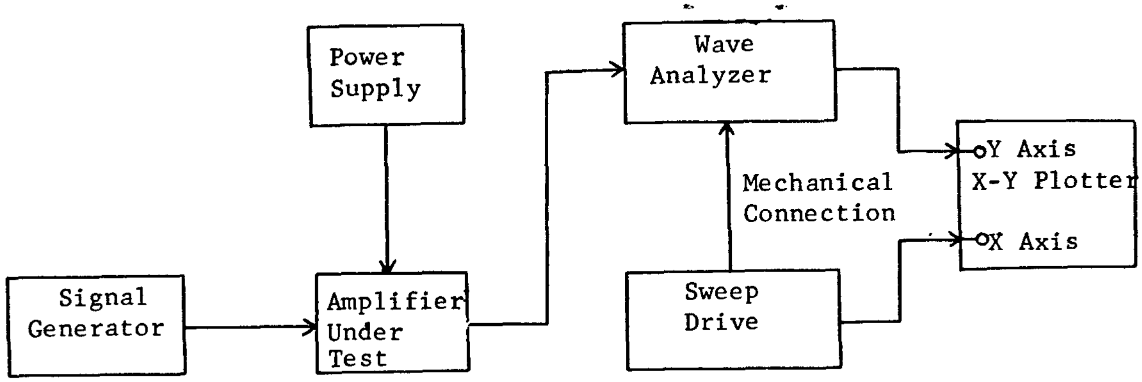


Figure 13. Typical Power Amplifier Harmonic Distortion Test Configuration

d. Slowly sweep the frequency range with the wave analyzer and calibrate the Y-axis of the plotter in volts per division. The maximum input to each axis of the plotter should produce 90 percent of full scale deflection.

e. Record at least one sweep of the full frequency range.

6.2.6.5 Magnetic Power Amplifier Test

a. Repeat the foregoing power amplifier tests using the respective test configuration when applicable. Refer to the manufacturing specifications when test configuration changes are necessary and for biasing information. A simple biasing test setup is shown in Figure 14.

6.2.7 Comparator Tests

NOTE: The test configuration shown in Figure 15, can normally be used in conducting all comparator tests.

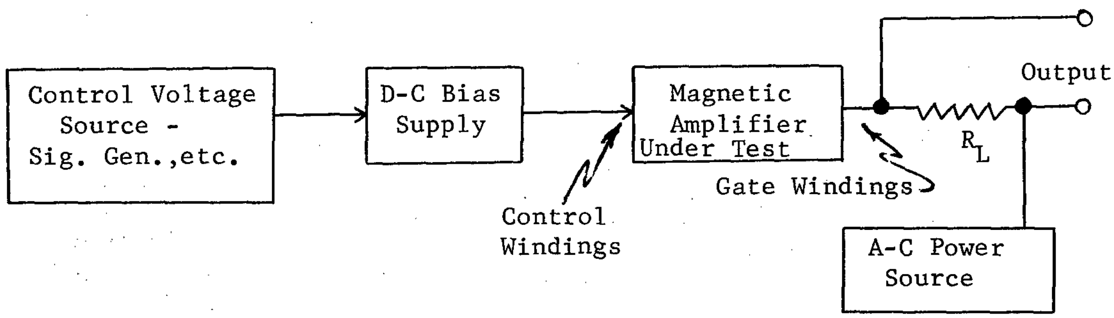


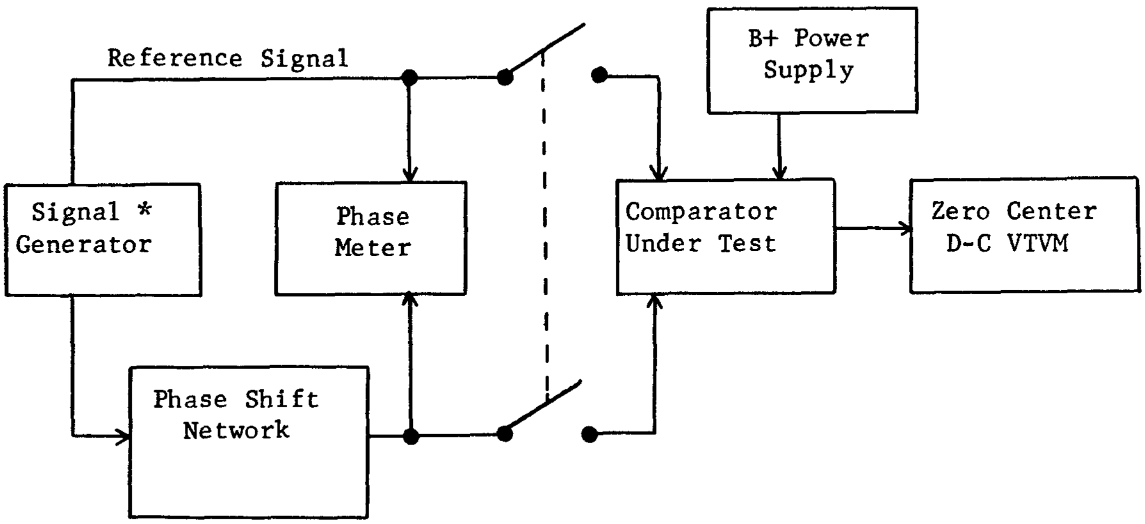
Figure 14. Method of Biasing Magnetic Amplifiers

6.2.7.1 Sensitivity and Linearity Test

a. Connect a signal generator, a phase shift network, a phase meter, and a zero-center d-c vacuum tube voltmeter to the comparator under test as shown in Figure 15.

b. Apply equipment power, allow a sufficient warm-up period, and adjust the input signal source to provide the specified amplitude and frequency.

c. Position the phase shifter so that the specified phase relationship for maximum comparator output exists between the input signals. Reduce the signal amplitude to zero.



* Connect potentiometer or decade box in series with one input to provide for amplitude adjustment.

Figure 15. Typical Comparator Test Configuration

d. Slowly increase the source signal amplitude until the specified comparator output appears on the VTVM.

e. Record the amplitudes of the input and output signals on a suitable data form and the phase angle of the input signal as indicated by the phase meter.

f. Increase the input amplitude in ten equal increments to the maximum amplitude, as specified, and record the amplitudes at each step on a suitable data form.

6.2.7.2 Output Voltage Versus Frequency Test

a. With the comparator connected as shown in Figure 15, apply equipment power, allow a sufficient warm-up period, and adjust the amplitude and phase of the comparator input, as specified, and maintain this value for the duration of the test.

b. Change the input frequency in ten equal increments to include the entire frequency range of the comparator.

NOTE: In the case of a comparator designed to operate at a single frequency, vary the input frequency in 2-percent increments over a range of plus or minus ten percent of the specified frequency.

c. Record the output amplitude and frequency at each setting on a suitable data form.

6.2.7.3 Output Versus Phase Test

a. With the comparator connected as shown in Figure 15, apply equipment power, allow a sufficient warmup period, and adjust the input signal frequency and amplitude to the specified values.

b. Adjust the phase angle to obtain a minimum output from the comparator and record the phase angle and output level on a suitable data form.

c. Set the phase angle so that the input leads the reference signal by 45 degrees. Vary the phase in 45-degree increments through a complete cycle.

d. Record the amplitude of the output voltage at each phase angle on a suitable data form.

e. Repeat steps (c) and (d) above, with the phase adjusted so that the input lags the reference signal by 45 degrees.

6.2.7.4 Stability and Null Test

a. With the comparator connected as shown in Figure 15, apply equipment power, allow a sufficient warmup period, and adjust the comparator inputs to cause zero output.

b. Record the output at 30-second intervals for a five minute period on a suitable data form.

c. Repeat steps (a) and (b) above, with the comparator inputs adjusted to produce maximum positive output.

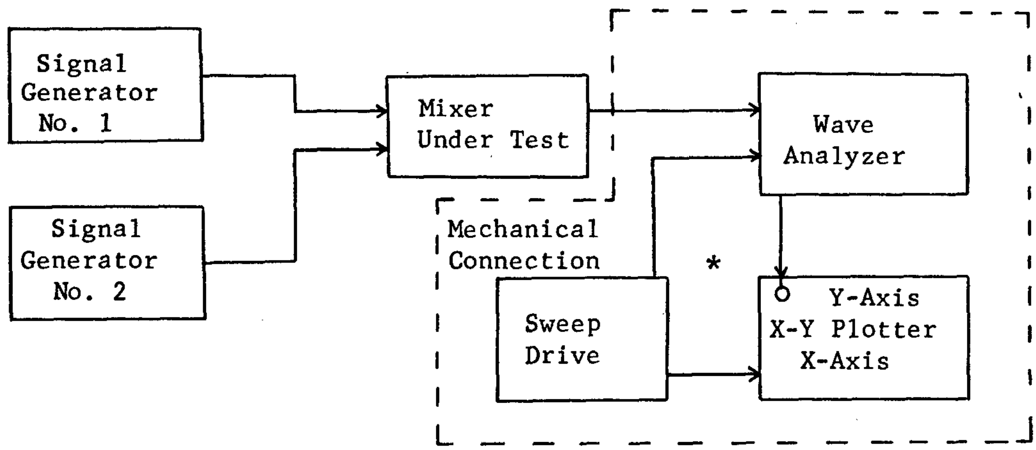
d. Repeat steps (a) and (b) above, with the comparator inputs adjusted to produce maximum negative output.

6.2.8 Mixer Tests

6.2.8.1 Output Amplitude Test

a. Connect two signal generators, a sweep drive unit, a wave analyzer, and an X-Y plotter or a distortion analyzer to the mixer under test as shown in Figure 16.

NOTE: Additional input signal generators can be connected if required. If a distortion analyzer is used in place of the equipment shown within the dashed area, disregard the calibration procedures for these equipments.



* A distortion analyzer may be used, in place of the equipment shown within the dashed area, for a direct phase angle indication.

Figure 16. Typical Mixer Circuit Test Configuration (Two Inputs Shown)

b. Apply equipment power, allow a sufficient warmup time, and adjust the signal generators for the specified sine wave value of the circuit under test.

c. Calibrate the X-axis of the X-Y plotter to include the specified frequency range, using the sweep drive output as the input signal. The selected sweep rate should be slow enough to permit the Y-axis of the plotter to be calibrated in volts per division (90 percent of full scale or largest input signal).

d. Record one full sweep of the frequency range at a slow speed and note the amplitude and frequency. A typical output record is shown in Figure 17.

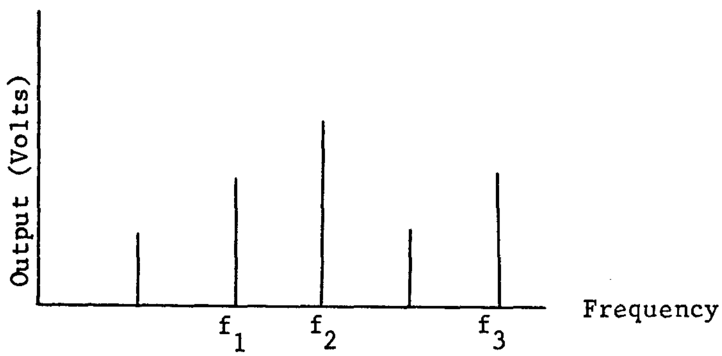


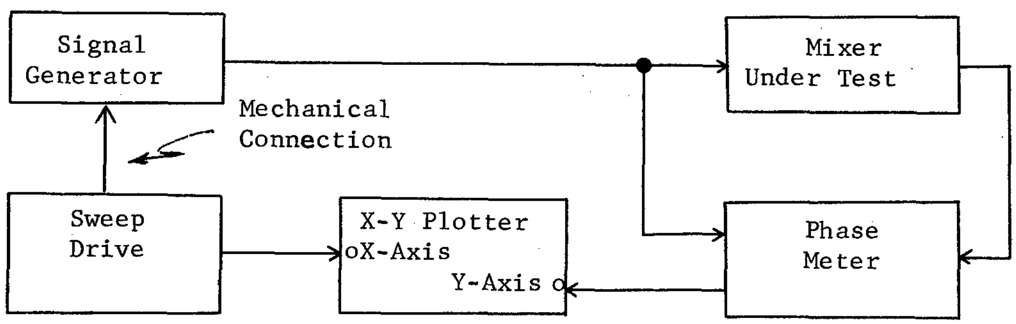
Figure 17. Typical Amplitude Test Record

6.2.8.3 Intermodulation Distortion Test

a. With the mixer connected as shown in Figure 16, apply equipment power, allow a sufficient warmup period, and record one full sweep of the frequency range using a slow sweep speed. Calibration of the X-Y plotter should remain the same as in step 6.2.8.1 (c). A maximum of two input signals shall be applied for a given test.

6.2.8.4 Phase Test

a. Connect a signal generator, a sweep drive unit, an X-Y plotter, and a phase meter to the mixer under test as shown in Figure 18.



(See paragraph 3.3 for test equipment peculiarities).

Figure 18. Typical Mixer Phase Test Configuration

b. Apply equipment power, allow a sufficient warmup time, and adjust the signal generator for the specified sine wave input value of the circuit under test.

c. Calibrate the X-axis of the plotter to include the mixer frequency range. The Y-axis shall be calibrated to include a phase shift from zero to 180 degrees by using the phase meter recorder-output signal.

d. Record one full sweep of the mixer frequency using a slow sweep speed.

e. Determine and record the phase relationship between any of the input frequencies. (NOTE: This can be accomplished using the plotter since the plotter axes are calibrated in degrees of phase shift versus frequency).

6.3 TEST DATA

6.3.1. Preparation for Test

Data to be recorded prior to testing shall include but not be limited to:

a. Nomenclature, serial number(s), and manufacturer's name of the test item

b. Nomenclature, serial number(s), accuracy tolerances, calibration requirements, and last date calibrated of the test equipment selected for the tests.

6.3.2 Test Conduct

Data to be recorded in addition to specific instructions listed below for each individual subtest shall include an engineering logbook containing in chronological order, pertinent remarks and observations which would aid in a subsequent analysis of the test data. This information may consist of temperatures, humidity, and other appropriate enviromental data, or other description of equipment or components, and functions and deficiencies.

6.3.2.1 Composite Tests

6.3.2.1.1 Linearity Test - Record a sufficient amount of the output signal to permit a determination of unit linearity, limiting action, and balance with zero input.

6.3.2.1.2 Frequency Response, Amplitude Test - Record the outputs of the test unit.

6.3.2.1.3 Frequency Response, Phase Test - Record the output of the test unit.

6.3.2.1.4 Transient Response Test - Record the input and output signals of the test unit to show the unit response time, stability, and gain characteristics.

6.3.2.2 Limiter Tests

6.3.2.2.1 Limiting Action Test - Record the output of the test unit.

6.3.2.2.2 Repeatability Test - Record five consecutive cycles of the limiter output.

6.3.2.3 Timer Tests

6.3.2.3.1 Time Interval Accuracy and Repeatability Test - Record ten cycles of timer operation. Record the average time interval.

6.3.2.3.2 Reset Time Interval Test - Record ten reset intervals. Record the average time interval.

6.3.2.3.3 Accuracy Versus Input Voltage Variation Test - Record ten cycles of timer operation and/or ten reset intervals.

6.3.2.4 Integrator Tests

6.3.2.4.1 Sensitivity Test - Record the integrator sensitivity value as measured with an oscilloscope.

6.3.2.4.2 Frequency Response Test - Record the output signals of the integrator.

6.3.2.4.3 Linearity and Response Time Test - Record the integrator linearity.

6.3.2.4.4 Stability Test - Record the output of the integrator until the output deteriorates beyond specifications.

6.3.2.4.5 Amplifier Integrator - Record the slope of the output.

6.3.2.5 Differentiator Tests

6.3.2.5.1 Frequency Response Test - Record the input and output signals of the differentiator.

6.3.2.5.2 Sensitivity Test - Record the minimum input signal amplitude and output rate of the differentiator.

6.3.2.5.3 Linearity and Response Time Test - Record the input and output waveforms of the differentiator.

6.3.2.5.4 Stability and Zero Return Time Test - Record the output of the differentiator with the input amplitude at zero, and with an input signal applied.

6.3.2.5.5 Amplifier Differentiator Test - Record the output of the differentiator.

6.3.2.6 Control Amplifier Tests

6.3.2.6.1 Sensitivity and Gain Test - Record the input and output signal levels.

6.3.2.6.2 Frequency Response Test - Record the amplifier output over the entire frequency range.

6.3.2.6.3 Stability Test - Record the amplifier input and output signals and any other than constant amplitude output with a constant amplitude input.

6.3.2.6.4 Harmonic Distortion Test - Record the amplitudes of the fundamental frequency and harmonic components.

6.3.2.6.5 Magnetic Power Amplifier Test - Record the same data required for all other Control Amplifier Tests as applicable.

6.3.2.7 Comparator Tests

6.3.2.7.1 Sensitivity and Linearity Test - Record the amplitude of the input and output signals and the phase angle of the input signals.

6.3.2.7.2 Output Voltage Versus Frequency Test - Record the comparator output over the entire frequency range.

6.3.2.7.3 Output Versus Phase Test - Record the amplitude of the output voltage at each phase angle.

6.3.2.7.4 Stability and Null Test - Record zero, maximum positive, and maximum negative output for five minutes each.

6.3.2.8 Mixer Tests

6.3.2.8.1 Output Amplitude Test - Record the amplitude of the output voltage over the entire frequency range of the mixer.

6.3.2.8.2 Harmonic Distortion Test - Record the amplitudes of the fundamental frequency and harmonic components.

6.3.2.8.3 Intermodulation Distortion Test - Record the amplitudes of the fundamental frequencies and harmonic components.

6.3.2.8.4 Phase Test - Record the phase relationship between any of the input frequencies to the mixer.

6.4 DATA REDUCTION AND PRESENTATION

6.4.1 Data Reduction

6.4.1.1 Composite Tests

6.4.1.1.1 Linearity Test - The output recording obtained for this subtest shall be annotated to show the unit linearity, limiting action, and balance of the computer with zero input.

6.4.1.1.2 Frequency Response, Amplitude Test - The output recording for this subtest shall be marked to show the lower frequency cutoff point, and the upper frequency cutoff points.

6.4.1.1.3 Frequency Response, Phase Test - The output recording for this subtest shall be annotated to explain any anomalies.

6.4.1.1.4 Transient Response Test - The output recording for this subtest shall be annotated to show the unit response time, stability, and gain characteristics of the computer under test.

6.4.1.2 Limiter Tests

6.4.1.2.1 Limiting Action Test - The recording obtained for this subtest shall be annotated to explain any anomalies of the limiter under test.

6.4.1.2.2 Repeatability Test - The linearity and limiting voltage characteristics of each cycle of operation shall be noted, and any differences shown.

6.4.1.3 Timer Tests

6.4.1.3.1 Time Interval Accuracy and Repeatability Test - Determine the percent of deviation as compared to the specified time interval as follows:

$$\text{Percent average deviation} = \frac{to - ta}{to} \times 100$$

Where:

to = Specified time interval
ta = Average time interval

$$\text{Percent maximum deviation} = \frac{to - tm}{to} \times 100$$

Where:

tm = Maximum deviation (the time interval farthest from that specified)

6.4.1.3.2 Reset Time Interval Test - Determine the percent of deviation from the reset time interval as previously described above.

6.4.1.3.3 Accuracy Versus Input Voltage Variation Test - Determine the average and maximum deviation as described in 6.4.1.3.1, and the percent change resulting from power level variations as follows:

$$\text{Percent change} = \frac{E_o - E_1}{E_o} \times 100$$

Where:

E_o = Specified voltage level
E_1 = Varied voltage level (90%, 91%, etc.)

6.4.1.4 Integrator Tests

6.4.1.4.1 Sentivity Test - The integrator sensitivity value shall be shown.

6.4.1.4.2 Frequency Response Test - The output recording of the integrator shall be annotated to show the amplitude and frequency at the cutoff points and any resonant or anti-resonant points.

6.4.1.4.3 Linearity and Response Time Test - Determine the response time as shown in Figure 19, by noting either the recording speed or including time markers on the recording. The response time is the time required for a change in the input to cause a change in the output.

NOTE: The slope value at 1/3 of maximum amplitude should be ½ the value obtained at 2/3 amplitude.

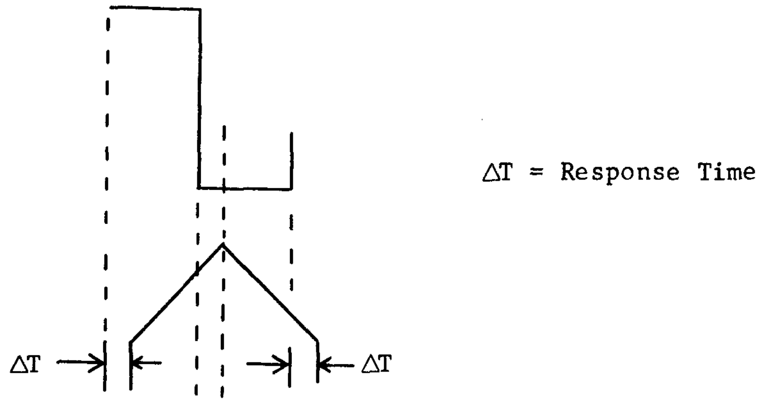


Figure 19. Integrator Response Time Waveform Characteristics

6.4.1.4.4 Stability Test - Determine the stability time (memory capability) by measuring the time interval between the removal of the integrator input and the point where the output deteriorates beyond specifications.

6.4.1.4.5 Amplifier Integrator - Determine the percent change in slope as follows:

$$\text{Percent change in slope} = \frac{M_o - M_1}{M_o} \times 100$$

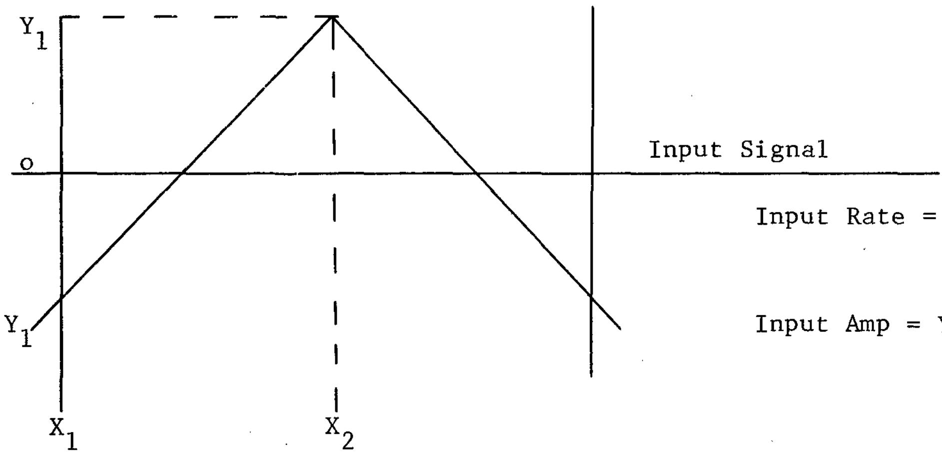
Where: M_o = Slope at specified B-plus voltage

M_1 = Slope at an incremental change from the specified B-plus voltage.

6.4.1.5 Differentiator Tests

6.4.1.5.1 Frequency Response Test - Annotate the points in the frequency range at which resonance or anti-resonance occurs. Also, determine and note the upper and lower cutoff frequencies (0.707) maximum amplitude).

6.4.1.5.2 Sensitivity Test - Compute the input amplitude and rate as illustrated in Figure 20.



$$\text{Input Rate} = \frac{Y_2 - Y_1 \text{ (Volts)}}{X_2 - X_1 \text{ (time)}}$$

$$\text{Input Amp} = Y_2 - Y_1 \text{ (Vpp)}$$

Figure 20. Differentiator Input Signal Amplitude and Rate Characteristics

6.4.1.5.3 Linearity and Response Time Test - Determine the linearity and response time for each input amplitude level as shown in Figure 21. Note that as the input rate increases, the output amplitude should also increase.

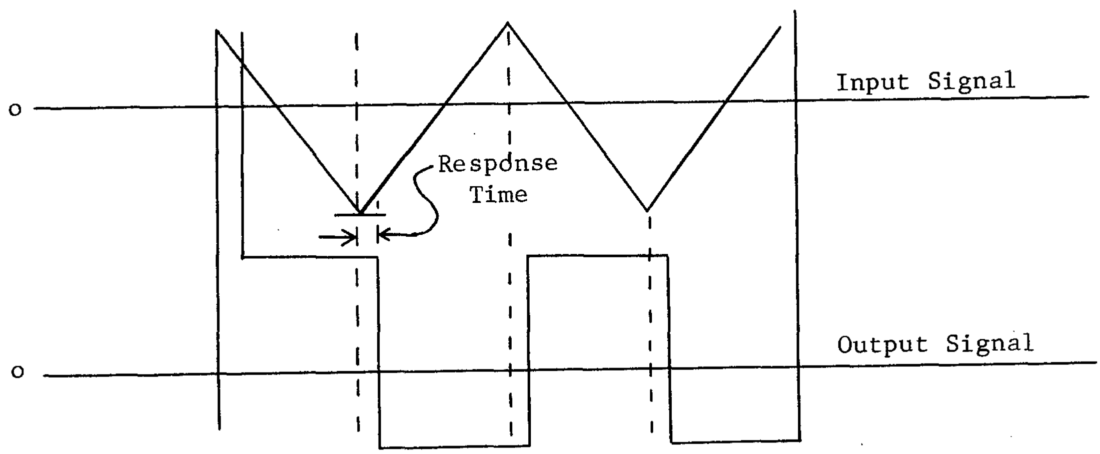


Figure 21. Differentiator Linearity and Response Time Waveform Characteristics

6.4.1.5.4 Stability and Zero Return Time Test - Determine the time delay as illustrated in Figure 22. With the input amplitude at zero, the output of the differentiator should be zero. Note any other output present under the above conditions.

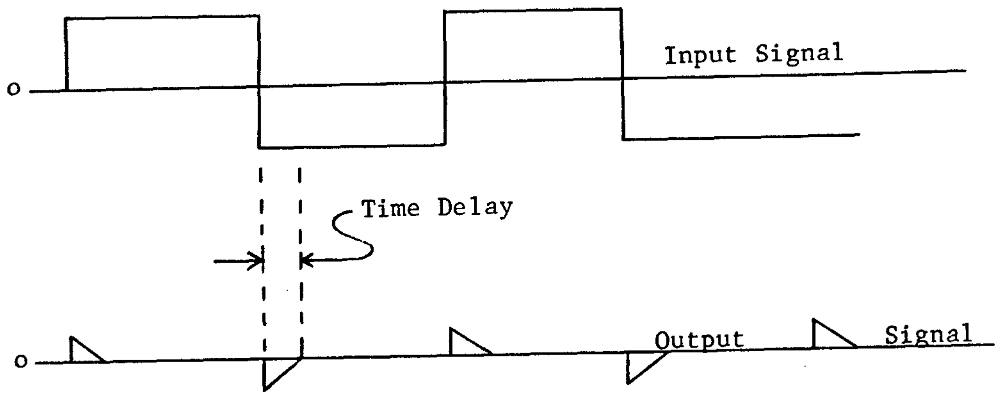


Figure 22. Differentiator Stability And Zero Return Time Waveform Characteristics

6.4.1.5.5 Amplifier Differentiator Test - Plot the percent of B-plus voltage change versus the percent change of the output rate on graph paper. Determine the output amplitude as described in paragraph 6.4.1.5.3. Compute the percent change in output amplitude versus the percent change in B-plus voltage using the following equations:

$$\text{Percent of change in B-plus} = \frac{E_N - E_1}{E_N} \times 100 \qquad \frac{\text{Percent Change in Output Amplitude}}{\text{Percent Change in B-plus Voltage}}$$

Where: E_N = Normal B-plus

E_1 = Increment of change

$$\text{Percent change in amplitude} = \frac{E_N - E_1}{E_N} \times 100$$

Where: E_N = Output amplitude with normal B-plus

E_1 = Output amplitude at varied B-plus setting

6.4.1.6 Control Amplifier Tests

6.4.1.6.1 Sensitivity and Gain Test - Compute the voltage and power gain, using the following equations:

$$Av = \frac{Vout}{Vin}$$

Where: Av = Voltage gain

Vin = Input signal amplitude

Vout = Output signal amplitude

NOTE: Power gain can only be computed if the load resistor and amplifier input resistance are known.

$$Ap = \frac{Po}{Pi} = \frac{Eo^2 / R_L}{Ein^2 / Rin}$$

$$Ap \text{ in db} = 10 \log_{10} \frac{Eo^2 / R_L}{Ein^2 / Rin}$$

Where: Eo = Output signal amplitude
Ein = Input signal amplitude
R_L = Amplifier load resistor
Rin = Amplifier input resistance

6.4.1.6.2 Frequency Response Test - Plot a graph on semilog paper of frequency versus output voltage. Plot output on the Y-axis and frequency on the X-axis, or log axis.

6.4.1.6.3 Stability Test - With an input of constant amplitude, the amplifier should produce an output of constant amplitude. Note any variation in the output under this condition which indicates amplifier drift.

6.4.1.6.4 Harmonic Distortion Test - Determine the percent harmonic distortion as shown in Figure 23, and described as follows:

$$\text{Percent Harmonic Distortion} = \frac{A_2^2 + A_3^2 + A_n^2}{A_1^2} \text{ X } 100$$

Where: A_1 = Amplitude of the fundamental frequency
A_2, A_3, A_n = Amplitude of the harmonic components

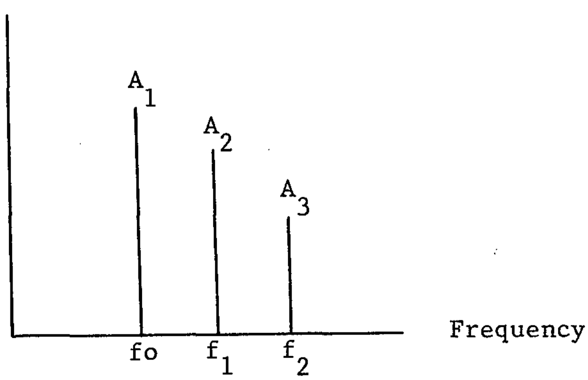


Figure 23. Typical Power Amplifier Harmonic Distortion Test Record

6.4.1.6.5 Magnetic Power Amplifier Test - Data shall be reduced as described for preceding control amplifier tests as applicable.

6.4.1.7 Comparator Tests

6.4.1.7.1 Sensitivity and Linearity Test - Plot a graph of the input versus the output. The graph should show the input amplitude on the X-axis and the output amplitude on the Y-axis.

6.4.1.7.2 Output Voltage Versus Frequency Test - Plot a graph of the frequency versus amplitude. The graph should show the frequency on the X-axis and the amplitude on the Y-axis.

6.4.1.7.3 Output Versus Phase Test - Plot a graph showing the phase angle on the X-axis and the output voltage on the Y-axis.

6.4.1.7.4 Stability and Null Test - Plot graphs of the outputs versus time, for each of the three test conditions. The graphs should show time on the X-axis and output on the Y-axis.

6.4.1.8 Mixer Tests

6.4.1.8.1 Output Amplitude Test - Annotate any variations in the output recordings.

6.4.1.8.2 Harmonic Distortion Test - Determine the percent of harmonic distortion as shown in Figure 24, and described as follows for each of the mixer inputs:

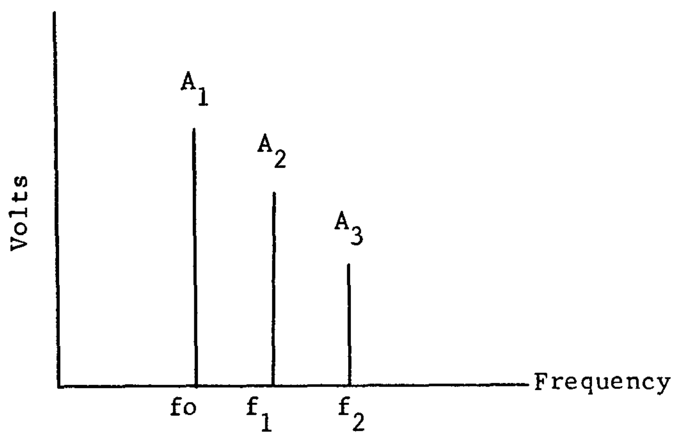


Figure 24. Typical Harmonic Distortion Test Record

$$\text{Percent Distortion} = \frac{A_2^2 + A_3^2 --- A_n^2}{A_1^2} \times 100$$

Where:

A_1 = Amplitude of the fundamental frequency

$A_2, A_3 --- A_n$ = Amplitude of harmonic components

6.4.1.8.3 Interdemodulation Distortion Test - Determine the interdemodulation distortion as shown in Figure 25, and described as follows, for each frequency combination.

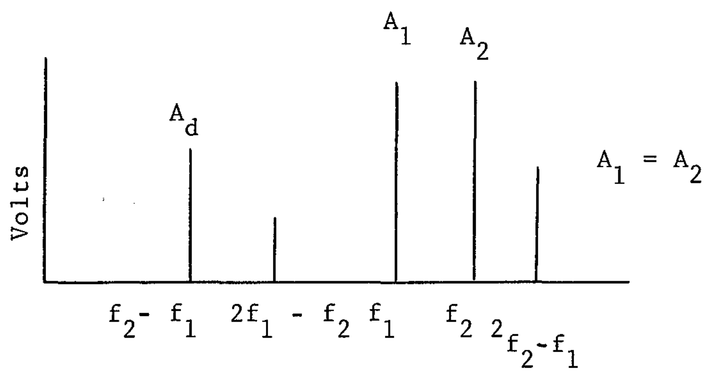


Figure 25. Typical Harmonic Distortion Test Record

$$\text{Percent Distortion} = \frac{A_d}{A_1 + A_2} \times 100$$

Where:

A_1 = Amplitude of input signal F_1

A_2 = Amplitude of input signal F_2

A_d = Amplitude of difference frequency signal (F_2-F_1)

6.4.1.8.4 Phase Test - Annotate any variations in the phase relationship between any of the input frequencies.

6.4.2 Presentation

Processing of raw subtest data shall consist of organizing the data into tabular form under the appropriate subtest title. All test data shall be properly marked for identification and correlation to the test item in accordance with paragraph 6.3, as a minimum.

A written report shall accompany all test data and shall consist of conclusions and recommendations drawn from test results. The test engineer's opinion, concerning the success or failure of the item(s) evaluated, should be included. In addition, equipment specifications that will serve as the model for a comparision of the actual test results should be included.

Equipment evaluation usually will be limited to comparing the actual test results to the equipment specifications and the requirements as imposed by the intended usage. The results may also be compared to data gathered from previous tests of similar components.

GLOSSARY

1. Amplifier: An amplifier is a device whose output is an enlarged reproduction of the input signal.

2. Comparator: Comparator circuits detect deviation from a preselected value of time or amplitude difference between two input signals.

3. Differentiator: A differentiator is a device which produces an output proportional to the rate of change of the input signal amplitude.

4. Gain: Gain is a measure of output voltage versus input voltage.
   $$\text{Voltage gain} = \frac{\text{output voltage}}{\text{input voltage}}$$

5. Integrator: An integrator functions to produce an output with a rate of increase or decrease that is proportional to the input signal

6. Linearity: A characteristic of a circuit whose output is directly proportional to the input.

7. Limiter: A transducer whose output is constant for all inputs above a critical value.

8. Mixer: A mixer circuit or device combines information from two or more sources.

9. Response Time: Response time is defined as the time required for a change of the input to cause a change in the output (measured to the leading edge of output pulse).

10. Stability: Generally speaking, stability is the tendency to remain in a given state or condition, without spontaneous change. Stability is a function of damping, for a critically damped circuit only one overshoot should result.

11. Timer: A time delay device is used to control a specific function at a predetermined period of time.

COMPUTERS (ELECTRONIC)

APPENDIX A

1. GENERAL

The following discussion provides for a better understanding of the circuits to be evaluated by this Materiel Test Procedure and is intended to show the relationship of computer equipment to related missile components.

2. COMPUTER SYSTEM AND COMPOSITE TESTS

A computer system, when used as the primary guidance component, consists of an assembly of subcircuits and components arranged in a manner to provide for the reception and processing of error signals, which are in turn used to develop control signals. The control signals are used by related components of the missile system. Figure A-1, is a block diagram of a basic missile guidance system. The engineering tests that provide for an analysis of the computer system as described, will hereafter be referred to as composite tests. The composite tests have been designed to provide for a system-type analysis of the computer characteristics. The following paragraphs describe various types of circuits, some of which might be similar to those in a computer system, which are used in many applications to provide separate operational functions. The circuit descriptions are in the same order and the circuit nomenclature is the same as that for the various engineering tests described in paragraph 6.2.

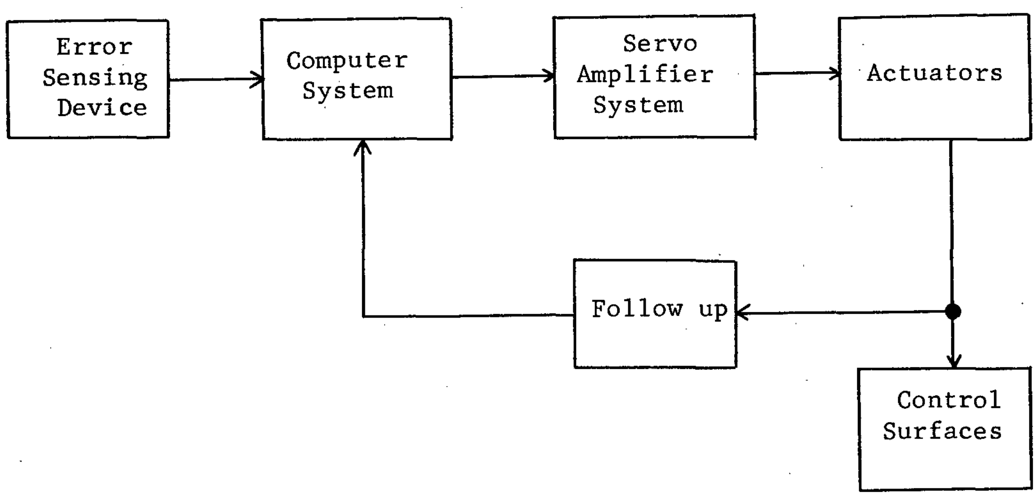


Figure A-1. Basic Missile Guidance System

3. LIMITER CIRCUITS

A limiter generally is used to restrict the peak to peak, or peak amplitude, of a signal to a specified maximum value. An ideal limiter would have a constant ratio of output to input voltage for all values of input voltage up to the limiting level. The ratio of the change in output to the change in input voltage should be zero when the input is above the limiting value (constant output for increased input).

4. TIMER CIRCUITS

A time delay device is used to control a specific function at a predetermined period of time. A timer normally requires an electrical or mechanical trigger for activation. The output is usually a signal applied to the circuitry and is dependent upon the switching of electrical contacts. Timers that are required to perform more than one consecutive timing function must have reset capabilities. Electrical timers operate from an electrical power source, while mechanical timers require a spring or other mechanical means to provide operating power.

5. INTEGRATOR CIRCUITS

The function of an integrator is to produce an output with a rate of increase or decrease that is proportional to the input signal. The integration of a voltage with respect to time represents a summation or accumulation of voltage over a specified time.

An integrator should reset linearly to an signal level which may be applied (if the input is doubled, the output should increase at twice the rate). The circuit reaction to an input signal should occur rapidly to provide a minimum time lag between the input and output signals. The integrator circuit should also have memory capabilities (if an output, E_o, exists and the input is zero, the output should remain at E_o).

The three most common types of electronic integrators are the R-C, R-L, and amplifier or Miller integrator.

6. DIFFERENTIATOR CIRCUITS

A differentiator is a device which produces an output proportional to the rate of change of the input signal amplitude. If the input signal amplitude is changing at a constant rate, the output amplitude will be constant. If the input signal amplitude is either zero or constant, the output will be zero. The three most common types of electronic differentiators are R-C, R-L, and amplifier.

7. CONTROL AMPLIFIER CIRCUITS

An amplifier is a device whose output is an enlarged reproduction of the input signal. Voltage amplifiers are designed to develop the greatest possible voltage across the load while power amplifiers are designed to deliver the greatest possible power to the load.

A control amplifier, when commanded by an input signal, may be used to actuate a relay, hydraulic valve, or electric meter. Operation of a vacuum tube or transistor amplifier requires a d-c power source. Operation of a magnetic amplifier requires a d-c bias supply and an a-c power source.

8. COMPARATOR CIRCUITS

A comparator detects deviation from a preselected value of time or amplitude difference between two input signals. One of the input signals normally is a reference signal. The comparator output is zero when the input signals are of the desired relationship. If the time or amplitude relationship between the input signals is not the preselected value, the output will be either positive or negative, depending on whether the difference is greater or less than the preselected value.

9. MIXER CIRCUITS

A mixer is a circuit or device which combines information from two or more sources. A mixer may only consist of a resistive network or it may also contain components for amplifying the input signals. If a mixer is to function properly, it must be capable of combining the input signals in the correct proportion, sense, and amplitude.