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SINGLE PARAMETER TESTING

PHASE D

FINAL REPORT

NAS 8-11715

PART III

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1.0 INTRODUCTION

The purpose of this report is to show the applicability of single parameter testing techniques and in particular the two techniques studied in Phase A, B and C of the program to the components which the Electrical Test and Analysis Branch of the Reliability and Quality Assurance Laboratory is responsible for testing. The four component groups within the branch are the Measuring, RF, Telemetry, and Networks Group. The particular component test procedures considered in these four areas are listed in Appendix A.

The objective of single parameter testing is to simultaneously determine several individual parameters of a component or system thereby obtaining faster checkout time. Two techniques were utilized in Phase A, B and C effort of NAS 8-11715, Part III, to achieve this objective (see references 1-5). A block diagram of the implementation of the growing exponential probing signal technique is shown in Figure 1-1. The probing signals are stored in a memory device such as a tape recorder or small digital computer. The orthogonal filter bank, estimator, timing control, and sample and hold circuits are programmed on an analog computing device such as a small commercially available analog computer or a specially designed rack of analog computer components.

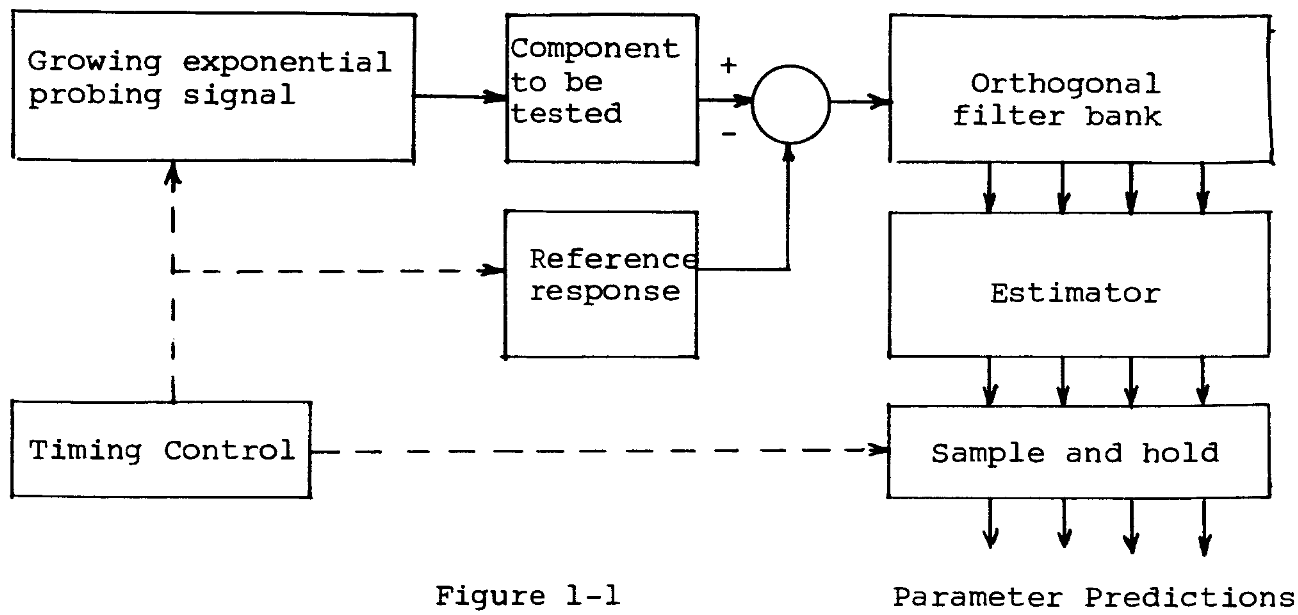


Figure 1-1

Testing Using Growing Exponential Probing Signals

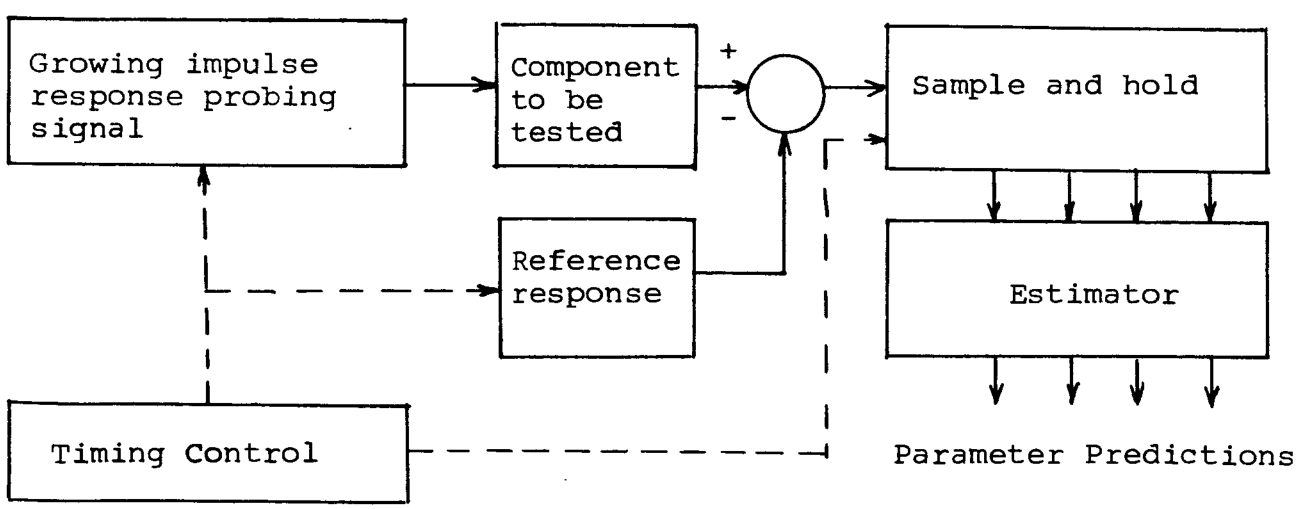


Figure 1-2

Testing Using Growing Impulse Response Probing Signals

The implementation equipment necessary for testing using growing impulse response probing signals (Figure 1-2) is similar to the first method.

The input probing signal must be generated by other equipment if the component input is other than an electrical signal. For example an accelerometer would be driven by a shake table and the shake table could be controlled by the signal from the memory device.

The function of the reference response block in each block diagram can be performed in three different ways. It can be a reference response of a nominal system recorded on the memory device, or second, a model of the nominal system implemented on the analog computing device, or third, a nominal component. For the second and third way, the input probing signal is fed to the model (or nominal component) as well as the component to be tested.

An outline of the steps necessary to implement these techniques is:

1. Develop a component model which can be used in the determination of an estimator.

2. Obtain a reference response of the component to be tested. This response can be determined by the statistical measurement of a number of good components. Once the nominal response is determined it can be stored on tape.

3. The estimator is determined by methods described in the Phase C report (Reference 4).

4. The fourth step is the implementation and checkout of the technique with the actual hardware to be tested.

The general technical approach of the Phase A, B and C effort was restricted to predicting transfer function parameters of linear systems or components which can be described by transfer functions (i.e., the input-output gain and phase shift as a function of frequency). The philosophy of single parameter testing can also be applied to other parameters which change the input-output characteristics of a device.

During the Phase C extension task (as reported in Reference 5) success was noted in the area of measuring such system parameters. In particular, the characteristics of a system component that limited the amplitude of the output waveform could be measured but a component which had a deadband effect in the system could not be measured, at least with the technique used at that time. Thus it is shown that some system parameters other than transfer function parameters can be measured with the techniques under investigation.

Single parameter testing techniques are also applicable to several general classes of equipment such as hydraulic, pneumatic and other electrical components as well as systems involving these components. Examples of hydraulic components which can be considered are valves, pumps and motors. Pneumatic components which can be considered for single parameter testing are valves, rotary actuators and controllers. Examples of electrical components are motors, generators, amplifiers, rotating amplifiers and filters.

2.0 MEASURING GROUP COMPONENTS

Descriptions of the measuring components listed in Appendix A and the procedures used to test the components were analyzed. Many of the component test procedures can be divided into categories for purposes of this report, for example the seven test procedures which deal with types of pressure transducers. The information presented in this section for each category of components is: a general description, acceptance level testing, final checkout and calibration level testing, tests which single parameter testing techniques can perform, how these tests are now performed and a list of the documents which were examined. A discussion of the single parameter testing equipment which would be required is presented in Section 1.0.

The major test which is performed on the components by the Measuring Group is to check the calibration of the component against data pack values supplied by the vendor. An example specification is that the new test data must agree within $\pm$ 50 mv with the test data provided by the vendor. One of the objectives of Phase E of the single parameter testing program is the development of a procedure to determine the linearity of a component. With the development of such a technique the linearity could be remeasured at the final checkout and calibration level of testing. The single parameter test would employ one testing signal as opposed to several sequential testing signals to obtain the component linearity, thus obtaining a time savings. Remeasuring linearity would assure that the desired specifications are met and eliminate the case where the data pack value plus 50 mv might not satisfy the original linearity requirement.

2.1 Component Category - AC Amplifier
Group responsible - Measuring Group
Test procedures - QUAL-AAT-2005

AC amplifiers are used as signal conditioners for the transducers in the measurement systems. The AC amplifier has a transfer function of:

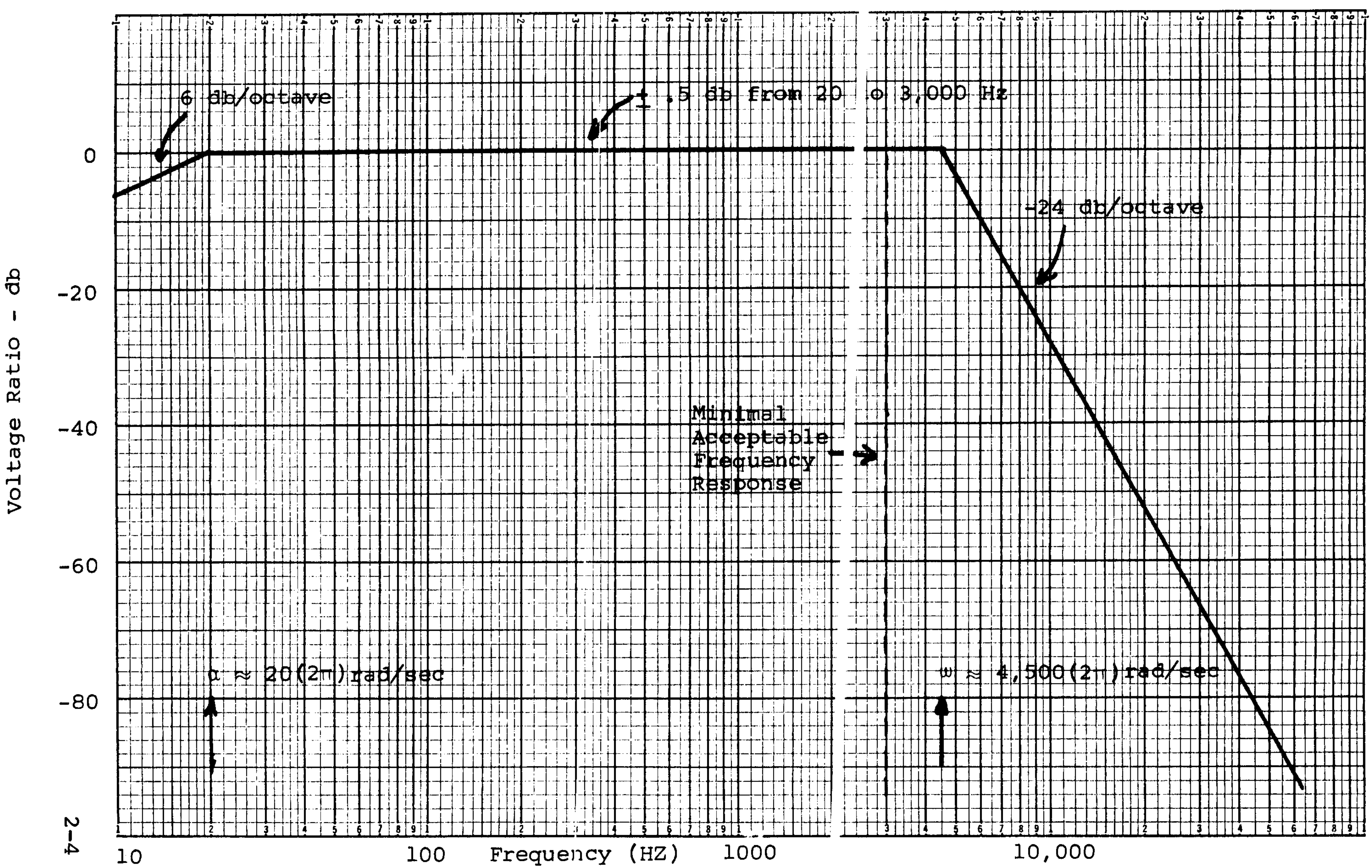
$$\frac{E_o}{E_{in}}(S) = \frac{KS\ \omega^4 \alpha}{(S+\omega)^4\ (S+\alpha)}$$

which is plotted as a function of frequency in Figure 2-1. The gain factor, K, is adjustable from 1 to 50 in two course ranges. The output of the amplifier is limited between 5 and 7 vdc at the upper limit level and between zero and 0.8 vdc at the lower limit level. The output nonlinearity of the amplifier should not exceed $\pm$ 2% of full scale for any gain setting, within the specified output range.

The final checkout and calibration testing procedures include:

- Visual inspection
- Bias adjustment
- Gain adjustment

The AC amplifier is then tested (66B26124) together with an accelerometer, accelerometer and emitter follower, or microphone and emitter follower as an assembly. The assembly is tested to match the given calibration curve for that combination of components.



Straight Line Approximate Frequency Response

Figure 2-1

The acceptance level testing (see footnote) conducted (60B73095) on the AC amplifier is:

- Visual inspection
- Insulation resistance
- Voltage gain and gain control resolution
- Frequency response
- Output ripple and noise
- Output linearity*
- Gain stability
- Emitter follower power supply
- Output limiting*
- Temperature

The single parameter testing techniques developed in Phases A, B and C could simultaneously perform the frequency response test and output ripple and noise test. The results of studying nonlinear components and functions during Phase E will determine if single parameter testing techniques can be applied to performing the linearity and output limiting tests.

The frequency response test is performed at the acceptance testing level by measuring the amplifier output at 28 sequential input testing frequencies. The data is plotted and must fall within specified limits. The linearity test is performed by taking data at 10 sequential test points. These points must be within ± 2% of full scale value of the best straight line for any gain setting. Besides the power supplies, cables, etc., which are

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Note: Those acceptance level tests which can be performed with presently developed single parameter testing techniques will be underlined in this section. Those tests which can be performed if successful results are obtained in Phase E are underlined and starred in this section.

necessary for component operation, the additional equipment necessary to perform the frequency response test and the linearity test consists of the input oscillator and output measuring and recording devices such as a DVM and oscillograph.

Using single parameter testing techniques the frequency response information and the linearity information could each be obtained with a single growing exponential probing signal thus gaining a proportional savings in time. The test equipment necessary to perform single parameter testing is shown in Figures 1-1 and 1-2 and discussed in Section 1.0.

The documents on AC amplifiers which were examined were:

QUAL-AAT-2005, AC Amplifier
60B73095, Amplifier Module, Alternate Current, Specification for
60B73111, Amplifier Assembly, AC
60B26124, Calibrated Set, Accelerometer, AC Amplifier, Emitter Follower

2.2 Component Category - Accelerometers
Group responsible - Measuring Group
Test procedures - QUAL-AAT-2006, 2018, 2019, 2020, 2042, 2045, 2065, 2066, 2089, 2104, 2105, 2106.

A typical accelerometer includes a mass suspended so that it is free to move in one direction only against a restraining spring. Viscous damping is provided by oil and the movement of the mass can be sensed by a potentiometer. The transfer function of an accelerometer is of the form

$$\frac{E_o}{A_{in}}(s) = \frac{K}{s^2 + 2\zeta\omega s + \omega^2}$$

The final checkout and calibration testing which is done by the Measuring Group consists of a

Visual inspection
Static test
Accelerometer range test
Noise level test

The acceptance tests which are performed (60B72145) are:

Visual examination
Isolation resistance
Output voltage
Hi-Lo calibration
Sensitivity
Hysteresis*
Amplitude response
Temperature
Linearity *

The single parameter testing techniques developed in Phases A, B and C can perform the output voltage test, the amplitude response test, and the sensitivity test. Tests which might be included after the study of nonlinearities in Phase E are the linearity test and the hysteresis test.

The present procedure for the output voltage test is to measure the output noise voltage with zero g acceleration input at three different power supply levels (24, 28 and 32v). The amplitude response is measured at 16 sequential sinusoidal acceleration input frequencies. The output data is then plotted and compared to acceptance limits. The sensitivity test is performed at 40 acceleration increments for each of three power supply levels. The linearity and hysteresis determination is made from the sensitivity test data.

Using single parameter testing techniques the output voltage test, the sensitivity test, and the amplitude response could be determined with just one testing signal instead of 16 sequential signals. An acceleration input source which can be continuously modulated would be required to develop the single parameter testing input signal. The development of a single parameter testing linearity test would lead to a reduction from 40 sequentially applied input signals to one growing exponential testing signal.

In addition to the test procedures listed at the start of this section, the following drawings and documents were examined:

60B72145	Accelerometer, Servo
60B72045	Accelerometer
50M12438	Accelerometer
50M10297	Servo Accelerometer Unit Assembly
50M10131	Accelerometer
2-QH-IU-110E-72 (PII) S-IU-10	Servo Accelerometer Measurements Test Procedure
Checkout procedures for S-IB-1	Measurement Systems
Checkout procedures for S-IU	Measuring Systems

2.3 Component Category - DC Amplifiers

Group responsible - Measuring Group
Test procedures - QUAL-AAT-2001, 2004, 2051, 2052, 2054, 2062, 2103

DC Amplifiers are used as signal conditioners for the transducers in the measurement systems. The DC amplifier can be described by the transfer function

$$\frac{E_o}{E_{in}}(s) = \frac{K}{(s + \omega_1)(s + \omega_2)}$$

within the linear operating region. The linear output range is limited between 5 and 7 vdc at the upper limit and between 0 and 0.8 vdc at the lower limit.

The final checkout and calibration testing which is performed by the Measuring Group consists of:

Visual inspection
Transducer excitation power supply and checking relays
Amplifier gain
Amplifier noise
Linearity

The DC amplifier acceptance tests which are performed (60B73061) are:

Visual inspection
Insulation resistance
Zero drift and offset
Voltage gain and gain resolution
<u>Frequency response</u>
Common mode rejection
<u>Output ripple and noise</u>
<u>Linearity</u> *
<u>Output limiting</u> *
Gain stability
Transducer excitation power supply and checking relays
Temperature

The single parameter testing techniques developed in Phases A, B and C could simultaneously perform the frequency response test, output ripple and noise test. The results of the nonlinearity study during Phase E will determine if single parameter testing techniques can be applied to performing the linearity and output limiting test.

The frequency response test is performed at the acceptance testing level by measuring the amplifier output at 12 sequential input testing frequencies. The data is plotted and must fall within specified limits. The linearity test is performed by taking data at 10 sequential test points. These points must be within ± 1 percent of full scale value of the best straight line for any gain setting. Besides the power supplies, cables, etc., which are necessary for component operation, the additional equipment necessary to perform the frequency response test and the linearity test consists of the input oscillator and output measuring and recording devices such as a DVM and oscillograph.

Using single parameter techniques the frequency response information and the linearity information could each be obtained with a single growing exponential probing signal thus gaining proportional savings in time. The test equipment necessary to perform single parameter testing is shown in Figures 1-1 and 1-2 and discussed in Section 1.0.

The documents on DC amplifiers which were examined are:

QUAL-AAT-2001, DC Amplifiers
QUAL-AAT-2004, DC Amplifiers
QUAL-AAT-2051, DC Amplifiers
QUAL-AAT-2052, DC Amplifiers
QUAL-AAT-2054, DC Amplifiers
QUAL-AAT-2062, DC Amplifiers Modules without Range Cards
QUAL-AAT-2103, DC Amplifier Assemblies (Astrionics)
MSFC-SPEC-133A, DC Amplifier Modules, Specifications for
60B73061, Amplifier Module, Direct Current

2.4 Component Category - Emitter Follower
Group responsible - Measuring Group
Test procedures - QUAL-AAT-2007, 2008, 2074, 2077

The emitter follower is designed to match high output impedance devices such as piezoelectric transducers into standard electronic circuits. The input impedance of the emitter follower is not less than 50 megohms at 20 Hz, 25 megohms at 100 Hz, 5 megohms at 1000 Hz and 2.5 megohms at 3000 Hz. The unit operates over an input range of 6 millivolts to 5 volts peak to peak over the frequency range of 20 Hz to 3200 Hz. The transfer function has the following general form:

$$\frac{E_o}{E_{in}}(S) = \frac{K}{S + \omega}$$

which has an approximate unity voltage gain.

The emitter follower is not tested as an individual component by the measuring group but is tested in conjunction with accelerometers (QUAL-AAT-2007 and 2008), with accelerometer and AC amplifier (QUAL-AAT-2074), and with microphone and AC amplifier (QUAL-AAT-2077). The final checkout and calibration tests which are performed in these procedures are:

Visual inspection
Calibration test

The emitter follower is tested as an individual component at the acceptance testing level (60B73078). The acceptance tests performed are:

Visual inspection
Dimensional inspection
Insulation resistance
Output resistance
Input impedance
Gain and Linearity*
Frequency response
Noise
Calibration voltage
Temperature test

The single parameter testing techniques developed in Phases A, B and C can be used to simultaneously perform the gain test, noise test and the frequency response test. The results of Phase E will determine if the linearity test can be performed using single parameter testing techniques.

The frequency response test is performed at nine sequentially applied input frequencies between 20 and 3200 Hz and with a signal level of 100 mv p-p. From this data, a frequency response curve is plotted. This plot must conform to a standard response curve within given tolerances. The linearity is determined by applying a 1 kHz signal at 10 sequential amplitudes between 6 mv p-p and 5 v p-p. Besides the power supplies, cables, etc., which are necessary for component operation, the additional equipment necessary to perform the frequency response test and the linearity test consists of the input oscillator and output measuring and recording devices such as a DVM and oscillograph.

Using single parameter testing techniques the frequency response information and the linearity information could each be obtained with a single growing exponential probing signal thus gaining a proportional savings in time.

The test equipment necessary to perform single parameter testing is shown in Figures 1-1 and 1-2 and discussed in Section 1.0.

The documents on emitter followers which were examined were:

QUAL-AAT-2007, Emitter Follower & Accelerometer
QUAL-AAT-2008, Emitter Follower & Accelerometer
QUAL-AAT-2074, Calibrated Set: Microphone, Emitter Follower, AC Amplifier
QUAL-AAT-2077, Calibrated Set: Microphone, Emitter Follower, AC Amplifier
60B73078, Emitter Follower
Checkout Procedures for S-IB-1 Measurement Systems
Checkout Procedures for S-IU Measuring Systems

2.5 Component Category - Pressure Transducers
Group responsible - Measuring Group
Test procedures - QUAL-AAT-2015, 2031, 2033, 2038, 2040, 2063, 2064.

Pressure transducers are electromechanical measuring devices which convert mechanical pressure to an electrical signal, the electrical signal output being directly proportional to the pressure applied. The transfer function for the pressure transducer is of the form

$$\frac{E_O}{P_{in}}(S) = \frac{K}{S + \omega}$$

The final checkout and calibration testing which is done by the Measuring Group consists of:

Visual inspection
Linearity test

The acceptance tests which are performed (60B72199) are:

Visual inspection
Insulation resistance
Case grounding
Potentiometer resistance
End point tolerances
Independent linearity*
Static error*
Dynamic error*
Proof pressure

In the qualification testing of the pressure transducers a time constant test is also performed. The techniques which have been studied in the single parameter testing program Phases A, B and C would be applicable to the determination of the transducer time constant, sensitivity, and assurance of the proof pressure. Work in the area of nonlinearities to be conducted during Phase E may lead to a technique for the testing of the static error, dynamic error and independent linearity tests.

The present Measuring Group test procedures call for measurement of the transducer for nine sequential input pressure levels. These readings are then compared to the vendor supplied data pack values to determine acceptibility. A single parameter testing procedure would determine the transducer linearity with one continuous test signal as opposed to taking data at sequential test points. A variable pressure source would be necessary as the input testing signal.

The documents on pressure transducers which were examined were:

QUAL-AAT-2015, Pressure Transducer
QUAL-AAT-2031, Pressure Transducer with Amplifier
QUAL-AAT-2033, Differential Pressure Transducer
QUAL-AAT-2038, PSIA Pressure Transducer
QUAL-AAT-2040, PSIA Pressure Transducer with Amplifiers
QUAL-AAT-2063, PSIA Pressure Transducer
QUAL-AAT-2064, PSID Pressure Transducer
60B72199, Transducer, Pressure
Checkout Procedures for S-IB-1 Measurement Systems
Checkout Procedures for S-IU Measuring Systems
MIL-T-23518T, Transducer, Pressure

2.6 Component Category - Rate Gyroscopes
Group responsible - Measuring Group
Test procedures - QUAL-AAT-2028, 2041, 2058

A rate gyroscope is a single-degree-of-freedom gyro with an elastic restraint on its movement about the free, or output, axis so that the angular deflection of the output axis is proportional to the angular velocity about the input axis. The transfer function which represents the rate gyro is of the form

$$\frac{E_o}{\theta_{in}}(s) = \frac{K\,S}{S^2 + 2\zeta\,\omega S + \omega^2}$$

The final checkout and calibration testing which is performed by the Measuring Group consists of:

Visual inspection
Hi-Cal, Null, Lo-Cal check
Linearity and sensitivity
Cross-Axis sensitivity

The acceptance tests which are performed (60B72043) are:

Visual examination
Insulation resistance
Output voltage
Stops*
Range, linearity and sensitivity *
Hysteresis*
Natural frequency
Damping
Hi-Lo calibration
Temperature

The single parameter testing techniques developed in Phases A, B and C could simultaneously perform the noise output determination part of the output voltage test, the natural frequency test and the damping test. The results of Phase E will determine if the range test, the linearity and sensitivity test, the stops test, and the hysteresis test can be performed by the single parameter testing techniques. A variable angular rate input source would be necessary for the single parameter testing input signal.

The stops test is performed by increasing (and decreasing) the input angular rate and measuring the maximum (and minimum) obtainable output voltage. This indicates the position of the mechanical stops. The range, linearity, sensitivity and hysteresis are determined from data taken at 1 deg/sec input angular rate increments for a total of 40 sequential data points. The test is repeated for three input power supply levels so that the total is 120 data points at the acceptance testing level. The natural frequency and damping test are performed using a shaker table to determine amplitude and frequency ratio data from which the amplitude response curve can be drawn. Sequential data is taken at several angular input frequencies.

The following drawings and documents were examined:

QUAL-AAT-2028, Rate Gyro and Adaptor
QUAL-AAT-2041, Rate Gyro
QUAL-AAT-2058, Angular Rate Gyro
50M10359, Rate Gyro
50M10409, Rate Gyro
60B72043, Gyroscope, Angular Rate
MIL-G-21437A, Gyroscope, Rate
MIL-G-60143, Gyroscope, Rate
Checkout Procedures for S-IB-1 Measurement Systems

2.7 Component Category - Miscellaneous
Group responsible - Measuring Group
Test procedures - QUAL-AAT-2000, Turbine Tachometer
QUAL-AAT-2023, First Motion & Cutoff Module
QUAL-AAT-2068, Sync Buffer Unit

These three components are being treated as a category since in many respects they are being tested in the same manner by the Measuring Group. An input signal is applied to each component and the output waveform is displayed. From the display, the parameters of interest are observed and recorded on the component approval form. This information is summarized in Table 2-1.

The testing performed on these components uses the general philosophy of single parameter testing. That is, using one input testing signal, the several parameters of interest are obtained from the output waveform. In these three cases, it is not necessary to process the output waveform to determine the parameters of interest since they can be read directly from the waveform and therefore the development of an single parameter testing estimator is not recommended for these components.

Component	Input Signal	Display Device	Parameters Observed
Tachometer	Constant angular rotation	Oscillograph	Waveform frequency, amplitude, distortion, symmetry, bias
First Motion & Cutoff Module	Electrical Step Function	Oscillograph	Waveform amplitude, rise time, decay time
Sync Buffer Unit	Electrical square wave	Oscilloscope	Waveform amplitude, frequency, rise time, fall time, ringing

Table 2-1

2.8 Component Category - Miscellaneous
Group responsible - Measuring Group
Test procedures - QUAL-AAT-2013, Frame Rate and Frequency to DC Converter
QUAL-AAT-2037, Voltage Inverter
QUAL-AAT-2061, Frequency to DC Converter

These components are being grouped together since the final checkout and calibration level testing which is performed on them is essentially the same. The testing consists of:

Visual inspection
Noise level
Calibration check

At the acceptance level of testing for these components, it is assumed that a frequency response test is performed for which the single parameter test techniques developed in Phases A, B and C would be applicable. Obtaining the information needed using just one growing exponential probing signal would achieve a testing time reduction.

One of the objectives of Phase E of the program will be to develop a single parameter testing technique to determine the linearity of a component. If a technique can be developed, it will be suitable to testing for the linearity of these three components.

2.9 Assemblies - Accelerometer, AC Amplifier
Accelerometer, Emitter Follower, AC Amplifier
Microphone, Emitter Follower, AC Amplifier
Group responsible - Measuring Group
Test procedures - QUAL-AAT-2005, 2007A, 2006, 2007, 1008, 2074, 2101, 2077

The assemblies listed above are subject to the following tests at the final checkout and calibration testing level:

Visual inspection
Calibration test

All are basically discussed as components in other parts of this section and in this discussion we will treat these assemblies as integral units.

The single parameter testing procedures, developed in Phase A, B and C are applicable to the testing of these assemblies. We will discuss the testing of the accelerometer, emitter follower, AC amplifier assembly as a typical example and show how single parameter testing may be performed. The total transfer function for the subsystem is:

$$\frac{E_o}{A_{in}}(s) = \left[\frac{K_1}{\frac{s^2}{\omega_1^2} + \frac{2\zeta s}{\omega_1} + 1}\right] \left[\frac{K_2}{\left(\frac{s}{\omega_2} + 1\right)}\right] \left[\frac{K_3\ s}{\left(\frac{s}{\omega_3} + 1\right)\left(\frac{s}{\omega_4} + 1\right)}^4\right]$$

This transfer function can now be tested to measure the following parameters, ω_1, ζ_1, ω_2, ω_3, ω_4 and $K = K_1K_2K_3$. Deviations in these parameters would indicate malfunctions of one or more of the components. The overall gain would be established, and corrections in gain could be made by adjustment of the AC amplifier gain control. A unit passing the single parameter test would assure that each component is operating within specifications.

One application problem with a single parameter test may be to drive the input acceleration with an exceptable input signal to allow the measurement of output parameters. In the microphone assembly, a proper driving sound signal would need to be provided.

The advantage of such a testing procedure is that it would eliminate the testing at various freouencies to establish assembly frequency responses (66B26124). Documents which were reviewed in addition to the procedures listed above were:

60B73095, Amplifier Module, AC, Specification for
60B7311, Amplifier Assembly, AC
60B26124, Calibrated Set: Accelerometer, AC Amplifier, Emitter Follower
MIL-A-60146 Amplifier, Electronic Control
Checkout Procedures for S-IB-1 Measurement Systems
Checkout Procedures for S-IU Measuring Systems

3.0 RF GROUP COMPONENTS

Descriptions of the RF components listed in Appendix A and the procedures used to test the equipment were analyzed. The components consisting of transponders (ODOP, Type C Azusa, and C-Band) and receivers (AN-DRW13 and MCR-503), are of a complexity such that the two techniques developed in Phases A, B and C could not be applied at this time. In simpler systems, the assumption in the mathematics of neglecting high order Taylor series terms (see Phase C report, reference 4) does not seriously affect the accuracy of the parameter prediction. With a component of the complexity of a receiver, the accuracy would be affected. Future development of single parameter testing techniques may lead to procedures for testing these RF components.

4.0 TELEMETRY GROUP COMPONENTS

Descriptions of the telemetry components listed in Appendix A and the procedures used to test this equipment were analyzed. It is concluded that the two techniques being evaluated at this time would not be suitable to test telemetry equipment because of the digital nature of the telemetry signals. The single parameter testing philosophy could be used to develop testing techniques for telemetry equipment but these techniques would be enough different from our present techniques that the projection as to what testing information could be obtained and how accurate it would be, can not be made at this time.

5.0 NETWORKS GROUP COMPONENTS

The scope of the objectives of the program do not extend to the type of components tested by the Networks Group and therefore the single parameter testing techniques developed in Phase A, B and C are not applicable in this area.

6.0 COST EFFECTIVENESS CONSIDERATIONS

The economics of developing a single parameter testing technique for a given component will depend upon a number of the following cost effectiveness considerations.

1. Testing level - the cost effectiveness of the single parameter testing technique will be a function of the testing level at which it is applied. Examples of testing levels are:

   a. design and development phase testing

   b. qualification testing

   c. production acceptance testing

   d. final checkout and calibration testing

   e. operational checkout testing

   f. trouble-shooting and maintenance testing

   A good discussion of the objectives of these testing levels can be found in reference 6. Once a single parameter test technique is developed for application at one testing level it could then be used at the later levels.

2. Number of components to be tested - the benefit to be gained by developing a single parameter testing technique will be a function of the number of components of a given type to be tested.

3. Number of parameters to measure - the cost effectiveness will be a function of the number of component parameters to be measured. A single parameter testing technique development

would be justified to determine five or six component parameters but not for a component with only one parameter to test.

4. Number of data points needed to determine a parameter - for example a frequency response may require data to be taken at many test points with a large potential time savings or a particular time constant may require only one data point with no potential time savings.

5. Component model development - the first step in developing a single parameter testing technique is to obtain an accurate nominal model of the component to be tested. For some components the transfer function is available or can be readily determined and therefore, the model could be easily developed. For other components an accurate model would be difficult to obtain due to the complexity, and the nonlinearities involved.

6. Component complexity - the time required to develop the single parameter testing technique after the model is obtained, will be proportional to the component complexity.

7. Free information - a single parameter testing technique may give additional parameter information with no increase in testing time when compared to conventional testing techniques.

8. Degradation due to testing - a single parameter testing technique will take less time to perform than conventional testing techniques and therefore cause less component degradation due to testing. The use of smooth input testing signals as opposed to impulses or step functions will also mean less degradation.

9. Accuracy of parameter determination - the required accuracy for predicting a given parameter will depend on the testing level and also the particular parameter. The accuracy of parameter determination with single parameter testing techniques will in general be less than with conventional testing techniques.

10. Range of parameter variation - the required accuracy for predicting a given parameter will depend on the testing level and also the particular parameter. For example, in the final checkout and calibration phase it would be adequate to know that a parameter is far from the nominal value without knowing what the particular value is since the component would then be rejected. If a component parameter varies outside of a given range, the prediction accuracy of all of the parameters is decreased with a single parameter testing technique. The fact that a parameter has under gone a large change will be evident, however, and the component can be rejected.

11. Reliability requirements - the realiability requirements for a given component, particularly in the case of space vehicle components, may justify or demand increased testing at a given testing level. For example, some tests that are normally considered part of acceptance testing may need to be repeated at the final checkout and calibration testing level.

12. Test equipment complexity - the number, cost, weight, calibration and set-up time, and general complexity of the test eouipment required to perform the tests for a given component with conventional techniques versus a single parameter testing technique are considerations.

13. Qualifications of testing personnel - an engineer would be required to develop a component single parameter testing technique but it would be applied by personnel normally assigned to testing such components.

14. Test simplicity - single parameter testing techniques will in general be easier to apply than conventional testing techniques but more complex to develop.

15. General purpose test equipment - can the single parameter test equipment with only adjustments be used to test several of the different components which must be tested.

16. Time - this ties together several items which have been previously discussed such as: number of items to test, number of parameters to measure, component model availability, component model development time, etc. How critical the time factor is will depend upon the testing level.

The above items are representative of some of the factors which need to be considered in doing a cost effectiveness evaluation of the development of a single parameter testing technique for a given component. There is an interaction between many of the items on the above list. Time limits and the information available do not perfit a complete cost effectiveness evaluation for each of the 158 components which are being considered in this study phase but the above list is included in this report to give an example of factors that should be considered during such an evaluation.

7.0 CONCLUSIONS

The main objective of Phase D of this program, has been to assess the general usefulness of single parameter testing techniques as applied to components which the Electrical Test and Analysis Branch are responsible for testing. The particular components which were found to be applicable, and their associated characteristics which could be tested by single parameter techniques are given in the body of this report.

Of the 108 component test procedures used by the Measuring Group it was found that single parameter testing techniques are applicable for 43 of the procedures. After the development of nonlinear testing techniques the number of applicable procedures would be increased and more parameters will be able to be measured on the components which are presently applicable. In the RF Group, Telemetry Group and Networks Group, no test procedures were found applicable at this time, due partly to the type of components, the complexity of the components and the limits of the present techniques.

In the assessment of general classes of equipment the present techniques are basically applicable. Brief investigations of electromechanical, pneumatic and hydraulic systems and components showed that the methods developed are applicable and the nonlinearities which are to be expected included limiting, dead-band, and hysteresis.

The nonlinear analysis to be performed in Phase E will be particularly concerned with the linearity and limiting characteristics since these were found to be prominent in most of the equipment tested according to the test procedures. The methods to be developed will follow the lines of the previous analytical effort and also the work reported in references 9 and 10. The object will be to analytically show the procedures necessary to measure the nonlinear characteristics and the dynamic parameters described by the transfer functions.

Thus single parameter testing techniques were found to be applicable to many Saturn components and also general classes of equipment. It is recommended that if modification of present testing procedures is contemplated, that it should be conducted at all levels of testing to achieve the maximum benefit. The tests for a particular component should be developed by the vendor to be used in his qualification and acceptance testing and also be used by the customer for acceptance and final checkout and calibration testing.

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APPENDIX A

Measuring Group

No.	Equipment
2000	Turbine Tachometer
2001	DC Amplifiers
2002	Liquid Level Probes
2004	DC Amplifiers
2005	AC Amplifiers
2006	Accelerometers
2007	Emitter Follower & Accelerometer
2008	Emitter Follower & Accelerometer
2009	Propellant Tank Test
2010	Zone Box
2011	22½ Volt Power Supply
2012	Fuse Module
2013	Frame Rate & Frequency to DC Converter
2014	Liquid Level Rack
2015	Pressure Transducers
2016	5-Volt Power Supply
2017	Camera Lights
2018	Glennite Accelerometers
2019	Accelerometers
2020	Donner Accelerometers
2021	Thermocouples
2022	Pulse Divider
2023	1st Motion & Cutoff Module

Measuring Group

No.	Equipment
2024	Resistance Thermometers
2025	Cont. Liquid Level Probe
2026	8, 25, 40 Second Timers
2027	Thermistors
2028	Rate Gyro & Adapter
2029	Rise Rate Detector
2030	Resistance Thermometer
2031	Pressure Transducer
2032	Measurement Calibrator
2033	PSID Pressure Transducer
2034	Rack Select Module
2035	Continuity Test
2036	Inverter Frequency Measuring Adapter
2037	Voltage Inverter
2038	PSIA Pressure Transducer
2039	Not Assigned
2040	PSIA Pressure Transducer
2041	Rate Gyro
2042	Servo Accelerometer
2043	Calorimeter
2044	Remote Calibrator
2045	Spin Type Accelerometers
2046	Frequency Dividers
2047	Engine Cutoff Sensor, Lox
2048	Flow Meter

Measuring Group

No.	Equipment
2049	Liquid Level Sensor
2050	Pyrotechnic Liquid Level Det.
2051	D.C. Amplifiers
2052	D.C. Amplifiers
2053	Calorimeters
2054	D.C. Amplifiers
2055	Speed Sensing Transducer
2056	Spectrum Analyzer
2057	Time Correlation Unit
2058	Angular Rate Gyro
2059	Liquid Loading Electronics
2060	Microphone Assembly
2061	Frequency - To - DC Converter
2062	DC Amplifiers
2063	PSIA Pressure Transducers
2064	PSID Pressure Transducers
2065	Accelerometer
2066	Servo Accelerometer
2067	Strain Gage
2068	Sync Buffer Unit
2069	Lox Tank
2070	Flowmeter
2071	Fuel Tank
2072	Liquid Level Detector LOX and Fuel
2073	Liquid Level Detector LOX and Residual

Measuring Group

No.	Equipment
2074	Calibrated Set: Accelerometer A.C. Amplifier Emitter Follower Cable
2075	Calibrated Set: Accelerometer A.C. Amplifier
2076	DC Amplifier Assembly; For Leak Detectors
2077	Calibrated Set: Microphone, Emitter Follower
2078	Cut-off Sensor: Engine Fuel Depletion
2079	Transducer, Temperature Resistance Type
2080	Potentiometer, Switch
2081	Pulse Converter
2082	Transducer Absolute Pressure
2083	Temperature Sensor
2084	Cable End Cap; LOX, LOX Residual, and Fuel
2085	Switch, Single Pole Double Throw
2086	Transducer, Temperature Resistance Type
2087	Switch, Valve Positioning
2088	Flight Combustion Monitor System
2089	Servo Accelerometer Set
2090	Coil, Pickup
2091	Lox Loading Probe
2092	Flowmeter
2093	Separation Transducer
2094	Transducer Assembly Thermocouple
2095	Transducer Assembly, Thermocouple

Measuring Group

No.	Equipment
2096	Heater, LOX Fill and Drain Valve
2097	Slosh Electronics
2098	Measurement Calibrator and Measuring Rack Selector
2099	Instrumented Base Heat Shield
2100	Electronic Controller Temperature
2101	Accelerometer, AC Amplifier, AC Amplifier Set
2102	Indicator Assembly Main Fuel Valve
2103	DC Amplifier Assemblies (Astrionics)
2104	Accelerometer, Vibration
2105	Accelerometer, Vibration
2106	Accelerometer, Vibration
2107	Cables Ext.
2108	F-1 Engine Functional Checkout

APPENDIX A

Telemetry Group

No.	Equipment
4001	Airborne Tape Recorder
4003	RF Power Amplifier
4004	Single Side Band Tel Ass'y
4005	Telemetry Calibrator
4008	Telemetry Transmitter
4009	Remote Digital Sub-Multiplexer
4010	Model 270 Time Division Multiplexer Ass'y
4011	PCM/RF Assembly
4012	Telemetry Calibrator
4013	Model A Telemetry Ass'y Model Al Telemetry Ass'y X06E Telemetry Ass'y X06D-1 Telemetry Ass'y
4014	Model B Telemetry Ass'y Model B11 Telemetry Ass'y
4015	Model 301 PCM/DDAS Ass'y
4016	RF Assembly
4018	Model 410 Digital Multiplexer
4019	Computer Interfact Unit
4020	Vibration Multiplexer
4021	Telemetry Calibration, Power and Control Ass'y
4022	VCO
4023	Mixer Amplifier
4024	TM Ass'y, Mod A/3
4025	DC Power Isolator
4026	SSB/FM Top Deck Ass'y

APPENDIX A

R.F. Group

No.	Equipment
4500	Transponder, ODOP
4501	Antenna ODOP
4502	Transponder, Type "C" Azusa
4503	Deleted from Vehicle
4504	Command Receiver AN DRW13
4505	Transponder C-Band
4506	Antenna C-Band
4507	Antenna Azusa
4508	Deleted from Vehicle
4509	Antenna Telemetry
4510	Antenna Command
4511	Power Divider Telemetry
4512	Command System Power Divider
4513	Telemetry Voltage Standing Wave Ratio (VSWR) Measuring Ass'y
4514	Command Directional Coupler
4515	Telemetry R.F. Multicoupler
4516	Telemetry Coaxial Switch
4517	Telemetry R.F. Terminator
4518	T.V. Antenna
4519	Hybrid Ring
4520	T.V. Camera, Camera control & transmitter
4521	Command Receiver MCR-503
4522	Telemetry VSWR Monitor