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Technical Report 527

HIGH TORQUE-TO-INERTIA SERVO SYSTEM FOR STABILIZING SENSOR SYSTEMS

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FD Groutage
Avionics Systems Branch
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April 1980

Final Report

Prepared for
Naval Air Systems Command
Code Air-360H

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Work was done by the Avionics Systems Branch under 63303N, W0447-AA, under the direction of the NAVAIR Electromagnetic Radiation Source Elimination (ERASE) Program Manager, Dennis Distler, AIR-360H.

Released by
FM Tirpak, Head
Sensors Division

Under authority of
RE Shuttters, Head
Surface/Aerospace Surveillance
Department

ACKNOWLEDGMENT

The author extends sincere appreciation to Daryl E. Smith for his contribution to this report. Mr. Smith was responsible for deriving the Fortran computer code for many of the math models used in the development of the servo system.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NOSC Technical Report 527 (TR 527)	2. GOVT ACCESSION NO. AD-A086705	3. RECIPIENT'S CATALOG NUMBER (9)
4. TITLE (and Subtitle) HIGH TORQUE-TO-INERTIA SERVO SYSTEM FOR STABILIZING SENSOR SYSTEMS Candidate systems include missile guidance, surveillance, and tracking.	5. TYPE OF REPORT & PERIOD COVERED Final ~~TR~~ report - July 1979 - January 1980	
7. AUTHOR(s) F. Dale Groutage	8. CONTRACT OR GRANT NUMBER(s)	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Ocean Systems Center San Diego, CA 92152	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 633 03N W0447AA	
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Air Systems Command, Electromagnetic Radiation Source Elimination (ERASE) Program, Code AIR-360H	12. REPORT DATE April 1980	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 12 275	13. NUMBER OF PAGES 236	
15. SECURITY CLASS. (of this report) Unclassified		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited. (14) NOSC/TR-527		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) (17) W0447AA		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Platform stabilization Stabilizing sensors Missile guidance Surveillance Tracking		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This is a technical report on the design and development of a high torque-to-inertia servo system for stabilizing a sensor system. The design philosophy leads to a low cost/high performance system. The stabilizing element developed is universal and has application for 1) missile guidance, 2) surveillance, and 3) tracking sensor systems. The servo design is based on math models and is used to develop performance specifications and perform evaluations.		

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OBJECTIVE

Establish the design and develop a servo system for space stabilizing and command positioning a sensor system. Provide growth potential in the design for alternate sensors or sensor weight to be added to the gimbal structure without servo system performance degradation.

RESULTS

1. A high torque-to-inertia servo system for space stabilizing a gimbal sensor was developed. The high torque-to-inertia concept led to a low-cost design configuration with multisensor growth potential which would allow additional weight to be affixed to the gimbal structure.
2. Math model designs were formulated for the sensor system/stabilization platform in time- and frequency- domains.
3. A system control interface was developed to test and monitor the servo system in both the stabilization and slave command modes.
4. Performance levels were established for the stabilization and the slave command modes of operation.

RECOMMENDATION

Review some of the gimbal mechanical designs for minimizing friction.

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1. INTRODUCTION

This report covers the design and development of a universal servo system for space stabilizing a sensor system for tracking applications.

1.1 BACKGROUND ON SPACE STABILIZED SENSORS FOR MISSILE GUIDANCE

Space stabilized sensors for missile guidance are used for the following reasons:

- (1) They provide an inertial reference from which the line of sight rate can be measured.
- (2) Body motion is decoupled from the guidance signals.
- (3) The target is tracked (sensor system pointed at the target through a mechanical gimbal system) where the sensor system is maintained boresighted on the target.

Alternate ways of achieving the above characteristics have been derived using "fixed body" (sensor system centerline fixed relative to the missile body centerline) sensor systems. An example of the fixed body sensor is the electronic beam steering sensor by means of phased array antennas. The fixed body systems are rather atypical of tactical missiles and will not be specifically addressed. These beam steering systems are in many ways analogous to the gimballed system as far as the resulting overall missile guidance is concerned.

This report presents in detail the design and development of a space stabilizing sensor system platform. The aspects of how and why gimballed stabilization platforms achieve the above criterion (inertial reference, body motion decoupling, and target tracking) will be expanded upon.

The design philosophy is based on a high torque-to-inertia ratio which is detailed in the "Stabilized Platform Design" section.

The primary emphasis of this report relates to a space stabilization platform used for stabilizing a missile guidance sensor. The platform, however, is not restricted to this application. It is equally well suited to other applications such as stabilizing a sensor for surveillance and data gathering systems. In essence the development presented in this report relates to a state of the art/high technology space stabilizing sensor platform. Many systems, whether they be missile guidance, surveillance, or other type of tracking systems require that the tracking sensor be space-stabilized. This report covers the various phases of the development of a high torque-to-inertia space stabilizing sensor platform with universal respect to a number of applications. Reference 1 presents examples of systems that could utilize stabilized platforms for surveillance sensor or missile guidance systems.

1. Groutage, FD, Strike Drone - A Defense Suppression Concept Using Unmanned Cruise/Loiter Attack Vehicle, SAE Transactions, Vol. 87, 1978.

2. MATH MODEL DEVELOPMENT

A math model for the stabilized platform was developed and from this model design specifications and predicted system performance were established.

2.1 SENSOR MEASUREMENT GEOMETRY

The fundamental function of a space-stabilized sensor is to measure and provide estimates of these measured guidance signals to the missile control section. The fundamental measurement made by the sensor is the angular position of the target relative to the sensor centerline or boresight. The angular information required for missile guidance control is the angular line of sight rate. This assumes that missile guidance is via proportional navigation. Missile guidance control can be structural around a number of different guidance laws, reference 2. The guidance law assumed in this document was proportional navigation.

Figure 1 illustrates the geometry for the sensor/missile/target angular relationships.

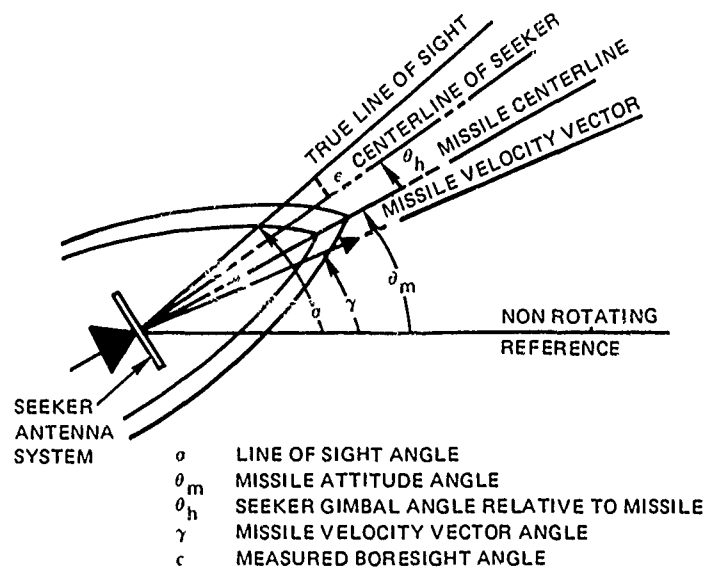


Figure 1. Sensor/missile/target angular relationship.

A block diagram can be generated based on the geometric relationships described in figure 1.

$$\epsilon = [\sigma - \theta_m - \theta_h] T_1(s) \quad (1)$$

where $T_1(s)$ is the sensor transfer function.

2. Paarmann, LD, Faraone, JN, and Smoots, CW, Guidance Law Handbook for Classical Proportional Navigation, ITT Research Institute, GACIAC HB-78-07, 1978.

This equation can be translated to a diagram using two summing junctions as follows:

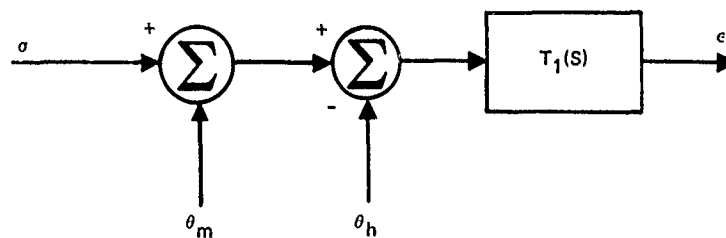


Figure 2. Block diagram of equation 1.

Using rates rather than position quantities, figure 2 is changed as follows:

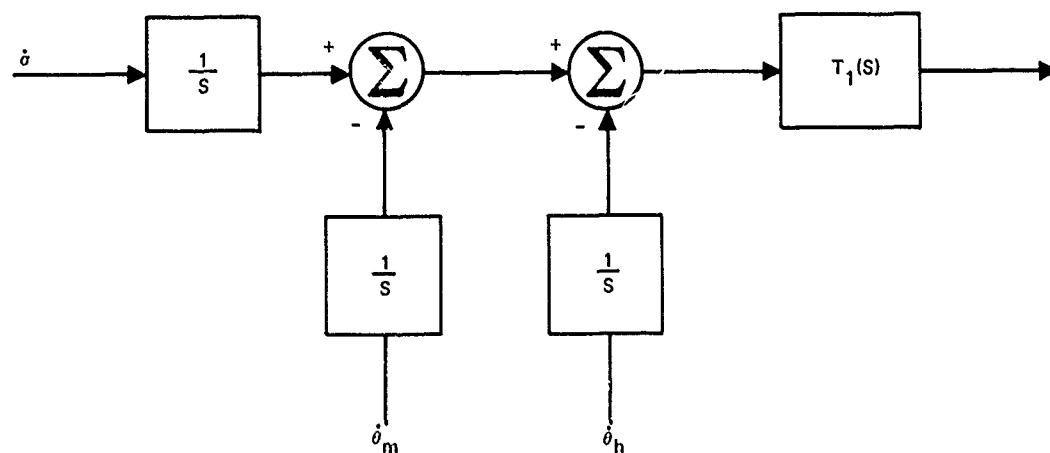


Figure 3. Block diagram of measured boresight error signal ($\dot{\sigma}$, $\dot{\theta}_m$ and $\dot{\theta}_h$ are rate quantities).

To be an inertial reference a device must maintain a fixed attitude in space or be space stabilized. Space stabilization is accomplished by means of a rate sensor mounted on the element to be fixed or stabilized in inertial space. Missile body motion or base motion, body rate ($\dot{\theta}_m$) is sensed by the rate sensor which generates an output voltage proportional to the missile body rate. The rate sensor output voltage is used to generate a head rate opposing the missile body rate. The net rate sensor input then becomes the difference between head rate and missile body rate. The purpose of this servo loop is to maintain zero head rate relative to inertial space. The degree to which stabilization can be achieved is determined by the loop gain. For stability, a compensation/shaping network is included in the loop which maintains a required phase/gain margin.

Incorporating the elements of the stabilization loop into a block diagram relative to the geometry of figure 1 is illustrated in figure 4.

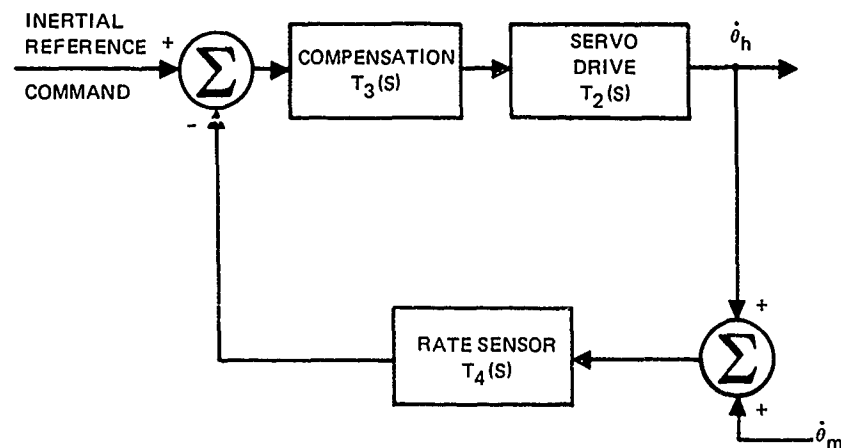


Figure 4. Stabilization loop.

Figures 3 and 4 are combined relative to the geometry of figure 1 which results in stabilized tracking sensor system which is shown in figure 5

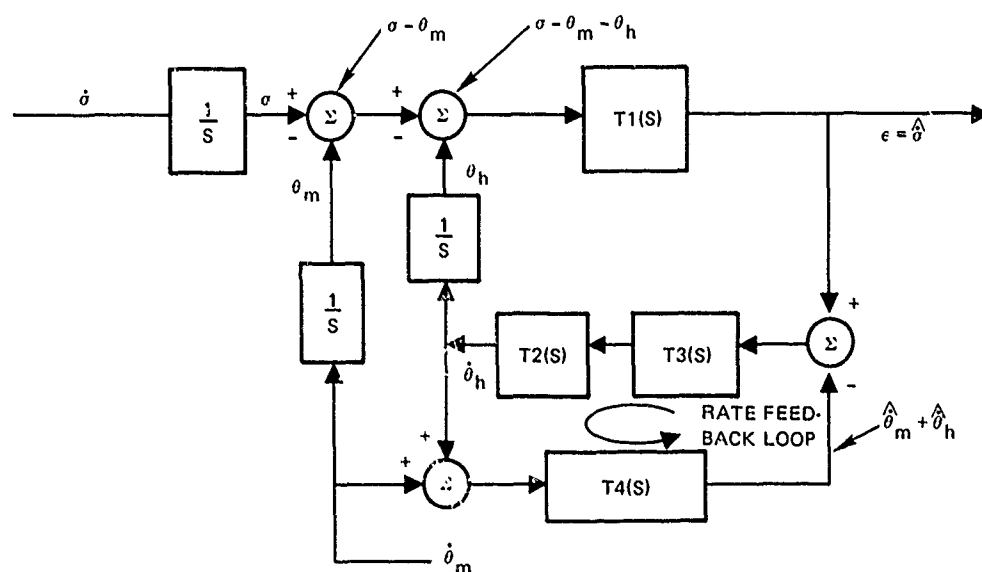


Figure 5. Sensor tracker system.

The following definitions hold for the transfer functions and variables in figure 5:

$T_1(s)$ is Sensor Transfer function

* $T_2(s)$ is Torque Source — Servo Drive/Load Inertia transfer function

$T_3(s)$ is the electronic servo gain and compensation networks Transfer functions

$T_4(s)$ is the Transfer function of the rate Sensor which is physically mounted to the gimbal structure.

$\epsilon = \hat{\sigma}$ is the measured Line of Sight (LOS) rate or the estimated LOS rate.

$\hat{\theta}_m$ is the measured value of the missile body angular rate in a particular plane.

$\hat{\theta}_h$ is the measured value of the Sensor gimbal angular rate in a particular plane.

Figure 5 is the starting point for the design, development and analysis of a space-stabilized sensor system.

2.2 MATH MODEL

Figure 5 was formulated based on sensor/missile/target angular relationships. Figure 5 can be reconfigured as shown in figure 6.

*Usually consists of torque motor, torque motor servo amplifier, and load, which includes gears, gimbals and sensor load inertia.

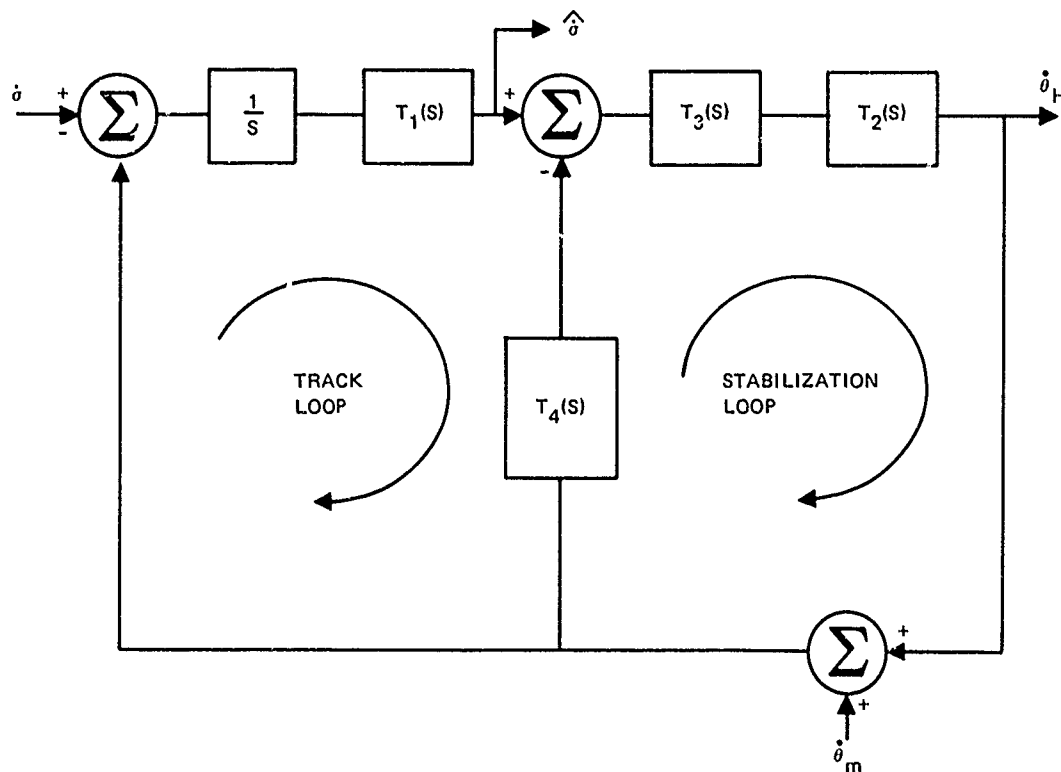


Figure 6. Generalized block diagram of sensor/stabilized platform.

$T_4(s)$ has the units of volts/rad/sec.

$T_1(s)$ has the units of volts/radian.

$T_3(s)$ has the units of volts/volt.

$T_2(s)$ has the units of rad./sec./volt.

The stabilization and the track loops are the fundamental servo loops that are designed together since they are the heart of the stabilized platform system. The slave loop is independent of the track loop and can be designed separately. Therefore, two models must be developed:

1. Stabilization/Track, and
2. Slave loop models.

The stabilization loop provides the body motion decoupling properties that were mentioned earlier as a desired requirement of the space stabilized platform. The stabilization loop, also referred to as the stab loop, is drawn separately as illustrated in figure 7.

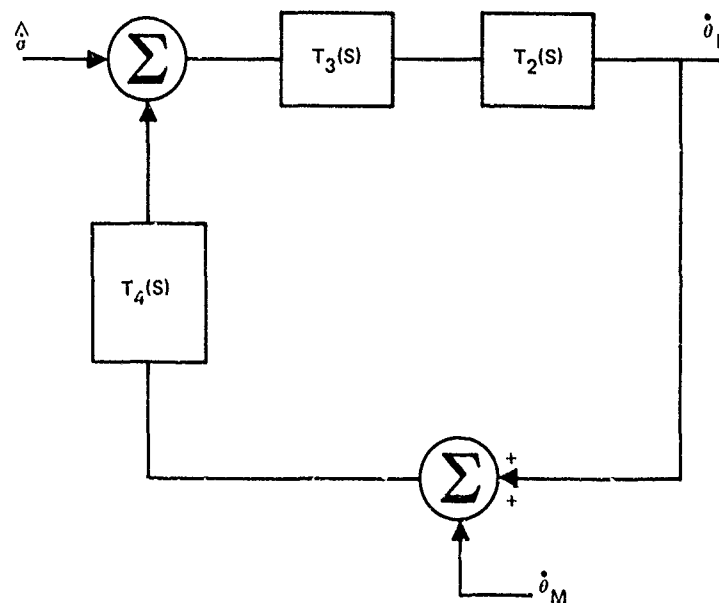


Figure 7. Generalized block diagram of stabilization loop.

The transfer function of the gimbal movement ($\dot{\theta}_h$) as a function of steering commands ($\hat{\sigma}$) is as follows:

$$\frac{\dot{\theta}_h}{\hat{\sigma}} = \frac{T_3(s) T_2(s)}{1 + T_3(s) T_4(s) T_2(s)} \quad (3)$$

where the assumption is made that $\dot{\theta}_m$ is zero.

The transfer function of the gimbal movement ($\dot{\theta}_h$) as a function of body motion inputs is as follows.

$$\frac{\dot{\theta}_h}{\dot{\theta}_m} = \frac{-T_4(s) T_3(s) T_2(s)}{1 + T_4(s) T_3(s) T_2(s)} \quad (4)$$

It is easily seen that for the magnitude of $T_2(s) T_3(s) T_4(s)$ large or

$$|T_2(s) T_3(s) T_4(s)| \gg 1 \quad (5)$$

that

$$\theta_h \approx -\theta_m$$

This illustrates the body motion decoupling principle of a space stabilized platform. Another way of looking at the body motion decoupling properties of the space-stabilized platform is to examine figure 5. Body motion decoupling implies that the platform subtracts out the motion caused by missile body movement, θ_m , from the desired estimated line of sight guidance signal, $\hat{\sigma}$. Figure 5 is reconfigured as shown in figure 8.

By applying the condition of equation (5) to the transfer function block where body motion feeds into the platform loop, the block diagram illustrated in figure 8 can be simplified as shown in figure 9.

Note that the body motion term $\dot{\theta}_m$ cancels itself out of the steering command, $\hat{\sigma}$. In section 4.0 a detailed analysis and data are presented on the level of body motion that is contained (or corrupts) the desired missile steering command ($\hat{\sigma}$). Of course it is immediately obvious that the desired situation is as modeled in figure 8. There is no corruption of the steering command; however, this is not achievable in reality. Some level of body motion will corrupt the missile guidance steering command. It is this level of corruption that is expanded upon in section 4.0.

2.2.1 Torque Source Model - $T_2(s)$

The torque source and type of configuration are the basic determinations that must be made to quantify the gimbal drive element or the blocks that make up the $T_2(s)$ transfer function of figure 5. Actually the torque source is only one element of the $T_2(s)$ transfer function. $T_2(s)$ is the overall transfer function of the servo amplifier, torque source and gimbal/load. The torque source was selected as an electrical dc, armature controlled torque motor. Other alternatives could have been hydraulics, pneumatics, or electrical motor/clutch drive systems. For the particular guidance sensor environment, torque requirements

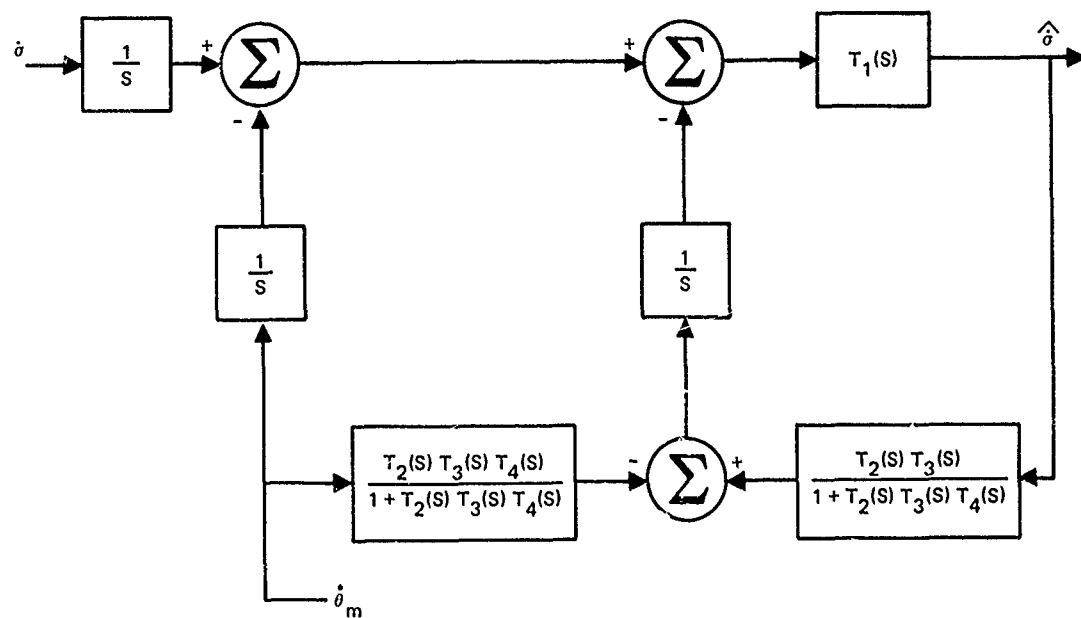


Figure 8. Block diagram of stabilized platform.

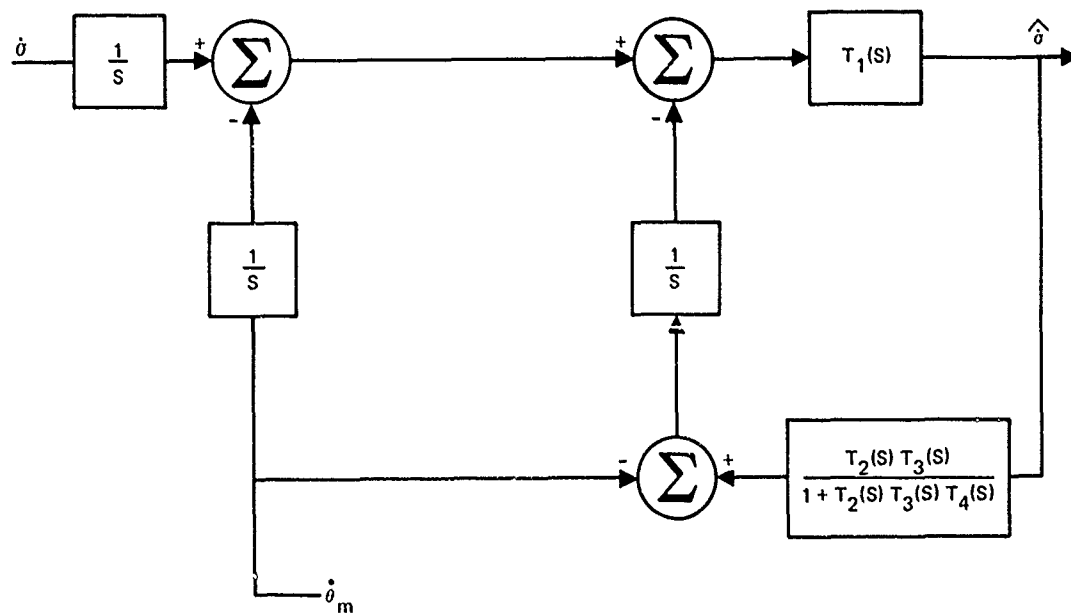


Figure 9. Simplified block diagram of stabilized platform.

and packaging constraints the dc armature controlled torque motor approach was selected. Once this selection was made the configurations as to the control of the torque source needed to be determined.

Basically there are two choices of drive control, voltage, or current. The parameters for relating the control (voltage or current drive) are: (1) system response, (2) velocity error constant, and (3) isolation to extraneous signals and torque sources. A model for each of the control drives is illustrated in figures 10 and 11 (10 is the Current Drive and 11 is the voltage drive servo control). Derivation of each of these models are presented in Appendix C.

In figure 11, the voltage control configuration, it is noted that the servo amplifier is outside the feedback path of the servo motor as compared to the configuration of figure 10, the current control servo drive system. The servo motor and the load for the system of figure 11 is relatively independent of the servo amplifier. The servo amplifier gain is strictly an electronic gain. Therefore, in a response comparison between the voltage drive and the current drive systems, the voltage drive system would consist of the motor/load elements while the current drive system would include the servo amplifier characteristics. Figure 12 shows a simplified block diagram of the servo drive and the electronic gain/compensation elements of a servo system.

For a comparison the transfer function V_R/V_C must be evaluated for both types of drive systems.

The transfer functions for the two different servo drive controls are:

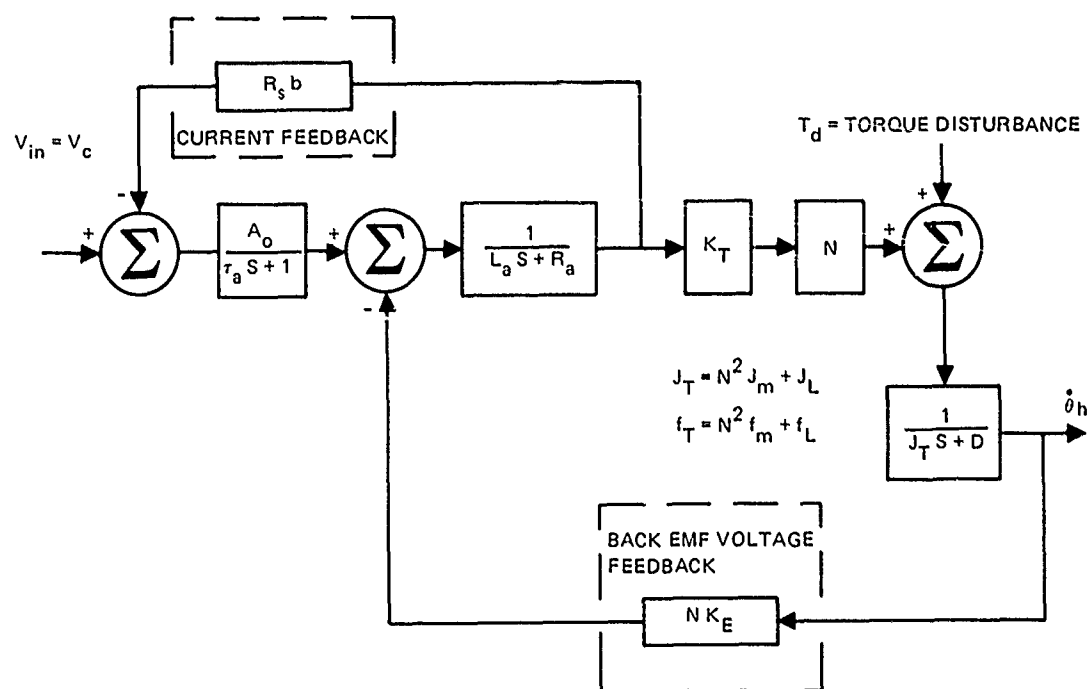
$$T_4(s) = \frac{\dot{\theta}_h}{V_c} = \frac{A_O K_T N}{L_a J_t \tau_a S^3 + (L_a \tau_a D + \tau_a J_t R_a + L_a J_t) S^2 + (DL_a + \tau_a DR_a + J_t R_a + A_O R_{sb} J_t + K_T K_E N^2 \tau_a) S + R_a D + A_O R_{sb} D + N^2 K_T K_E} \quad (6)$$

for current drive, and

$$T_4(s) = \frac{\dot{\theta}_h}{V_c} = \frac{A_{CL} K_T N}{L_a J_t S^2 + (J_t R_a + DL_a) S + R_a D + N^2 K_T K_E} \quad (7)$$

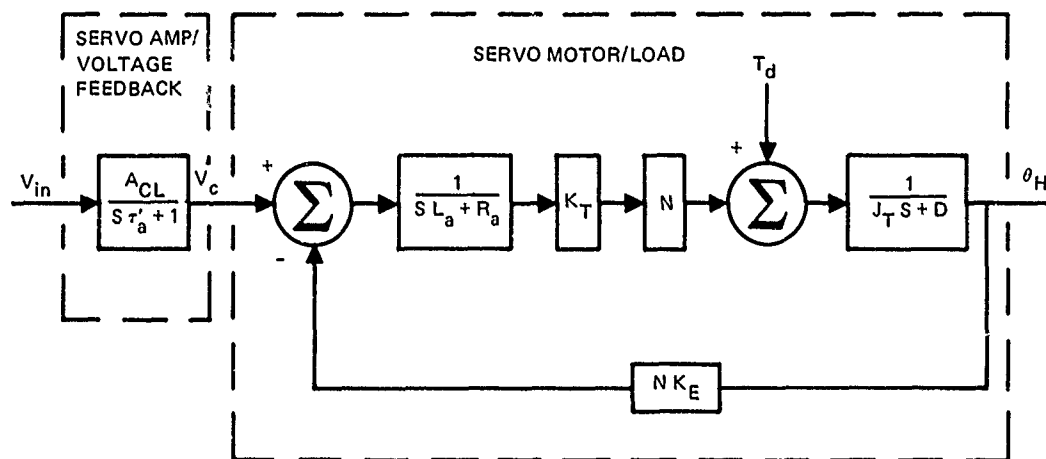
for voltage drive.

The above equations (6 and 7) can be analyzed using inverse La Place transform theory. That is, the corresponding time responses for each type of system can be evaluated for identical inputs. A time domain analysis using an integration routine on the computer can also be used to evaluate the time domain response of the servo drive systems. The La Place transform technique does not take into consideration the nonlinearities of the system while the time integration procedure does. Both of these analysis techniques as well as the computer programs are contained in Appendix E. The current drive system is a third-order system (due to amplifier dynamics) and the voltage drive is a second-order system.



- A_o = AMPLIFIER OPEN LOOP GAIN
- N = GEAR TRAIN RATIO
- R_s = CURRENT SENSING RESISTOR
- b = CURRENT FEEDBACK GAIN
- K_T = MOTOR TORQUE CONSTANT
- K_E = BACK EMF VOLTAGE CONSTANT
- τ_a = OPEN LOOP AMPLIFIER BREAK POINT
- L_a = ARMATURE INDUCTANCE
- R_a = ARMATURE RESISTANCE

Figure 10. Block diagram of current drive servo control.



$A_{CL} \propto \frac{\beta-1}{\beta}$ WHERE β IS THE VOLTAGE FEEDBACK OR RATIO OF THE INPUT (R_1) TO INPUT & FEEDBACK RESISTOR:
 $\tau'_a \propto \frac{r_a}{\beta A_o} \left(\frac{R_i}{R_i + R_c} \right)$

Figure 11. Block diagram of voltage drive servo control.

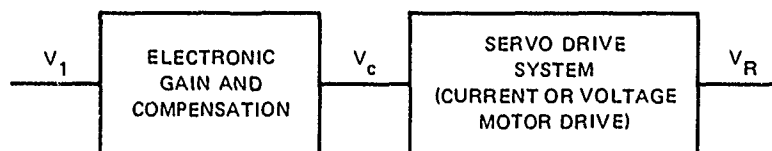


Figure 12. Servo drive system.

The eigen values for each of these systems are evaluated. The location of the roots of these two different types of systems will specify the kind of performance that can be achieved. Specifically, the characteristic roots govern the behavior of the system; therefore, as part of the evaluation criterion to establish which servo control will be used a close look will be taken at where in general the roots lie for these two systems. The transfer functions in expanded form are presented in equations (6) and (7). A typical set of values for a candidate torque motor is as follows:

$$R_a \triangleq \text{armature resistance} = 3.0\Omega$$

$$L_a \triangleq \text{armature inductance} = .0014 \text{ Henries}$$

$$K_T \triangleq \text{motor torque constant} = 24.8 \text{ in-oz/amp}$$

$$K_E \triangleq \text{back EMF constant} = .177 \text{ V/Rad/sec}$$

The driving amplifier (servo amplifier) open loop parameters are:

$$A_o = \text{open loop gain} = 100,000 \text{ volt/volt}$$

$$\tau_a = \text{time constant} = .02 \text{ sec}$$

The parameters that are not specifically known or defined, but are in a relative ball park are the load inertia and viscous damping. Typical values of these parameters are in the following range:

$$.5 \leq J_L \leq 5.0$$

$$.1 \leq D \leq 3.0$$

The gear ratio is the parameter that is not fixed. This parameter can be selected to optimize the performance of the servo drive system. The range of values for the gear ratio (for practical considerations) range from direct to gear ratios of around 50.

Appendix E (figures E-6 and E-7) presents a set of data on gear ratio parameter variations to establish the optimum gear ratio.

Returning to equations (6) and (7) with the above values for the parameters it is seen that the low frequency eigen value for the current drive system is very close to zero and the other two roots, which are complex, are far-out roots and do not influence the response in the region of interest. For the outer gimbal the three eigen values are:

$$S = -.159$$

and

$$S = -1.096 \times 10^3 \pm 5.975 \times 10^4$$

The dominant root is the real root at $-.159$.

The voltage drive configuration has two real roots. The dominant root sets at

$$S = -34.1986$$

with the other root at

$$S = -2108.8168$$

The dominant root for the current drive system is 215 times closer to the origin. This real root near the origin greatly increases the low frequency gain and therefore the velocity error constant of the current drive system as compared to the voltage drive system.

The time response data for each system with a step input is illustrated in figures E-2 and E-3. For the obvious reasons illustrated in these figures the current drive system was chosen as the type of servo drive for the stabilized sensor platform.

2.2.2 Stabilization/Track Loop Models

Basically the derivation of the math model for the stabilization/track loops comes from the generalized block diagram presented in figure 6. The three major elements that make up the stabilization loop are the rate sensor ($T_4(s)$), the torque source/load ($T_2(s)$), and the electronic gain/compensation ($T_3(s)$). The rate sensor is an off-the-shelf item. The specifications of the given rate sensor depends in large upon the specific requirements it must meet for required performance and operating environment. Appendix A presents in detail the definition of the rate sensor, its characteristics/specifications, and rationale for selection.

General specifications for the rate sensor chosen (Honeywell two-axis rate sensor, GG2500) are presented in table 1, and a cutaway view and an outline drawing showing size and configuration are shown in figure 13.

2.2.2.1 Rate Sensor Model – $T_4(s)$. The transfer function for the rate sensor/readout electronics is

$$T_4(s) = \frac{-K_{MHD} K_2}{(\tau_4 S + 1)^3} \quad (8)$$

where K_{MHD} is the rate sensor gain in $V_{RMS}/\text{rad/sec}$. and K_2 is the demodulator gain in V_{DC}/V_{RMS} . The denominator of equation (8) defines a third-order low pass noise filter.

2.2.2.2 Stabilization/Track Loop Compensation Model – $T_3(s)$. A lag-lead type of compensation was chosen to stabilize the servo loop and implement the high acceleration gain and set the bandwidth. The lag portion of the compensation allows a higher low frequency gain to be achieved and thereby a higher acceleration gain. The type of lead compensation chosen provides a minimum phase at a design frequency which sets the closed loop bandwidth. The gain is adjusted so that the zero dB crossover is at the minimum phase location. There is a fair amount of latitude available with this kind of design philosophy. If more loop gain is required for stabilization, isolation properties and acceleration properties, the lag portion of the compensation network can be adjusted. An integrator is incorporated

Parameter	
Scale Factor	GG2500LC02: $15 \pm 5\%$ mv rms/deg/sec GG2500LC03: $15 \pm 1\%$ mv rms/deg/sec
Zero Rate Error (includes run-up repeats)	GG2500LC02: 0.5 deg/sec. max. GG2500LC03: 0.15 deg/sec max.
Linearity	0.1% of max. rate (max dev from best str line)
Cross Coupling (axis change vs. input rate)	0.5% of full scale (max dev from best str line) ⁽¹⁾
Hysteresis	0.01 deg/sec max.
Threshold	0.01 deg/sec max.
Acceleration Sensitivity	0.05 deg/sec/g max.
Output Noise at Null	100 mv rms max. (using 1000-Hz bandwidth meter)
Rate Input Range	± 480 deg/sec
Frequency Response	100 Hz min. without electronics
Ref Gen Output	1V min. rms each axis
Ref Gen Phase Angle	90 ± 0.5 degrees
Performance Stability With Environments	
Zero Rate Error Stability Over All Environments	0.15 deg/sec
Acceleration Sensitivity Stability Over All Environments	0.03 deg/sec/g
Scale Factor Change - vs - Temperature	$\pm 2\%$
Input Axis Change - vs - Temperature	± 0.5 deg
Excitation Requirements	
Motor	26 ± 2 volt rms 400 Hz 2 ϕ , 4 watts max.
Preamp	$\pm 15 \pm 3$ Vdc, 4 ma max. with 500 mv max p-p ripple
Environments	
Overrange Capability	20,000 deg/sec
Temperature	-65°F to +160°F
Vibration	MIL-STD-810, Method 514, Proc II 2 hr/axis - time schedule V of Table 514-II, Curve H (10g peak sine) 1/2 hr/axis - time schedule II of Table 514-II, Curve Q (10g peak sine) 1/2 hr/axis - time schedule II of Table 514-II, Curves AH (11.9g rms random) and AK (20.7g rms random)
Shock	2 drops/axis each direction, 12 drops total each level: 40g, 18 ms; 400g, 1.5 ms; 100g, 6 ms; 500g, 0.75 ms; MIL-STD-810, method 516, proc IV
Acceleration	100g, each direction - each axis
Useful Life	Life tested to 1000 hours
Temperature Shock	MIL-STD-810, method 503, proc I + 71°C to -54°C to +71°C, four (4) hours each temp - 5 minutes between chambers

⁽¹⁾When operated with amplifier-demodulator readout electronics. Deviation is expressed as a percent of opposite axis full scale.

Table 1. MHD rate sensor specifications (GG2500LC02 and GG2500LC03).

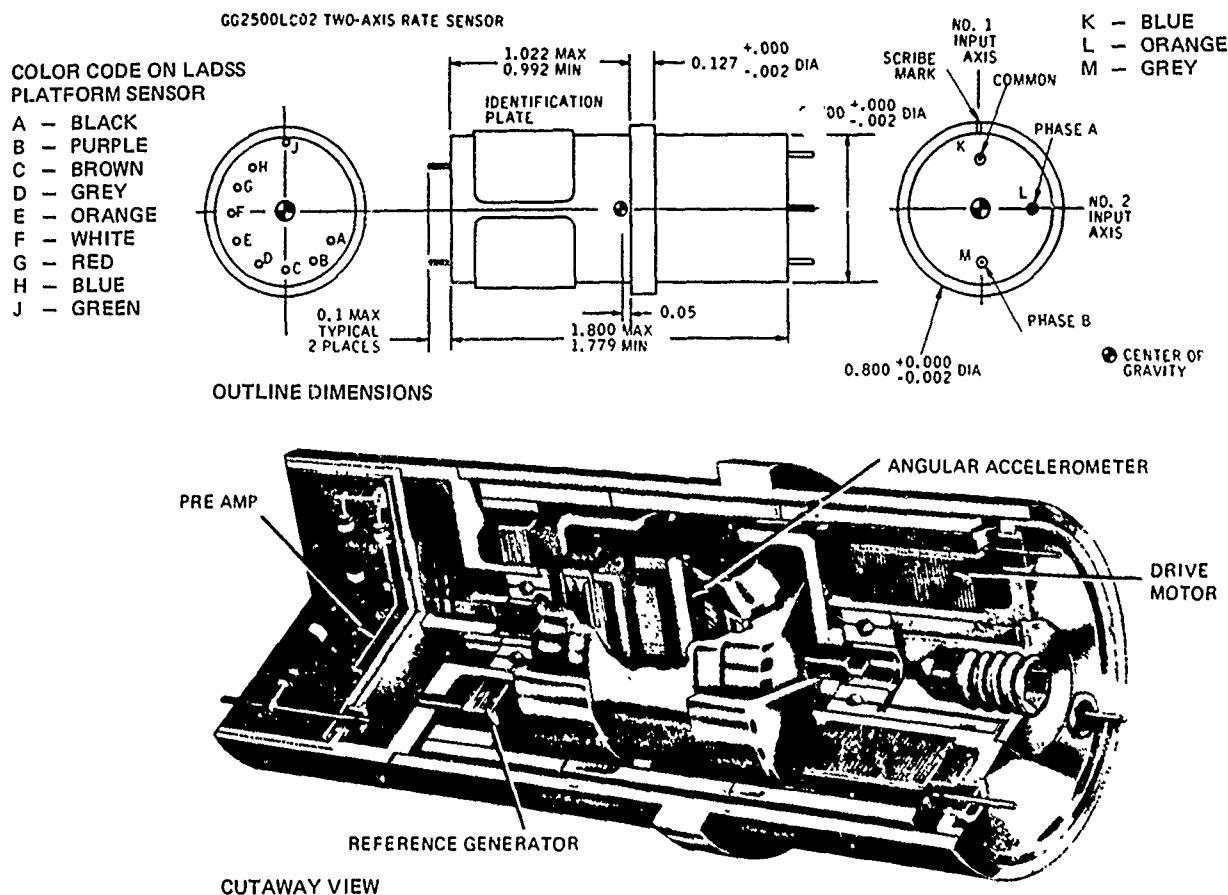


Figure 13. Outline dimensions and cutaway view of rate sensor.

into the compensation network to yield a type one system. References 3, 4, and 5 present compensation techniques for these types of servo system. The compensation transfer function is

$$T_2(s) = \frac{K_3 (\tau_2 S + 1) (\tau'_2 S + 1) (\tau_5 S + 1)}{S (\tau_3 S + 1) (\tau'_3 S + 1) (\tau_6 S + 1)} \quad (9)$$

The lead time constants are τ_2 , τ'_2 , τ_3 , and τ'_3 where

$$\tau_2, \tau'_2 > \tau_3, \tau'_3 \quad (10)$$

The lag time constants are τ_5 and τ_6 where $\tau_5 < \tau_6$.

3. Horowitz, IM, Synthesis of Feedback Systems, Academic Press, 1963.

4. Davis, SA, Feedback and Control Systems, Simon and Schuster, Technical Outlines, New York, 1974.

5. Shinnars, SM, Modern Control Systems Theory and Applications, Addison-Wesley Publishing Company 1972.

2.2.2.3 Stabilization/Track Loop Math Model. The complete math model for the stabilization/track loops model is defined in the block diagram of figure 14. Included in this diagram is the saturation nonlinearities which are due to amplifier saturations of the various amplifiers in the servo amplifier drive system, the compensation network and the rate sensor feedback system. Appendix B presents data on the servo amplifier used in the system. This math model is the basis for the synthesis/design of the stabilized platform track mode. All of the analysis for performance evaluation was accomplished using this model.

A number of items need further exploration. The output of the sensor is the all important estimate of the line-of-sight rate, designated $\hat{\sigma}$. This value is in units of volts, therefore, it is related to the angular values of radians through a scale factor. This scale factor is the product K_2 times K_{MHD} .

The estimated value of the line-of-sight is the quantity that is input to the flight control systems of a guided missile. Since this parameter is referenced to a scale factor; that is, a specific voltage equates to a given line-of-sight rate through a linear relationship, and any gains in the loop which are not constant would contribute to an error in the estimate of the line-of-sight rate. Gain variations are caused by a number of different phenomena such as temperature, acceleration bias, nonlinear seeker guidance measurements and radome error slopes. These items are mentioned at this time to point out that total missile performance is a function of the sensor/stabilization platform's ability to generate accurate line-of-sight measurements. The major contributor to the line-of-sight rate degradation relative to the platform design is the effect of acceleration bias on the rate sensor in the feedback loop. The sensor gains and radome error slope degradation to the line-of-sight rate is not a function of the platform design. The track loop model does include the sensor function but this is only for performance evaluations. There are numerous references on the sensor nonlinearity gain and radome error slope degradation of the line-of-sight rate, see references 6 and 7. Since the rate sensor is a major element of the stabilization platform, the effect of acceleration bias and how it affects the estimated line-of-sight rate ($\hat{\sigma}$) will be examined. As an example refer to the data presented in table 1. We find that the acceleration sensitivity of the MHD rate sensors (GG2500LC02 and GG2500LC03) is 0.05 deg/sec/g max. For a 10 "G" acceleration the rate sensor will contribute a 0.5 deg/sec error in the estimated line-of-sight rate. In this example suppose that $K_2 = 14$ volts Dc/volts rms and that $K_{MHD} = 0.8595$ volts rms/rad./sec and assume that the platform is moving at a rate of two degrees/sec. The voltage being sent to the flight control system is then 0.4190255 volts. Now if the platform, while moving at a two deg/sec rate is subjected to a 10 "G" acceleration, the voltage being sent to the flight control system will be 0.3149986 volt which is an erroneous input to the autopilot since the estimated line-of-sight rate is actually two degrees/sec, but the autopilot is looking at a 1.5 degree/sec. signal which it takes as the line-of-sight rate.

2.2.3 Slave Loop Model

The slave loop, shown in figure 15, is a position type one servo system. The function of the slave loop is to position the sensor or slave the movement of the sensor to an

6. Naval Electronics Laboratory Center, San Diego, CA, NELC TR 2023, Radome Development for a Broadband RF Missile Sensor, by FD Groutage, 1976.
7. The Analytic Science Corporation, TR-170-4, Performance Evaluation of Homing Guidance Laws for Tactical Missiles, 1973.

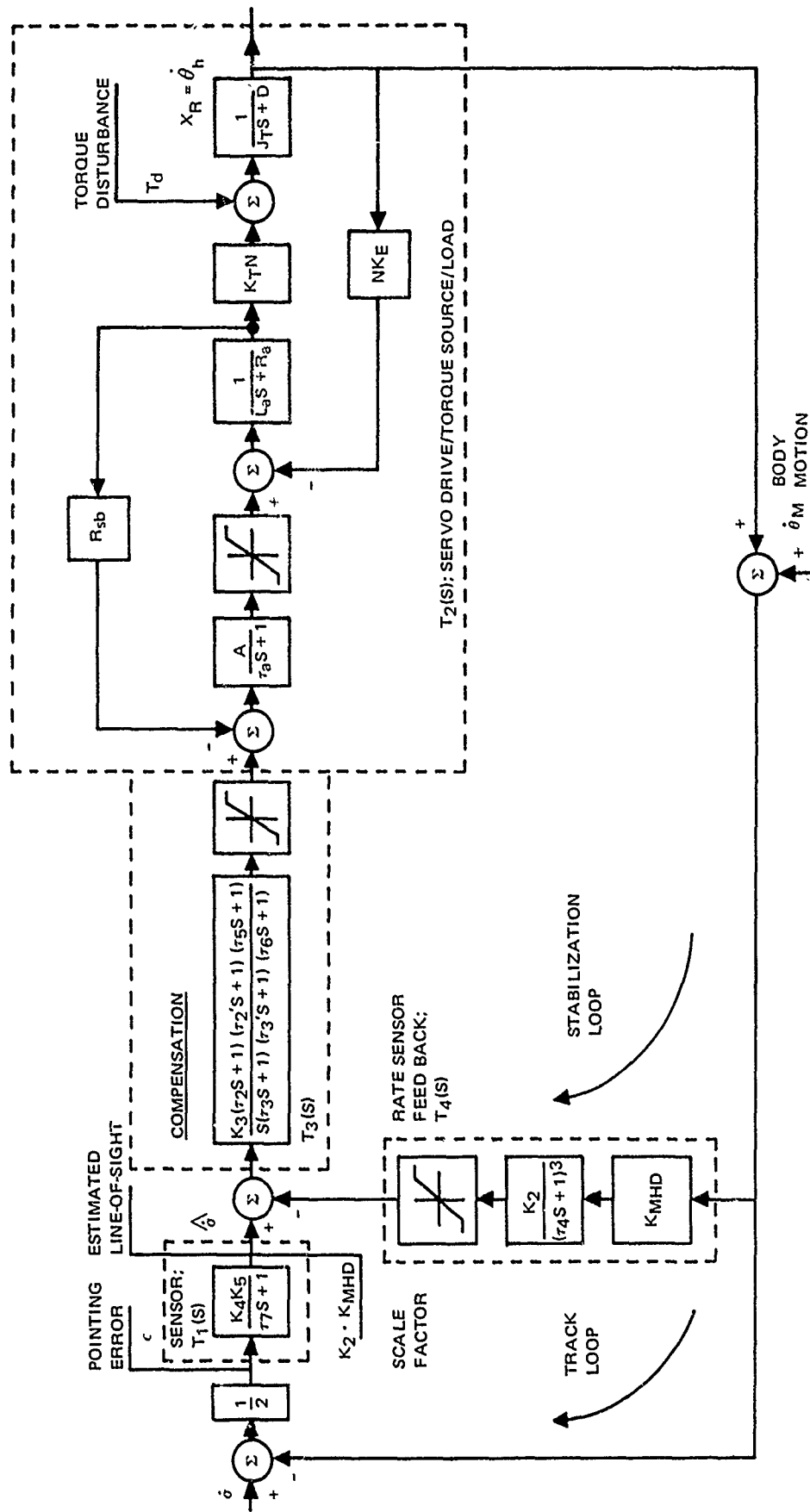


Figure 14. LADSS stabilized platform track/stabilization loops block diagram.

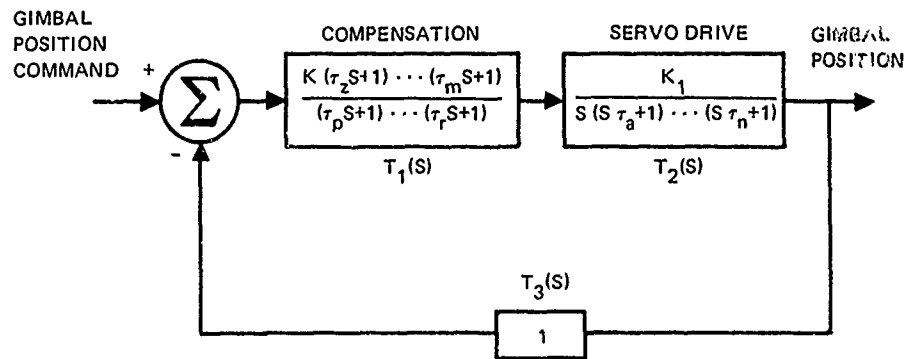


Figure 15. Slave loop representative block diagram.

input command signal. For a position command following type of servo system, the final steady-state position error is a function of the position constant, K_p .

The steady-state error for a type 1 system for a position input is zero.

$$K_p = L(s)|_{s=0} \quad (11)$$

where

$$L(s) = T_1(s) T_2(s) T_3(s) \quad (12)$$

is the loop transfer function.

JJ D'Azzo, (ref. 8), presents a chapter on basic servo system characteristics relative to the steady-state performance of the system.

2.2.3.1 Slave Loop Compensation. The slave loop compensation block is essentially a lag-lead network. The electronic gain or loop gain adjustment is also contained in this block. This type of compensation allows the gain margin, phase margin, and bandwidth to be specified. Contained within the compensation block is a nonlinearity as a result of the limiting of the electronic amplifier used to synthesize the network. Figure 16 illustrates the model of the compensation network.

2.2.3.2 Slave Loop Math Model. The complete math model of the slave loop is presented in figure 17. This figure represents the elements comprising the position Type 1 servo system. The servo drive/torque source/load element is identical to that shown in figure 14, a block diagram of the track/stabilization loop.

8. D'Azzo, JJ and Hoopis, CH, Feedback Control Systems Analysis and Synthesis, McGraw-Hill Book Company.

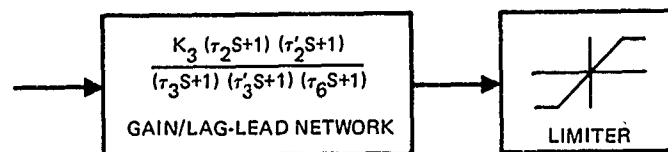


Figure 16. Slave loop compensation network.

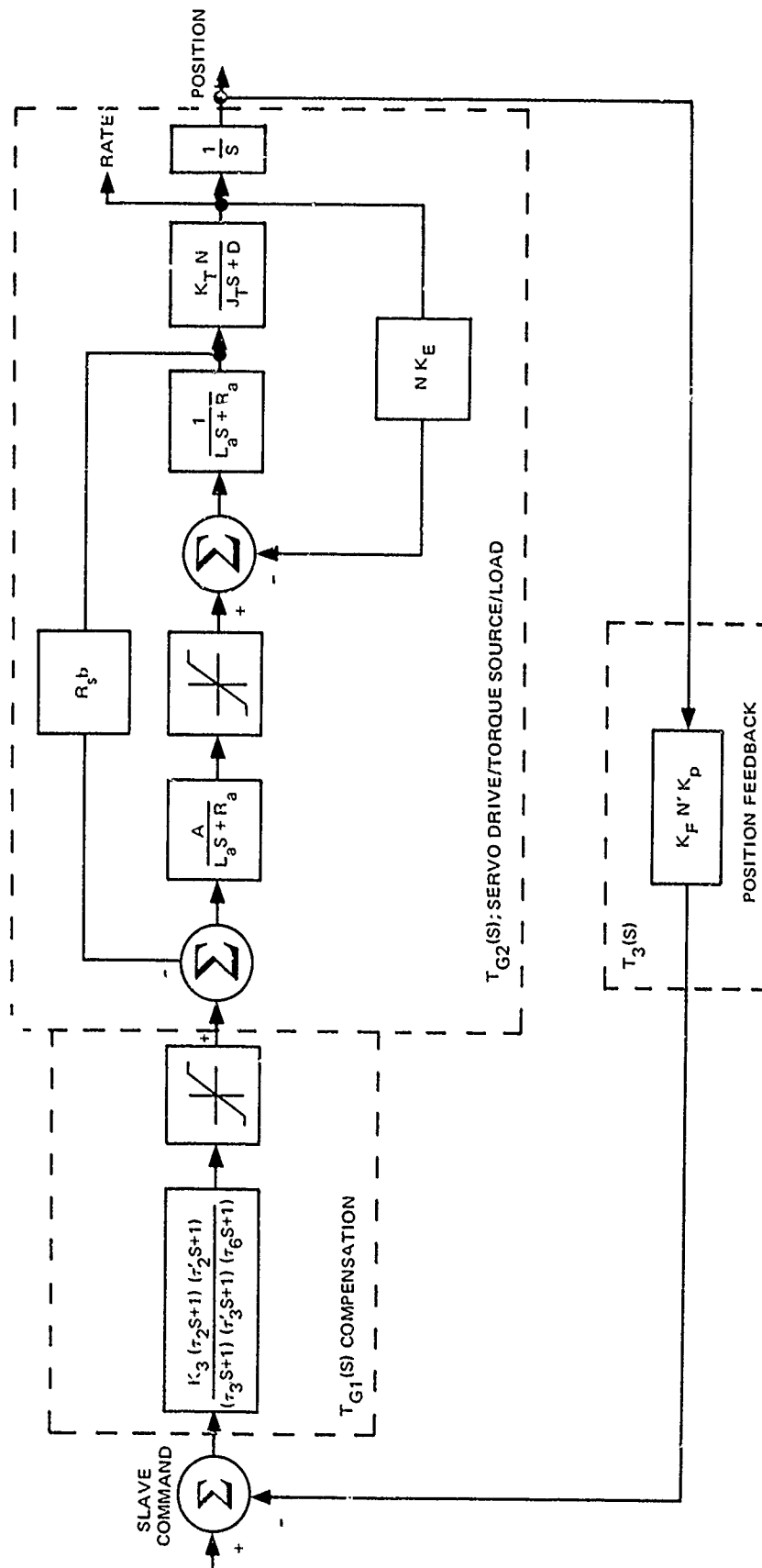


Figure 17. Slave loop of sensor servo platform.

3. STABILIZED PLATFORM DESIGN

3.1 DESIGN PHILOSOPHY

The paramount design criterion was a high torque-to-inertia ratio for the following reasons:

- (1) Leads to a low cost design.
- (2) Allows growth to multiple sensors on the stable member of the platform.
- (3) Achieves high isolation from unwanted inputs such as base or body motion and extraneous torques.
- (4) Has high acceleration and high velocity performance.

With the high torque-to-inertia ratio as the basic approach, the design philosophy addressed two major areas: 1) mechanical design, and 2) servomechanism design. The mechanical design addressed the gimbal type and drive arrangement. The servo design addressed the servomechanism performance and specifications for the track/stabilization and slave loops independently. Performance specifications for both the frequency and time domain were established. Once these specifications were established the problem was reduced to that of a synthesis problem or one of formulating a system that will meet the desired performance specifications. This, to say the least, is not an easy problem. There are many approaches to the synthesis problem each of which may lead to a unique solution. In control system engineering problems there are many solutions that could conceivably satisfy a set of performance specifications. It is the synthesis problem and the solution thereof that present the greatest challenges to the control system engineer. It is in this area that creativity and ingenuity applied with basic engineering are the ingredients for the desired solution.

3.2 MECHANICAL DESIGN

A two degree of freedom stabilized platform consists of a set of gimbals such that a member attached to the gimbal set can be positioned about a pivot point (virtual or fixed) in any of a number of positions within the gimbal travel limits. Figure 18 is a simplified representation of two degrees of freedom motion for a member attached at a pivot point on a fixed base. There are a number of ways that the two degrees of freedom of motion can be achieved through various gimbal schemes. Usually these gimbal arrangements are called inner and outer gimbals. Each gimbal has a separate drive source to move the gimbal. It turns out that for an inner/outer gimbal arrangement at least one of the gimbal drive torque sources must be physically displaced with the gimbal movement (for a geared torque drive system). The torque source that moves or is physically displaced when the gimbals move is the inner gimbal drive source. The outer gimbal drive source can be made stationary, ie, it is not physically displaced with gimbal movement. The inner gimbal drive source can be attached to the inner gimbal and thus will be physically displaced when the inner gimbal moves, or it can be attached to the outer gimbal and will only be displaced when the outer gimbal moves. There are advantages to this last arrangement, inner gimbal drive physically attached to outer gimbal. Figure 19 illustrates this concept. The outer gimbal is a semicircle

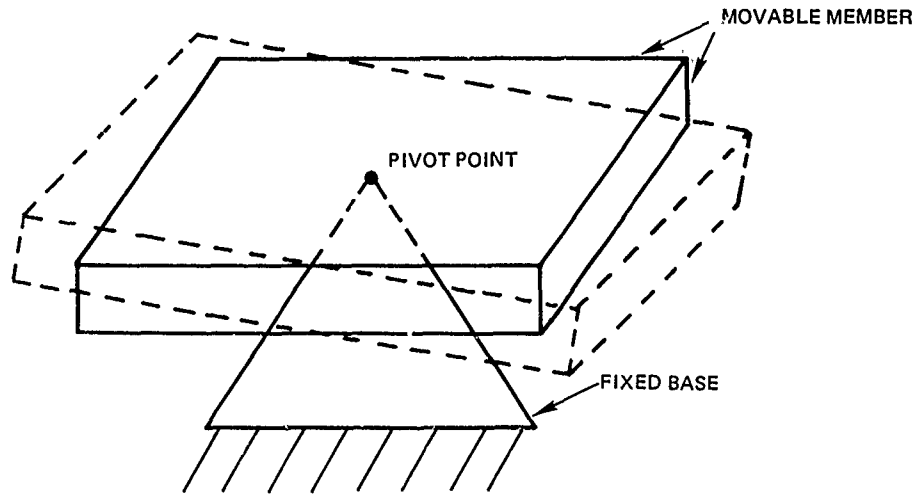


Figure 18. Simplified pivot platform.

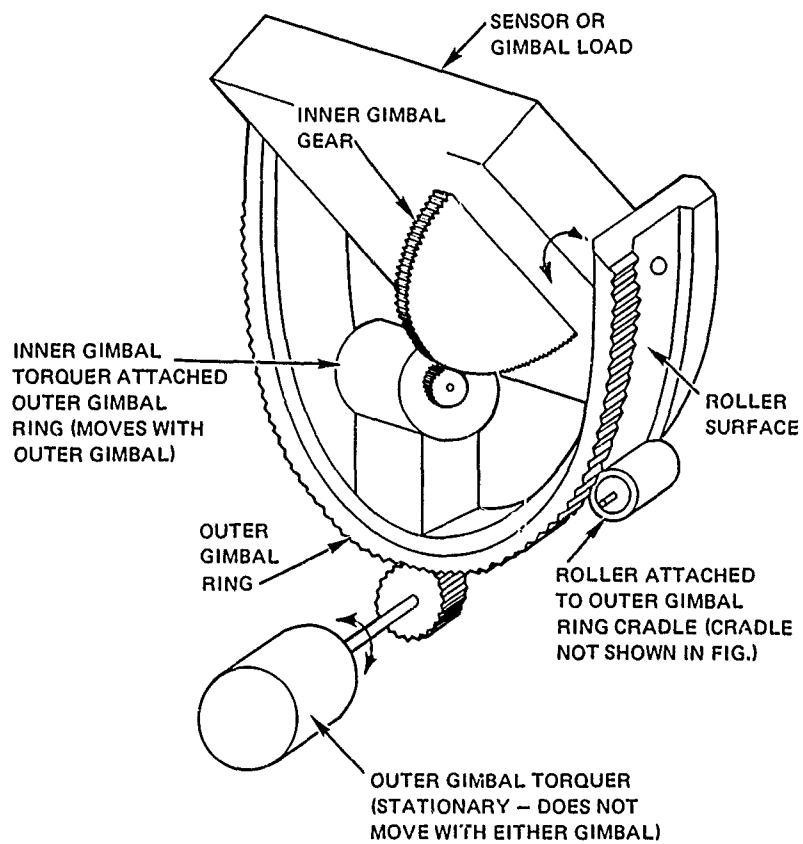


Figure 19. Inner/outer gimbal configuration showing inner gimbal torquer attached onto the outer gimbal.

(bail ring) which is driven, through a gear train, by a fixed stationary torque source. The bail ring choice for an outer gimbal has the following advantages:

- (1) It leads to a virtual pivot point which allows the sensor or load to be physically positioned at the pivot point. (In many sensor applications this is extremely important.)
- (2) It lends itself to larger/heavier sensor loads because volume within the semi-circle can be utilized for sensor packaging.
- (3) The sensor/load is physically attached at two points (inner gimbal bearing points) which allows the heavier/stiffer loads and maintains higher mechanical resonances.

The advantages of the inner gimbal drive source being physically attached to the outer gimbal is that the torque source can be made physically much larger yielding a larger inner gimbal torque value. Traditionally the inner gimbal torque source has been physically located on the inner gimbal. With this arrangement movement of the inner gimbal consisted of the load and the torquer. The weight of the torquer adds directly to the inner gimbal inertia and therefore is of prime concern since the driving design parameter is a high torque-to-inertia ratio. With this arrangement (inner gimbal torque source physically located on an inner gimbal) not only are smaller torque values achievable, but the total inner gimbal inertia is increased leading to a smaller torque-to-inertia ratio, rather than a larger torque-to-inertia ratio. In contrast, the design arrangement that places (physically mounts) the inner gimbal torque source on the outer gimbal leads to a high torque-to-inertia design. The inertia of the outer gimbal is increased by the addition of the inner gimbal torquer; however, the outer gimbal torquer is mounted to a reference that does not move with either inner or outer gimbal movement. It can therefore increase in size yielding a larger torque value to drive the outer gimbal with the added weight.

The inner/outer gimbal and torque drive arrangement shown in figure 19 has another paramount advantage - it lends itself to an optimum gearing arrangement. Figure 20 presents a typical curve showing speed of response to gear ratio. It is seen from this figure that a direct drive system is far from optimum. In fact it approaches the same performance as a very high gear ratio system. The semicircle bail ring/inner gimbal drive located on outer gimbal design is of a geometrical shape and configuration such that optimum gearing can be taken advantage of.

3.3 SERVO MECHANISM DESIGN

As mentioned earlier, two separate independent servo loops are used in the sensor platform: 1) Track/stabilization loop used for null tracking a target to generate an estimate of the line-of-sight rate and decouple base or body motion from the estimated line-of-sight rate and provide a space stabilized inertial reference, and 2) Slave loop used to position the sensor or slave the sensor to a commanded position input. Figures 15 and 17 are block diagrams of these two servo loops respectively. Since these two loops are independent, each will be treated as separate designs.

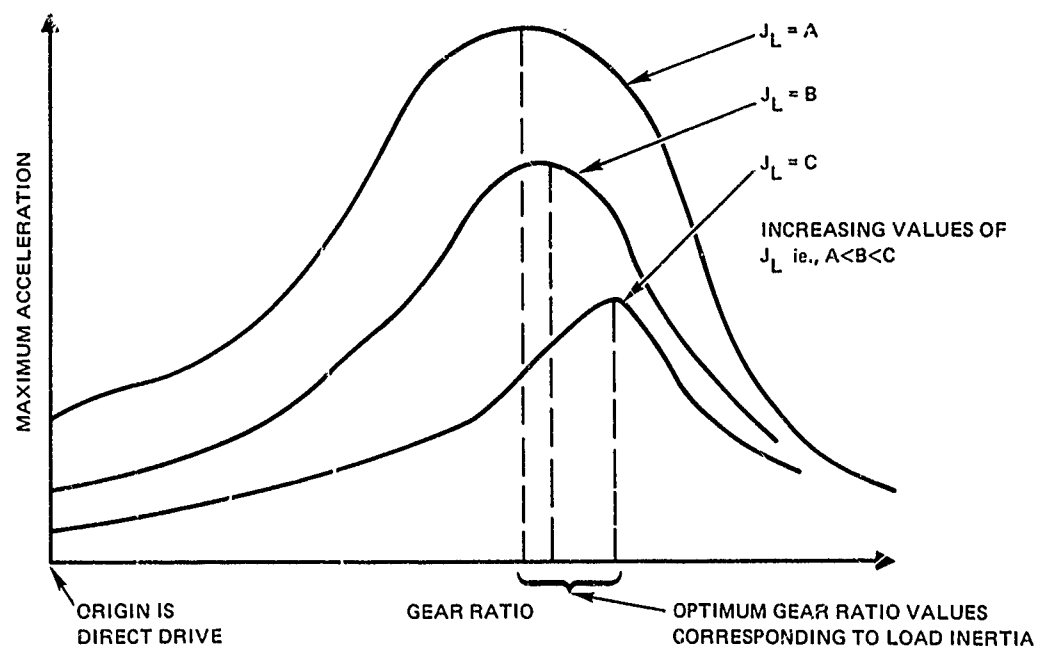


Figure 20. Typical response curve as a function of gear ratio and load inertia.

A. PERFORMANCE SPECIFICATIONS

Performance specifications (ref 9) may be divided into three sub groups:

1. Frequency-domain specifications.
2. Time-domain specifications.
3. Specifications on statistical bases.

The first two are the most popular and dominate the literature. These will be used to establish the design parameters and performance specifications of the servo loops.

B. FREQUENCY-DOMAIN SPECIFICATIONS

Frequency-domain specifications are those which relate to the relationships between the sinusoidal input and outputs of a servo mechanism. A list of the more common frequency-domain specifications found in the control systems literature are:

1. Bandwidth

9. Elgerd, I., Control Systems Theory, McGraw-Hill Book Company, 1967.

2. Phase margin (and crossover frequency)
3. Gain margin
4. M peak (and peak frequency)
5. Deviation ratio
6. Error-constant-bandwidth ratio
7. Output impedance
8. Gain-bandwidth product

Not all of these specifications are mutually exclusive. A more concise list of the frequency-domain performance specifications are

1. Bandwidth BW
2. M peak M_p
3. Peak frequency ω_p
4. Output impedance Z

Figure 21 presents a typical magnitude plot from which the definition of the frequency-domain performance specifications are illustrated.

In figure 21 BW_3 is the three dB bandwidth. This is the servo bandwidth normally referred to as just BW. The BW_6 bandwidth is referred to as the 6 dB bandwidth. $|T(j\omega)|$ is the magnitude of the total closed loop system transfer function as a function of $j\omega$. (See ref 14 for bandwidth definitions.)

Each of the basic frequency-domain specifications will be discussed briefly.

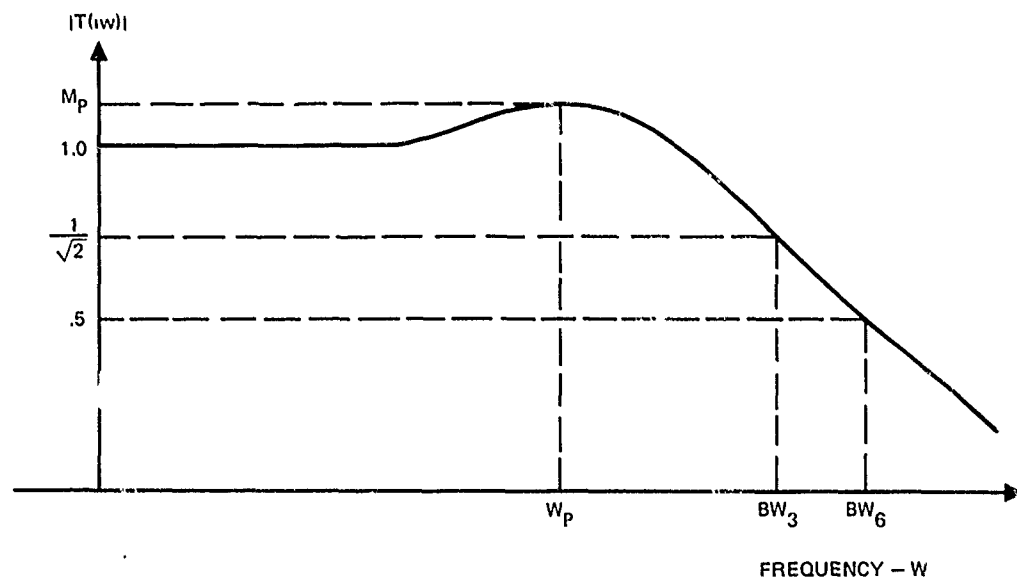


Figure 21. Frequency-domain performance specification definitions.

14. Watkins, BO, Introduction to Control Systems, the MacMillan Company, New York, 1969.

C. BANDWIDTH BW

BW is probably the most significant performance specification as it gives indication of the speed of response. Horowitz [ref 3], pages 192 and 194, presents an empirical formula with the rise time to the bandwidth. However, noise rejection and price considerations require low BW. The choice of BW is thus a compromise affair that will differ from case to case.

M Peak, M_p , and Peak Frequency ω_p

These quantities are basically stability specifications. The magnitude of the peak relates to the settling time (refer to time-domain specifications), ie, the time required for the oscillations to die out. There is also a correlation between M_p and the sharpness with which the magnitude falls off with the percent overshoot. Jaworski [ref 10] presents empirical transient formulae relationships between frequency-domain and time-domain performance specifications.

Output Impedance Z

A maximum specification on Z will guarantee that the servo will perform properly over the expected load range. It is particularly important to realize that Z will vary with frequency, and it is therefore necessary to specify its peak value. The corresponding time-domain specification, compliance, is obviously not sufficient to predict intolerable output oscillations that could result from periodic load variations if applied at a frequency corresponding to peak impedance.

It should be stressed that the impedance specifications make sense only in those cases where, in reality, we can expect load fluctuations.

Time-Domain Specifications

Probably the most common of all performance specifications are those that relate the transient output of a system to a test input, usually in the form of a step function. Conceivably, one could specify time-domain performance specifications in terms of many various types of test inputs, and it is therefore appropriate to give some of the reasons why we chose this particular one:

1. A step is easy to apply and is sufficiently drastic.
2. No physical system is capable of following a step completely.
3. A large amount of information is available in the literature relating to this type of test input.
4. From a knowledge of the step-function response, it is possible to compute the response for any arbitrary input.

The last fact is demonstrated in figure 22. We wish to compute the response at time t for the general input function $i(\tau)$, assuming that we know, either from analysis or

10. Jaworski, ZE, Empirical Transient Formulae, Electronic Engineering, September, 1954.

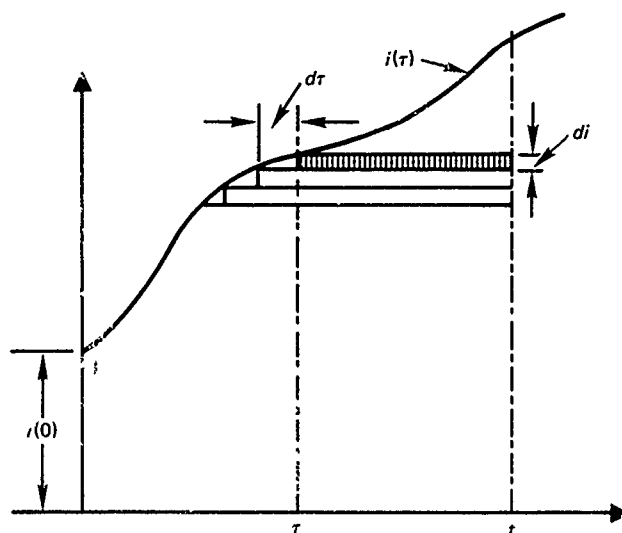


Figure 22. A general signal $i(\tau)$ can be considered as composed of elementary step functions.

from experiment, the response $g(\tau)$ for a unit step input applied at $t = 0$. The input function $i(\tau)$ can be considered composed of the infinitesimal step functions shown shaded in the figure.

By superposition, we obtain the output at time t from all these step functions of amplitude di plus the initial step of magnitude $i(0)$:

$$\begin{aligned} o(t) &= i(0)g(t) + \int_0^t g(t - \tau) di = i(0)g(t) + \int_0^t g(t - \tau) \frac{di}{d\tau} d\tau \\ &= i(0)g(t) + \int_0^t g(t - \tau) i'(\tau) d\tau \end{aligned}$$

As in the case of frequency-domain performance specifications, we find that the literature abounds with suggested figures of merit. The five time-domain performance specifications which will be used are:

1. Delay time T_D
2. Rise time T_R
3. Percentage overshoot PO
4. Settling time T_S
5. Final (static) value of error FVE.

These are illustrated in figure 23. Explanation of these time-domain performance specifications is expanded in the following paragraphs.

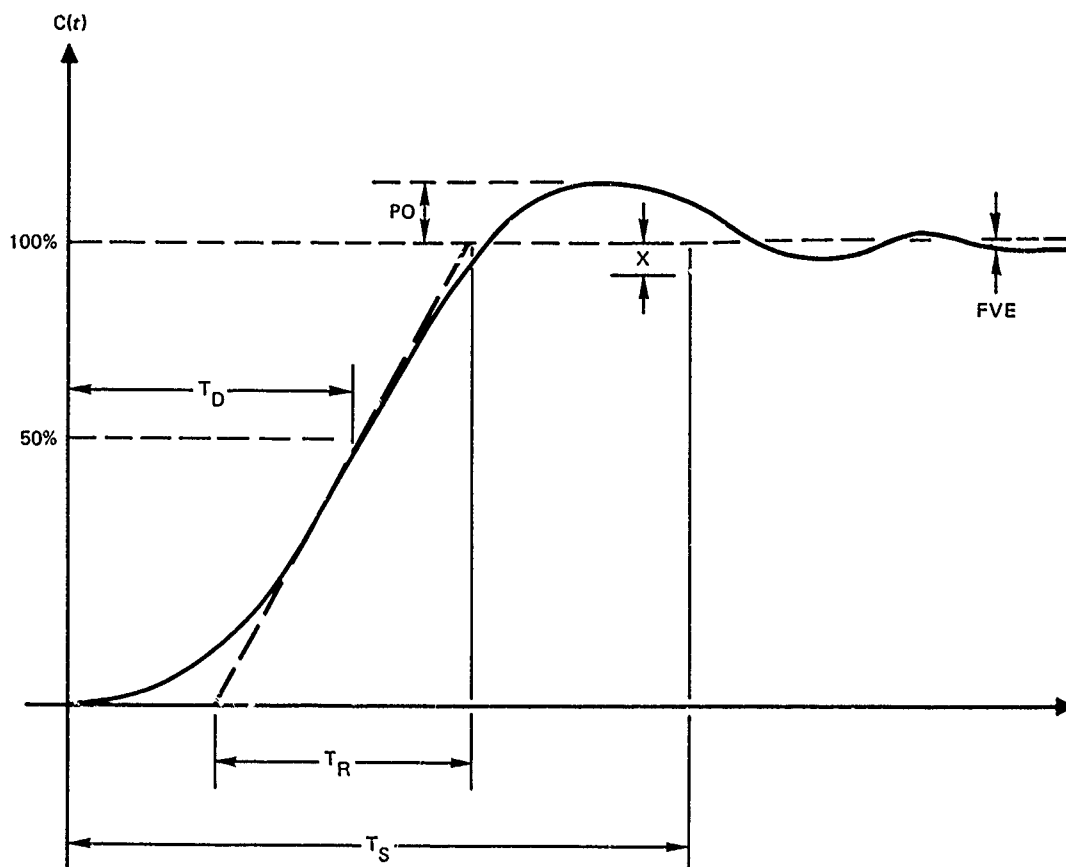


Figure 23. Time-domain performance specification definitions.

Delay Time T_D

This quantity is a measure of the "delay" of the servo and is defined as the time interval between the application of the input step and the moment when a substantial output is observed, usually defined as 50 percent of the step amplitude. The delay time is closely associated with the second item in the set of PS, the rise time.

Rise Time T_R

This quantity expresses the sharpness of the leading edge of the output. Several definitions exist—the one suggested here is based upon the rate of the pulse increase at the moment the output pulse "arrives," i.e., at time T_D . Both delay and rise time are closely related to the bandwidth specification in the frequency domain.

Overshoot PO and Settling Time T_S

These two quantities specify the degree of stability of the servo. They therefore are closely associated with M peak and peak frequency in the frequency domain. T_S is defined as the time it takes for the output to settle down within a specified x percent of the final value.

Time-domain specifications are those which are generally used to specify system performance. In the design procedure, however, it is often easier to work in the frequency domain. The synthesis processes can then be one of relating frequency-domain specifications to time-domain specifications. Analytically this is quite easily done for a second order system. Melsa and Schultz [ref 11] present a thorough treatment of relating time-domain to frequency-domain specifications for second- and third-order systems. Figures 24(A) and (B) present frequency- and time-domain performance specifications with tolerances specified by the shaded areas. The synthesis procedure is to examine, in the frequency domain, the magnitude of the closed loop system response. By knowing the mapping from the frequency to time-domain, the time-domain specifications can be evaluated. If requirements are not met (in the time domain), system parameters can be changed and the frequency-domain specifications reexamined. As can be seen this is an iterative process. Since the mapping between frequency and time-domain specifications (for higher order systems) is based on empirical relations, the procedure is somewhat trial and error. Trial and error is probably the most widely used synthesis procedure. Elgerd [ref 9] classifies synthesis methods into three categories (trial-and-error, analytical, and optimal). For the classical control system problem the trial-and-error is the most useful and widely used.

3.3.1 Slave Loop Performance Specification

The designer has, for classical control system design, another means of specifying system performance. This is with the error constants. Basically those most commonly used are the acceleration-error constant, position-error constant and velocity-error constant. Referring to the time-domain specifications for a step input, the error defined in figure 24B as the final value of error relates directly to the error constant. The slave loop is a Type 1 system, therefore it has a zero final value error for a position input. As will be seen in the following section, the acceleration error constant will be of importance to the design of the track/stabilization loop. The desired performance specifications for the inner and outer gimbal for the slave loop design are presented in table 2.

3.3.2 Stabilization/Track Loop Performance Specifications

The stabilization/track loop is quite different from slave loop. Its function is to provide an estimate of the line-of-sight rate to the guidance computer by means of a rate tracking servo loop. The sensor is stabilized such that it is an inertial reference. This is required for low data rate systems. The sensor maintains its look angle in inertial space even during loss of tracking data. The stabilization loop is designed to have a very high acceleration constant and an infinite K_v .

11. Melsa, JL, and Schultz, DG, Linear Control Systems, McGraw-Hill Book Company, 1969.

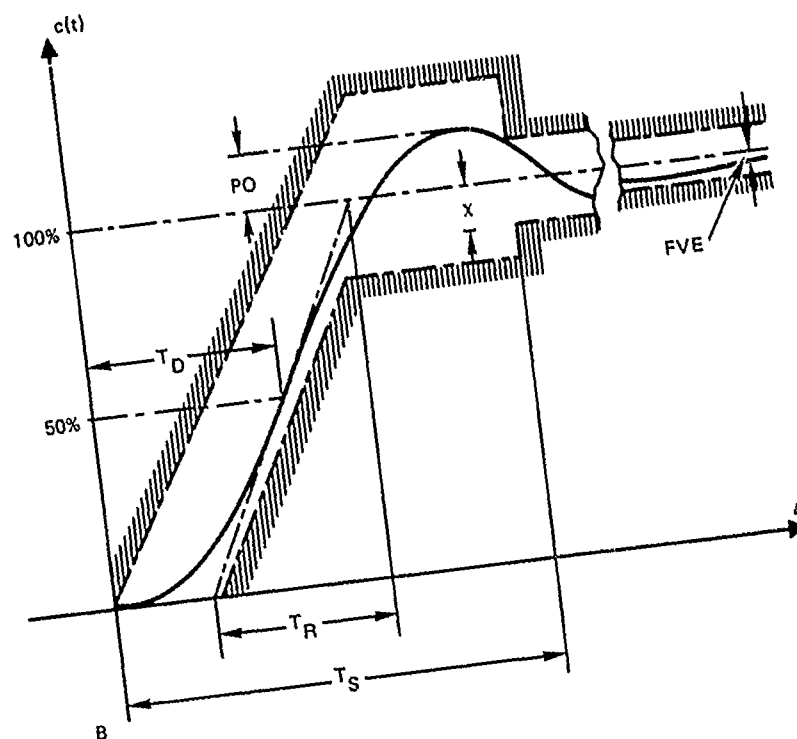
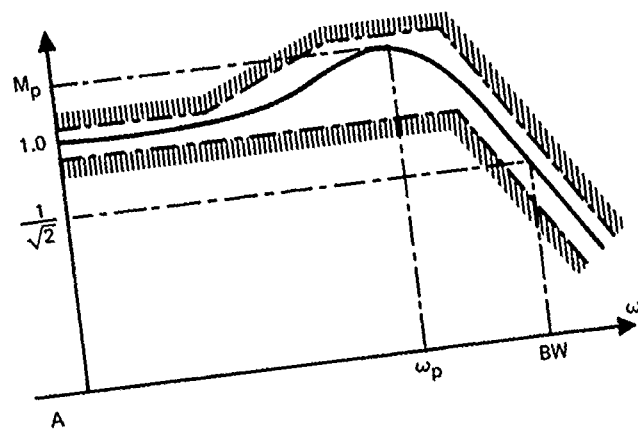


Figure 24. Frequency- and time-domain performance specifications.

Design/Performance Parameters	Inner Gimbal	Outer Gimbal
Rise Time	.025 sec	.025 sec
Delay Time	.01 sec	.01 sec
Percent Overshoot	10%	10%
Settling Time	.1 sec	.1 sec
Velocity Error Constant	40,000.00	40,000.00
BW	200 rad 30 Hz	200 rad 30 Hz
M _p	3 dB	3 dB

Table 2. Slave loop design specifications.

Infinite K_v implies zero steady state rate tracking error. The more paramount design requirements placed on the stabilization/track loop is the isolation design requirements. These design requirements are isolation of the estimated rate tracking signal and pointing error from extraneous rate signals and disturbance torques. The higher the acceleration error constant, the better the isolation achieved.

The isolation properties from extraneous disturbance signals are functions of frequency. Therefore, the design requirements must specify the minimum isolation over a frequency region. This frequency region is usually tied to the airframe characteristics for the particular airframe in which the stabilized platform will be used. The short period poles of the airframe transfer function characterize the higher frequency natural resonances in the airframe/autopilot system. The design goal is to have the isolation of the disturbance signals reach their minimum values beyond the natural frequency responses of the airframe/autopilot.

The isolation properties for extraneous signals (for a type II system) all have the same general characteristics; see figure 25. For low frequencies isolation is large. It reaches a minimum and then increases with increasing frequencies.

The desired design specifications for the track/stabilization loop (inner and outer gimbals) are presented in tables 3 and 4.

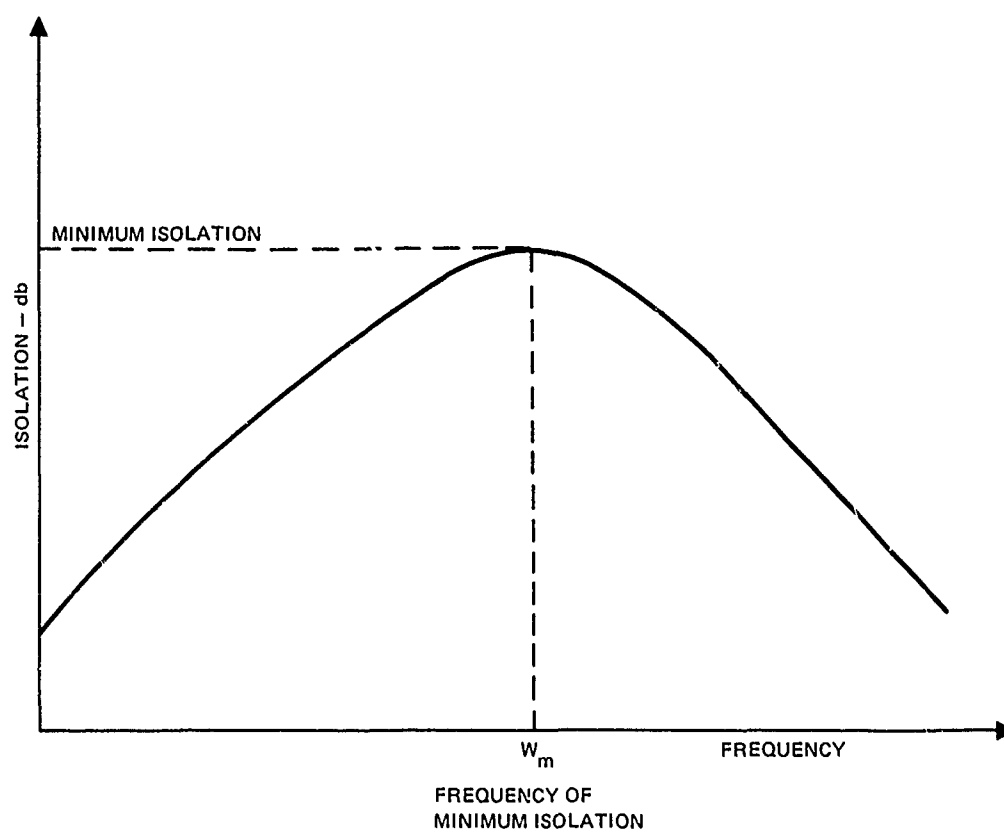


Figure 25. Typical isolation curve.

Design/Performance Parameters	Inner Gimbal	Outer Gimbal
Rise Time	0.005 sec	0.005 sec
Delay Time	0.002 sec	0.002 sec
Percent Overshoot	20%	20%
Settling Time	0.1 sec	0.1 sec
Acceleration Error Constant	200,000.00	250,000.00
BW	500 rad	500 rad
M_p	3 dB	3 dB

Table 3. Stabilization loop design specifications.

Design/Performance Parameters	Inner Gimbal (Isolation - dB)	Outer Gimbal (Isolation - dB)
Maximum Tracking Rate	100 deg/sec	100 deg/sec
Minimum Isolation:		
$\frac{\hat{\sigma}}{\hat{\theta}} \Big _{S=1; 10 \text{ rad}}$	80; 60	80; 60
$\frac{\hat{\sigma}}{Td} \Big _{S=1; 10 \text{ rad}}$	100; 60	100; 60
$\frac{\epsilon}{\hat{\theta}} \Big _{S=1; 10 \text{ rad}}$	100; 60	100; 60
$\frac{\epsilon}{Ta} \Big _{S=1; 10 \text{ rad}}$	100; 80	100; 80

Table 4. Track loop design specifications.

4. STABILIZED PLATFORM DESIGN PERFORMANCE

The stabilized sensor platform was designed to meet the performance requirements as specified in the previous sections. This section briefly presents the design performed for each of the modes of the stabilized sensor platform.

4.1 SLAVE LOOP DESIGN PERFORMANCE

Figures 26 through 37 present the design and performance characteristics of the slave loop for both the inner and outer gimbals.

For the outer gimbal the open loop uncompensated frequency response is presented in figure 27. The loop frequency response after being compensated is shown in figure 29. This figure presents the gain and phase margins for the slave loop outer gimbal. The phase margin is 40 degrees and the gain margin is 20 dB. The closed loop frequency response (response from which the bandwidth can be evaluated) is presented in figure 30. The time response for the slave loop outer gimbal is shown in figure 31. The inner gimbal design performance data is presented in figures 32 through 37.

The summary section of this report presents the design configurations and the design performance for each of the servo loops. Much of the performance criterion presented in table form in the Summary section was summarized from the curves and figures presented in this section.

4.2 STABILIZATION LOOP DESIGN PERFORMANCE

Figures 38 through 47 relate to the stabilization loop design (inner and outer gimbals) and the design performance criterion. Specifically, figures 38 through 42 deal with the inner gimbal while figures 43 through 47 deal with the outer gimbal. Figure 38 is the frequency plot of the uncompensated loop. The magnitude of the frequency response reaches zero dB after the phase reaches a minus 180 degrees. In fact the phase has reached approximately a minus 240 degrees, thus, some form of compensation is required. A comparison of figures 33 and 38 (open loop frequency response curves for the slave loop and stabilization) shows that the compensation network of the stabilization loop must increase the phase considerably over that of the slave loop compensation network. In addition to a lead network to increase the phase at the 0 dB crossover a low frequency lag network is added to allow the gain to be increased and yield a higher acceleration constant. The magnitude and phase plots of the stabilization network frequency response curve is shown in figure 39. The phase reaches a peak at approximately 500 radians, therefore, the closed loop bandwidth can be approximately set at 500 radians. By examining figures 40 and 41, the open loop and closed loop frequency response curves, it is seen that the system is stable (conditionally stable) and that the bandwidth is approximately 750 radians. The phase margin is 59 degrees. The gain margin, for increasing gain, is 12 dB and is 20 dB for decreasing gain. The time response for the stabilization loop is shown in figure 42. All of the nonlinearities of the system are reflected in the time response curve these nonlinearities are not included in the frequency response curves because frequency response techniques deal only with linear systems.

4.3 TRACK LOOP DESIGN PERFORMANCE

Figures 48 through 59 present the track loop performance data. Briefly these figures present data of disturbance isolation, closed loop frequency and time response characteristics of the track loop. Figures 48 through 53 present the outer gimbal data and figures 54 through 59 present the inner gimbal data. The isolation curves are used to establish the level of body or base motion that can be tolerated for acceptable tracking or steering information and the level of mass imbalance that is tolerable. The level of tolerable mass imbalance can be established from the extraneous torque disturbance isolation curves, figures 49 and 51. The maximum tracking rates are derived from the frequency response curve of figure 52. It is seen that a flat response is maintained out to 2 radians; that is, the estimated line-of-sight rate follows the true line-of-sight rate out to 2 rad/sec with no appreciable degradation. Again both inner and outer gimbal data is presented. Figures 48 through 53 are for the outer gimbal and 54 through 59 for the inner gimbal. Comparative statements of the inner gimbal data can be made in the same light as was done for the outer gimbal data.

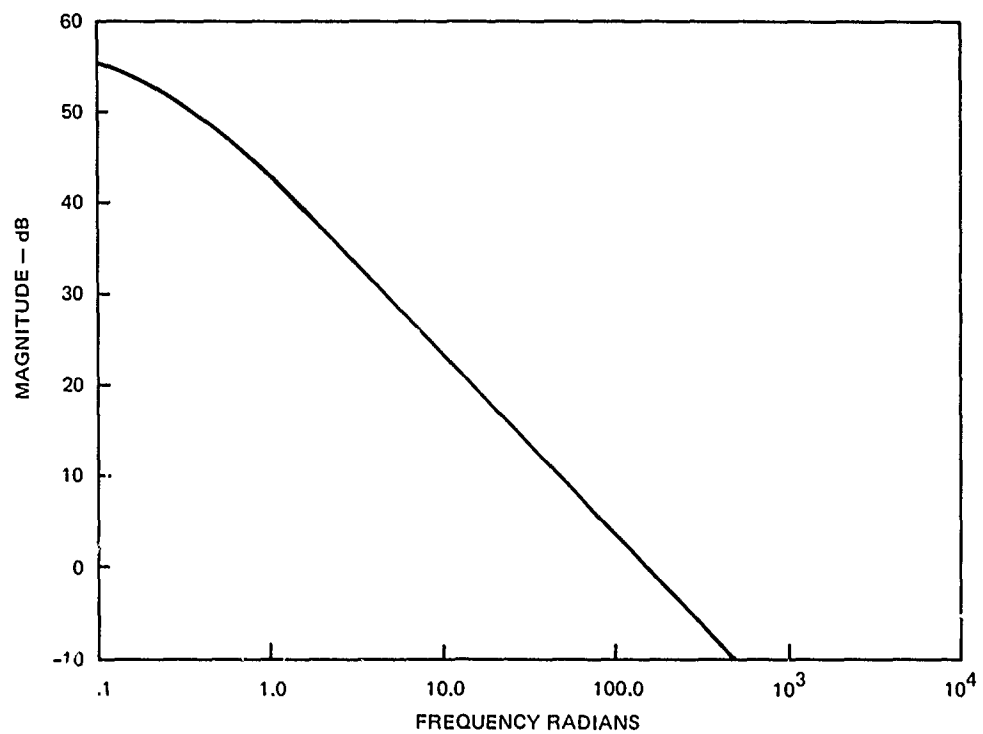


Figure 26. Servo amp/motor/load frequency response (inner gimbal).

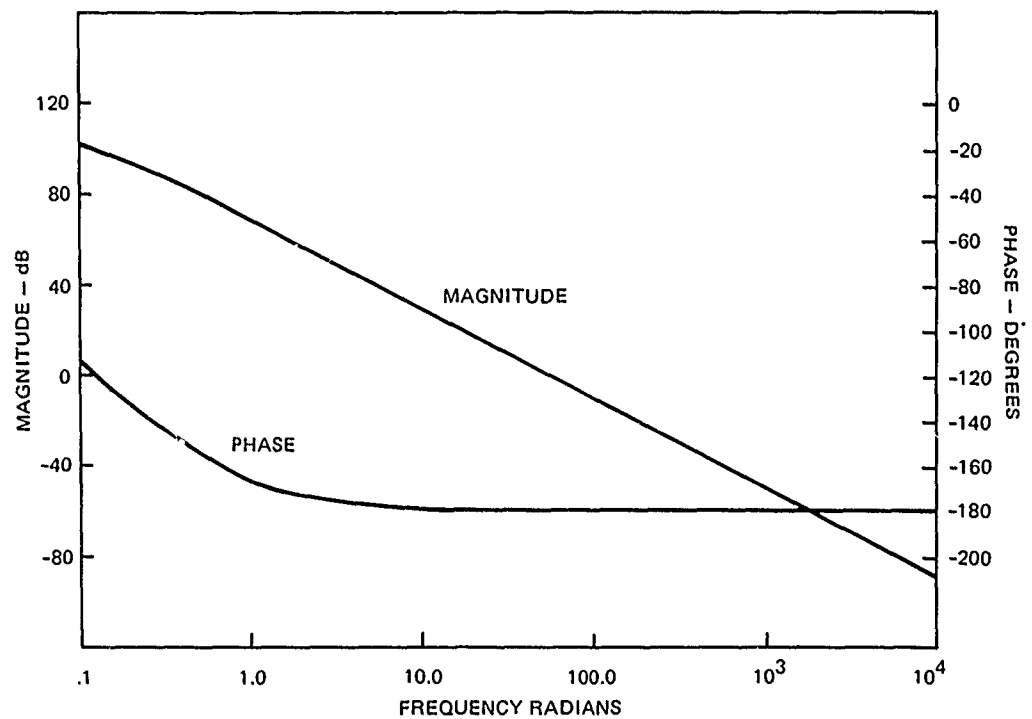


Figure 27. Slave loop (open loop) uncompensated frequency response (inner gimbal).

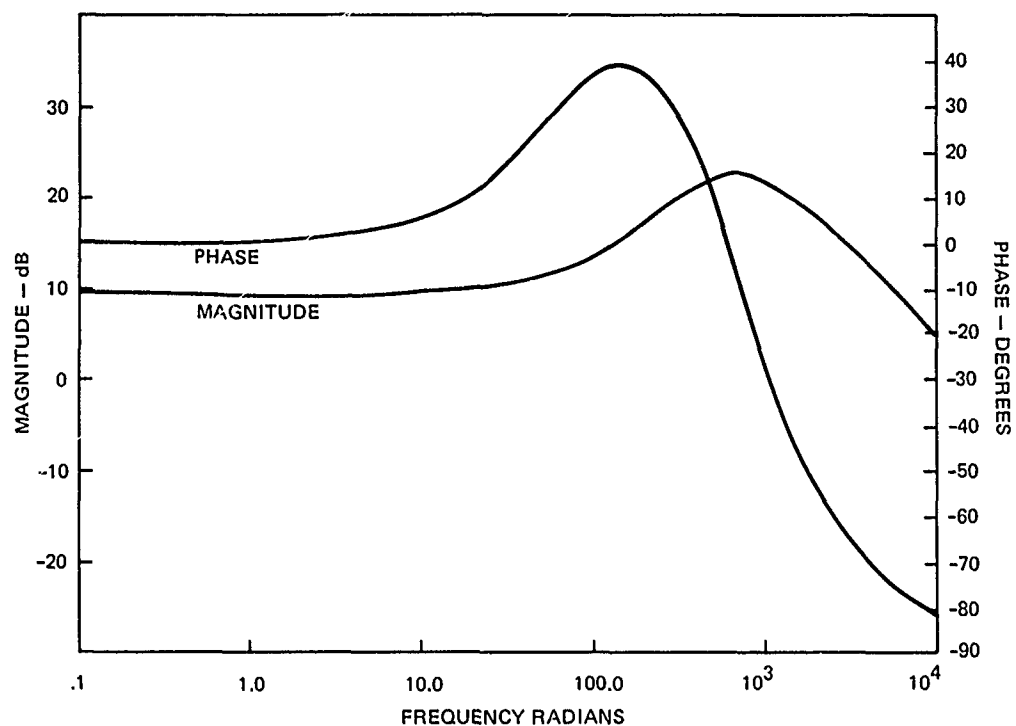


Figure 28. Slave loop compensation network frequency response (inner gimbal).

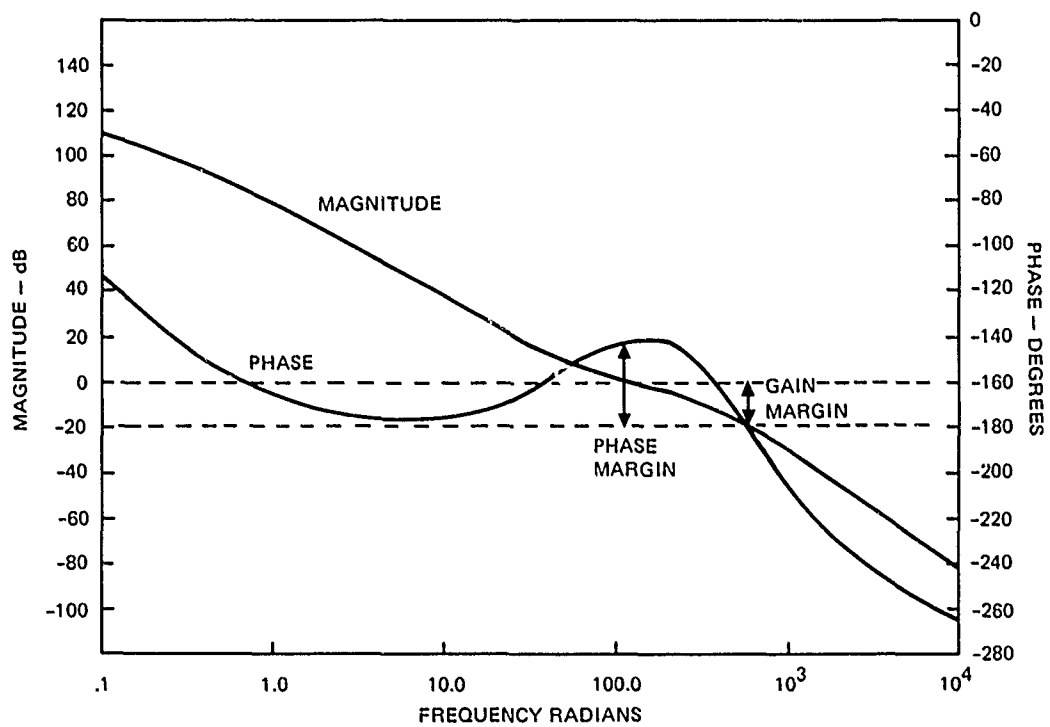


Figure 29. Compensated slave loop (open loop) frequency response (inner gimbal).

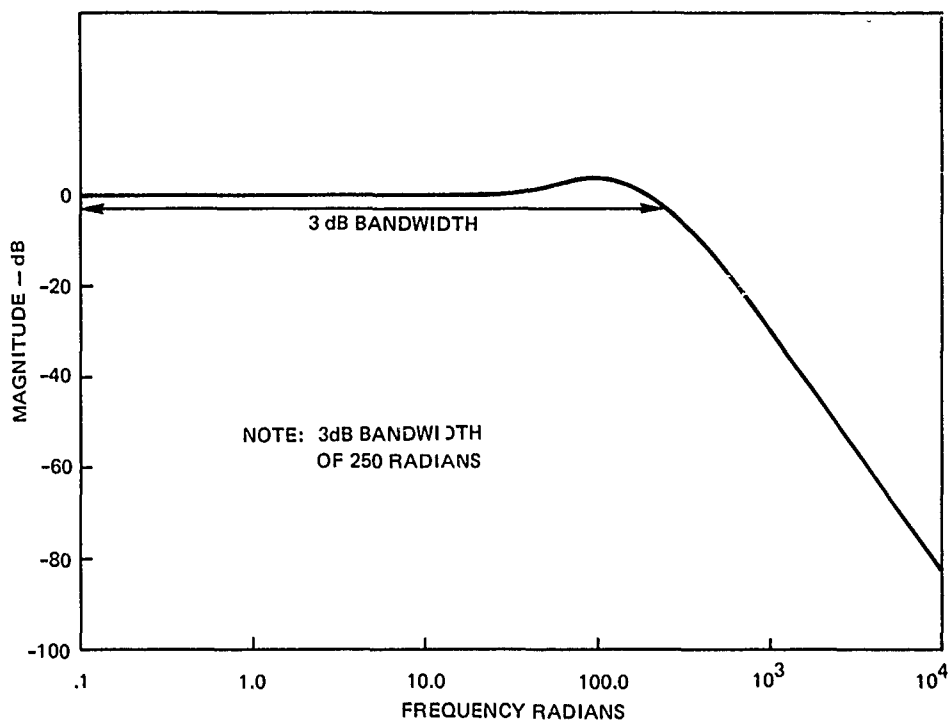


Figure 30. Slave loop (closed loop) frequency response (inner gimbal).

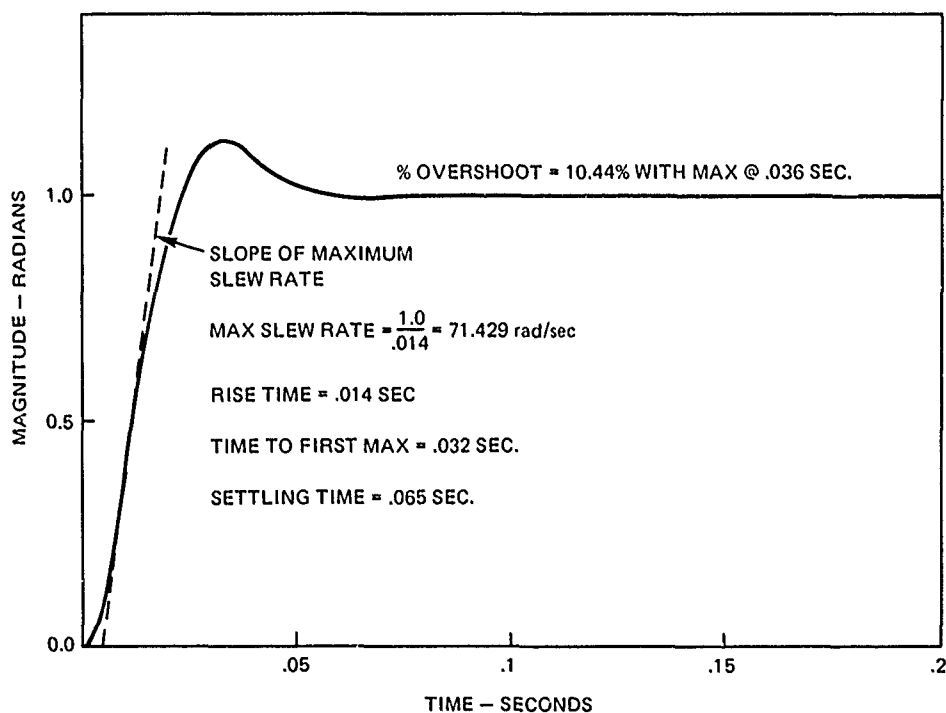


Figure 31. Slave loop inner gimbal time response.

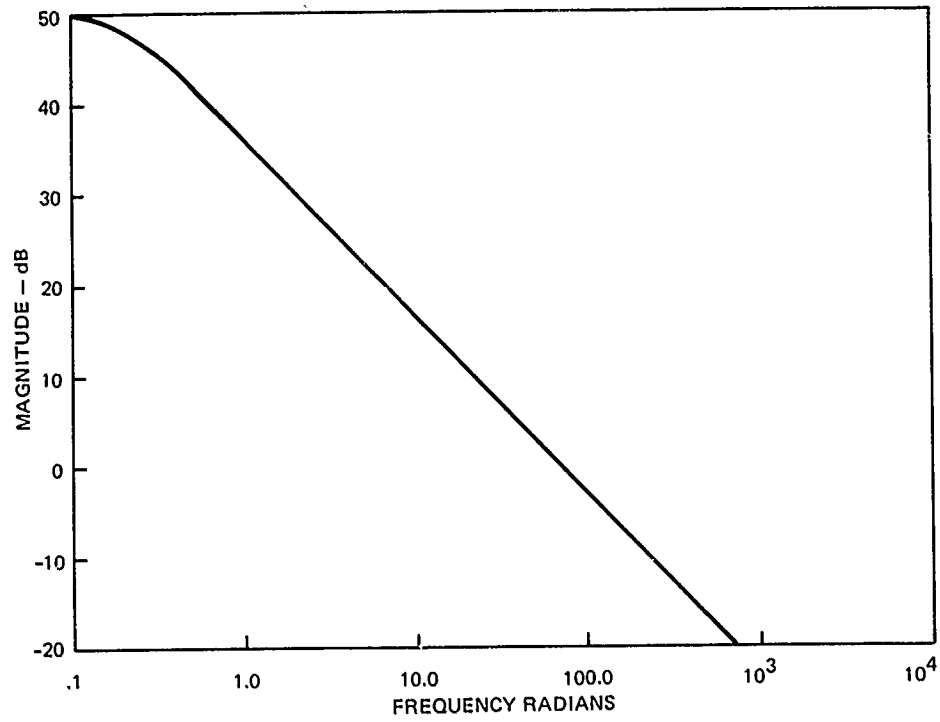


Figure 32. Servo amp/motor/load frequency response (outer gimbal).

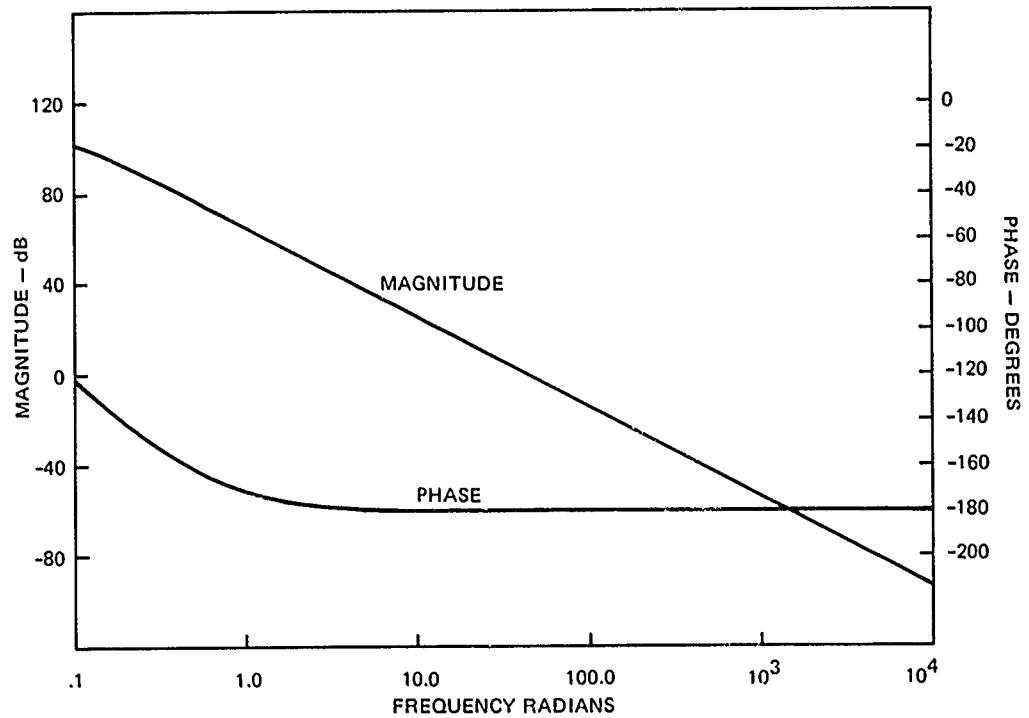


Figure 33. Slave loop (open loop) uncompensated frequency response (outer gimbal).

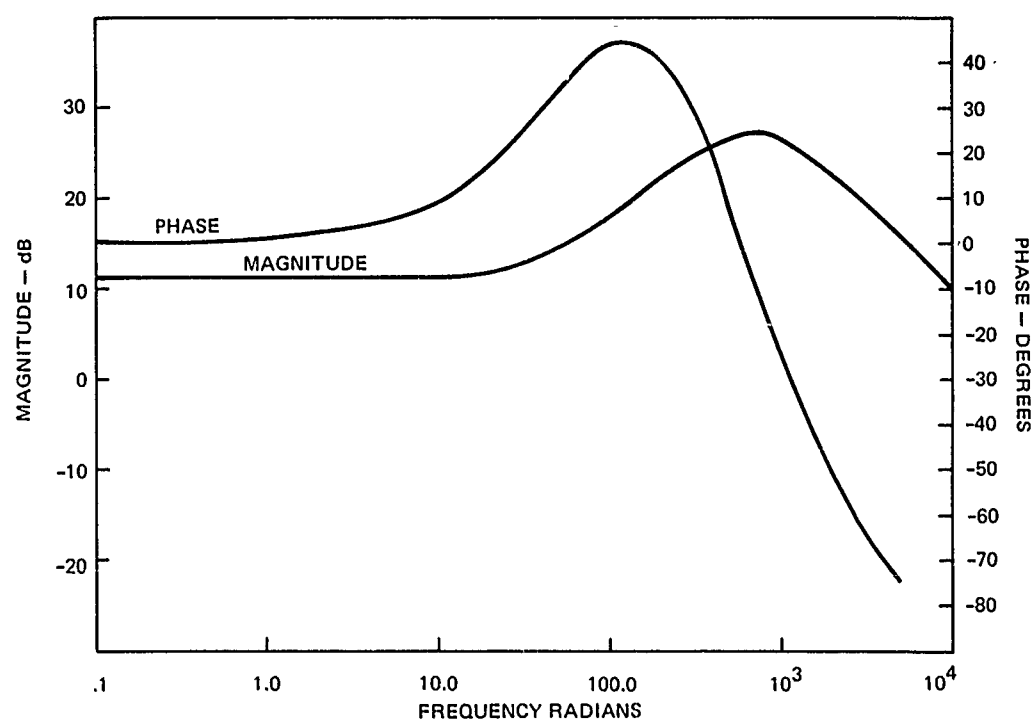


Figure 34. Slave loop compensation network frequency response (outer gimbal).

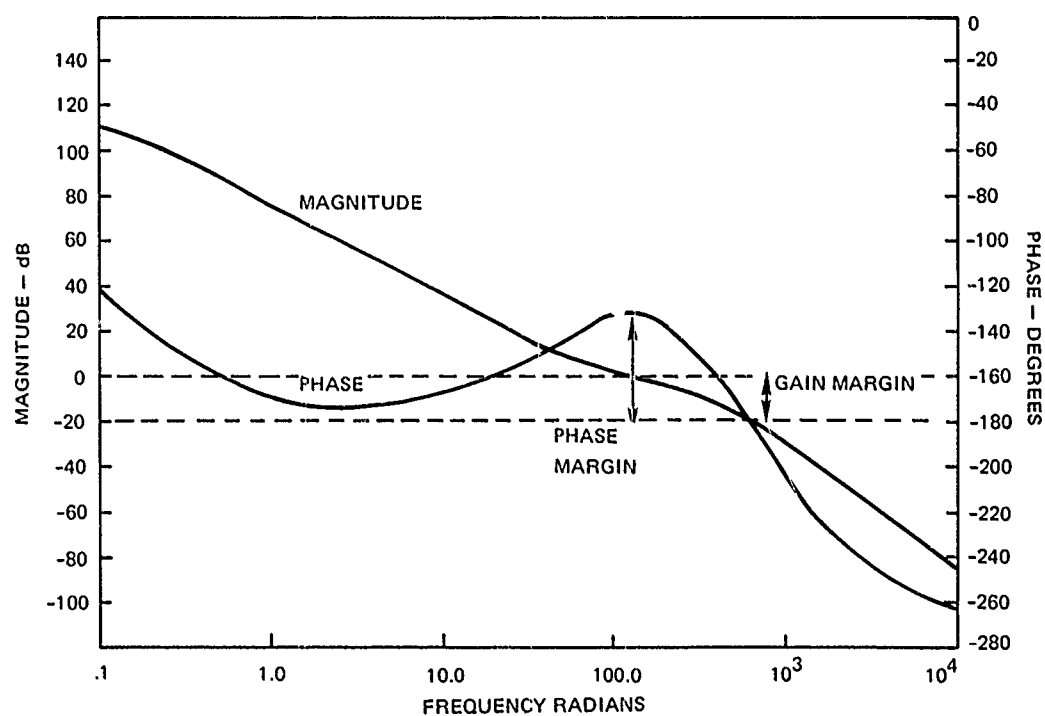


Figure 35. Compensated slave loop (open loop) frequency response (outer gimbal).

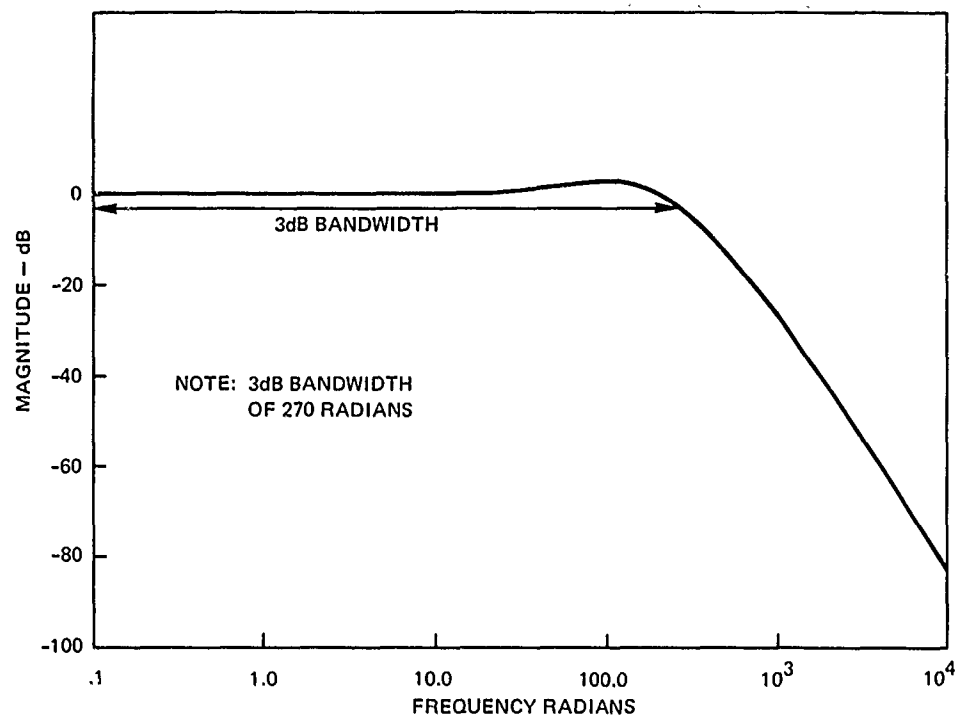


Figure 36. Slave loop (closed loop) frequency response (outer gimbal).

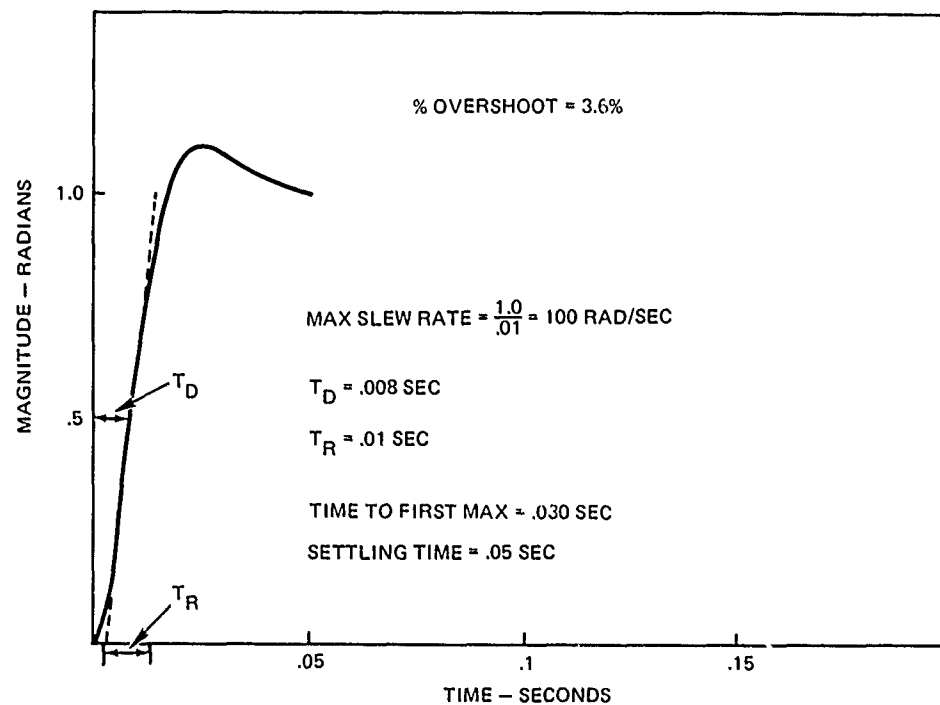


Figure 37. Slave loop outer gimbal time response.

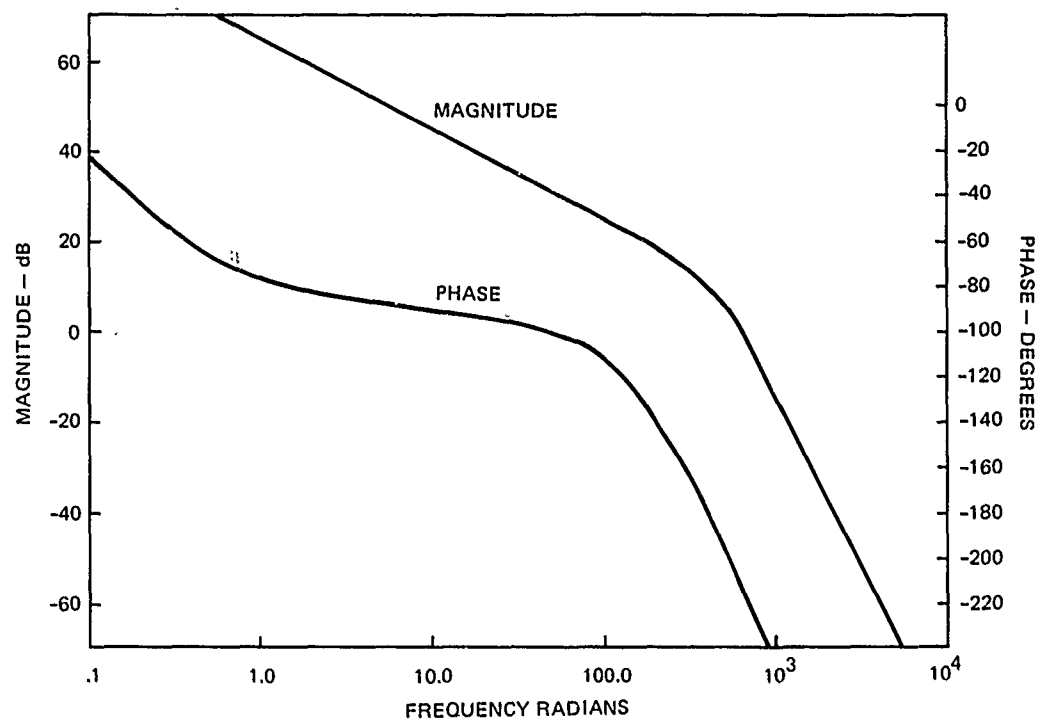


Figure 38. Stabilization loop frequency response (inner gimbal) uncompensated.

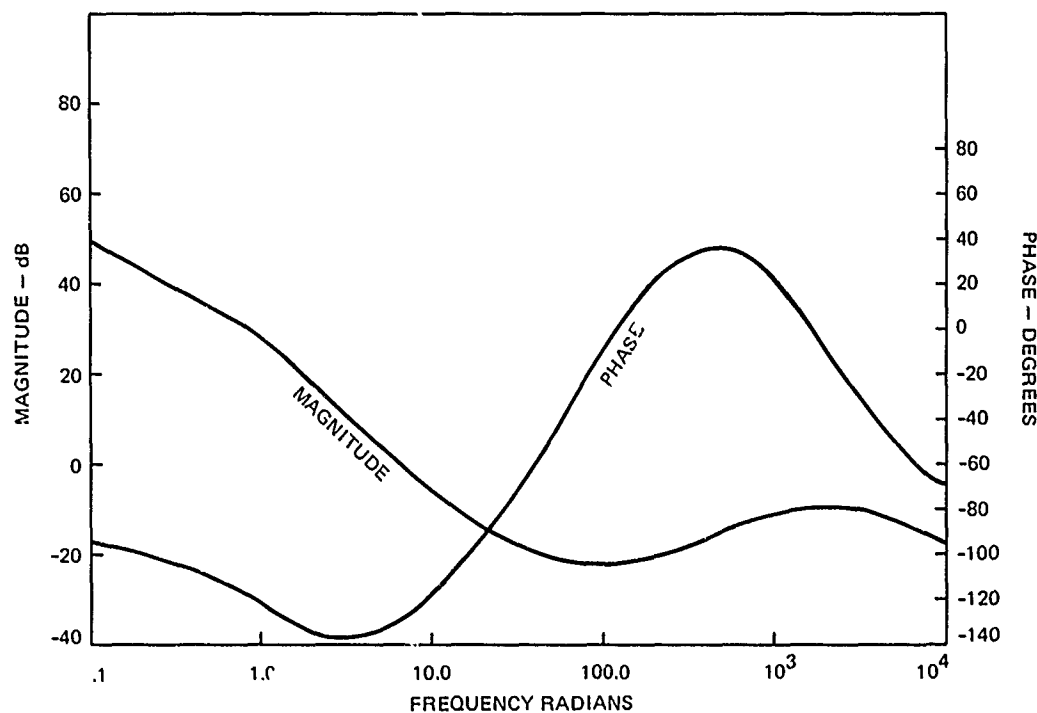


Figure 39. Stabilization loop compensation - inner gimbal.

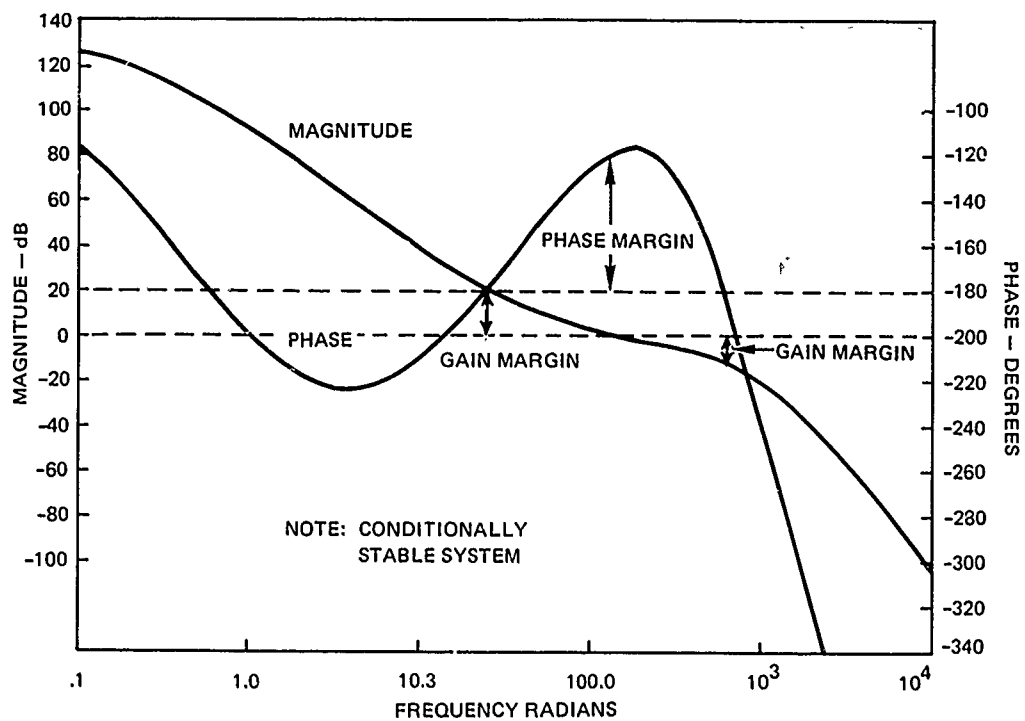


Figure 40. Stabilization loop frequency response compensated (inner gimbal).

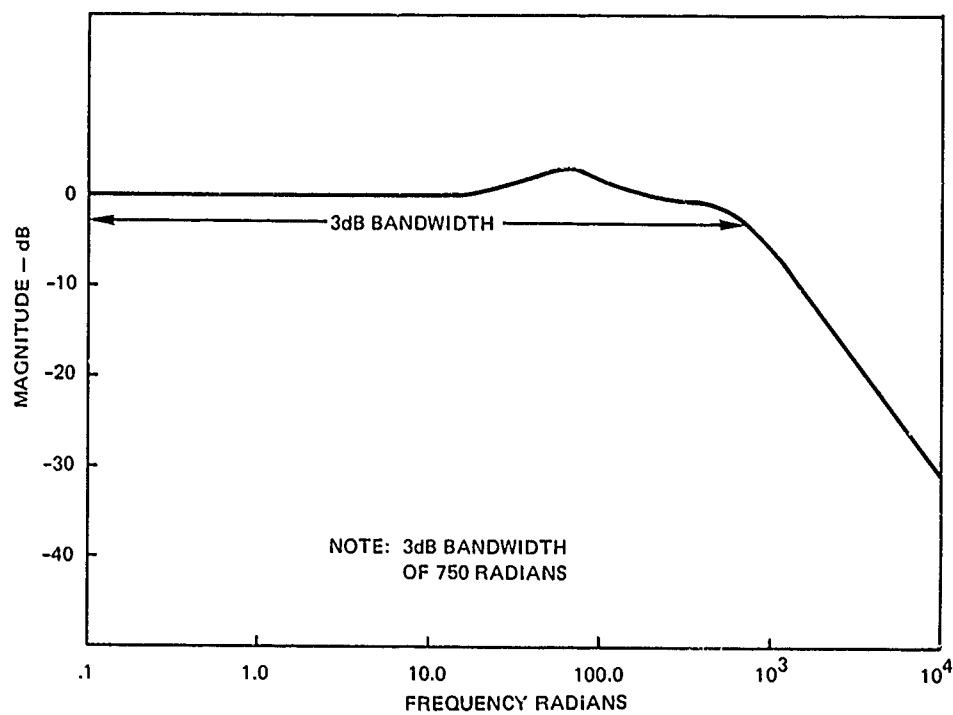


Figure 41. Stabilization closed loop frequency response (inner gimbal).

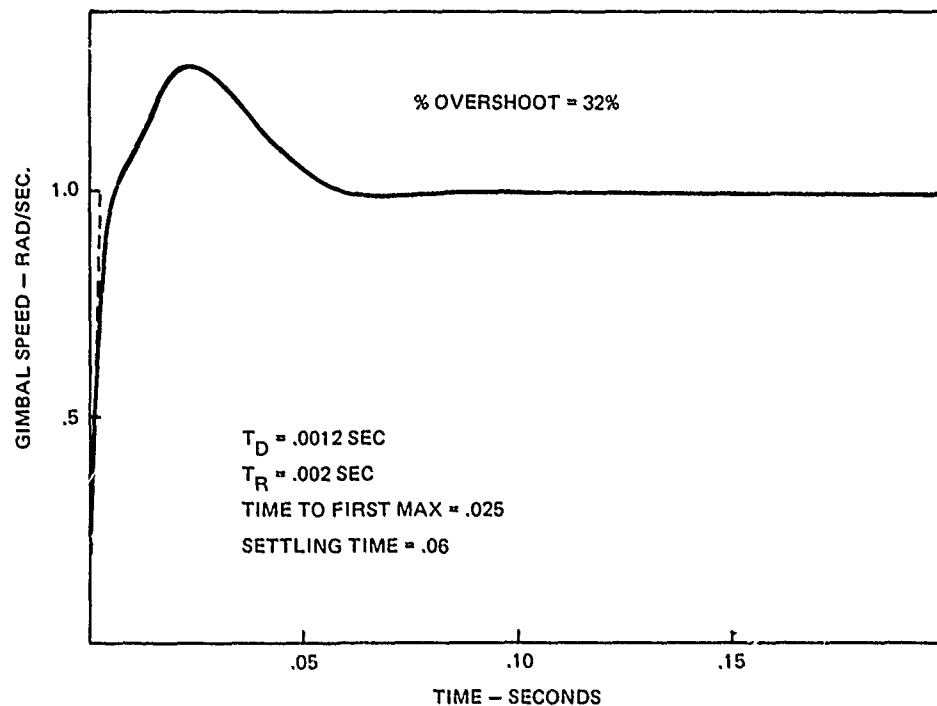


Figure 42. Stabilization loop time response (inner gimbal).

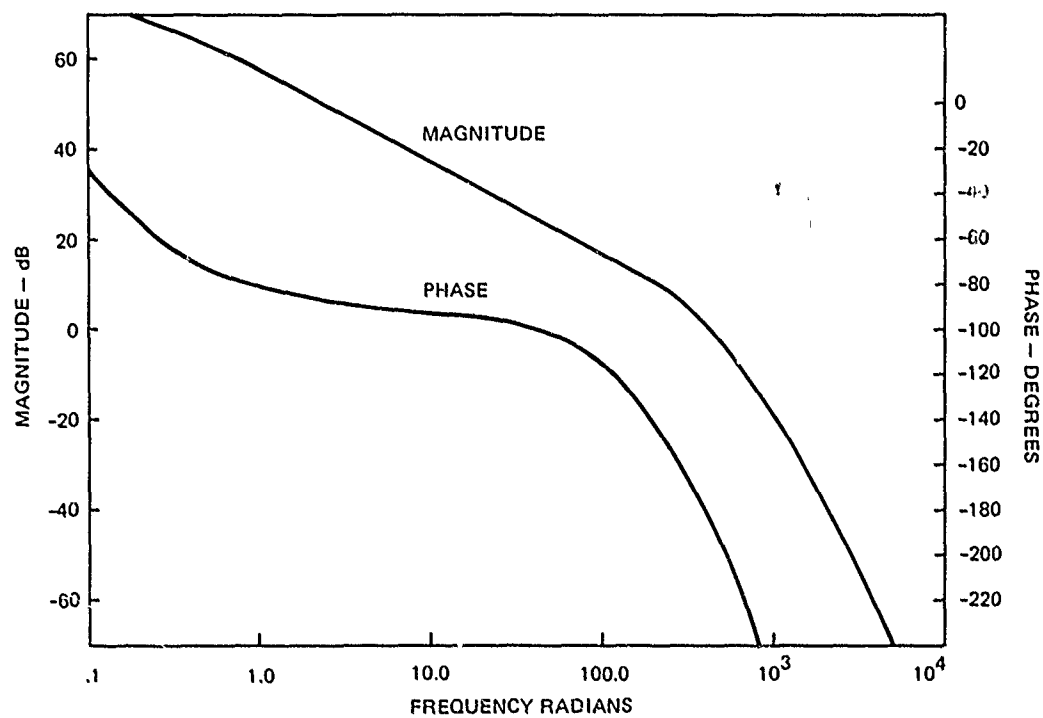


Figure 43. Stabilization loop frequency response (outer gimbal) uncompensated.

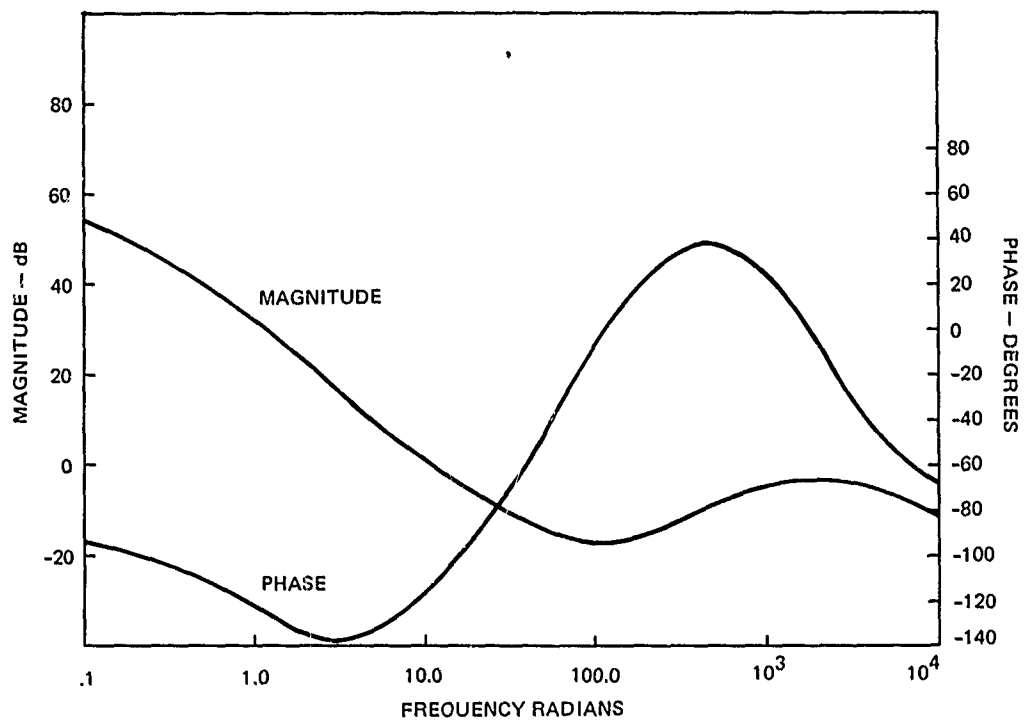


Figure 44. Stabilization loop compensation - outer gimbal.

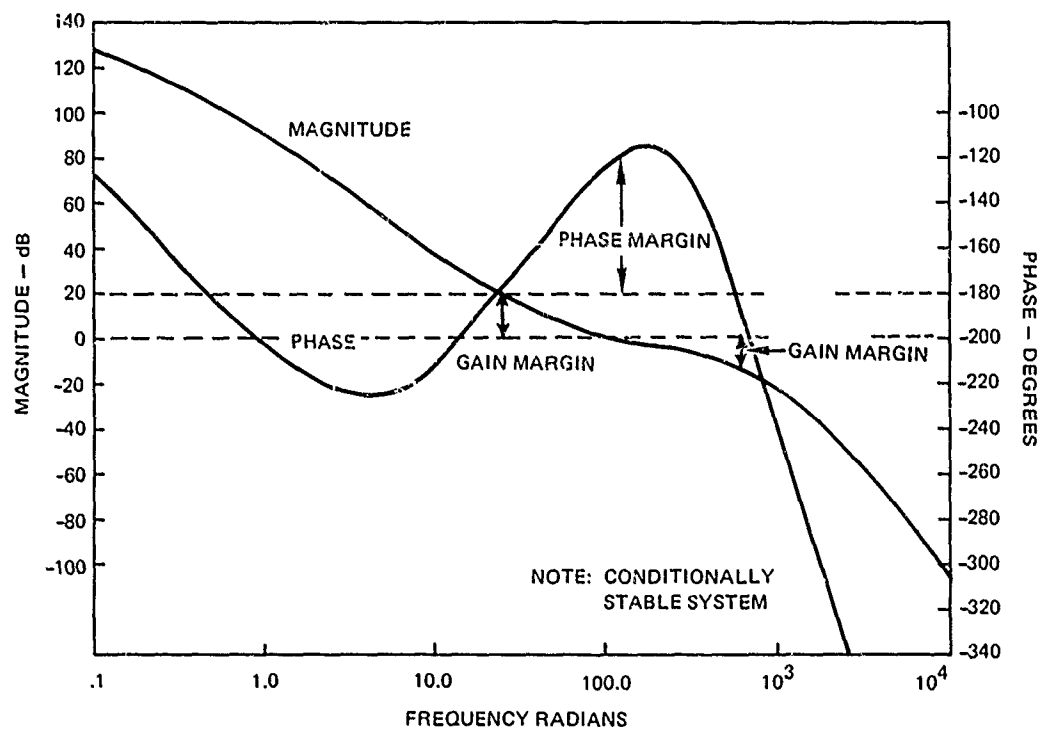


Figure 45. Stabilization loop frequency response compensated (outer gimbal).

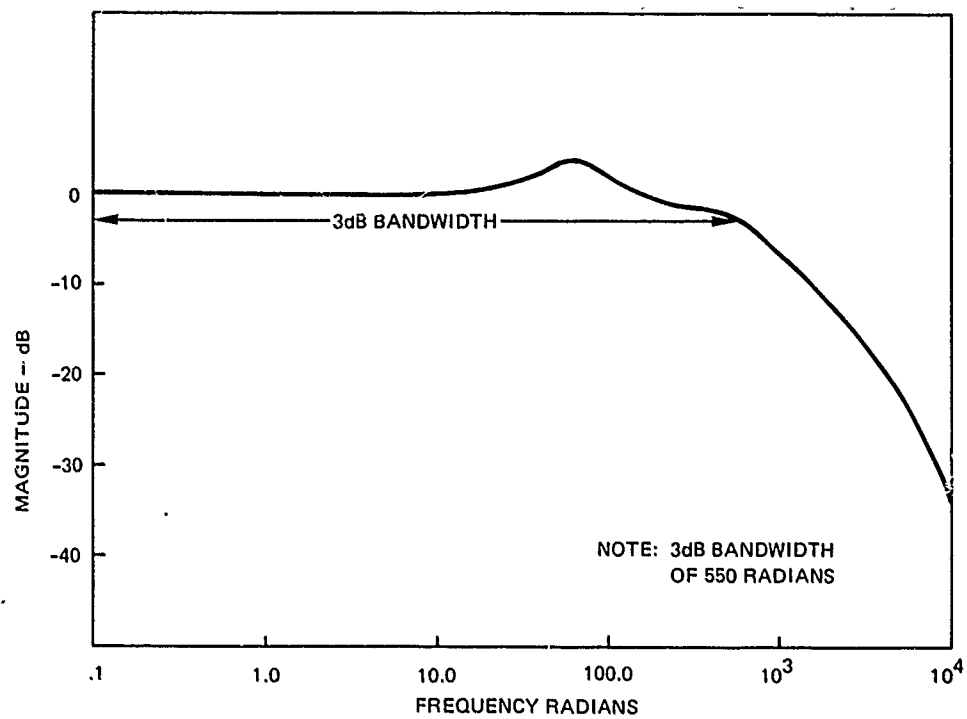


Figure 46. Stabilization closed loop frequency response (outer gimbal).

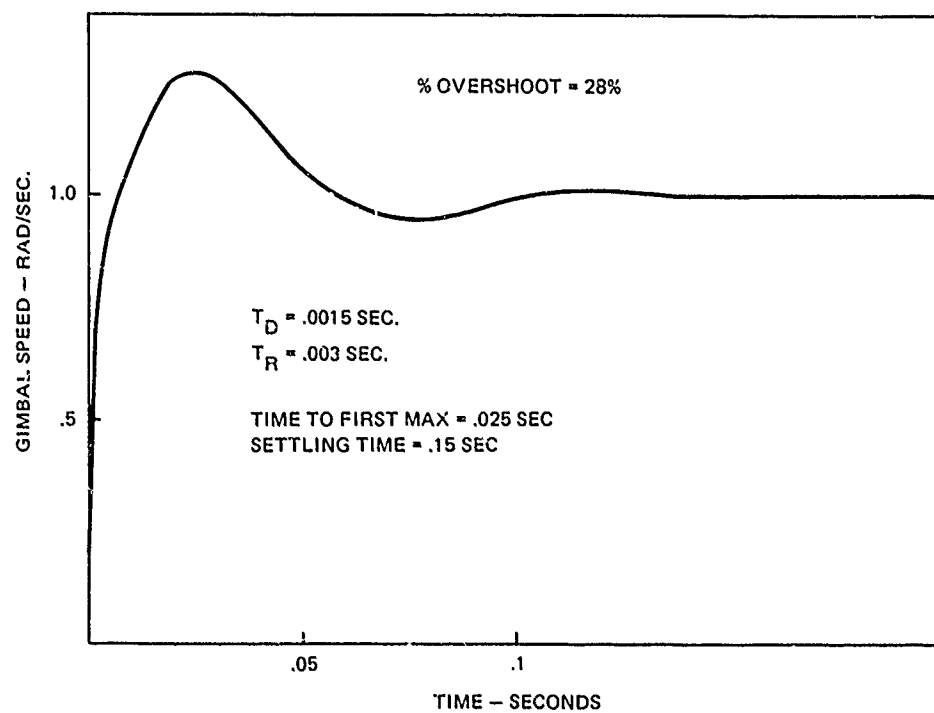


Figure 47. Stabilization loop time response (outer gimbal).

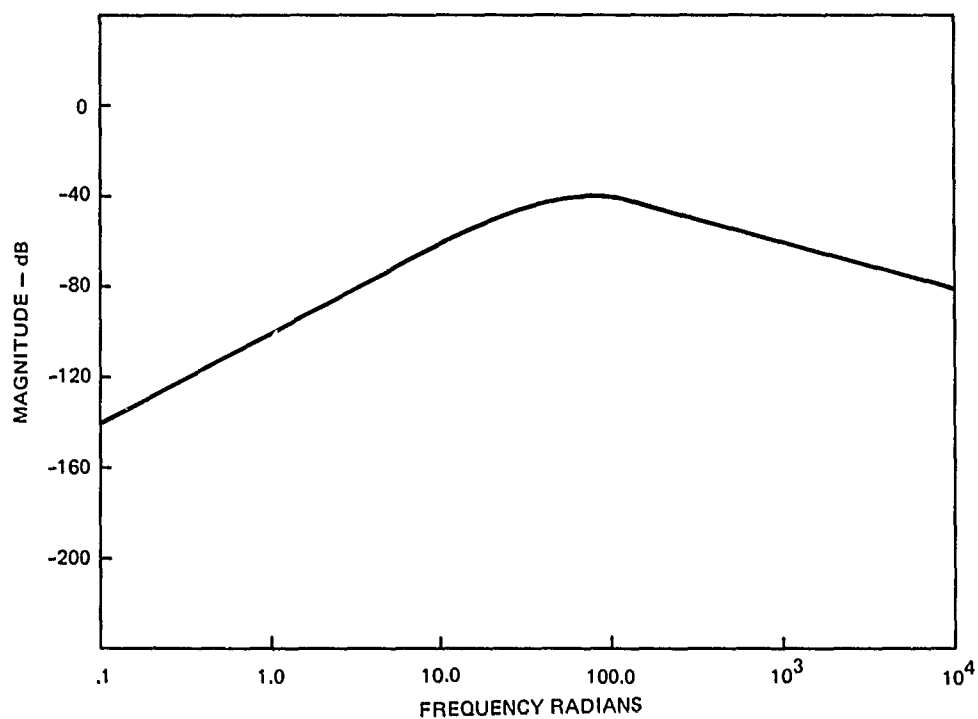


Figure 48. Frequency response of pointing error to body motion disturbance $\epsilon/\dot{\theta}$ (outer gimbal).

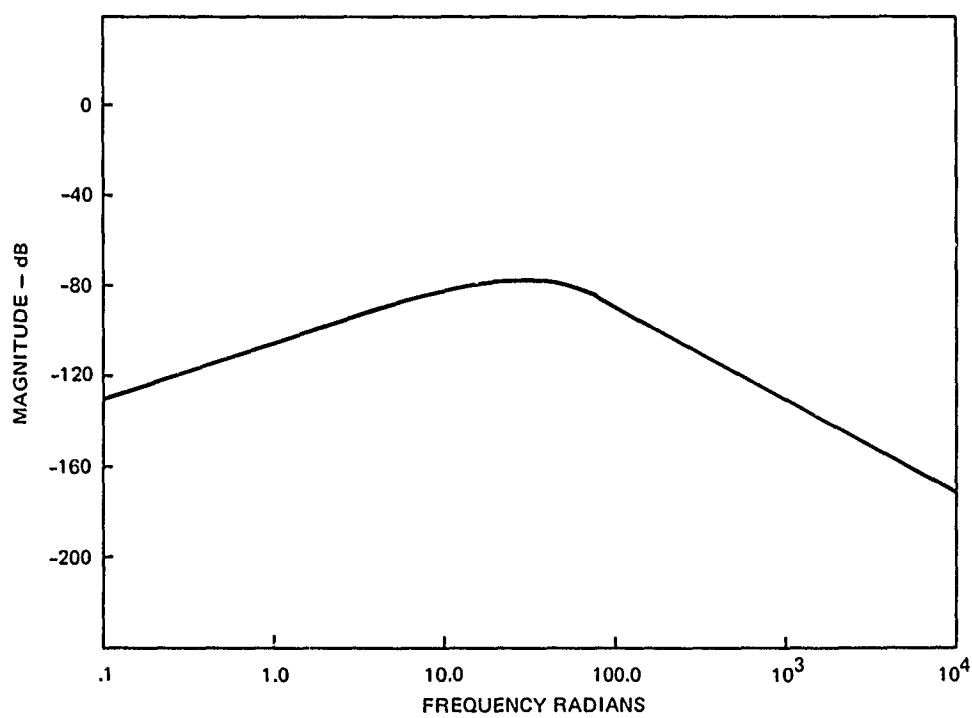


Figure 49. Frequency response of pointing error to torque disturbance ϵ/T_d (outer gimbal).

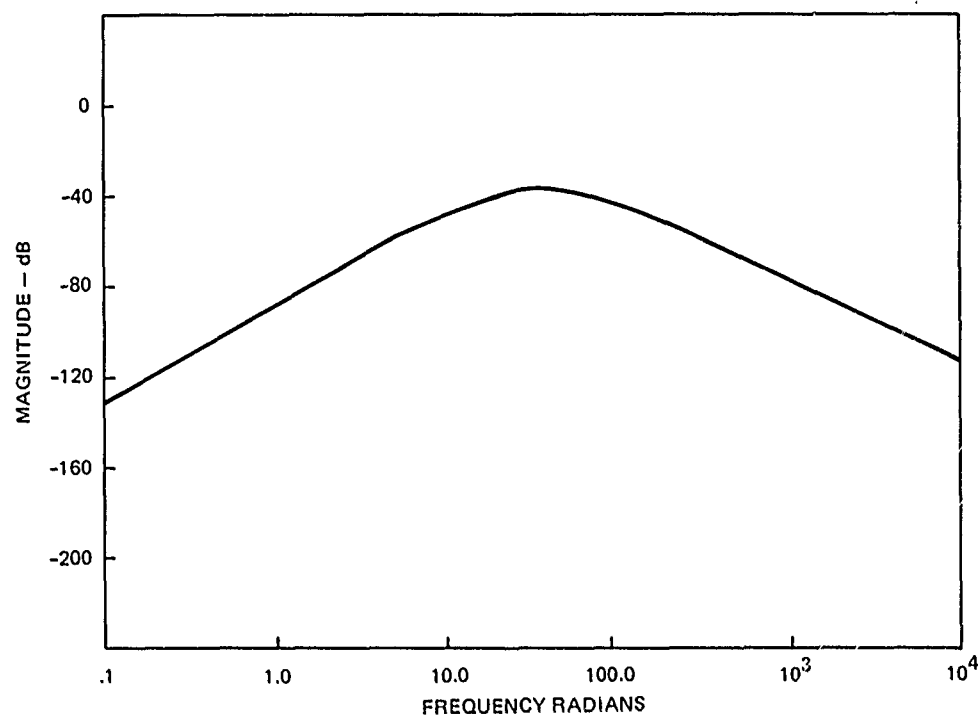


Figure 50. Frequency response of estimated line-of-sight to body motion disturbance $\hat{\sigma}/\dot{\theta}$ (outer gimbal).

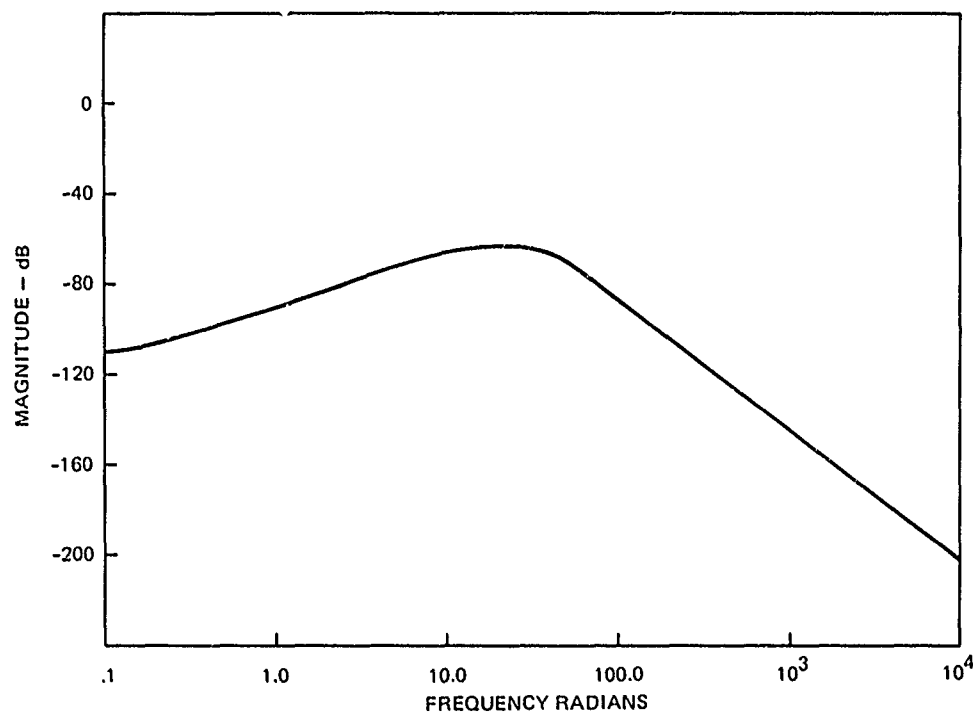


Figure 51. Frequency response of estimated line-of-sight to torque disturbance $\hat{\sigma}/T_d$ (outer gimbal).

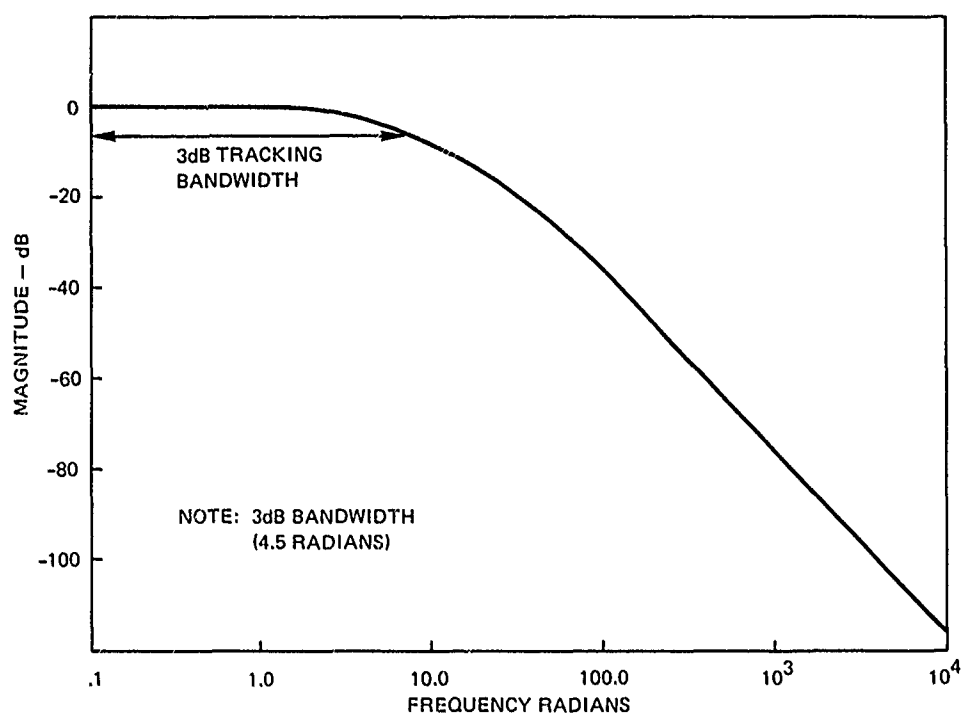


Figure 52. Frequency response of track loop $\hat{\theta}/\dot{\theta}$ transfer function (outer gimbal).

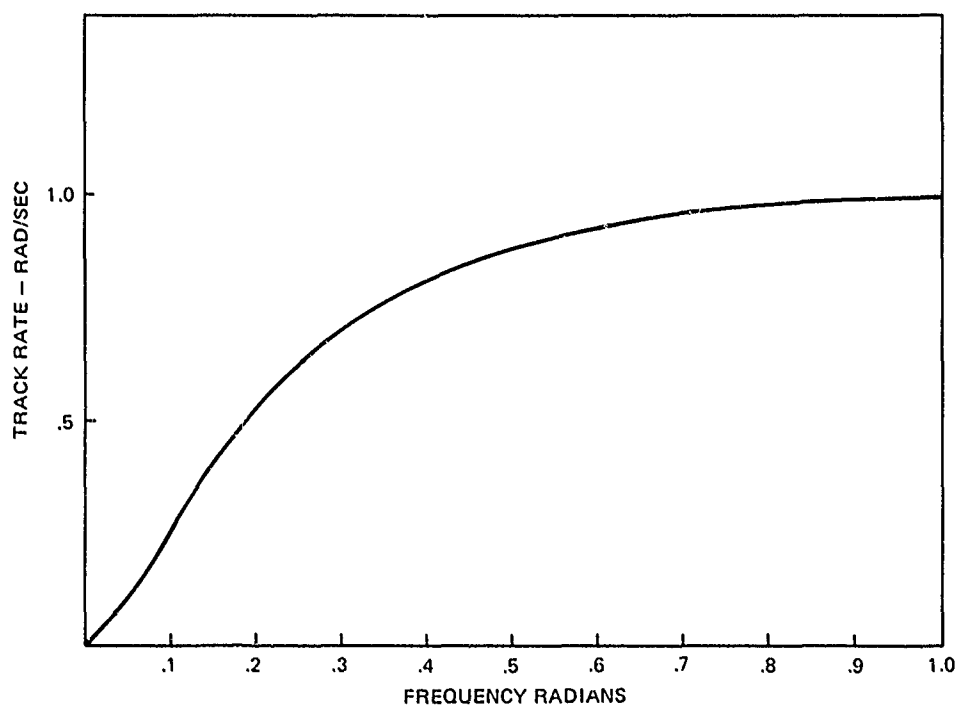


Figure 53. Track loop time response (outer gimbal).

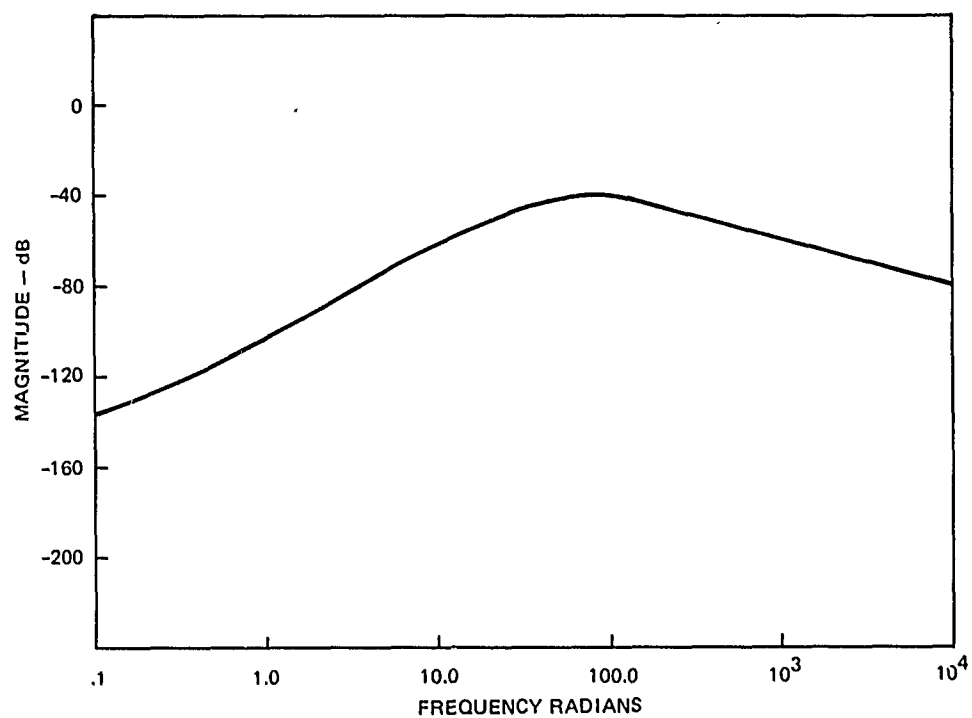


Figure 54. Frequency response of pointing error to body motion disturbance $\epsilon/\dot{\theta}$ (inner gimbal).

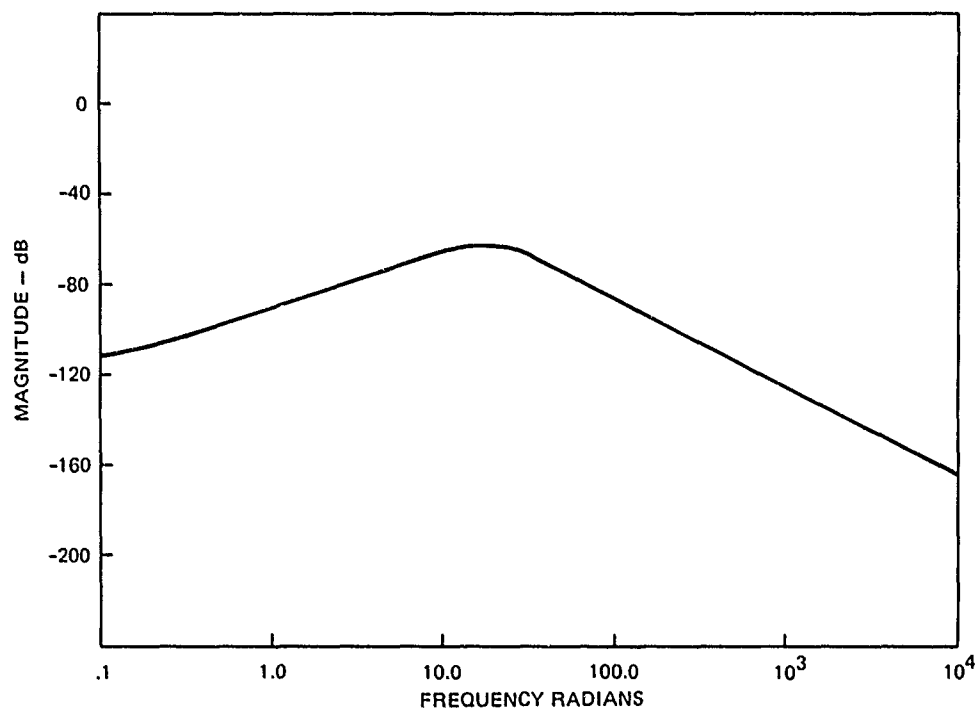


Figure 55. Frequency response of pointing error to torque disturbance ϵ/T_d (inner gimbal).

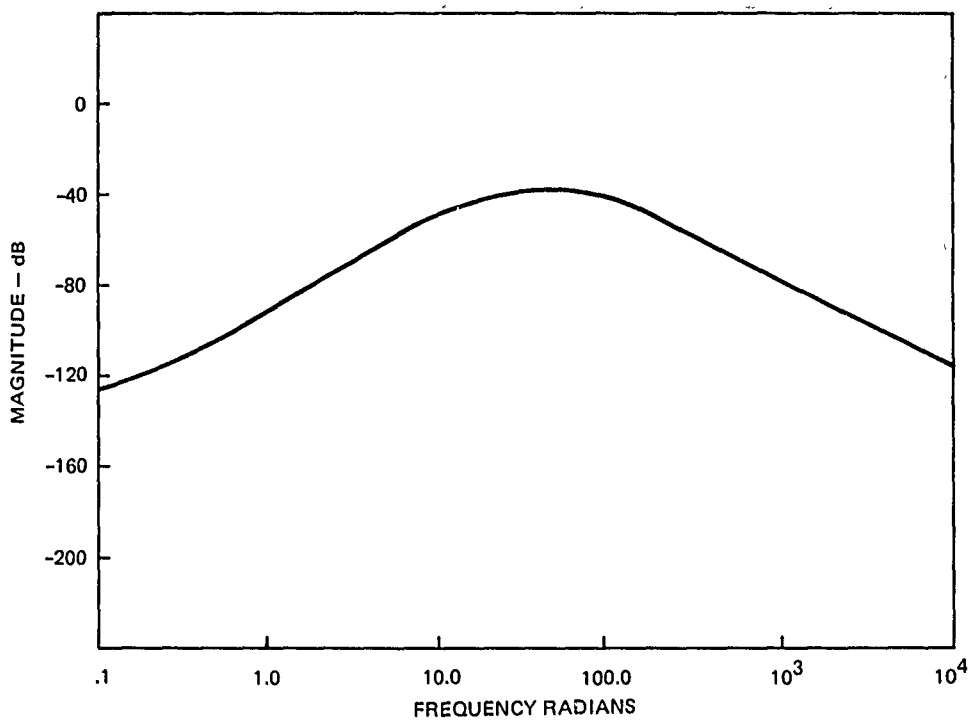


Figure 56. Frequency response of estimated line-of-sight to body motion disturbance $\hat{\sigma}/\dot{\theta}$ (inner gimbal).

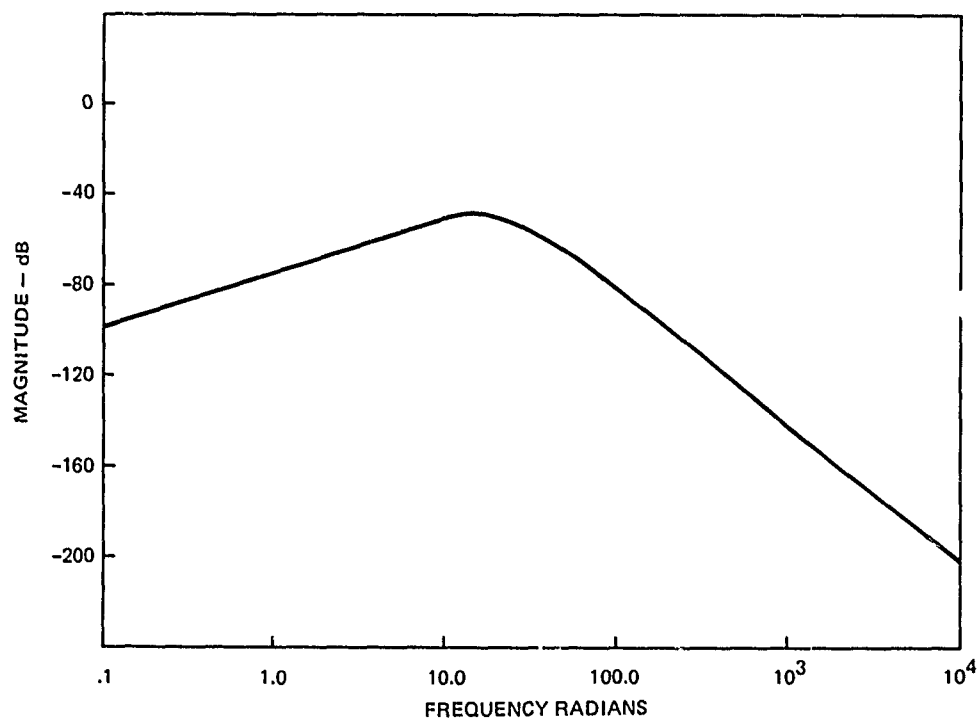


Figure 57. Frequency response of estimated line-of-sight to torque disturbance $\hat{\sigma}/T_d$ (inner gimbal).

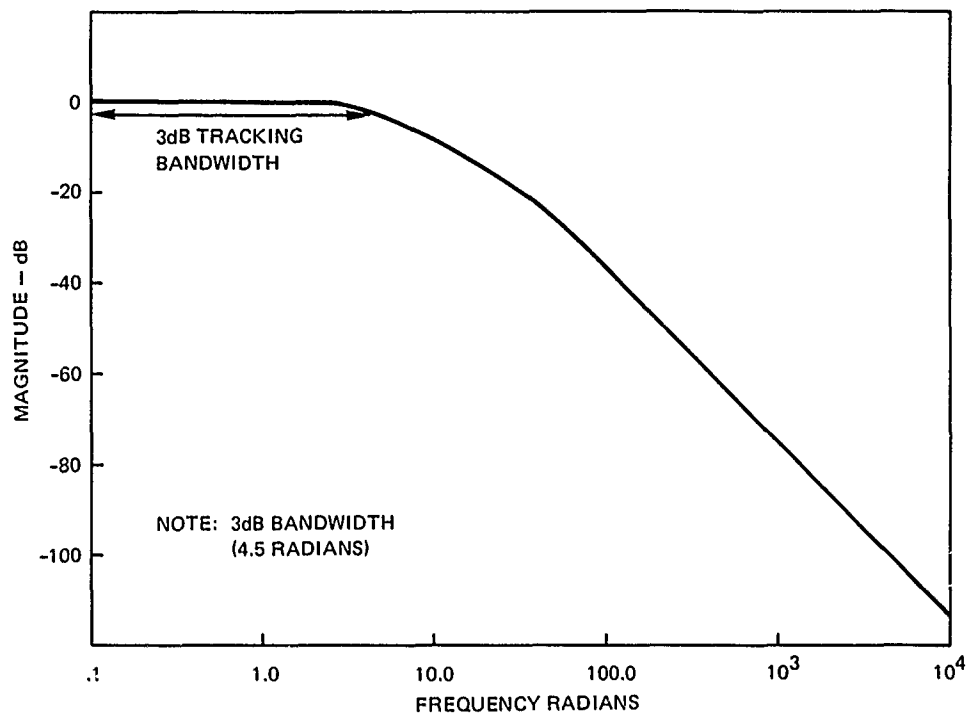


Figure 58. Frequency response of track loop $\hat{\sigma}/\sigma$ transfer function (inner gimbal).

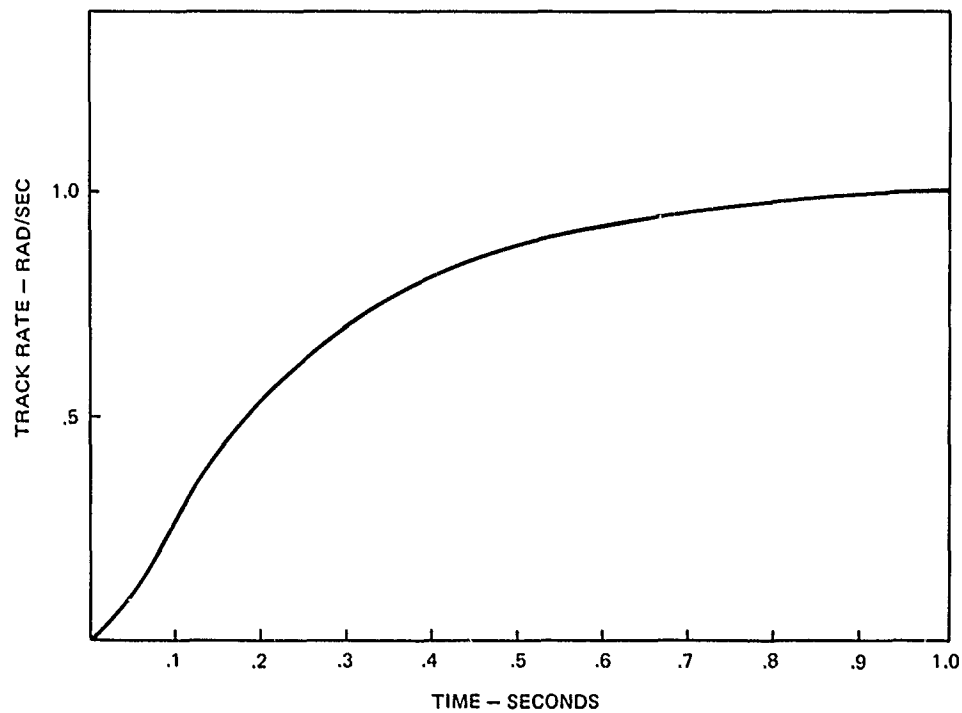


Figure 59. Track loop time response (inner gimbal).

5. SUMMARY

A stabilized sensor is required for modern day missile guidance applications. This is particularly essential for air-to-air guidance missiles. The stabilized sensor provides the following:

- (1) An inertial reference from which line-of-sight rates can be measured.
- (2) It decouples body motion and extraneous torque disturbances from the guidance signals.
- (3) The target tracking sensor is maintained in an optimum boresight region of operation.

This report covers the design and development of such a space stabilized platform for a missile guidance or surveillance sensor. The design philosophy was based on a high torque-to-inertia ratio. This philosophy leads to a low cost system. The high torque-to-inertia system has excellent extraneous torque disturbance isolation. This allows higher tolerances on mass imbalances. It is the "Swiss watch" manufacturing process in the conventional space stabilized platforms which needed to be maintained to achieve the low mass imbalance requirements. Traditionally this Swiss watch type of manufacturing carries along with it high machining costs. Torque is essentially a cheap commodity. By maintaining higher torque level in the servo design, a design approach was established which led to overall lower system costs. In addition, the tracking and slew rate performance of the platform was greatly increased as a result of the high torque-to-inertia criterion.

The design performance of the platform is summarized in tables 5 through 7. Each table relates to a separate mode of operation or servo loop.

Figures 60 and 61 present the block diagrams of the finalized designs for the servo loops. Tables 8 and 9 present the values for the individual parameters shown in the block diagrams of figures 60 and 61. Figures 62 and 63 show the system hardware, ie, the antenna sensor mounted to the gimbal.

Design/Performance Parameters	Inner Gimbal	Outer Gimbal
Rise Time	0.014 sec	0.01 sec
Delay Time	0.011 sec	0.008 sec
Percent Overshoot	12.64%	10.7%
Settling Time	0.065 sec	0.05 sec
Velocity Error Constant	40 288.88 1/sec	46 482.4 1/sec
Bandwidth	250 rad	270 rad
M _p	4 dB	3 dB

Table 5. Slave loop design performance.

Design/Performance Parameters	Inner Gimbal	Outer Gimbal
Rise Time	0.002 sec	0.0025 sec
Delay Time	0.0015 sec	0.00175 sec
Percent Overshoot	28%	28%
Settling Time	0.06 sec	0.1 sec
Acceleration Error Constant	225 568.21/sec ²	300 040.44/sec ²
Bandwidth	750 rad	550 rad
M _P	3.2 dB	4 dB

Table 6. Stabilized loop design performance.

Design/Performance Parameters	Inner Gimbal (Isolation - dB Track Rate - deg/sec)	Outer Gimbal (Isolation - dB Track Rate - deg/sec)
Maximum Track Rate	143.24	114.6
Minimum Isolation:		
$\left. \frac{\hat{\sigma}}{\dot{\theta}} \right _{S=1; 10 \text{ rad/sec}}$	92; 48	90; 48
$\left. \frac{\hat{\sigma}}{T_d} \right _{S=1; 10 \text{ rad/sec}}$	75; 50	90; 66
$\left. \frac{\epsilon}{\dot{\theta}} \right _{S=1; 10 \text{ rad/sec}}$	104; 60	100; 60
$\left. \frac{\epsilon}{T_d} \right _{S=1; 10 \text{ rad/sec}}$	90; 64	106; 82

Table 7. Track loop design performance.

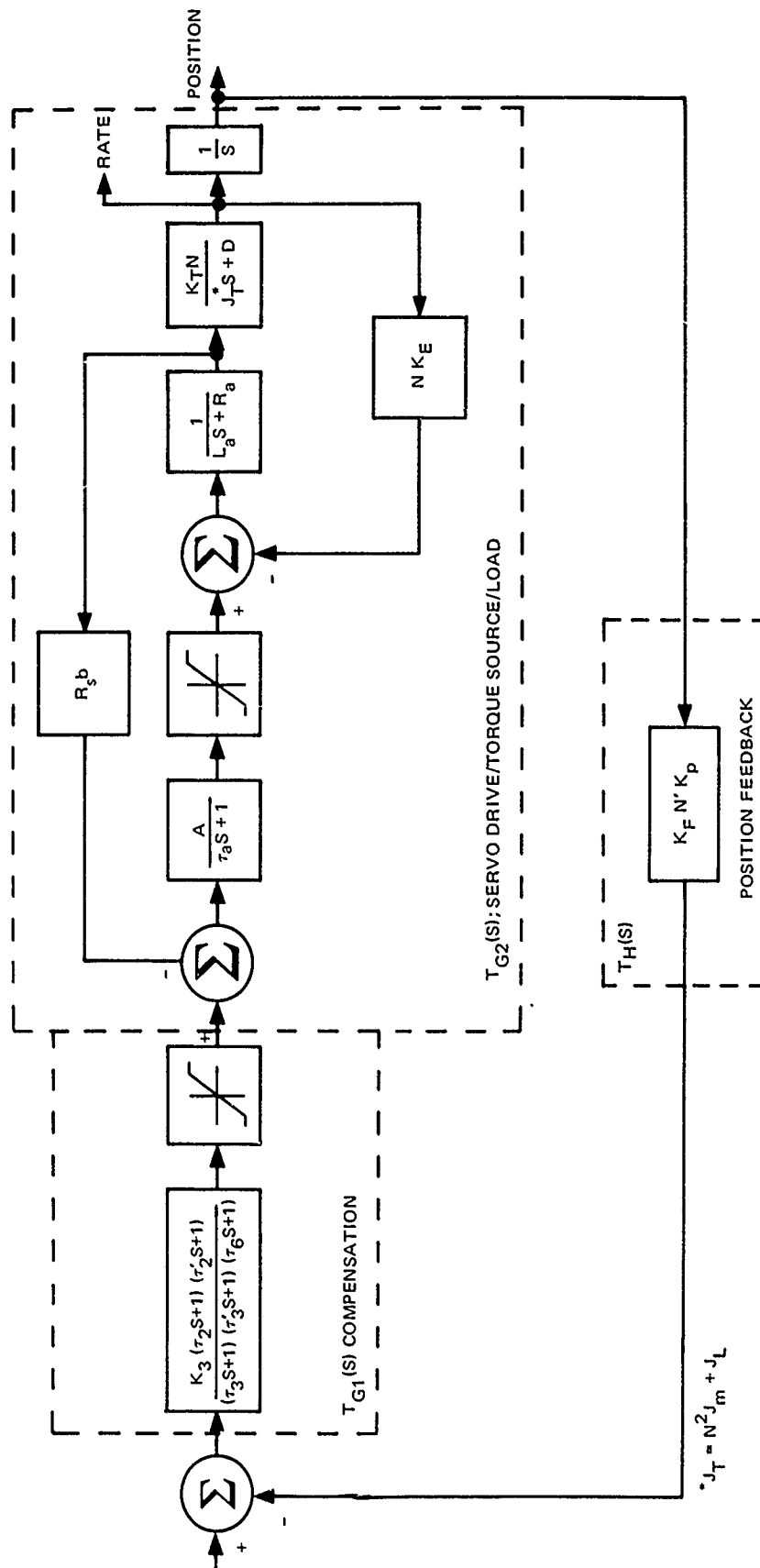


Figure 60. Sensor servo platform, slave loop.

Sensor:

Parameter	Units	Inner Gimbal	Outer Gimbal
K ₄	Vdc/Vdc	7.0	7.0
K ₅	Vdc/Rad/sec	7.0	7.0
τ_7	sec	.025	.025

Compensation Network:

Parameter	Units	Inner Gimbal	Outer Gimbal
K ₃	Vdc/Vdc	46.68	84.72
τ_2	sec	.01	.01
τ_2'	sec	.01	.01
τ_5	sec	.1	.1
τ_3	sec	.0005	.0005
τ_3'	sec	.0005	.0005
τ_6	sec	.8	.8

Limiter: All limiters are ± 20 volts.

Rate Sensor Feedback:

Parameter	Units	Inner Gimbal	Outer Gimbal
K ₂	Vdc/Vrms	14.0	14.0
τ_4	sec	.0015	.0015
K _{mhd}	Vrms/Rad/sec	.8595	.8595

Servo Drive System: Same as those of slave loop of table 9.

Table 8. Stabilization track/loop parameter values.

Compensation Network:

Parameter	Units	Inner Gimbal	Outer Gimbal
K_3	Vdc/Vdc	4.668	5.086
τ_2	sec	.018	.0195
τ'_2	sec	.018	.0195
τ_3	sec	.0015	.0015
τ'_3	sec	.0015	.0015
τ_6	sec	.024	.020

Limiter: All limiters are ± 20 volts.

Servo Drive/Torque Source/Load:

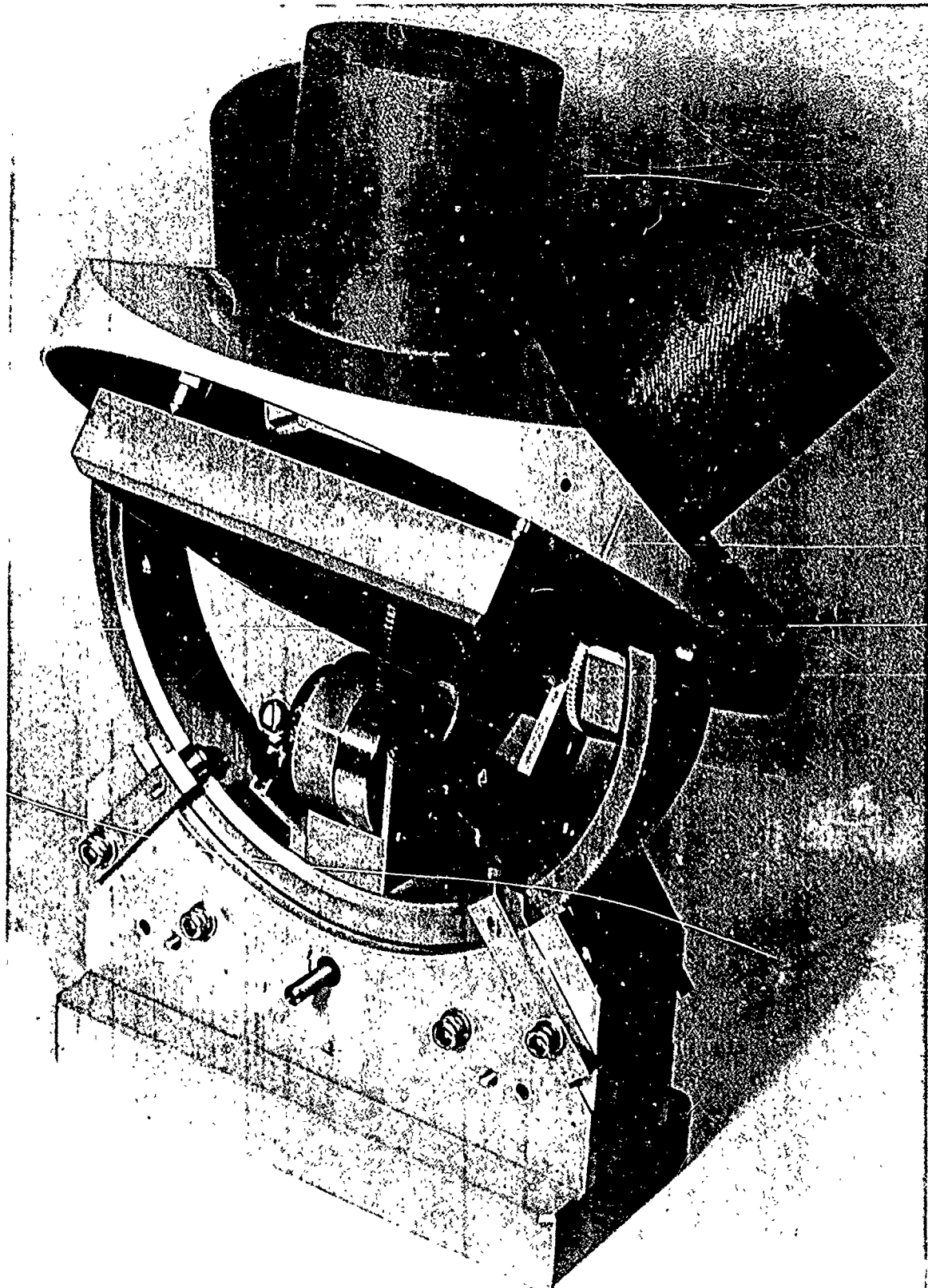
(These values are for slave and stabilization loops)

Parameter	Units	Inner Gimbal	Outer Gimbal
A	Vdc/Vdc	100 000.00	100 000.00
τ_a	sec	.02	.02
L_a	Millihenries	.0027	.0014
D	oz-in-sec	.622	.706
R_a	ohms	9.317	3.0
R_{sb}	ohms	1.0	1.0
J_m	oz-in-sec ²	.0015	.016
J_L	oz-in-sec ²	2.47	3.30
K_T	oz-in/amp	19.75	24.6
N	Gear ratio	12.8	8.5
K_E	Vdc/rad/sec	.141	.177

Position Feedback:

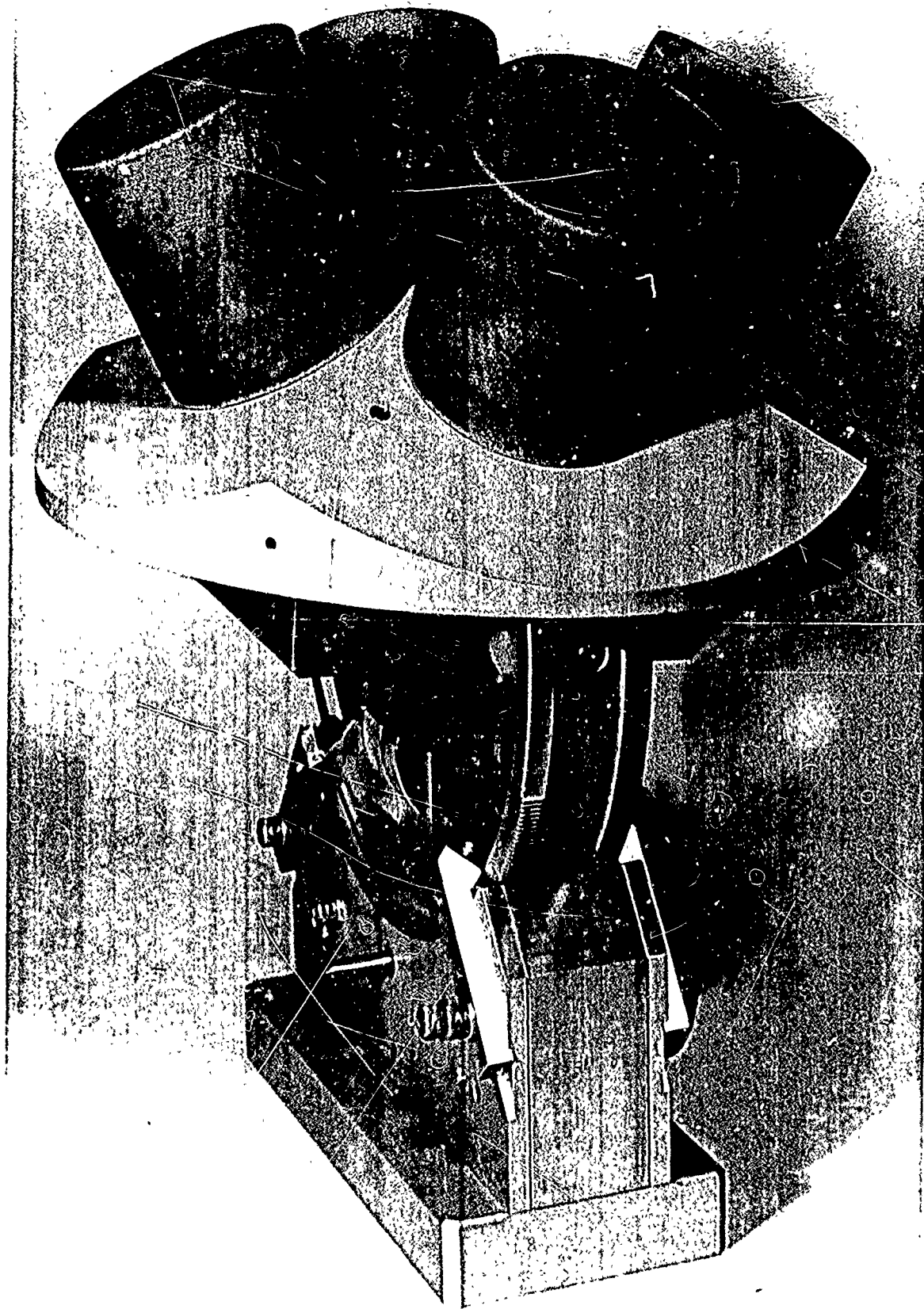
Parameter	Units	Inner Gimbal	Outer Gimbal
K_F	Vdc/Vdc	1.5	2.295
N	Pot gear ratio	3.0	8.5
K_p	Vdc/rad	4.776	1.592

Table 9. Slave loop parameter values.



LRO 356 4-79A

Figure 62 Stabilization platform/sensor system showing outer and inner gimbal.



LRO 354 4-79A

Figure 63 Stabilizing platform and sensor mounted to stable platform.

6. REFERENCES

1. Groutage, FD, Strike Drone -- A Defense Suppression Concept Using Unmanned Cruise/Loiter/Attack Vehicle, SAE Transactions, Vol. 87, 1978.
2. Paarmann, LD, Faraone, JN, and Smoots, CW, Guidance Law Handbook for Classical Proportional Navigation, ITT Research Institute, GACIAC HB-78-07, 1978.
3. Horowitz, IM, Synthesis of Feedback Systems, Academic Press, 1963.
4. Davis, SA, Feedback and Control Systems, Simon and Schuster, Technical Outlines, New York, 1974.
5. Shinnars, SM, Modern Control Systems Theory and Applications, Addison-Wesley Publishing Company, 1972.
6. Naval Electronics Laboratory Center, San Diego, CA, NELC TR 2023, Radome Development for a Broadband RF Missile Sensor, by FD Groutage, 1976.
7. The Analytic Science Corporation, TR-170-4, Performance Evaluation of Homing Guidance Laws for Tactical Missiles, 1973.
8. D'Azzo, JJ and Hoopis, CH, Feedback Control Systems Analysis and Synthesis, McGraw-Hill Book Company.
9. Elgerd, I, Control Systems Theory, McGraw-Hill Book Company, 1967.
10. Jaworski, ZE, Empirical Transient Formulae, Electronic Engineering, September, 1954.
11. Melsa, JL, and Schultz, DG, Linear Control Systems, McGraw-Hill Book Company, 1969.
12. Baumeister, Theodore, Editor, Mechanical Engineer's Handbook, McGraw-Hill Book Company, 1967.
13. Levy, EC, A New Table of LaPlace Transformation Pairs, The Book Page Company, Los Angeles, CA, 1963.
14. Watkins, BO, Introduction to Control Systems, The MacMillan Company, New York, 1969.

APPENDIX A

TECHNICAL DESCRIPTION OF RATE SENSOR

This appendix is essentially a reprint of technical product data supplied to NOSC by Honeywell.* The technical description in this appendix covers the Honeywell GG 2500 rate sensor and the readout electronics (demodulator and filters) associated with the rate sensor.

*Honeywell, Avionics Division, Minneapolis, Minnesota, GG2500 MHD (Magnetohydrodynamic) Two-Axis Rate Sensor, February 1978

SECTION I
GG2500 MHD (MAGNETOHYDRODYNAMIC)
TWO-AXIS RATE SENSOR

The Honeywell GG2500 is a new concept subminiature, high performance, two-axis rate sensor specifically designed for large volume producibility. It has been qualified to environmental requirements of MIL-STD-810B for gyros installed in airplanes, helicopters, and air and ground launched missiles. It is ideally suited for tactical missile seekerhead stabilization, aircraft and missile autopilot application, and rate measuring for fire control systems.

Direct benefits to the user are:

- Subminiature size and weight; two-axis information from a unit only one-fourth the volume of two conventional rate gyros
- Excellent Linearity ($< 0.1\%$ FS)
- Negligible Hysteresis (< 0.01 deg/sec)
- Low Temperature-Sensitivity
- Low G-Sensitivity
- Wide Dynamic Range (10^6)
- Frequency Response Independent of Temperature
- Over-Rate Capability 20,000 deg/sec

SECTION II PERFORMANCE

The performance characteristics of the GG2500 are listed in Table 1. These characteristics, unless specified otherwise, apply for any of the environments shown in the table.

Table 1. MHD Rate Sensor Specifications
(GG2500LC02 and GG2500LC03)

<u>Parameter</u>	<u>Performance</u>
Scale Factor	GG2500LC02: $15 \pm 5\%$ mV rms/deg/sec GG2500LC03: $15 \pm 1\%$ mV rms/deg/sec
Zero Rate Error (includes run-up repeats)	GG2500LC02: 0.5 deg/sec max. GG2500LC03: 0.15 deg/sec max.
Linearity	0.1% of max. rate (max. dev. from best STR line)
Cross Coupling (axis change vs. input rate)	0.5% of full scale (max. dev. from best STR line) ⁽¹⁾
Hysteresis	0.01 deg/sec max.
Threshold	0.01 deg/sec max.
Acceleration Sensitivity	0.05 deg/sec/g max.
g^2 Sensitivity	1×10^{-3} deg/sec/ g^2 max.
Output Noise at Null	100 mV rms max. (using 1000-Hz bandwidth meter)
Rate Input Range	To ± 480 deg/sec
Frequency Response	100 Hz min. without electronics
Ref. Gen. Output	1 V rms min. each axis
Ref. Gen. Phase Angle	90 ± 0.5 degrees
<u>Performance Stability with Environments</u>	
Zero Rate Error Stability over all Environments	0.15 deg/sec
Acceleration Sensitivity Stability over all Environments	0.03 deg/sec/g
Scale Factor Change - vs - Temperature	$\pm 2\%$
Input Axis Change - vs - Temperature	± 0.5 deg
<u>Excitation Requirements</u>	
Motor	26 ± 2 volt rms 400 Hz 2 ϕ , 4 watts max.
Preamp	$\pm 15 \pm 3$ Vdc, 4 mA max. with 500 mV max. p-p ripple
Weight	70 grams max.

(1) When operated with amplifier-demodulator readout electronics, Deviation is expressed as a percent of opposite axis full scale.

SECTION III

ENVIRONMENTAL CAPABILITY

The GG2500 is designed to meet or exceed environmental requirements of MIL-STD-810B as it applies to gyros intended for installation in aircraft, helicopters, and air and ground launched missiles; and has been successfully qualified to the environmental levels listed in Table 2. Performance before, during, and after each exposure has been measured; these results have been used to establish performance capability. See Figures 1 and 2 for the installation drawing and sensor schematic.

Table 2. Environments

Environments	Limits
Overrange Capability	20,000 deg/sec
Temperature Operating Non-Operating	-65°F to +160°F -65°F to +220°F
Altitude	MIL-STD-810B, Method 500, Proc II to 60,000 Ft.
Temperature Shock	MIL-STD-810, Method 503, Proc 1 + 71°C to -54°C to +71°C, four (4) hours each temp -5 minutes between chambers.
Vibration	MIL-STD-810, Method 514, Proc II 2 hr/axis - Time Schedule V of Table 514-II, Curve H (10 G Peak Sine) 1/2 hr/axis - Time Schedule II of Table 514-II, Curve Q (10 G Peak Sine) 1/2 hr/axis - Time Schedule II of Table 514-II, Curves AH (11.9 G RMS Random) and AK (20.7 G RMS Random)
Shock	2 drops/axis each direction, 12 drops total each level: 40 G, 18 MS; 400 G, 1.5 MS; 100 G, 6 MS; 500 G, 0.75 MS; MIL-STD-810, Method 516, Proc IV
Acceleration	100 G, each direction - each axis
Magnetic Sensitivity	.05 deg/sec/gauss max
EMI Susceptability	MIL-STD-461
Useful Life	Life tested to 1000 hours

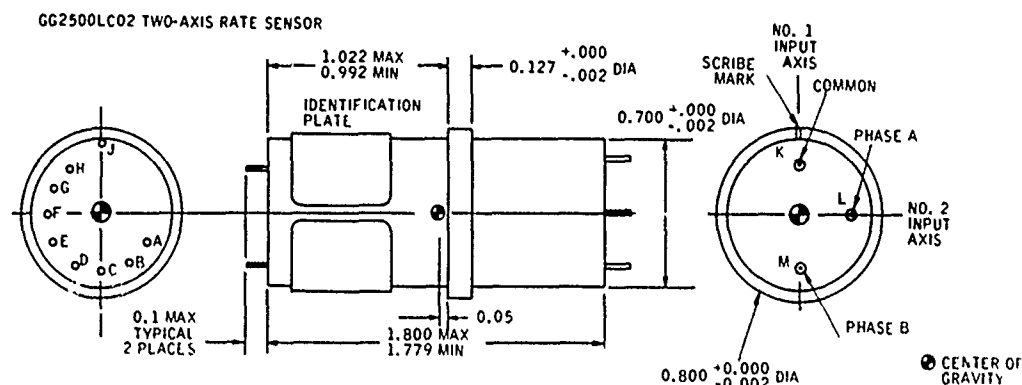
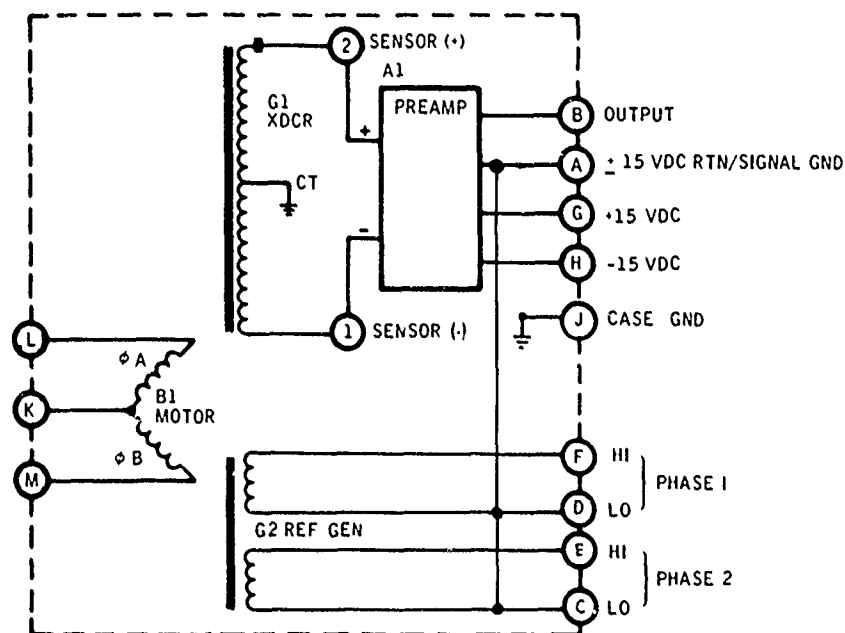


Figure 1. Installation Drawing



TERMINALS 1 & 2 ARE NOT ACCESSIBLE

Figure 2. Sensor Schematic

SECTION IV TECHNICAL DESCRIPTION

OPERATING PRINCIPLE

The GG2500 Rate Sensor is a non-gyro sensor; it does not depend on the momentum of a spinning wheel for operation. An angular accelerometer is used in the basic sensor. By rotating the accelerometer at a constant speed about an axis perpendicular to its input axis, an input rate in a plane normal to the spin axis is changed to a time varying angular acceleration that is sensed by the accelerometer.

To obtain further insight into the operation, consider an angular accelerometer that is being rotated at a constant rate, ω_S , about an axis perpendicular to the angular accelerometer input axis. If a rate exists perpendicular to this rotation axis, the instantaneous rate about the angular accelerometer input axis is:

$$\omega_O = \omega_X \sin \omega_S t \text{ (see Figure 3)}$$

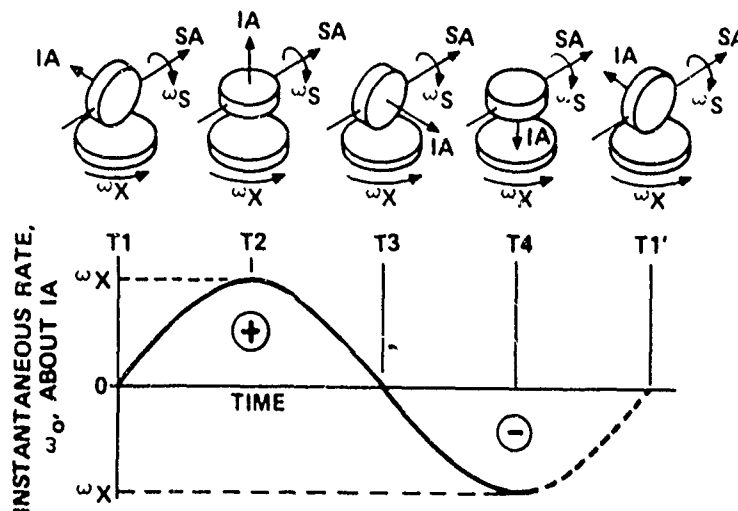


Figure 3. MHD Theory of Operation

The angular acceleration about the input axis, therefore, is:

$$\dot{\omega}_o = \frac{d\omega_o}{dt} = \omega_s \omega_x \cos \omega_s t$$

By these means the input rate is changed to a time-varying angular acceleration. The rotating accelerometer acts as an integrator that provides an ac output voltage, which is directly proportional to rate, at a frequency equal to the rotation frequency.

PHYSICAL CONSTRUCTION

A cross section of the complete rate sensor is shown in Figure 4. The sensor consists of the angular accelerometer, a hysteresis-synchronous drive motor, a two-phase reference generator, a slip ring assembly to transfer the accelerometer output signal from the rotating element, and an integrally mounted accelerometer preamplifier. The entire sensor is fabricated from a high permeability nickel iron alloy that serves as an effective magnetic shield. Laser welding of all internal and external joints ensures structural integrity and hermeticity under severe environments.

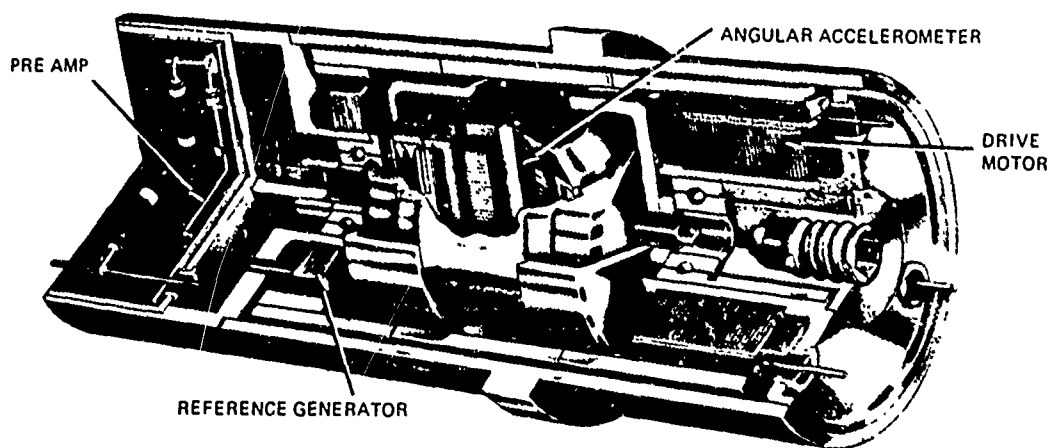


Figure 4. GG2500 Rate Sensor

MOTOR DESIGN

The rotor drive is a two-phase hysteresis synchronous motor wound to operate with an excitation of 26 V at 400 Hz. Since the stator is attached directly to the rate sensor case, it does not enter into the dynamics of rotor balance and mass stability as in a conventional gyro. In addition, the heat generated in the motor windings is conducted directly to the sensor mounting surfaces without passing through the rotor bearings, thus minimizing motor temperature rise and thermal gradients across the sensor.

REFERENCE GENERATOR

The two-phase reference generator provides the demodulator reference signals to permit the composite rate signal to be resolved into two-axis information. The stator is positioned on the rotor spin axis and is wound in a standard two-phase configuration. A diametrically charged ring magnet attached to the rotor provides the lines of flux required to generate a voltage in each winding. The reference generator output, when loaded with a 10K or greater resistive load, is greater than 1.0 V rms at the rotor frequency of 200 Hz.

ANGULAR ACCELEROMETER

The angular accelerometer used in the device is depicted in Figure 5. An annular ring of mercury exists between the radially oriented permanent magnet and the magnetic case, which provides the magnetic path. The existence of a rate input results in a relative motion of the magnetic field with respect to the mercury. This motion through the phenomenon of magneto-hydrodynamics (MHD) causes a voltage gradient across the mercury at right angles to the magnetic field and the relative motion. Contacts on either side

of the mercury ring provide a single turn primary for the transformer. The voltage generated across the mercury causes a current to flow through the single turn primary, which, in turn induces a corresponding voltage in the secondary winding.

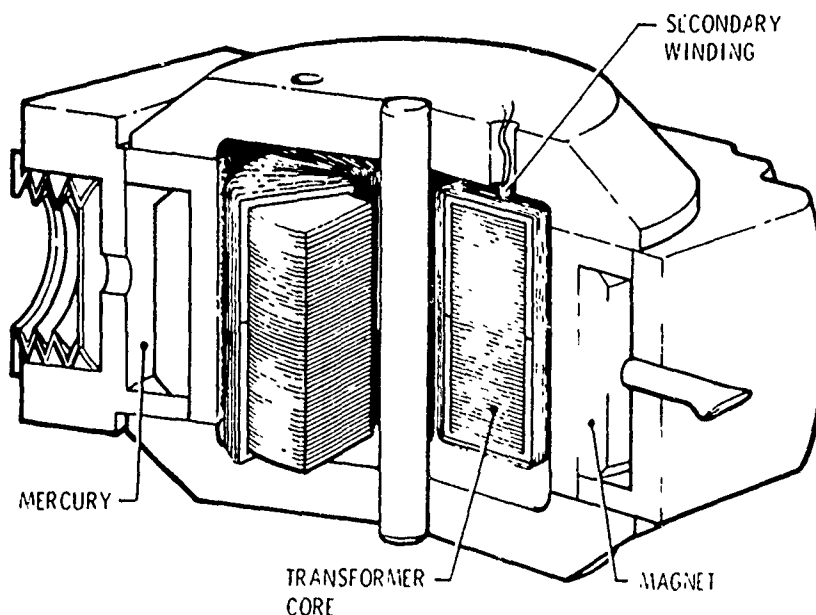


Figure 5. Angular Accelerometer

The voltage induced in the mercury is:

$$E = B l v$$

where

B = flux density

l = length of moving conductor

v = velocity of conductor relative to the magnetic field

In terms of angular velocity:

$$e = B l \omega_r$$

where

r = mean radius of the mercury

ω_r = angular velocity of the mercury relative to the magnetic field (or sensor case)

To determine the relationship between ω_r and the input angular rate ω_o , the open-loop transfer function for the angular accelerometer is examined:

$$\omega_r = \omega_o \left(\frac{\frac{I}{C} S}{\frac{I}{C} S + 1} \right)$$

where

ω_r = angular velocity of the mercury relative to the magnetic (or sensor case)

ω_o = angular input to case

I = polar moment of inertia of mercury

C = damping of mercury

S = La Place operator

In the practical case where $\left| \frac{I}{C} S \right|$ is much greater than one, the quantity within the parenthesis is unity to within one part in 10^7 . This means that the input rate and the rate between the magnetic field and the mercury are essentially identical and that the mercury is motionless about its input axis. Thus, the output of the MHD rate sensor is a true representation of the input rate.

Since both I and C are essentially constants over the operating temperature range, a method of temperature control to hold these parameters is not necessary.

ROTOR SUSPENSION

The rotor is mounted on two preloaded miniature precision ball bearings. Since the entire rotor and case structure are made from the same material, preload does not change as a function of ambient temperature changes. In a conventional gyro, mass balance instability can be caused by migration of lubricant from the rotor bearing, so lubrication is kept to an absolute minimum. Because the GG2500 does not operate by measuring precession torques, oil migration does not cause performance errors, so the lubricant can be applied copiously. The large amount of lubricant, coupled with inner race rotation and light loads, ensures long bearing life and stable device performance.

SLIP RING ASSEMBLY

The slip ring assembly is mounted on the rotor axis and, in conjunction with a case mounted brush block assembly, provides the means of coupling the accelerometer output signal to the preamplifier. Multiple brushes for each circuit result in extremely low contact resistance and noise free operation. Slip ring life tests have proven an operating life of greater than 2000 hours without degradation or any increase in contact resistance or slip ring noise.

PREAMPLIFIER ASSEMBLY

A thick-film hybrid circuit preamplifier is mounted integrally to the GG2500 Rate Sensor. This preamplifier functions as an interface between the low-level high-impedance sensor output and the external readout electronics. The input circuit of the preamplifier consists of a dual FET follower stage chosen for reasons of very low bias current (10 na) to minimize noise effects from slip ring resistance and dc offsets in the transformer core. The dual

FET stage drives an integrated circuit operational amplifier connected as a conventional non-inverting amplifier which furnishes the high-level low impedance output. The preamplifier assembly provides for scale factor and zero rate error (ZRE) calibration. A scale factor temperature compensation network has also been added to the preamplifier assembly.

A schematic of the GG2500 Rate Sensor is shown in Figure 2.

SECTION V READOUT ELECTRONICS

A dual-channel demodulator is required to resolve the output of the GG2500 Rate Sensor into two-axes of information. In addition, some filtering is required to shape the response characteristics of the device.

A block diagram of the Honeywell circuits is shown in Figure 6. The circuit consists of an input band-pass filter and demodulator driver amplifier, reference signal driver amplifiers, a two-channel demodulator, and third-order low-pass output filters.

Honeywell is in the final stages of developing a miniature readout electronics package (shown in Figure 7) using thick-film hybrid packaging techniques. Honeywell expects to fully qualify this package to the GG2500 Rate Sensor qualification levels and have it available for delivery in the last half of 1973.

Initially, the EG1030AD will be available in the following gains, and resultant full scale ranges when used with the GG2500 Rate Sensor:

Gain Vdc/V rms	Full Scale Range Deg/sec
5.8	57.3
3.33	100
1.11	300
.9	370

Two versions of the output filter will be available; one with a 70-Hz bandwidth, the other with a 100-Hz bandwidth. The amplitude and phase

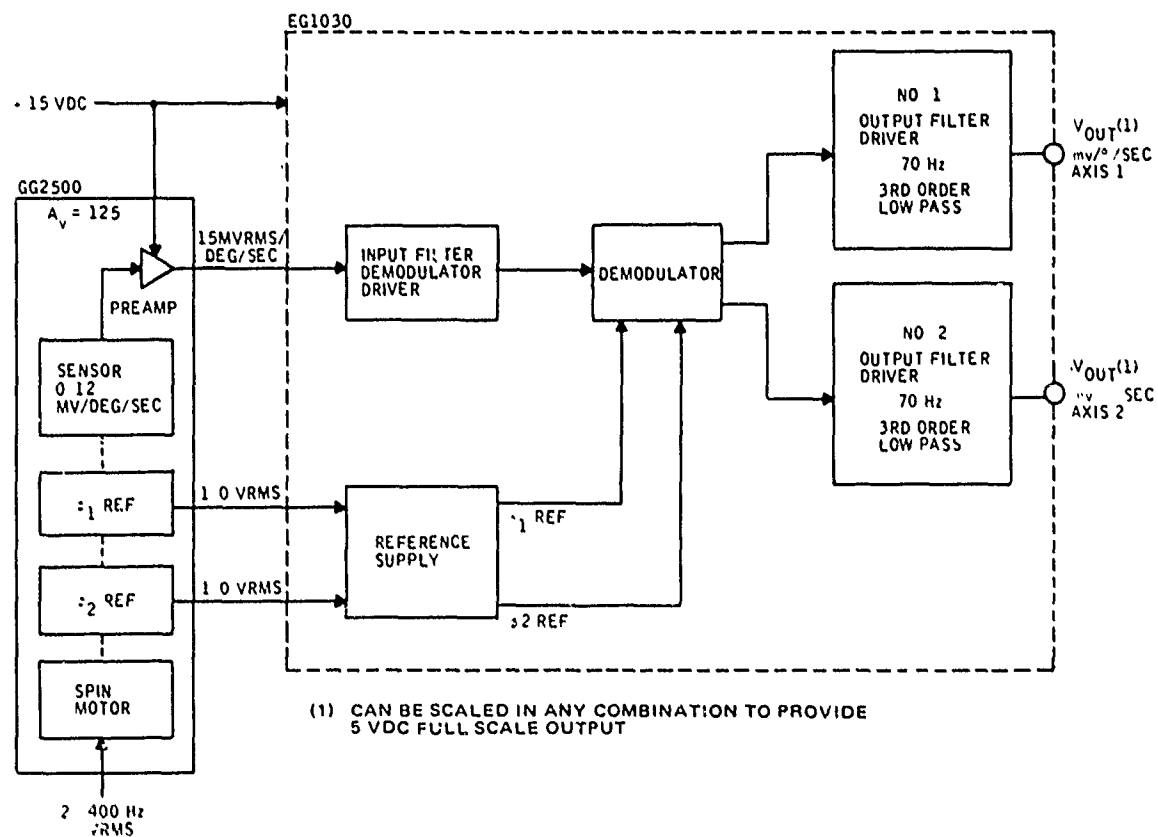


Figure 6. Block Diagram - GG2500LC Rate Sensor/EG1030AD Amplifier Demodulator Read-out Electronics.

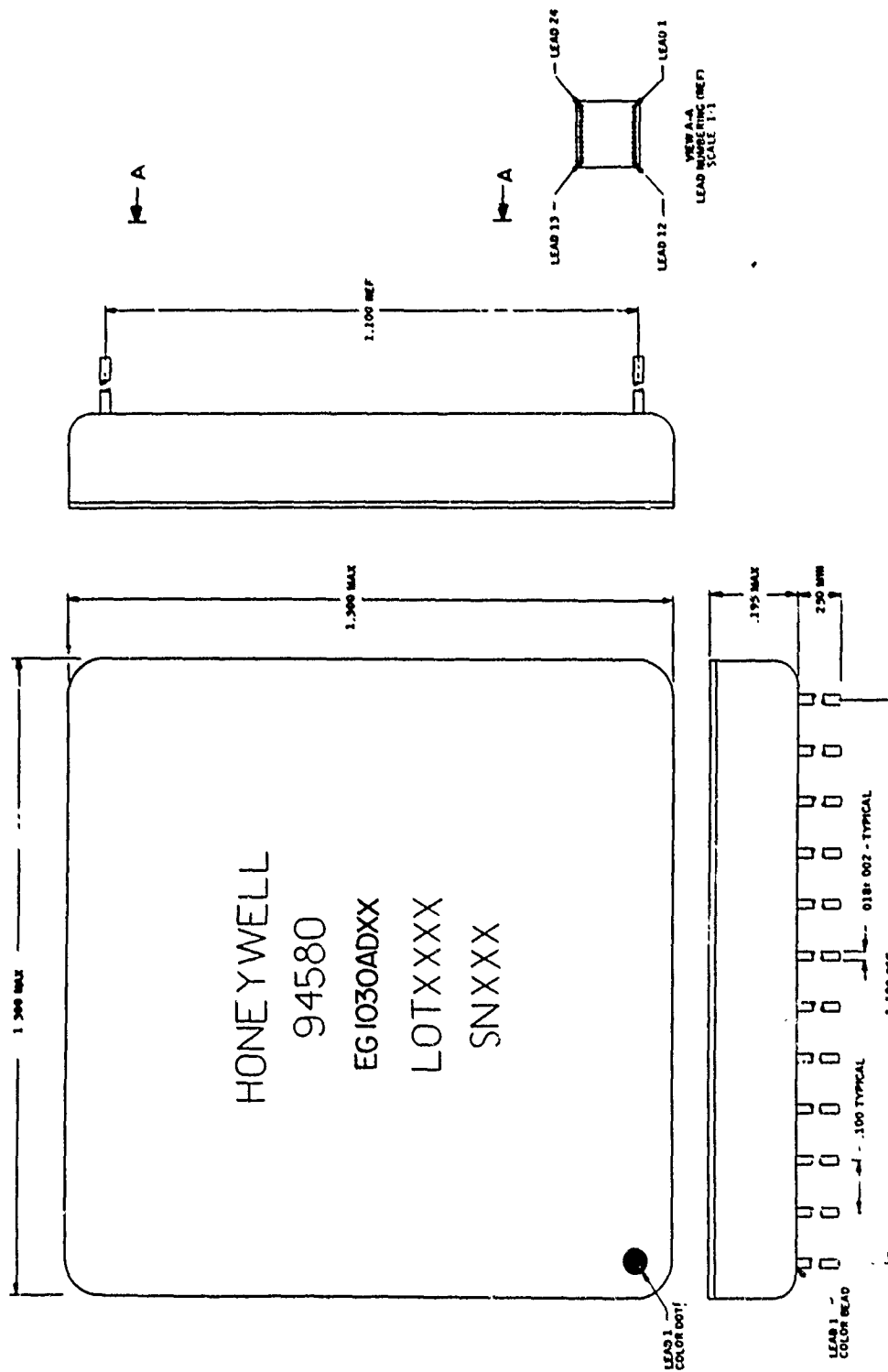


Figure 7. EG1030AD Outline Drawing

responses for these filters when used with a GG2500 Ratr. Sensor are shown in Figures 8 and 9.

The performance listed in Table 3 has been achieved using discrete components. It is expected that comparable performance will be realized with the thick-film circuitry. The quoted performance is for the EG1030AD when tested as a unit and does not include the contributions of the GG2500 MHD.

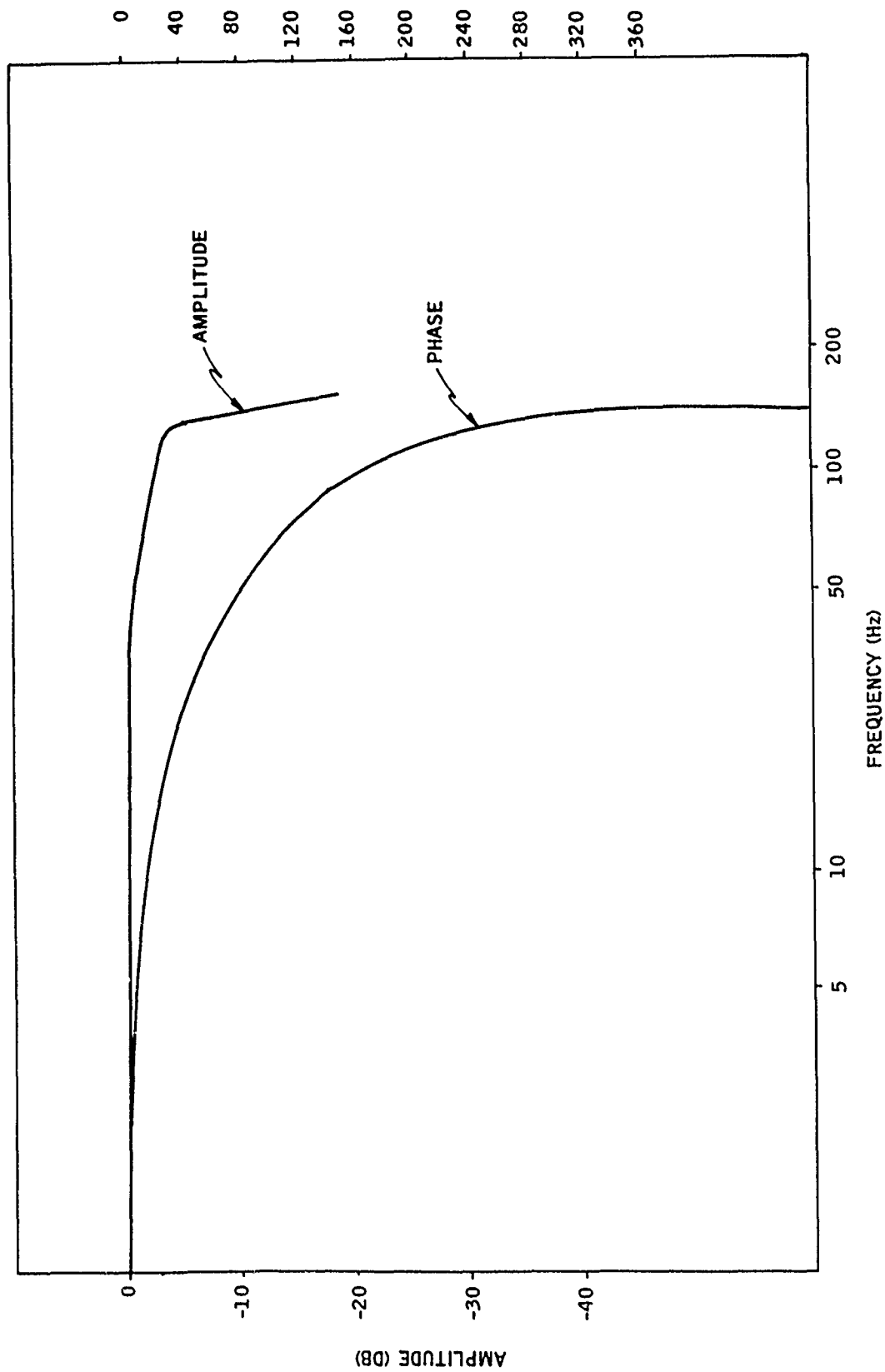


Figure 8. Amplitude and Phase Response - CG2500/
EGi030 (100 Hz Output Filter)

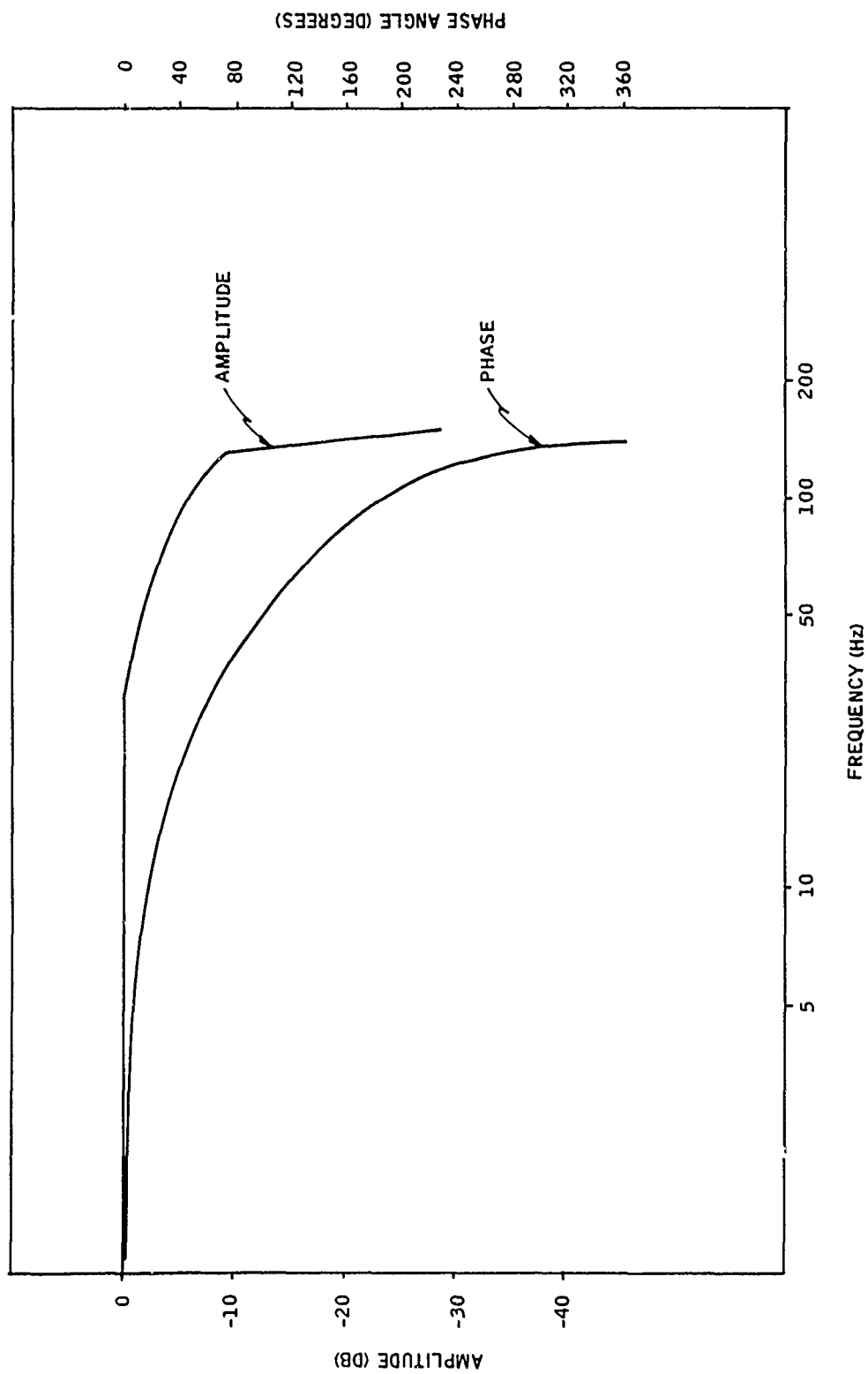


Figure 9. Amplitude and Phase Response - GG2500/
EG1030 (70 Hz Output Filter)

**Table 3. EG1030 Miniature Amplifier-Demodulator
Projected Performance**

Parameter	Projected Performance
Supply Voltage	$\pm 15 \pm 3 \text{ Vdc}$
Supply Current	15 mA at 60% F. S.
Output Range	$\pm 5 \text{ Vdc min.}$
Gain Set	$\pm 1\%$ max.
Gain Stability (OTR)	$\pm 1\%$ max. deviation
Offset	$\pm 1 \text{ mV max.}$
Offset Stability (OTR)	$\pm 0.10 \text{ deg/sec max. @ } 5.8 \text{ gain}$ $\pm 0.10 \text{ deg/sec max. @ } 3.33 \text{ gain}$ $\pm 0.15 \text{ deg/sec max. @ } 1.11 \text{ gain}$
Linearity	$\pm 0.03\%$ of F. S. (Max DEV from best STR line)
Cross coupling	$\pm 0.10\%$ of F. S. (Max DEV from best STR line) ⁽¹⁾
Phase Angle (OTR)	$\pm 0.15 \text{ deg. max. deviation}^{(2)}$
Output Noise	
Input Shorted	2 mV rms
At 60% F. S.	50 mV rms
Operating Temperature	$-65^\circ\text{F to } +200^\circ\text{F}$
Frequency Response	$-3 \text{ dB @ } 70 \text{ Hz}$ or $-3 \text{ dB @ } 100 \text{ Hz}$
Dynamic Output Impedance	Less Than 1 ohm
Weight	16 grams

(1) Deviation is expressed as a percent of opposite channel full scale.

(2) This parameter represents the change in the phase relationship between the signal and the reference voltages at the input to the demodulators.

SECTION VI SUPPORTIVE DATA

Typical data is presented to support and/or supplement the performance which was specified in Table 1.

FREQUENCY RESPONSE

The GG2500 is a wide-response device with an equivalent natural frequency of well beyond 100 Hz. The amplitude and phase response for the GG2500 is shown in Figure 10. It will be noted that as the input frequency approaches the spin frequency (200 Hz) there is considerable peaking before the output falls off to zero at 200 Hz. Therefore, Honeywell uses a third-order filter at the output of the amplifier-demodulator readout electronics to eliminate the peaking and yet at the same time maintain the maximum bandwidth. The amplitude and phase response for the combination of the GG2500 Rate Sensor and the EG1030 Amplifier-Demodulator Readout Electronics has previously been shown in Figure 8 for a 70-Hz filter and in Figure 9 for a 100-Hz filter.

SHORT-TERM ZRE STABILITY

A recording of the zero rate error (ZRE) from both channels over a 10-minute time period is shown in Figure 11. The maximum peak-to-peak excursion for either channel over the 10-minute time interval is 0.02 degree per second.

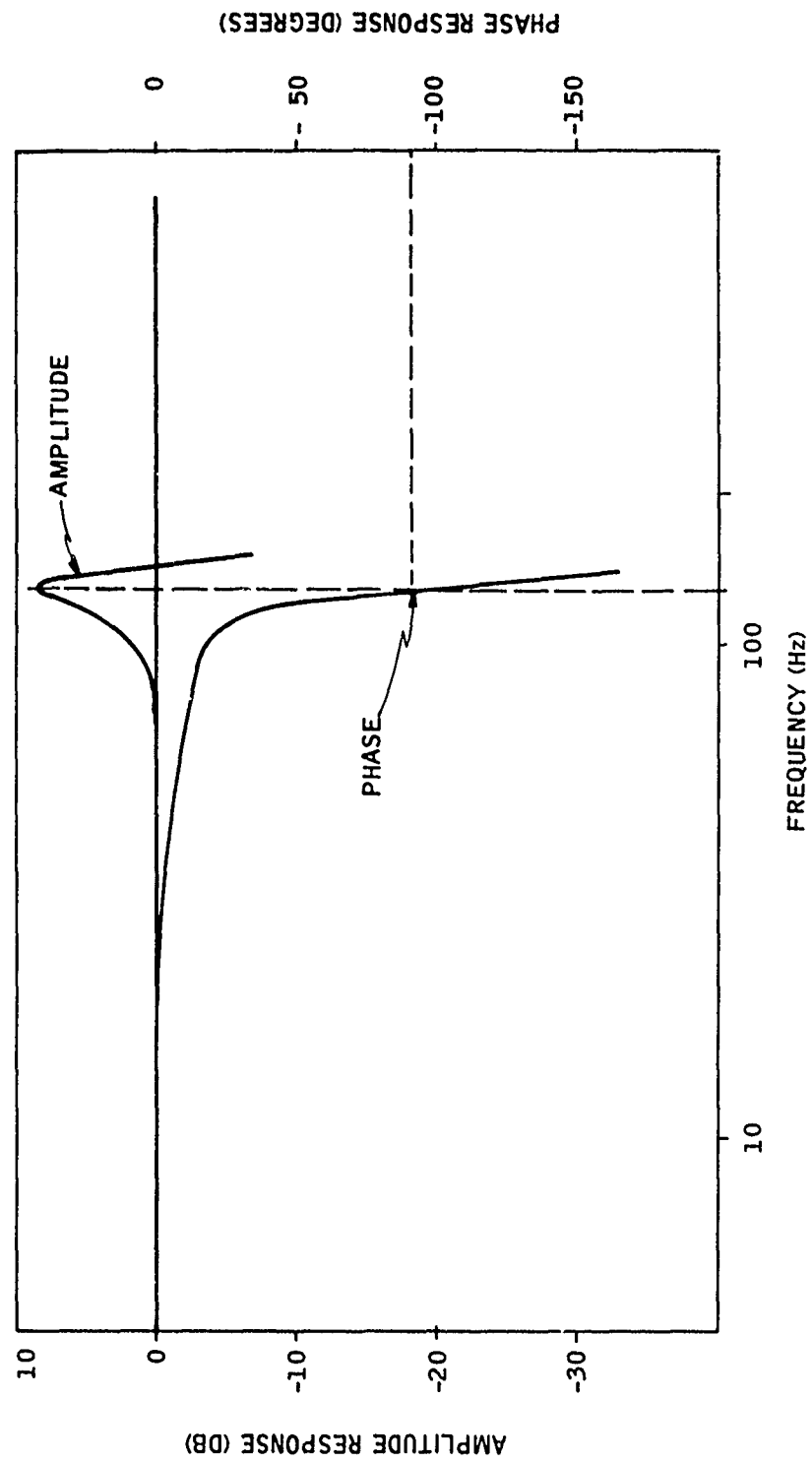


Figure 10. Amplitude and Phase Response -
GG2500 MHD

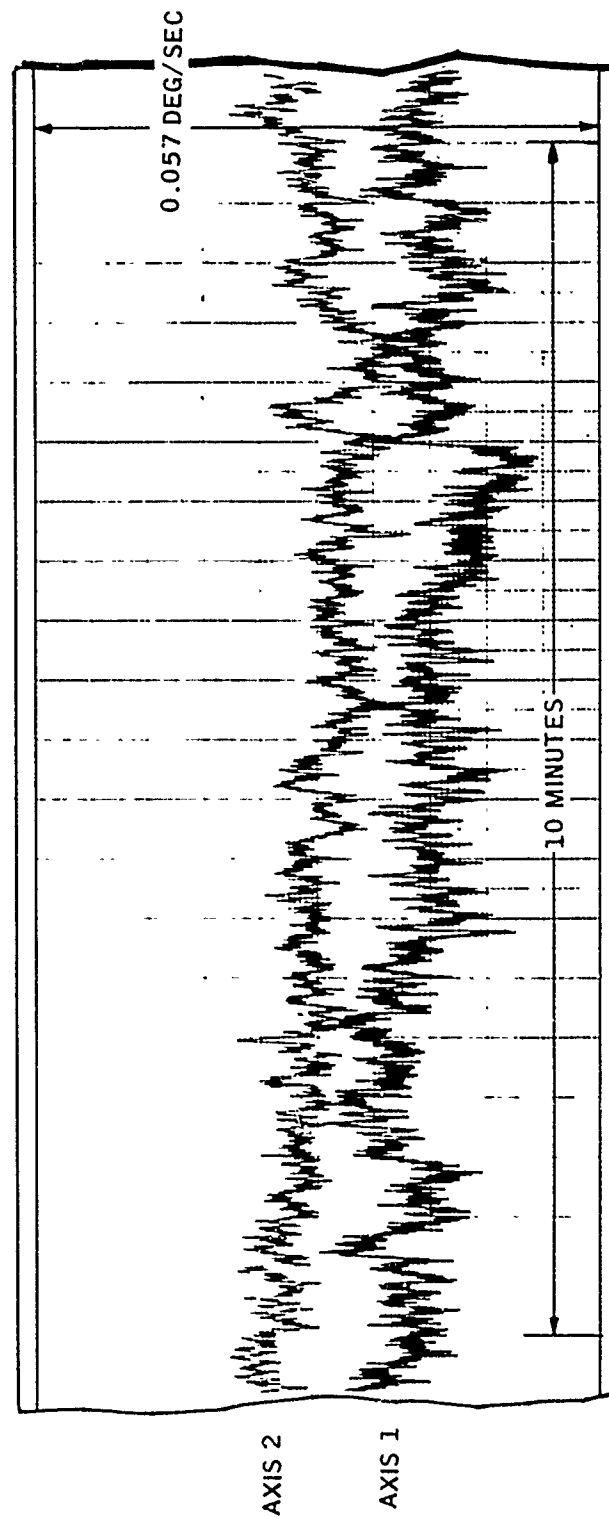


Figure 11. Short Term (10 Minutes) Zero Rate Error Stability

LINEARITY AND CROSS COUPLING

Honeywell defines linearity for the GG2500LC MHD Rate Sensor as the maximum deviation from a least-squares best-fit straight line expressed as a percentage of the full-scale input. In a like manner, cross coupling is defined as the maximum deviation from a least-squares best-fit straight line based on all output data points for input about the opposite axis and expressed as a percentage of the full-scale input of the opposite axis.

Since Honeywell specifies the full-scale range of the GG2500 MHD Rate Sensor at ± 480 deg/sec, this gives rise to the question of what is the performance capability for lesser full-scale ranges.

Linearity and cross coupling data is presented here for one GG2500 Rate Sensor (S/N S-8) for input ranges of 0 to ± 20 deg/sec, 0 to ± 60 deg/sec, and 0 to ± 480 deg/sec. In each case, the calculations were based on a least-squares best-fit straight line for that range. The data can be summarized as follows:

<u>Full-Scale Range</u>	<u>Linearity % Full-Scale (Spec = 0.1%)</u>	<u>Cross Coupling % Full-Scale (Spec = 0.5%)</u>
± 20 deg/sec	0.086	0.058
± 60 deg/sec	0.096	0.092
± 480 deg/sec	0.070	0.223

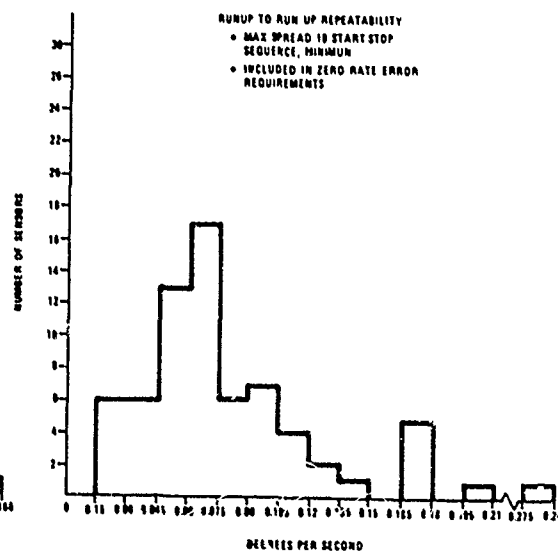
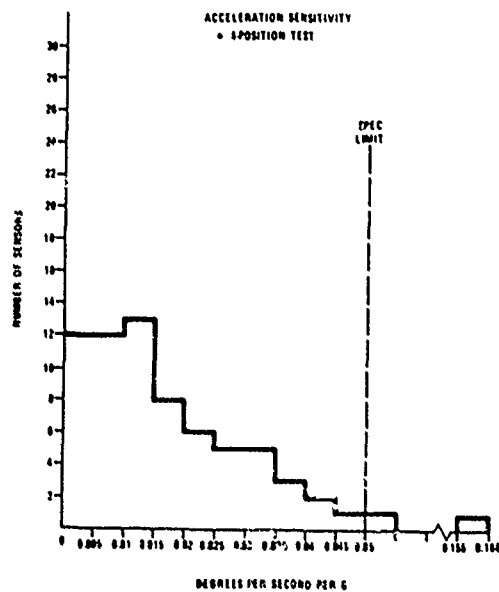
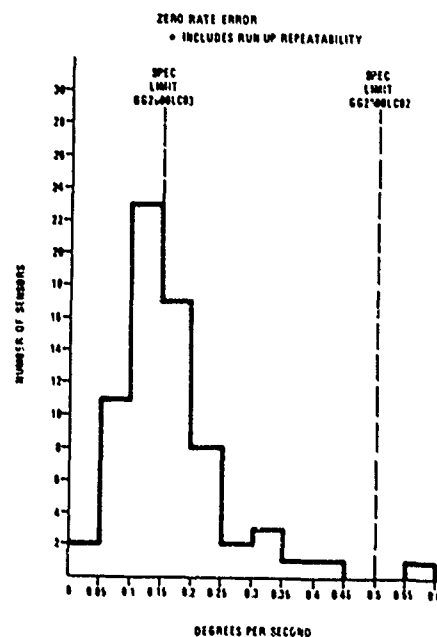
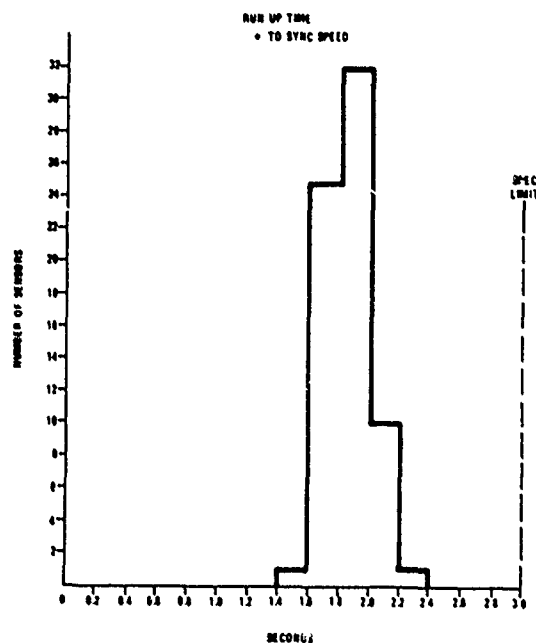
ANGULAR ACCELERATION SENSITIVITY

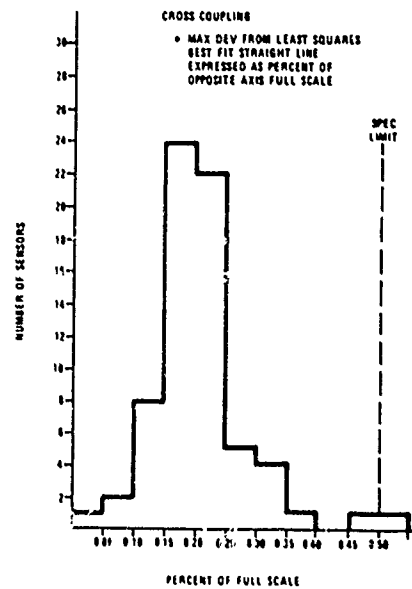
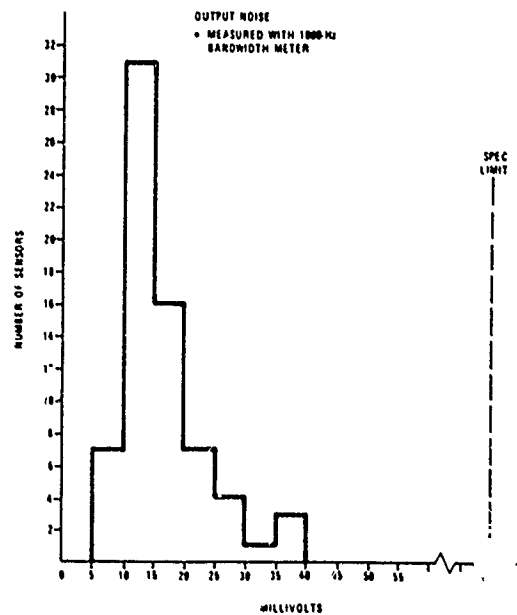
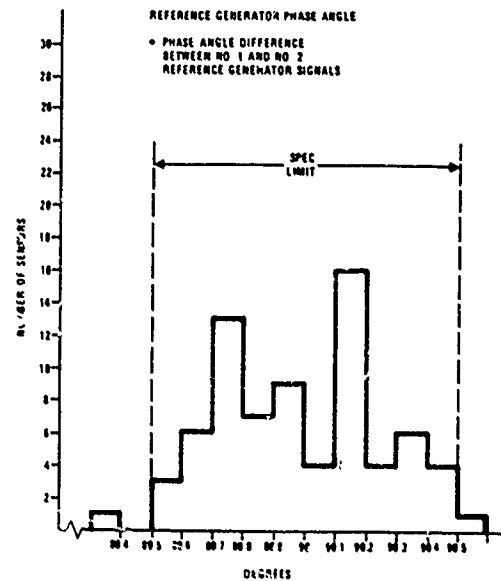
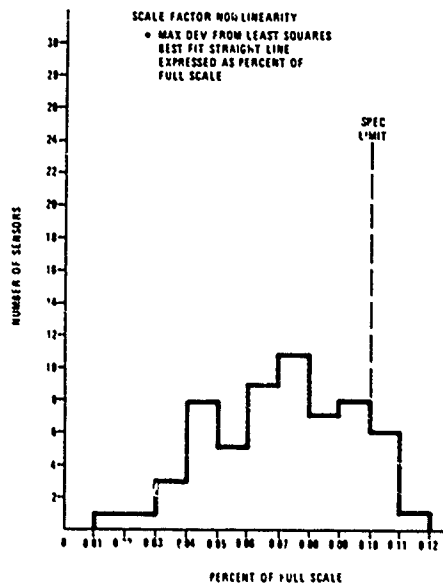
Since the basic transducer of the GG2500 is an angular accelerometer, a question that frequently arises is that of the sensitivity of the GG2500 to angular accelerations. As a matter of fact the GG2500 is virtually insensitive to angular accelerations. This is because the I/C time constant of the mercury torus is so great that at the frequencies of interest the transducer is basically an angular rate sensor.

As proof, consider the frequency response curves of Figure 10. Since these curves are run using an oscillating table the MHD was subjected to angular accelerations during these tests. It will be noted that the amplitude response curves are flat out to frequencies approaching the rotor speed. If the MHD were sensitive to these angular accelerations then the response curves should exhibit a 6 db per octave rise. Such was not the case. Honeywell has also run angular acceleration tests about the spin axis. Again no measurable effect was observed.

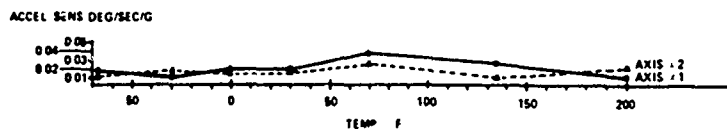
PERFORMANCE HISTOGRAMS

Histograms of critical performance parameters from the most recent 68 production units are shown below. Histograms of threshold and hysteresis are not plotted since they are within 0.01 deg/sec sensitivity of the device.

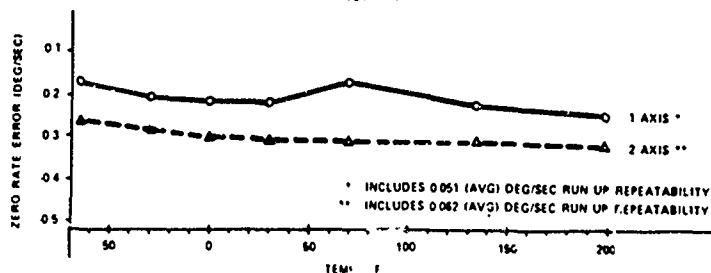




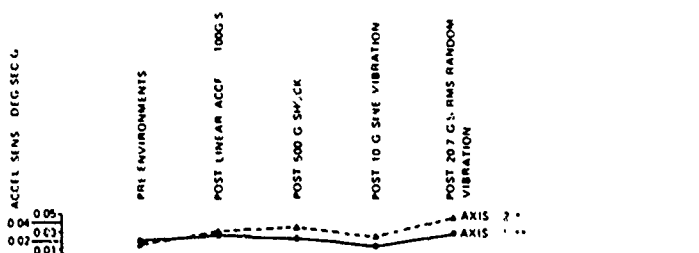
QUALIFICATION TEST PERFORMANCE DATA



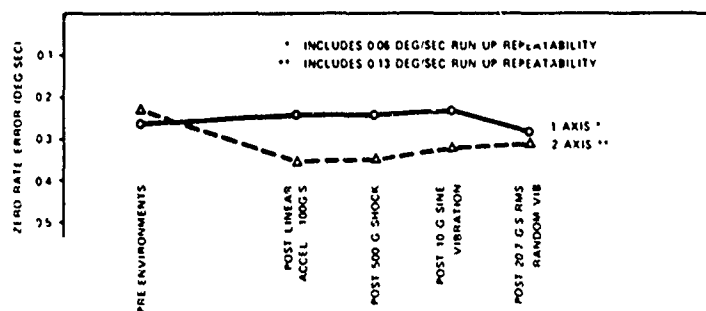
Acceleration Sensitivity Versus Temperature



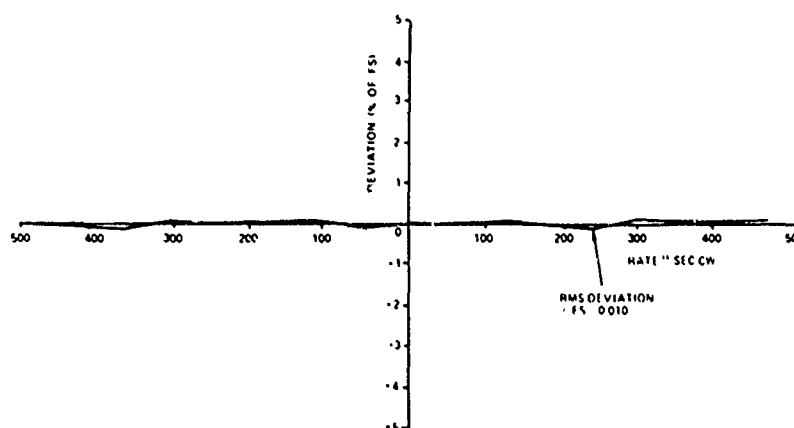
Zero Rate Error Versus Temperature



Acceleration Sensitivity Versus Environments



Zero Rate Error Versus Environments



Linearity Deviation

Detailed data is available for discussion on any GG2500 parameter.

APPENDIX 3
TORQUE MOTOR AND SERVO AMPLIFIER SPECIFICATIONS

CLIFTON PRECISION
LITTON SYSTEMS, INC.

ACCEPTANCE TEST DATA SHEET

UNIT TYPE: DPH-3320-A-2T
FUNCTION: TORQUE MOTOR POTENTIOMETER ASSEMBLY

<u>PARAMETER</u>	<u>UNITS</u>	<u>VALUE</u>
Rated Voltage	Volts	29.5
Terminal Resistance	Ohms	3.06
Stall Current (I_S)	Amps	9.65
No Load Speed	Rad/Sec	159
Torque Sensitivity	Oz-In/Amp	24.9
Peak Torque @ I_S	Oz-In	240
Back E.M.F.	V/Rad/Sec	178
Inductance	Millihenries	1.4
Friction Torque	Oz-In	5
Armature Inertia	Oz-In-Sec ²	.016
Acceleration	Rad/Sec ²	15,000
Pot Resistance	Ohms	5014
Linearity	Percent	.22

UNIT TYPE: DPH-1990-B-2T
FUNCTION: TORQUE MOTOR POTENTIOMETER ASSEMBLY

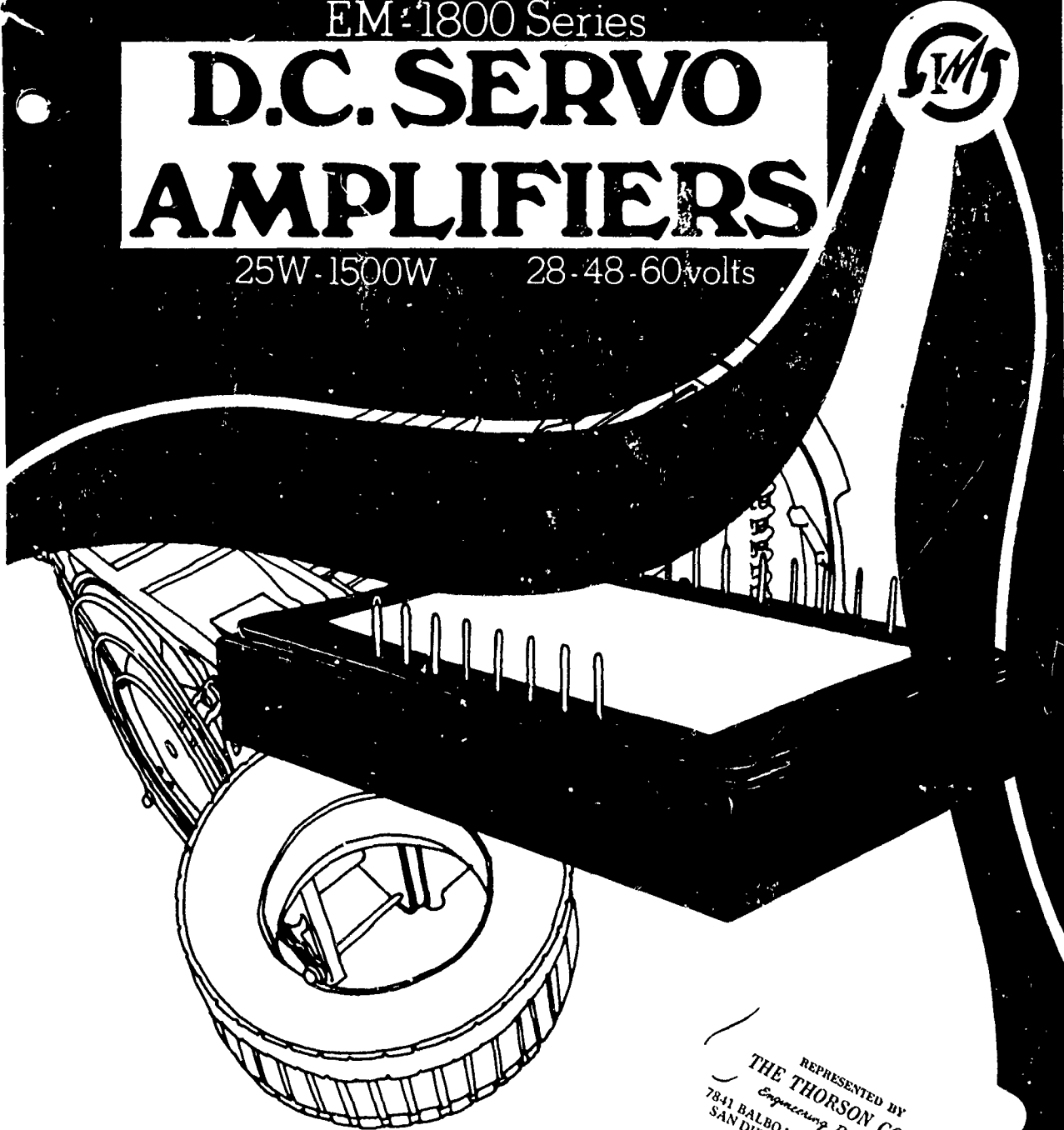
<u>PARAMETER</u>	<u>UNITS</u>	<u>VALUE</u>
Rated Voltage	Volts	28
Terminal Resistance	Ohms	9.301
Stall Current (I_S)	Amps	3.11
No Load Speed	Rad/Sec	199.91
Torque Sensitivity	Oz-In/Amp	18.837
Peak Torque @ I_S	Oz-In	56.64
Back E.M.F.	V/Rad/Sec	.135
Inductance	Millihenries	3.21
Friction Torque	Oz-In	1.28
Armature Inertia	Oz-In-Sec ²	.0015
Acceleration	Rad/Sec ²	37,760
Pot Resistance	Ohms	5171
Linearity	Percent	<.25

EM-1800 Series

D.C. SERVO AMPLIFIERS

25W-1500W

28-48-60volts



REPRESENTED BY
THE THORSON COMPANY
Engineering Representatives
7841 BALBOA AVENUE, SUITE 108
SAN DIEGO, CALIFORNIA 92111
(714) 292-8525

TTL logic-level inhibit

Specialty Products Division

- Single Power Supply (-15V bias supply not required for -B models).
- Aluminum Enclosure used for 25W Amplifier for Improved Heat Transfer.

- TTL Logic-Level inhibit gate for Computer Controlled Shutdown Applications.

- Dead Band in Current Amplifier Mode Reduced.
- Three Supply Voltage Families of Amplifiers for better Matching.

Description

The EM1800 Series Linear DC Servo amplifiers are designed to drive DC torque motors, other DC servo motors and low inertia motors. Versatility of application is made possible by user connections to program for either voltage amplifier or current amplifier operation. Adjustable gain and current limiting can be user programmed with external resistors. A TTL logic-level inhibit gate can also be provided as an option for computer controlled shutdown applications. The requirement for a low-power negative bias supply has been eliminated without changing form, fit, or function of the plug-in modular amplifiers. Special circuitry reduces deadband thereby minimizing crossover distortion. Power output capabilities of the plug-in amplifiers range from 25 to 300 watts. Amplifier assemblies using the plug-in amplifiers as drivers have power output capabilities of 400 to 1500 watts.

Connectors on the plug-in amplifiers are in the form of twenty .040 inch diameter gold-plated pins that protrude from the encapsulated module. Ease of application is made possible with the use of a mating socket (SO-1801) that fits all of the plug-in series amplifiers. The 25 watt amplifiers are encapsulated inside a black anodized aluminum shield. The 200 and 300 watt amplifiers have a surface ground aluminum platen on which is attached four NPN power transistors. This power bridge is driven by the basic 25 watt amplifier (see Figure 1) and the entire circuit is encap-

available made from a black anodized aluminum extrusion, with four drilled and tapped holes, and having a thermal resistance of approximately 1.2°C/W to fit the 200 and 300 watt amplifiers.

Higher power outputs can also be obtained by using the 25 watt amplifier module as a driver for an external H-type power bridge consisting of NPN silicon power transistors (see Figure 2). Amplifier assemblies using this technique are available for power outputs of 400 to 1500 watts complete with plug-in driver amplifier, socket, power transistors mounted to integral heat-sink, and forced air cooling where needed.

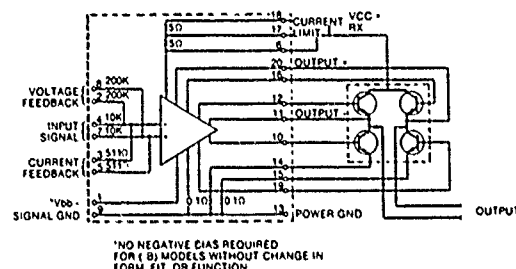


FIGURE 2

BLOCK DIAGRAM FOR EM1801, EM1806 & EM1817 WITH EXTERNAL BRIDGE

Operation

General

The input signal is applied to pins 4 and 7. Pin 7 is the offset adjust and is usually connected directly to pin 9 or through offset circuitry depending on whether the amplifier is connected for voltage or current operation. (See discussion under "Offset Adjustment"). Close-tolerance 10KΩ input resistors make up part of the total summing junction to a high gain differential amplifier. This input pre-amplifier generates differential output signals which drive an H-type power bridge. Special circuitry assures equal power dissipation in the bridge transistors under normal operating conditions where current output is below the set limit value. The bridge construction allows the use of a single-polarity high-voltage source and enables the output pins, 11 and 20, to switch polarity while the load floats above ground potential.

Single Power Supply

The -B designation identifies the amplifier model that does not require a -15V bias supply. The -A model should be selected for those applications where -15V bias supply is readily available. Both models have the same physical dimensions and are pin-for-pin interchangeable (Pin 1 has no-connection on the -B models).

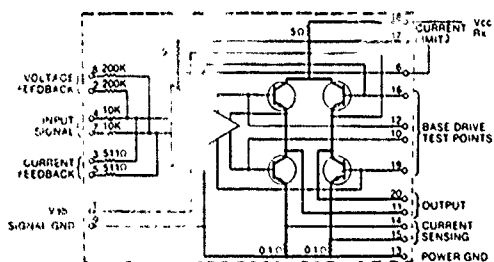


FIGURE 1

BLOCK DIAGRAM FOR EM1802, EM1803 & EM1818

sulated in a thermally-conductive epoxy.

Power dissipation capability of the amplifiers can be increased with the use of external heatsinks and/or forced air cooling. Most applications require the use of an external heatsink. The 200 and 300 watt amplifiers have a surface ground platen with four thru-holes to provide heatsink attachment. A heatsink (HS-1801) is

Supply Voltage Selection

Three amplifier families are available for operation with supply voltages of +28 Volt, +48 Volt, and +60 Volt. This expanded choice of supply voltages allows for better matching to minimize internal dissipation in the amplifier. MIL-STD-704 is applicable to the +28 Volt amplifiers.

Current Limit

An internal current-limit circuit senses and clamps the output current at 0.2 amperes. The value of the current-limit (I_{CL}) is adjustable to obtain higher currents by the use of an external current-limit resistor (R_x) which is connected between pins 17 and 18 with pin 17 jumpered to pin 6. The value of R_x is calculated by the formula:

$$R_x = \frac{2}{I_{CL} - 0.4} \quad \text{Eq. 1}$$

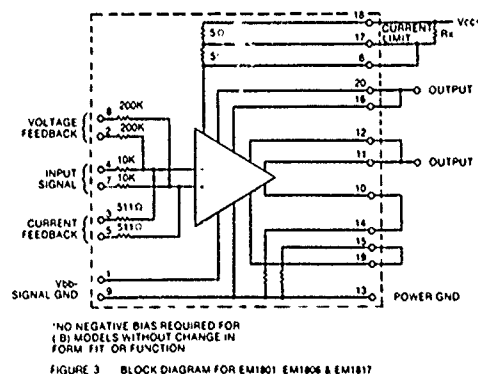
NOTE: The dissipation rating of R_x must be considered:

$$PD_{RX} = (I_{CL})^2 R_x \quad (\text{Double for safety margin}) \quad \text{Eq. 2}$$

Voltage Or Current Amplifier Operation

Voltage Amplifier

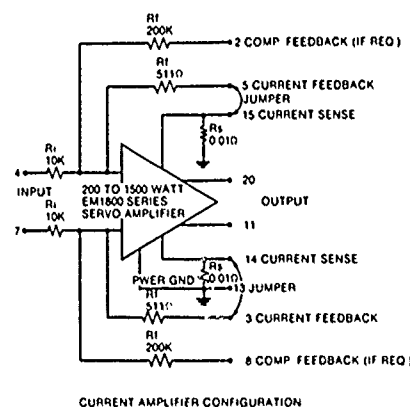
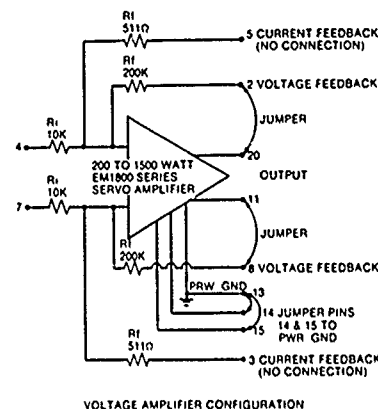
Programming for a voltage or a current amplifier becomes a simple matter of connecting the proper feedback to the input summing junctions. Whenever the 25 watt amplifier is used as a motor driver, it should be connected as shown in Figure 3 before the



feedback connections are applied. Otherwise, to achieve the voltage amplifier mode, jumper pin 20 to pin 2 and pin 11 to pin 8. In the voltage amplifier mode, pin 14 and pin 15 should be connected to power ground (pin 13) to avoid unnecessary power dissipation in the current sense resistors (see Figure 4). The voltage gain is factory set for 20V/V. Standard operational amplifier techniques can be used to change the gain within reasonable limits.

Current Amplifier

For the current amplifier mode, jumper pin 3 to pin 14 and pin 5 to pin 15 (see Figure 5). The current gain is factory set for the plug-in amplifiers at 0.5A/V. Standard operational amplifier feedback techniques can be used to change the gain within reasonable limits.

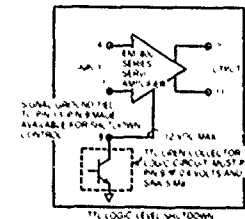
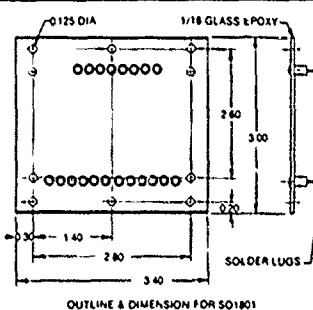
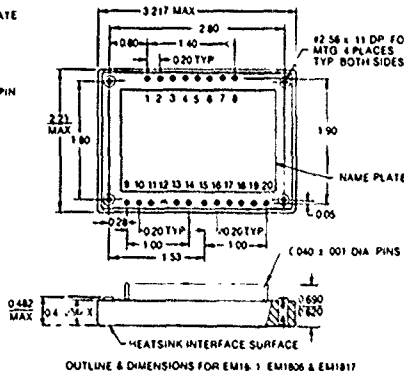
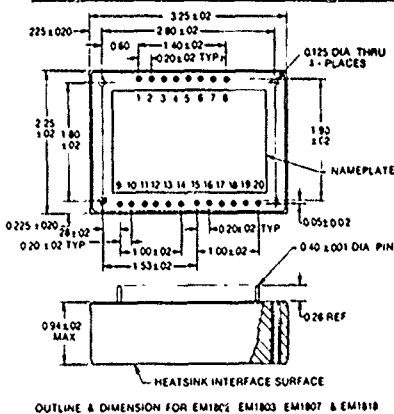
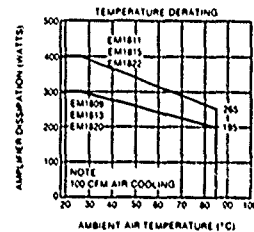
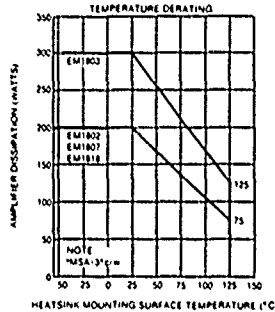
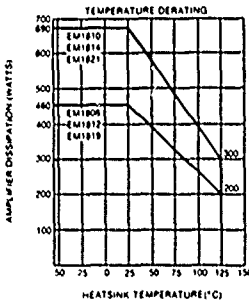
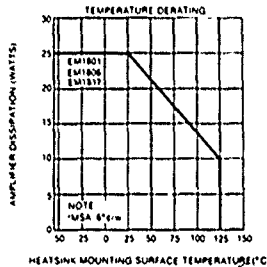
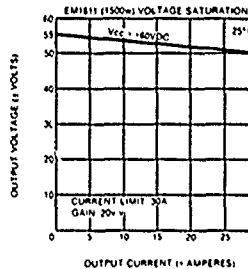
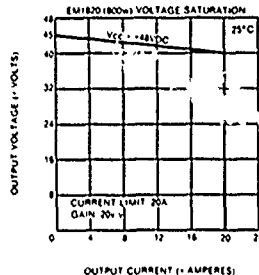
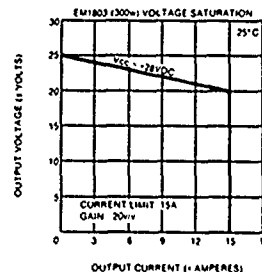
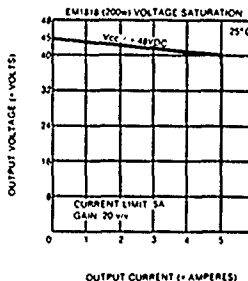
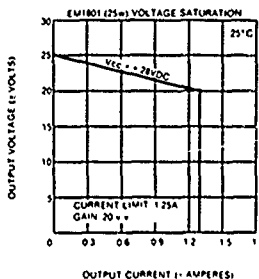
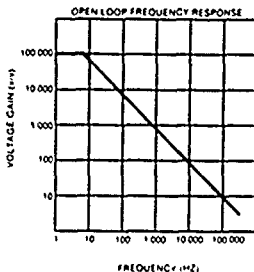


Operation in the current feedback mode with a reactive load can cause a phase shift between the output voltage and current. Because the feedback is a current related signal obtained across current sense resistors, the feedback will be phase shifted with respect to the input voltage. If enough shift occurs, the circuit may oscillate and compensation will be necessary. A series resistor-capacitor network connected in the voltage feedback circuit is one approach to compensation.

EM-1800 Series

25W-1500W

28-48-60volts

Specialty Products Division INLAND MOTOR

APPENDIX C TORQUE MOTOR MODEL DERIVATION FOR CURRENT AND VOLTAGE DRIVE

CURRENT DRIVE

The amplifier/motor control configuration for the current drive system is shown in figure C-1.

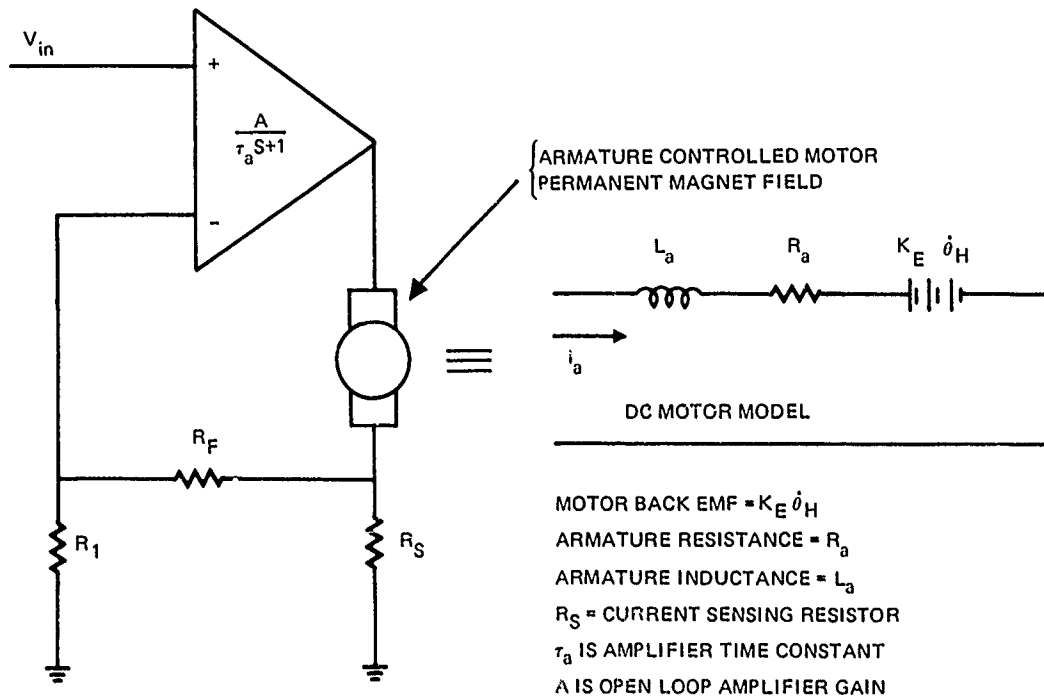


Figure C-1. Current drive amplifier/servo motor.

Figure C-2, the amplifier/motor configuration, shows the motor model incorporated into the diagram.

$$\text{Let } A' = \frac{A}{\tau_a s + 1}$$

then

$$V_2 = \frac{E_S R_F}{R_1 + R_F} = E_S b$$

where

$$b = \frac{R_F}{R_1 + R_F}$$

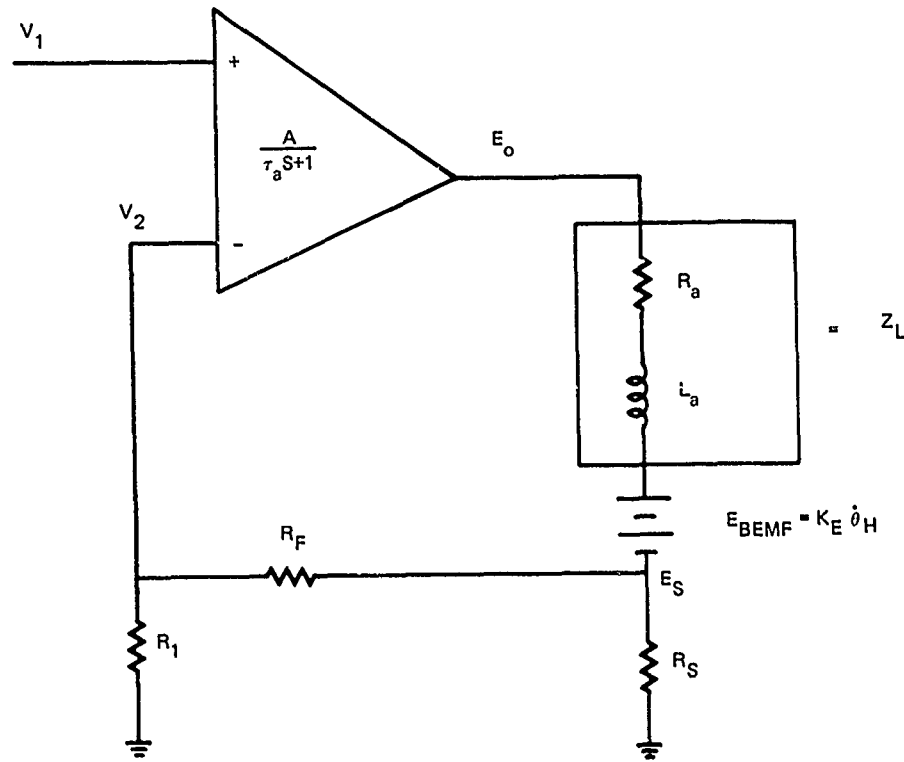


Figure C-2. Amplifier/motor diagram.

$$E_O = (V_1 - V_2) A'$$

$$\therefore V_2 = - \left(\frac{E_O}{A'} - V_1 \right) \quad (1)$$

$$I_L = \frac{E_O - E_{BEMF}}{Z_L} \text{ assuming } E_S \text{ is small}$$

$$E_S = I_L R_S$$

$$\therefore V_2 = \frac{(E_O - E_{BEMF}) b R_S}{Z_L} \quad (2)$$

Combining (1) and (2) and solving for E_O

$$- \frac{E_O}{A'} + V_1 = \left(\frac{E_O - E_{BEMF}}{Z_L} \right) b R_S$$

$$V_1 = \frac{E_O b R_S}{Z_L} - \frac{E_{BEMF} b R_S}{Z_L} + \frac{E_O}{A'}$$

$$V_1 = E_o \left(\frac{A R_s b + Z_L}{A' Z_L} \right) - \frac{E_{BEMF} R_s b}{Z_L}$$

$$E_o = \frac{V_1 + \frac{E_{BEMF} R_s b}{Z_L}}{\frac{A' R_s b + Z_L}{A Z_L}} \quad (3)$$

Also

$$E_o = I_L Z_L + E_{BEMF} \quad (4)$$

Now combine (3) and (4) and solve for I_L

$$I_L Z_L + E_{BEMF} = \frac{V_1 + \frac{E_{BEMF} R_s b}{Z_L}}{\frac{A' R_s b + Z_L}{A' Z_L}}$$

$$I_L Z_L = \frac{A' Z_L V_1 + E_{BEMF} A R_s b}{A' R_s b + Z_L} - E_{BEMF}$$

$$I_L Z_L = \frac{A' Z_L V_1 + E_{BEMF} A R_s b - E_{BEMF} A R_s b - E_{BEMF} Z_L}{A' R_s b + Z_L}$$

$$I_L Z_L = \frac{A' Z_L V_1 - E_{BEMF} Z_L}{A' R_s b + Z_L}$$

$$I_L = \frac{A' V_1 - E_{BEMF}}{A' R_s b + Z_L} \quad (5)$$

Now, replacing I_L by I_M

$$Z_L \text{ by } S L_a + R_a$$

and

$$E_{BEMF} \text{ by } K_E N \dot{\theta}_H$$

$$I_M = \frac{A' V_{in} - K_E N \dot{\theta}_H}{A' R_s b + S L_a + R_a} \quad (6)$$

$$\text{The load torque, } T_L, \text{ is given by } J_T S^2 \theta_H + D S \theta_A \quad (7)$$

where

$J_T = N^2 J_M + J_L$ is the total inertia and

N is the gear ratio

J_M is the motor inertia

J_L is the load inertia

D is the viscous damping

The desired torque is given by:

$$T_d = N K_T I_M \text{ where } K_T \text{ is the torque sensitivity constant} \quad (8)$$

Now we can equate the load torque (7) with the desired torque (8) to obtain an expression for the amplifier/motor/load transfer function θ_H/V_{in} .

$$N K_T I_M = J_T S^2 \theta_H + D S \theta_H$$

$$N K_T I_M = \dot{\theta}_H (J_T S + D)$$

Now substitute expression (6) for I_M

$$N K_T \left[\frac{A' V_{in} - K_E N \dot{\theta}_H}{A' R_s b + S L_a + R_a} \right] = \dot{\theta}_H (J_T S + D)$$

$$N K_T A' V_{in} - N^2 K_E K_T \dot{\theta}_H = \dot{\theta}_H (J_T S + D) (A' R_s b + S L_a + R_a)$$

$$N K_T A' V_{in} = \dot{\theta}_H \left[N^2 K_E K_T + J_T S A' R_s b + S^2 J_T L_a + S J_T R_a + D A' R_s b + S D L_a + D R_a \right]$$

$$\frac{\dot{\theta}_H}{V_{in}} = \frac{N K_T A'}{J_T L_a S^2 + (J_T A' R_s b + J_T R_a + D L_a) S + N^2 K_E K_T + D A' R_s b + D R_a}$$

or in another form

$$\frac{\dot{\theta}_H}{V_{in}} = \frac{N K_T A'}{(L_a S + R_a) (J_T S + D) + A' R_s b (J_T S + D) + N^2 K_E K_T} \quad (10)$$

Amplifier/Motor/Load Transfer Function

Substituting $\frac{A}{\tau_a S + 1}$ for A'

we get

$$\frac{\dot{\theta}_H}{V_{in}} = \frac{N K_T A}{(\tau_a S + 1) (L_a S + R_a) (J_T S + D) + A R_s b (J_T S + D) + N^2 K_E K_T (\tau_a S + 1)} \quad (11)$$

Thus the amplifier/motor/load block diagram is as follows:

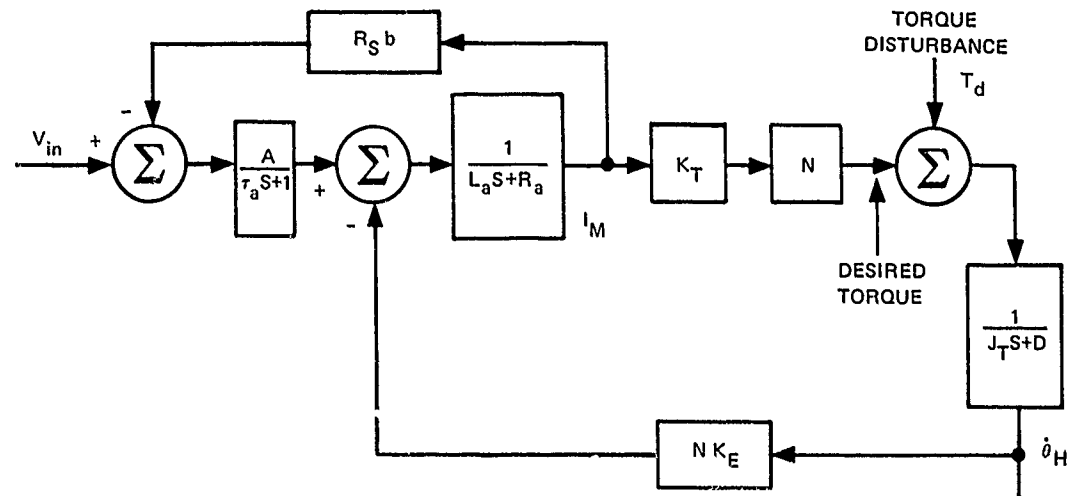


Figure C-3. Amplifier/motor/load block diagram for current drive servo control.

VOLTAGE DRIVE

The model for the DC armature controlled motor is shown in figure C-4.

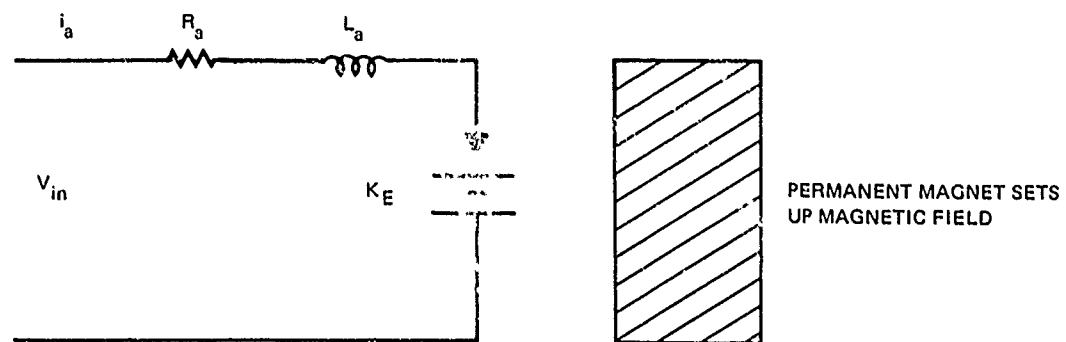


Figure C-4. DC armature controlled motor.

The voltage equation for the motor is

$$V = i_a R_a + \frac{di_a}{dt} L_a + K_E \dot{\theta}_M \quad (12)$$

Taking the LaPlace transform of each side of (12) we get

$$V(s) = I_a(s) R_a + S I_a(s) L_a + S K_E \theta_m(s) \quad (13)$$

The motor torque is

$$T_M = N K_T I_a \quad (14)$$

and the load torque is

$$T_L = J_T S^2 \theta_H(s) + D S \theta_H(s) \quad (15)$$

where

J_t is the total inertia

$$J_t = N^2 J_m + J_L \quad (16)$$

and

D is the total viscous damping

$$D = N^2 D_m + D_L \quad (17)$$

and

θ_H is the output shaft angle of the gear train (gimbal displacement)

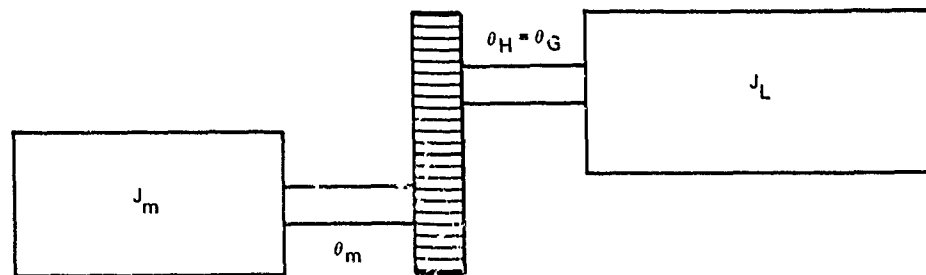


Figure C-5. Motor/load gear ratio diagram.

Substituting 14 into 13

$$V(s) = \frac{T_M R_a}{N K_T} + \frac{S T_M L_a}{N K_T} + S K_E N \theta_H \quad (18)$$

and equating motor torque to load torque (18) becomes

$$V(s) = \frac{s \theta_H}{N} \left[\left(\frac{J_T s + D}{K_T} \right) R_a + \left(\frac{J_T s^2 + D s}{K_T} \right) L_a + N^2 K_E \right] \quad (19)$$

from which the motor load transfer function is derived

$$\frac{\theta_H(s)}{V(s)} = \frac{N K_T}{s \left[J_t L_a s^2 + (J_t R_a + D L_a) s + D R_a + N^2 K_t K_E \right]} \quad (20)$$

or

$$\frac{\dot{\theta}_H}{V} = \frac{N K_T}{J_t L_a s^2 + (J_t R_a + D L_a) s + D R_a + N^2 K_t K_E} \quad (21)$$

The block diagram for the voltage drive servo control is shown in figure C-6.

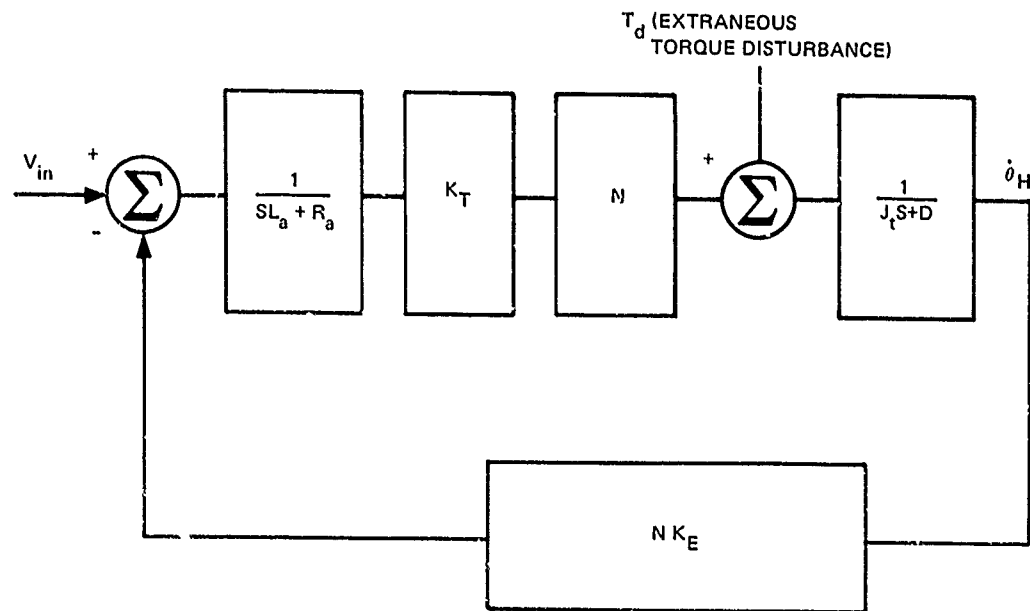


Figure C-6. Voltage drive servo control block diagram.

APPENDIX D LOAD INERTIA DERIVATION

This appendix deals with the mathematical derivation of the load inertia for both inner and outer gimbals. Figure D-1 shows the components that comprise the total load inertia. All of the components, excluding the hat, are exact calculations of inertia. The moment of inertia of the hat was an approximation due to its complex geometric shape. Ref 14 was used in the derivation of the following load inertias.

I. OUTER GIMBAL

The moment of inertia for the moving parts of the outer gimbal will be found by calculating the moments for each of the nine parts in figure 1, and adding them. The outer gimbal pivots about a line through the center of mass of the plate or through the axis of the bail ring. All moments will be referred to this line and then summed. The method of calculation for the moment of each part (I_z) will be to calculate the moment (I_{CM}) about the line through the center of mass of the part and parallel to the axis of rotation, then substitute this into the formula

$$I_z = I_{CM} + md^2, \quad (1)$$

12. Baumeister, Theodore, Editor, Mechanical Engineer's Handbook, McGraw-Hill Book Company, 1967.

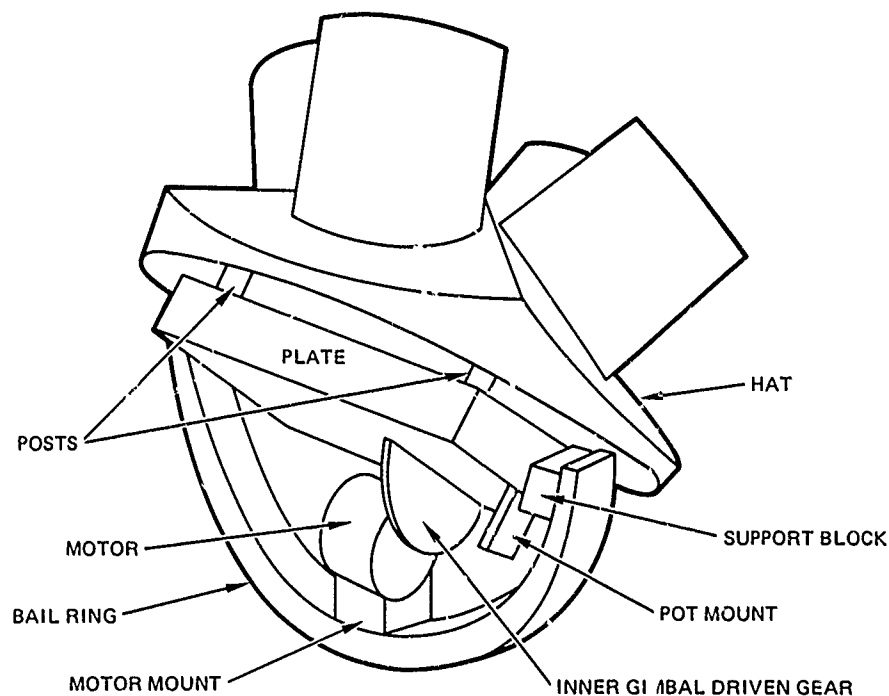


Figure D-1. LADSS platform moment of inertia.

where m is the mass of the part and d is the perpendicular distance from the center of mass of the part to the axis of rotation. Formulas for volumes, centroids and moments of inertia were found in CRC Standard Mathematical Tables 17th Edition. All parts are made of aluminum (density = 2700 Kg/m^3) except the inner gimbal driven gear which is brass (density = 8700 Kg/m^3). Note: all outer gimbal moments will be calculated for the zero position of the inner gimbal. The moment of inertia for the hat will not be calculated directly due to its complexity.

A. Plate

The center of mass of the plate lies on the axis of rotation, thus the following formula applies. $I_z = m/12 (a^2 + b^2)$. The dimensions of the plate are $.1524 \text{ m} \times .1524 \text{ m} \times .0254 \text{ m}$.

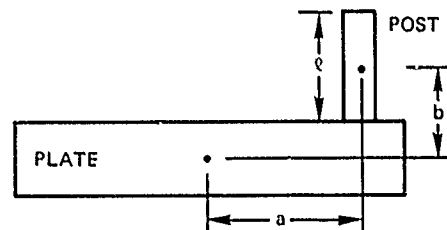
$$m = \rho V = (2700 \text{ Kg/m}^3) (.1524 \text{ m})^2 (.0254 \text{ m}) = \underline{1.592823 \text{ Kg}}$$

$$I_z = \frac{1.592823 \text{ Kg}}{12} [(.1524 \text{ m})^2 + (.0254 \text{ m})^2]$$

$$I_z = 3.16851 \times 10^{-3} \text{ Kg-m}^2$$

B. Posts

There are four cylindrical posts that hold the hat in place on the plate. The position of the posts is symmetric about the axis of rotation, therefore the total moment of inertia for all posts is four times the moment for one post.



Dimensions	$l = .04572 \text{ m}$
	$r = .00635 \text{ m}$
	$a = .0635 \text{ m}$
	$b = .03556 \text{ m}$

The moment of inertia about the center of mass (I_{CM}) is given by

$$m \left(\frac{r^2}{4} + \frac{l^2}{12} \right)$$

$$m = \rho V = \rho \pi r^2 l = (2700 \text{ Kg/m}^3) (\pi) (.00635 \text{ m})^2 (.04572 \text{ m})$$

$$m = .015637 \text{ Kg}$$

$$\text{Total mass for 4 posts} = .062548 \text{ Kg}$$

Then

$$I_{CM} = (.015637 \text{ Kg}) \left[\frac{(.00635 \text{ m})^2}{4} + \frac{(.04572 \text{ m})^2}{12} \right]$$

$$I_{CM} = 2.88158 \times 10^{-6} \text{ Kg-m}^2.$$

I_z for one post is given by $I_z = I_{CM} + md^2$, where $d = \sqrt{a^2 + b^2}$. Thus

$$I_z = (2.88158 \times 10^{-6} \text{ Kg-m}^2) + (.015637 \text{ Kg}) [(.0655 \text{ m})^2 + (.03556 \text{ m})^2]$$

$$I_z(\text{for one post}) = 8.57071 \times 10^{-5} \text{ Kg-m}^2.$$

For all four posts

$$I_z = 3.42828 \times 10^{-4} \text{ Kg-m}^2$$

C. Pot Mount

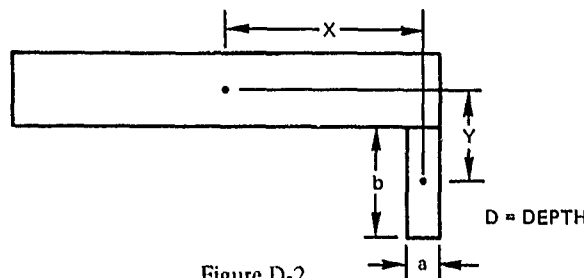


Figure D-2

$$a = .00508 \text{ m}$$

$$b = .0254 \text{ m}$$

$$x = .07366 \text{ m}$$

$$y = .0254 \text{ m}$$

$$D = .0381 \text{ m}$$

The moment of inertia about the center of mass is given by

$$I_{CM} = \frac{m}{12} (a^2 + b^2)$$

$$m = \rho V = \rho abD = (2700 \text{ Kg/m}^3) (.00508 \text{ m}) (.0254 \text{ m}) (.0381 \text{ m})$$

$$m = .0132735 \text{ Kg}$$

$$\therefore I_{CM} = \frac{(.0132735 \text{ Kg})}{12} [(.00508 \text{ m})^2 + (.0254 \text{ m})^2]$$

$$I_{CM} = 7.42174 \times 10^{-7} \text{ Kg-m}^2$$

Then I_z is given by $I_z = I_{CM} + md^2$ where $d = \sqrt{x^2 + y^2}$

$$I_z = (7.42174 \times 10^{-7} \text{ Kg-m}^2) + (.0132735 \text{ Kg}) [(.07366 \text{ m})^2 + (.0254 \text{ m})^2]$$

$$I_z = 8.1325 \times 10^{-5} \text{ Kg-m}^2$$

D. Support Block

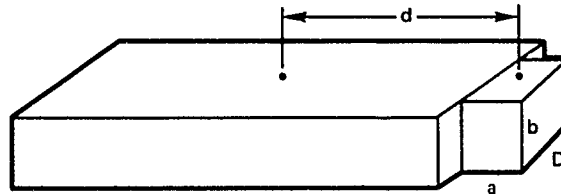


Figure D-3

$$a = .01778 \text{ m}$$

$$b = .0254 \text{ m}$$

$$D = .0254 \text{ m}$$

$$d = .08382 \text{ m}$$

$$m = \rho V = \rho abD = (2700 \text{ Kg/m}^3) (.01778 \text{ m}) (.0254 \text{ m})^2$$

$$m = 3.09716 \times 10^{-2} \text{ Kg}$$

$$I_{CM} = \frac{m}{12} (a^2 + b^2) = \frac{3.09716 \times 10^{-2} \text{ Kg}}{12} [(.01778 \text{ m})^2 + (.0254 \text{ m})^2]$$

$$I_{CM} = 2.48105 \times 10^{-6} \text{ Kg-m}^2$$

$$I_z = I_{CM} + md^2 = (2.48105 \times 10^{-6} \text{ Kg-m}^2) + (3.09716 \times 10^{-2} \text{ Kg}) (.08382 \text{ m})^2$$

$$I_z = 2.20081 \times 10^{-4} \text{ Kg-m}^2$$

E. Inner Gimbal Drive Gear

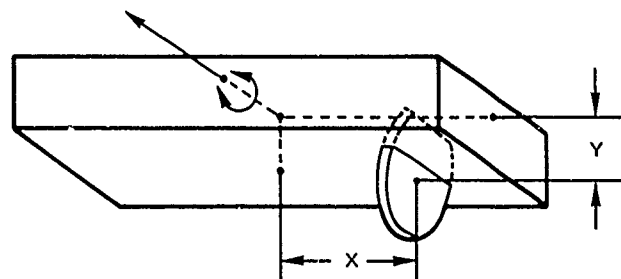


Figure D-4

This gear is half of a circular plate imbedded in the aluminum plate. The moment of inertia will be calculated for the full gear even though the slot was not allowed for in calculating the moment of the plate. The calculation will be as follows.

1. Calculate the mass, $m = \rho V$, using $\rho = 8700 \text{ Kg/m}^3$ for brass.
2. Calculate the moment of inertia about the diameter, I_d .
3. Find the location of the center of mass, $\bar{y}$ (perpendicular distance from diameter)
4. Find the moment of inertia about the line parallel to the diameter, through the center of mass, I_{CM} .
5. Calculate I_z using Eq 2.

Dimensions

$$r = .04953 \text{ m}$$

$$t = .00254 \text{ m (thickness)}$$

$$x = .03302 \text{ m}$$

$$1. \quad m = \rho V = \rho \cdot \frac{1}{2} \pi r^2 t$$

$$m = (8700 \text{ Kg/m}^3) \left(\frac{\pi}{2} \right) (.04953 \text{ m})^2 (.00254 \text{ m})$$

$$m = .085155 \text{ Kg}$$

2. Moment of inertia about diameter
element of mass is given by

$$\rho t r dr d\theta$$

Second moment of element about
diameter is given by

$$(\rho t r dr d\theta) (r \sin \theta)^2$$

Thus

$$I_d = \int_{\theta=0}^{\pi} \int_{r=0}^r \rho t r^3 \sin^2 \theta dr d\theta$$

$$I_d = \rho t \int_{\theta=0}^{\pi} \frac{r^4}{4} \sin^2 \theta d\theta$$

$$I_d = \frac{\rho t r^4}{4} \left[\frac{\pi}{2} - \frac{1}{4} \sin 2\pi - \left(0 - \frac{1}{4} \sin 0 \right) \right] = \frac{\rho t r^4}{4} \left(\frac{\pi}{2} \right)$$

$$I_d = \frac{\rho \pi t r^4}{8} = 5.22259 \times 10^{-5} \text{ Kg-m}^2$$

3. Distance of center of mass from diameter ($\bar{y}$) element of mass = $\rho t r dr d\theta$
First moment of element about diameter is given by $(\rho t r dr d\theta) (r \sin \theta)$

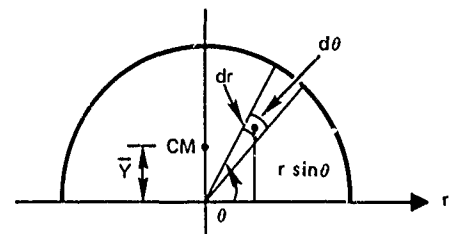


Figure D-5

Then

$$M_x = \int_{\theta=0}^{\pi} \int_{r=0}^r \rho t r^2 \sin \theta dr d\theta$$

$$M_x = \rho t \int_{\theta=0}^{\pi} \frac{r^3}{3} \sin \theta d\theta$$

$$M_x = \frac{\rho t r^3}{3} [-\cos \pi + \cos 0] = \frac{2\rho t r^3}{3}$$

Now,

$$\bar{y} = \frac{M_x}{m} = \frac{\frac{2\rho t r^3}{3}}{\frac{\rho \pi r^2 t}{2}} = \frac{4r}{3\pi}$$

$$\bar{y} = .021021 \text{ m}$$

4. To find the moment of inertia about the center of mass, I_{CM} use Eq. 2 with $I_z = I_d$, $d = \bar{y}$ and solve for I_{CM} .

$$I_d = I_{CM} + m\bar{y}^2 \Rightarrow I_{CM} = I_d - m\bar{y}^2$$

$$I_{CM} = (5.22259 \times 10^{-5} \text{ Kg-m}^2) - (.085155 \text{ Kg}) (.021021 \text{ m})^2$$

$$I_{CM} = 1.45974 \times 10^{-5} \text{ Kg-m}^2$$

5. Find I_z using Eq. 2 with $d = \sqrt{x^2 + \bar{y}^2}$

$$I_z = I_{CM} + m(x^2 + \bar{y}^2)$$

$$I_z = (1.45974 \times 10^{-5} \text{ Kg-m}^2) + (.085155 \text{ Kg}) [(.03302 \text{ m})^2 + (.021021 \text{ m})^2]$$

$$I_z = 1.45072 \times 10^{-4} \text{ Kg-m}^2$$

F. Inner Gimbal Motor

$$m = .2575 \text{ Kg (measured)}$$

$$r = .0254 \text{ m}$$

$$l = .0381 \text{ m}$$

$$d = .05842 \text{ m}$$

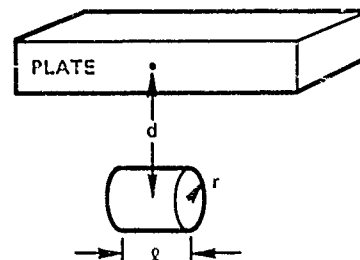


Figure D-6

$$I_{CM} = m \left(\frac{r^2}{4} + \frac{d^2}{12} \right) = (.2575 \text{ Kg}) \left[\frac{(.0254 \text{ m})^2}{4} + \frac{(.0381 \text{ m})^2}{12} \right]$$

$$I_{CM} = 7.26813 \times 10^{-5} \text{ Kg-m}^2$$

Then

$$I_z = I_{CM} + md^2 = (7.26813 \times 10^{-5} \text{ Kg-m}^2) + (.2575 \text{ Kg}) (.05842 \text{ m})^2$$

$$I_z = 9.515 \times 10^{-4} \text{ Kg-m}^2$$

G. Motor Mount

$$a = .02032 \text{ m}$$

$$b = .0381 \text{ m}$$

$$c = .0381 \text{ m}$$

$$d = .085 \text{ m}$$

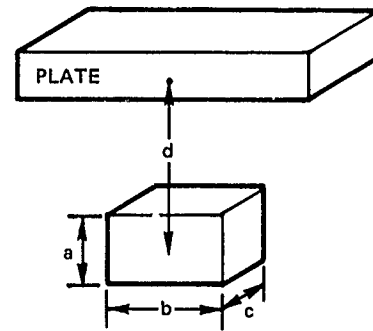


Figure D-7

$$m = \rho V = \rho abc = (2700 \text{ Kg/m}^3) (.02032 \text{ m}) (.0381 \text{ m}) (.0381 \text{ m})$$

$$m = .079641 \text{ Kg}$$

$$I_{CM} = \frac{m}{12} (a^2 + b^2) = \frac{.079641 \text{ Kg}}{12} \left[(.02032 \text{ m})^2 + (.0381 \text{ m})^2 \right]$$

$$I_{CM} = 1.23743 \times 10^{-5} \text{ Kg-m}^2$$

$$I_z = I_{CM} + md^2 = (1.23743 \times 10^{-5} \text{ Kg-m}^2) + (.079641 \text{ Kg}) (.085 \text{ m})^2$$

$$I_z = 5.87781 \times 10^{-4} \text{ Kg-m}^2$$

H. Bail Ring

$$r_1 = .09525 \text{ m}$$

$$r_2 = .106363 \text{ m}$$

$$h = .03683 \text{ m}$$

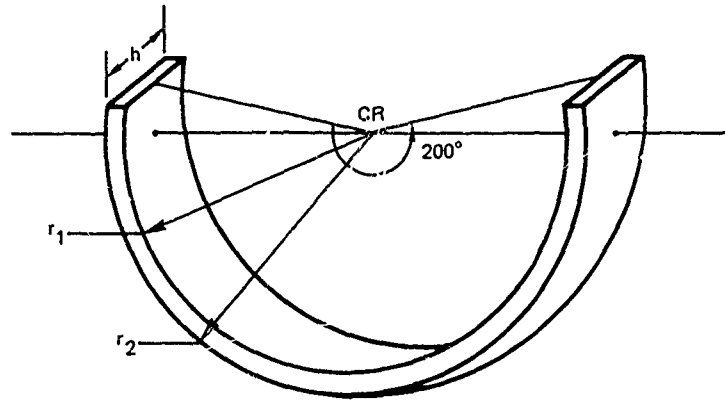


Figure D-8

$$m = \rho V = \rho \frac{200}{360} (\pi r_2^2 h - \pi r_1^2 h) = (\rho \pi h) \left(\frac{200}{360} \right) (r_2^2 - r_1^2)$$

$$m = (2700 \text{ Kg/m}^3) (\pi) (.03683 \text{ m}) \left(\frac{200}{360} \right) [(.106363 \text{ m})^2 + (.09525 \text{ m})^2]$$

$$m = .388859 \text{ Kg}$$

$$I_z = \frac{m}{2} (r_2^2 - r_1^2) = \frac{.388859 \text{ Kg}}{2} [(.106363 \text{ m})^2 + (.09525 \text{ m})^2]$$

$$I_z = 3.96358 \times 10^{-3} \text{ Kg-m}^2$$

I. HAT

The moment of inertia of the hat assembly will be approximated by a segment of a spherical shell. The dimensions of the shell were chosen such that, if it were made of aluminum, the mass would coincide with the measured mass, 1.06 Kg. Also the dimensions were chosen so that the center of mass of the shell is located at the estimated center of mass of the hat assembly. A cross section of the shell model is shown in figure D-9, with dimensions.

$$r_1 = .132801 \text{ m}$$

$$r_2 = .137595 \text{ m}$$

$$h_1 = .09398 \text{ m}$$

$$h_2 = .098774 \text{ m}$$

$$c_1 = .254 \text{ m}$$

$$c_2 = .26401 \text{ m}$$

$$\alpha = 2.558909 \text{ rad}$$

$$s = .038821 \text{ m}$$

$$C_M = \text{center of mass}$$

$$C_R = \text{center of rotation}$$

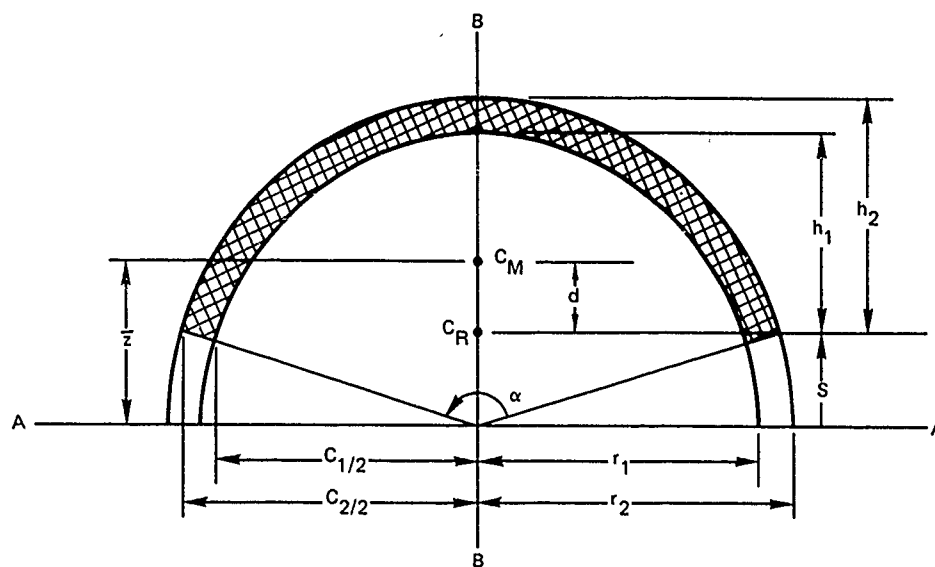


Figure D-9. Model of Hat assembly.

The following formulae were used in calculating some of the dimensions.

$$s = r_1 - h_1$$

$$\alpha = \sin^{-1} \frac{c_1}{2r_1} + \sin^{-1} \frac{c_2}{2r_2}$$

$$c = \sqrt{4h(2r - h)}$$

To find the moment of inertia of the shell, I_s , the following procedure will be used. First an expression for the mass will be found. Then the center of mass will be located using the expression $\bar{z} = M_p/m$ where M_p is the first moment about the plane A-A in figure D-9. Next the moment of inertia about the center of mass, I_{CM} , will be calculated and finally the moment of inertia about the center of rotation, I_{CR} , using Eq. 1.

A. The mass of the shell is given by ρV where $\rho = 2700 \text{ Kg/m}^3$ (the density of aluminum) and V is the volume. Using spherical coordinates, an element of mass is given by

$$\rho r^2 \sin \phi \, dr \, d\theta \, d\phi.$$

Thus the mass is given by

$$m = \rho \int_{\phi=0}^{\alpha/2} \int_{\theta=0}^{2\pi} \int_{r=r_1}^{r_2} r^2 \sin \phi \, dr \, d\theta \, d\phi$$

$$m = \frac{2\pi}{3} (r_2^3 - r_1^3) (1 - \cos \alpha/2)$$

Using the dimensions in figure 9, $m = 1.06 \text{ Kg}$.

B. Due to symmetry the center of mass lies on the line B-B in figure D-9. Thus the distance $\bar{z}$ must be calculated. To find $\bar{z}$, the first moment about the polar plane, M_p , must be calculated. Again, an element of mass is given by

$$\rho r^2 \sin \phi \, dr d\theta d\phi$$

and its distance from the polar plane is given by

$$r \cos \phi.$$

Thus

$$M_p = \int_{\phi=0}^{\alpha/2} \int_{\theta=0}^{2\pi} \int_{r=r_1}^{r_2} \rho r^3 \sin \phi \cos \phi \, dr d\theta d\phi$$

$$M_p = \frac{\pi \rho}{4} (r_2^4 - r_1^4) \sin^2 \left(\frac{\alpha}{2} \right)$$

Then

$$\bar{z} = \frac{M_p}{m} = \frac{3}{8} \frac{(r_2^4 - r_1^4)}{(r_2^3 - r_1^3)} \left(1 - \cos \frac{\alpha}{2} \right)$$

Substitution yields

$$\bar{z} = .087034 \, \text{m}$$

C. The moment of inertia about the line through the center of mass, perpendicular to line B-B, is found by summing the second moments of the mass elements. That is, the mass element times the distance from the line (x) squared. The mass element is as before and the distance squared is given by

$$x^2 = r^2 \sin^2 \phi + (r \cos \phi - \bar{z})^2$$

Thus the moment of inertia about the CM line is given by

$$I_{CM} = \int_{\phi=0}^{\alpha/2} \int_{\theta=0}^{2\pi} \int_{r=r_1}^{r_2} \rho r^2 \sin \phi [r^2 \sin^2 \phi + (r \cos \phi - \bar{z})^2] \, dr d\theta d\phi$$

$$I_{CM} = 3m \left[\frac{1}{5} \left(\frac{r_2^5 - r_1^5}{r_2^3 - r_1^3} \right) - \frac{\bar{z}}{4} \left(\frac{r_2^4 - r_1^4}{r_2^3 - r_1^3} \right) \left(1 + \cos \frac{\alpha}{2} \right) + \frac{\bar{z}^2}{3} \right]$$

$$I_{CM} = 1.13559 \times 10^{-2} \, \text{Kg-m}^2$$

D. The total moment of inertia about the axis of rotation can now be found using Eq. 1 with $d = \bar{z} - s$.

$$I_{CR} = I_{CM} + m(\bar{z} - s)^2$$

$$I_{CR} = 1.381986 \times 10^{-2} \text{ Kg-m}^2.$$

II. INNER GIMBAL

The elements that make up the inner gimbal inertia are the plate, posts, pot mount, inner gimbal drive gear and the hat (see figure D-1). Again, the moment of inertia of the hat will not be computed directly. The moments of the plate and posts need not be recomputed due to symmetry.

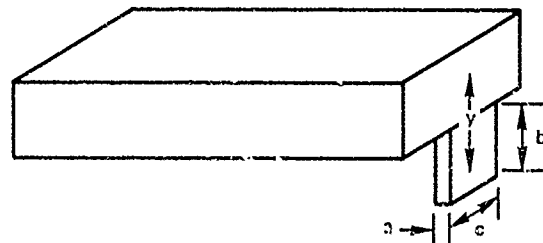
J. Pot Mount

$$a = .00508 \text{ m}$$

$$b = .0254 \text{ m}$$

$$c = .0381 \text{ m}$$

$$y = .0254 \text{ m}$$



The moment of inertia about the center of mass (I_{CM}) is given by:

$$I_{CM} = m \left(\frac{b^2 + c^2}{12} \right)$$

$$m = .0132735 \text{ Kg} \quad (\text{from section I.C. pg D-3})$$

$$\therefore I_{CM} = (.0132735 \text{ Kg}) \left(\frac{(.0254 \text{ m})^2 + (.0381 \text{ m})^2}{12} \right) = 7.42174 \times 10^{-7} \text{ Kg-m}^2$$

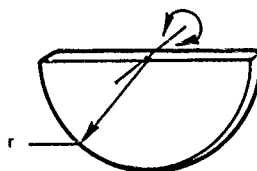
Then

$$I_z = I_{CM} + my^2$$

$$I_z = 7.42174 \times 10^{-7} \text{ Kg-m}^2 + (.0132735 \text{ Kg}) (.0254 \text{ m})^2$$

$$I_z = 1.088323 \times 10^{-5} \text{ Kg-m}^2$$

K. Gear Drive



Since the center of rotation passes through the center of the diameter of the semi-circle, the moment of inertia is given by:

$$I_z = m \frac{r^2}{2}$$

$$m = .085155 \text{ Kg} \quad (\text{from section I.E.1. pg D-5})$$

$$r = .04953 \text{ m}$$

$$\therefore I_z = (.085155 \text{ Kg}) \left[\frac{(.04953 \text{ m})^2}{2} \right]$$

$$I_z = 1.04452 \times 10^{-4} \text{ Kg-m}^2$$

III. TOTAL MOMENT OF INERTIA

I. Summary for Outer Gimbal

	Part	Mass (Kg)	Inertia (Kg-m ²)	Inertia oz-in-sec ²
A.	Plate	1.592823	3.16851×10^{-3}	.448661
B.	Posts	.062548	3.42828×10^{-4}	.048544
C.	Pot Mount	.0132735	8.1325×10^{-5}	.011516
D.	Support Blk	.0309716	2.20081×10^{-4}	.031163
E.	Gear	.085155	1.45072×10^{-4}	.020542
F.	Motor	.2575	9.515×10^{-4}	.134732
G.	Mount	.079641	5.87781×10^{-4}	.08323
H.	Bail Ring	.388859	3.96358×10^{-3}	.561243
I.	HAT	1.06	1.381986×10^{-2}	1.96037
	Total	3.57077	2.328054×10^{-2}	3.30

C. Summary for Inner Gimbal

	Part	Mass (Kg)	Inertia (Kg-m ²)	Inertia (oz-in-sec ²)
A.	Plate	1.592823	3.16851×10^{-3}	.448661
B.	Posts	.062548	3.42828×10^{-4}	.048544
J.	Pot Mount	.0132735	1.088323×10^{-5}	.0015411
K.	Gear	.085155	1.04452×10^{-4}	.0147904
I.	HAT	1.06	1.381986×10^{-2}	1.96037
	Total	2.8128	1.744653×10^{-2}	2.47

APPENDIX E

TIME-DOMAIN ANALYSIS OF AMPLIFIER/MOTOR/LOAD

This appendix derives the equations used for time-domain analysis of the servo drive system. The analysis was structured such that both the current drive and voltage drive systems could be evaluated with only changes to the input data for both versions of the time-domain computer programs (LaPlace Transform and Time Integration versions).

Figure E-2 presents comparative data between the two types of gimbal drive systems (current vs voltage) for both the inner and outer gimbals. The gimbal rate as a function of time is plotted for the comparative data. It is quite obvious from the curves that the current drive system is superior in response to that of the voltage drive system.

Two types of time-domain analysis were conducted to obtain the time-domain response data. The inverse LaPlace transform method, which is explained in detail in this section, was used to generate the comparative data for gear ratio optimization. The inverse LaPlace transform technique was very useful in obtaining the large amounts of data needed for the gear ratio optimization. Figures E-4 and E-5 illustrate the effects on the gimbal rate as a function of drive shaft gear ratio. It is quite obvious that a direct drive system is quite sluggish. As the gear ratio increases so does the gimbal response time — up to a point. As the gear ratio increases beyond some optimum value, the response starts to slow down. Figures E-6 and E-7 summarize the gear ratio optimization for the inner and outer gimbal system. The point to be noted about the inverse LaPlace transform technique is that it requires very little computer time to generate a large amount of time-domain data; thereby, being an economic means of generating this kind of data. The inverse LaPlace transform technique does not take into account the system nonlinearities. Therefore, a time integration program was written to incorporate the nonlinearities (limiters) that are shown in the diagram of figure E-1. The data presented in figures E-2 and E-3 was generated with the time integration computer program. Ref. 13 was used for the LaPlace transform analysis formulae.

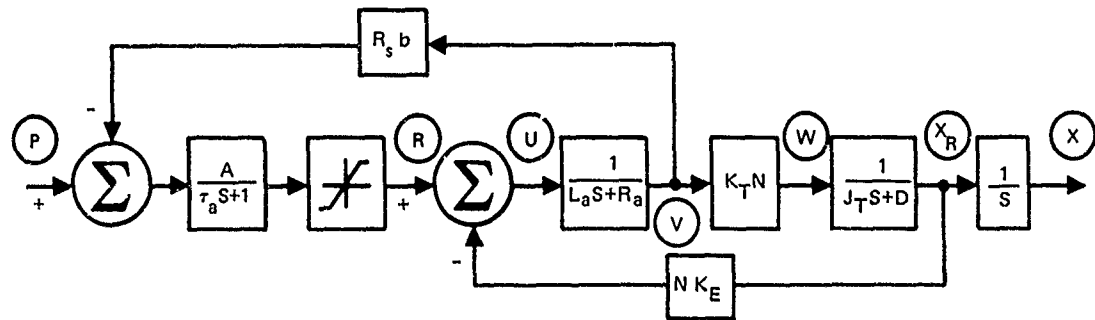
Following is a derivation of the LaPlace transform methodology for generating time domain analysis for both the current and voltage servo drive systems.

13. Levy, EC, A New Table of LaPlace Transformation Pairs, The Book Page Company, Los Angeles, CA, 1963.

LAPLACE TRANSFORM TIME-DOMAIN ANALYSIS

I. BLOCK DIAGRAMS

CURRENT DRIVE VERSION



VOLTAGE DRIVE VERSION

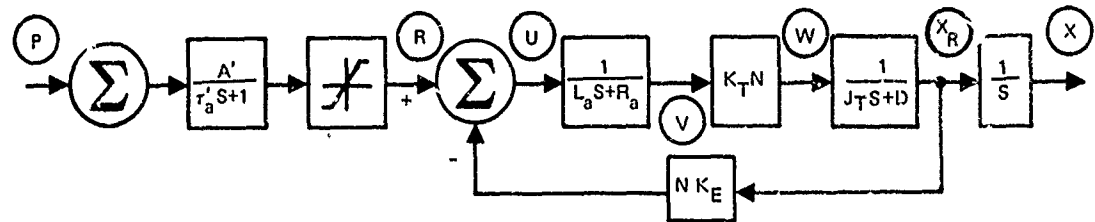


Figure E-1. Current and voltage block diagrams.

II. TRANSFER FUNCTIONS

a. Current drive version (rate output)

$$\frac{X_R}{P} = \frac{A K_T N}{(J_T S + D)(\tau_a S + 1)(L_a S + R_a) + A \cdot R_s b (J_T S + D) + N^2 K_E K_T (\tau_a S + 1)}$$

or

$$\frac{X_R}{P} = \frac{A K_T N / L_a J_T \tau_a}{S^3 + \left(\frac{L_a \tau_a' D + J_T L_a + J_T \tau_a R_a}{L_a J_T \tau_a'} \right) S^2 + \left(\frac{D L_a + \tau_a D R_a + J_T R_a + A R_s b J_T + N^2 K_E K_T \tau_a}{L_a J_T \tau_a'} \right) S + \left(\frac{R_a D + A R_s b D + N^2 K_E K_T}{L_a J_T \tau_a} \right)} \quad (1)$$

b. Voltage drive version (rate output)

$$\frac{X_R}{P} = \frac{A' K_T N}{(J_T S + D) (\tau'_a S + 1) (L_a S + R_a) + N^2 K_E K_T (\tau'_a S + 1)}$$

or

$$\begin{aligned} \frac{X_R}{P} = & \frac{A' K_T N / L_a J_T \tau'_a}{S^3 + \left(\frac{L_a \tau'_a D + J_T L_a + J_T \tau'_a R_a}{L_a J_T \tau'_a} \right) S^2 + \left(\frac{D L_a + \tau'_a D R_a + J_T R_a + N^2 K_E K_T \tau'_a}{L_a J_T \tau'_a} \right) S} \\ & + \left(\frac{R_a D + N^2 K_E K_T}{L_a J_T \tau'_a} \right) \end{aligned} \quad (2)$$

III. DESCRIPTION OF GAINS AND TIME CONSTANTS

A -- Amplifier gain (v/v)

τ_a -- Amplifier time constant (sec.)

L_a -- Motor inductance (henries)

R_a -- Armature resistance (ohms)

R_{sb} -- Current feedback sensing resistor (ohms)

K_T -- Torque sensitivity (oz-in/amp)

N -- Gear ratio (gimbal-to-motor)

J_T -- Total inertia. This is given by $J_T = N^2 J_M + J_L$ where J_M is the motor inertia and J_L is the load inertia

D -- Friction (oz-in-sec) (viscous friction)

K_E -- Back EMF (v/rad/sec)

A' -- Amplifier gain for voltage driven motor.

Referring to the properties of an inverting op amp

$$A' = \frac{1 - \beta}{\beta} \text{ where } \beta = \frac{R_1}{R_1 + R_f}$$

and R_1 is the input resistor, R_f is the feedback resistor. Choosing nominal values of $R_1 = 5K$ and $R_f = 20K$ yields a β of .2 and $A' = 4.0$.

τ'_a -- Time constant for voltage driven motor. Again referring to properties of inverting op amps

$$\tau'_a = \frac{\tau_a}{1 + \beta A}$$

Note that, with the appropriate calculation of A' and τ'_a the voltage drive transfer function is the same as the current drive with $R_s b = 0.0$.

IV. METHOD OF OBTAINING TIME RESPONSE

A hand check of the poles of equations (1) and (2), using preliminary gains and time constants, showed that the roots could get quite large (negatively). This fact eliminates numerical integration as an efficient cost effective method of calculating the time response, due to the extremely small integration interval needed to show the effects of the large roots. Thus, the LaPlace transform method was chosen.

Both the current drive (1) and voltage drive (2) transfer functions contain cubic functions of S in the denominator (for the rate output). To obtain the position output, (1) and (2) must be multiplied by $1/S$. Finally, to obtain the response to a unit step input, (1) and (2) must again be multiplied by $1/S$.

Therefore, we have two basic forms for the denominator: a cubic multiplied by S for rate output with unit step input and a cubic multiplied by S^2 for position output with unit step input. In order to comply with standard forms of LaPlace transform pairs, we must divide these forms into two cases. Case 1 occurs when the cubic equation has three real roots and Case 2 when there are one real root and two conjugate complex roots.

V. LAPLACE TRANSFORM PAIRS

a. Three real root case

1. Rate output

$$\left\{ \begin{array}{l} F(s) = \frac{1}{S(1+T_1 S)(1+T_2 S)(1+T_3 S)} \\ f(t) = 1 - \frac{T_1^2}{(T_1-T_2)(T_1-T_3)} e^{-t/T_1} - \frac{T_2^2}{(T_2-T_1)(T_2-T_3)} e^{-t/T_2} \end{array} \right. \quad (3)$$

$$- \frac{T_3^2}{(T_3-T_1)(T_3-T_2)} e^{-t/T_3} \quad (4)$$

2. Position output

$$\left\{ \begin{array}{l} F(s) = \frac{1}{S^2(1+T_1 S)(1+T_2 S)(1+T_3 S)} \\ f(t) = t - (T_1 + T_2 + T_3) - \frac{1}{(T_1-T_2)(T_2-T_3)(T_3-T_1)} \left[T_1^3(T_2 \right. \end{array} \right. \quad (5)$$

$$- T_3) e^{-t/T_1} + T_2^3(T_3 - T_1) e^{-t/T_2} + T_3^3(T_1 - T_2) e^{-t/T_3} \left. \right] \quad (6)$$

b. One real, two complex root case

1. Rate output

$$F(s) = \frac{1}{S(1+TS) \left(1 + \frac{2\xi}{\omega} S + \frac{1}{\omega^2} S^2\right)} \quad (7)$$

$$f(t) = 1 - \frac{T^2 \omega^2}{1 - 2T\xi\omega + T^2 \omega^2} e^{-t/T} + \frac{\sin(\omega \sqrt{1-\xi^2} t - \psi_R)}{\sqrt{1-\xi^2} (1 - 2T\xi\omega + T^2 \omega^2)^{1/2}} e^{-\xi\omega t} \quad (8)$$

where

$$\psi_R = \tan^{-1} \left(\frac{\sqrt{1-\xi^2}}{-\xi} \right) + \tan^{-1} \left(\frac{T\omega \sqrt{1-\xi^2}}{1 - T\xi\omega} \right)$$

2. Position output

$$F(s) = \frac{1}{S^2(1+TS) \left(1 + \frac{2\xi}{\omega} S + \frac{1}{\omega^2} S^2\right)} \quad (9)$$

$$f(t) = t - T - \frac{2\xi}{\omega} + \frac{T^3 \omega^2}{1 - 2T\xi\omega + T^2 \omega^2} e^{-t/T} + \frac{\sin(\omega \sqrt{1-\xi^2} t - \psi_p)}{\omega [(1-\xi^2)(1 - 2T\xi\omega + T^2 \omega^2)]^{1/2}} e^{-\xi\omega t} \quad (10)$$

where

$$\psi_p = 2 \tan^{-1} \frac{\sqrt{1-\xi^2}}{-\xi} + \tan^{-1} \frac{T\omega \sqrt{1-\xi^2}}{1 - T\xi\omega}$$

c. Note that, in all cases, $f(t) = \mathcal{L}^{-1}(F(s))$. Also, the cubic equations in (1) and (2) must be put into the form of the appropriate $F(s)$ in order to evaluate the inverse Laplace transform. Gain terms (numerator) in (1) and (2) multiply $f(t)$ since the Laplace transform is linear.

VI. FINDING THE ROOTS OF THE CUBIC

Any calculation, involving real numbers, done on a digital computer results in an approximation to the desired result due to truncation. Due to the large numbers encountered in the transfer functions under consideration, this approximation was not a good one. This was caused by addition and subtraction of very large numbers that had their first few significant digits in common.

Since the closed form solution of the cubic did not yield satisfactory results, a check was made using Newton's method. It was found that this method converged rapidly and yielded a better approximation to the actual roots.

A subroutine was written to find the roots of a cubic polynomial using Newton's method. The algorithm used can be found in "Elementary Numerical Analysis: an Algorithmic Approach" by Conte and de Boor, McGraw-Hill, 1972, pg 69. Essentially the algorithm uses Newton's method to find one real root of the cubic, where successive values of the polynomial and its derivative are calculated using nested multiplication. This method yields the coefficients of the quotient quadratic which can be solved to find the other two roots. Whether these roots are real or complex is indicated by a flag.

VII. TRANSFORMING THE TRANSFER FUNCTIONS INTO THE FORM USED IN THE LAPLACE TRANSFORM PAIRS

a. The transfer functions for both the current and voltage drive versions are of the form

$$F(s) = \frac{G'}{s^3 + p s^2 + q s + r},$$

where G' is the gain term $A K_T N / L_a \tau_a J_T$ or $A' K_T N / L_a \tau_a' J_T$. These must be put into the form used in the LaPlace transform pairs. Two cases are necessary depending on whether there are three real roots, or one real, two complex.

b. Three real root case

The transfer function

$$F(s) = \frac{G'}{s^3 + p s^2 + q s + r}$$

where

$$G' = \frac{A K_T N}{L_a \tau_a J_T} \text{ or } \frac{A' K_T N}{L_a \tau_a' J_T}$$

must be changed to the form

$$F(s) = \frac{G}{(1 + T_1 s)(1 + T_2 s)(1 + T_3 s)}.$$

Let R_1 , R_2 and R_3 be the real roots of the denominator. Then we can write

$$F(s) = \frac{G'}{(s - R_1)(s - R_2)(s - R_3)}.$$

$$F(s) = \frac{G'}{-R_1 R_2 R_3 (1 + s/-R_1)(1 + s/-R_2)(1 + s/-R_3)}$$

Let $T_1 = -\frac{1}{R_1}$, $T_2 = -\frac{1}{R_2}$ and $T_3 = -\frac{1}{R_3}$.

Then

$$F(s) = \frac{G' T_1 T_2 T_3}{(1 + T_1 S)(1 + T_2 S)(1 + T_3 S)}.$$

and we have

$$F(s) = \frac{G}{(1 + T_1 S)(1 + T_2 S)(1 + T_3 S)}$$

where

$$G = \frac{A K_T N \cdot T_1 T_2 T_3}{L_a \tau_a J_T} \quad \text{or} \quad \frac{A' K_T N T_1 T_2 T_3}{L_a \tau_a' J_T}$$

$$T_1 = -\frac{1}{R_1}$$

$$T_2 = -\frac{1}{R_2}$$

$$T_3 = -\frac{1}{R_3}$$

Now equation (4) can be used to ascertain the rate output time response, and equation (6) for the position output time response.

c. One real, two complex root case

The transfer function

$$F(s) = \frac{G'}{S^3 + pS^2 + qS + r}$$

where

$$G' = \frac{A K_T N}{L_a \tau_a J_T} \quad \text{or} \quad \frac{A' K_T N}{L_a \tau_a' J_T}$$

must be changed to the form

$$F(s) = \frac{G}{(1 + TS) \left(1 + \frac{2\xi}{\omega} S + \frac{1}{\omega^2} S^2 \right)}.$$

Let R and $\alpha \pm \beta i$ be the roots of the denominator. Then we can write

$$F(s) = \frac{G'}{(S - R) [S - (\alpha + \beta i)] [S - (\alpha - \beta i)]}$$

Let $T = -\frac{1}{R}$, then

$$F(s) = \frac{G' T}{(1 + TS) [S^2 - 2\alpha S + (\alpha^2 + \beta^2)]}$$

$$F(s) = \frac{G' T}{(1 + TS) (\alpha^2 + \beta^2) \left(1 - \frac{2\alpha}{\alpha^2 + \beta^2} S + \frac{1}{\alpha^2 + \beta^2} S^2 \right)}$$

Let $\omega^2 = \alpha^2 + \beta^2$, $\zeta = -\frac{\alpha}{\omega}$ and $G = G' T / \omega^2$.

Then

$$F(s) = \frac{G}{(1 + TS) \left(1 + \frac{2\zeta}{\omega} S + \frac{1}{\omega^2} S^2 \right)}$$

where

$$T = -\frac{1}{R}$$

$$\omega^2 = \alpha^2 + \beta^2$$

$$\zeta = -\frac{\alpha}{\omega}$$

$$G = \frac{A K_T N T}{L_a J_T \tau_a \omega^2} \text{ or } \frac{A' K_T N T}{L_a J_T \tau_a' \omega^2}$$

VIII. ALGORITHM FOR COMPUTING TIME RESPONSE OF AMPLIFIER/MOTOR/LOAD

- a. 1. Read all gains and time constants, stop time and time increment.
2. Compute p, q and r, the coefficients of the cubic polynomial that make up the denominator of the polynomial.
3. Call subroutine to compute roots of the cubic
4. If (one real, two complex roots: $r, \alpha \pm \beta i$) then
5. Compute T, ω , ζ , G, ψ_R , ψ_p
6. While time $\leq$ stop time do
7. increment time (t)
8. compute rate and position using eq (8) & (10)
9. output
10. end do
11. else (three real root case)

12. compute T_1, T_2, T_3 & G
13. while time $\leq$ stop t do
14. increment time (t)
15. compute rate and position using eq (4) & (6)
16. output
17. end do
18. end if
19. stop

b. Notes:

1. Notice that the algorithm does not refer to current or voltage drive. The choice of types of drive is made by appropriately setting the input variables. Set A to A' , τ_a to τ_a' and R_s to 0.0. See Section III.
2. The algorithm was implemented in FORTRAN. In the implementation, the names of the variables correspond to the variables used in this write-up (eg, ZETA = ζ , OMEGA2 = ω^2 , $T = t$, $TT = T$ etc.)
3. The subroutine cubic referred to in step 3 returns three values, R_1 , R_2 & R_3 , and a flag. If the flag = 1 then R_1 is the real root R in Section VII.c. and $R_2 = \alpha$, $R_3 = \beta$. If the flag = 0 then R_1 , R_2 & R_3 are the three real roots referred to in Section VII.b.
4. In the implementation, intermediate variables are used to store portions of the inverse LaPlace transform formulas (4), (6), (8), (10). Eg, $TRM1 = 1 - 2T\zeta\omega + T^2\omega^2$. This is done to reduce the size of the assignment statements for rate and position and to reduce the number of computations done in the loop.

TIME INTEGRATION TIME-DOMAIN ANALYSIS

The time integration methodology was required to take into account the nonlinearities of the system. The drawback of this analysis procedure is the cost in running the computer model. Basically the time integration methodology takes an n^{th} order differential equation and breaks it down into n first order differential equations or in other words the system is defined by a system of state variables¹. The system of first order differential equations defining the servo drive system is summarized on figure E-8. These equations are integrated by an integration routine every sampling period.

Figure E-8 is a block diagram of the servo drive system which is a math model used to formulate the system of "first order" differential equations used in the time-domain analysis (time integration) computer program.

Computer Program listings and sample of output data for both the LaPlace and time integration analysis procedures are included in the following section LADSS*AMLTR and LADSS*AML 301.

1. State variables may be defined as the minimum set of variables that provide full knowledge of the system's behavior.

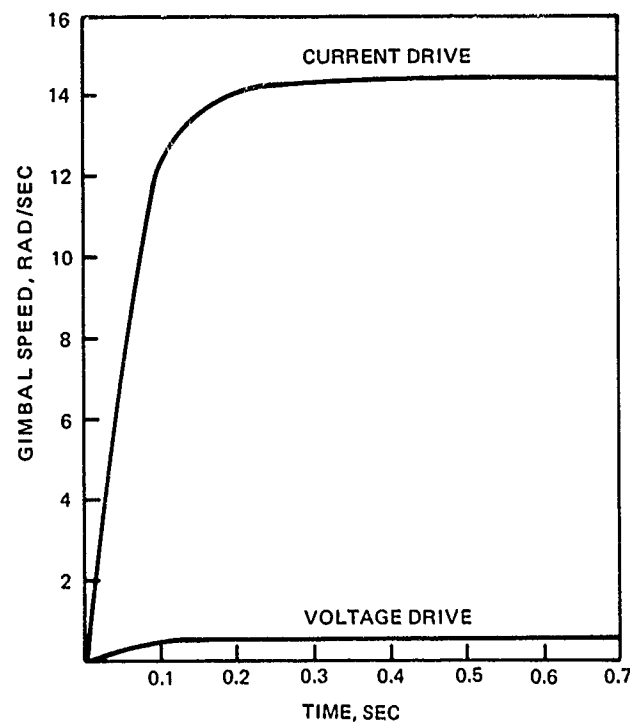


Figure E-2. Time response — comparison between voltage and current drives for inner gimbal.

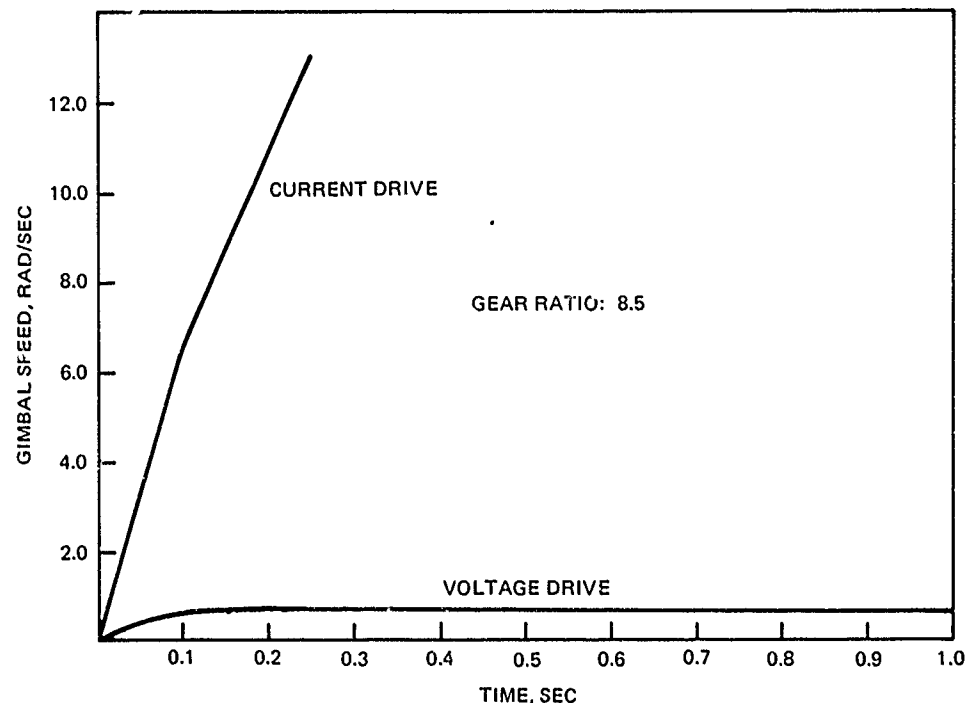


Figure E-3. Amplifier/motor load time response — comparison between voltage and current drives for outer gimbal.

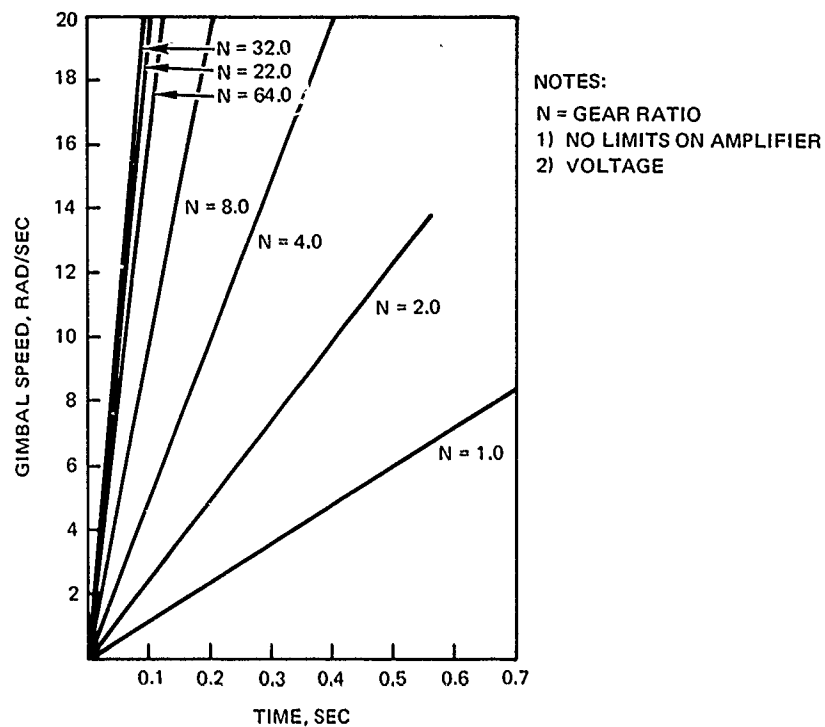


Figure E-4. Amplifier/motor/load time response as function of gear ratio (inner gimbal current drive).

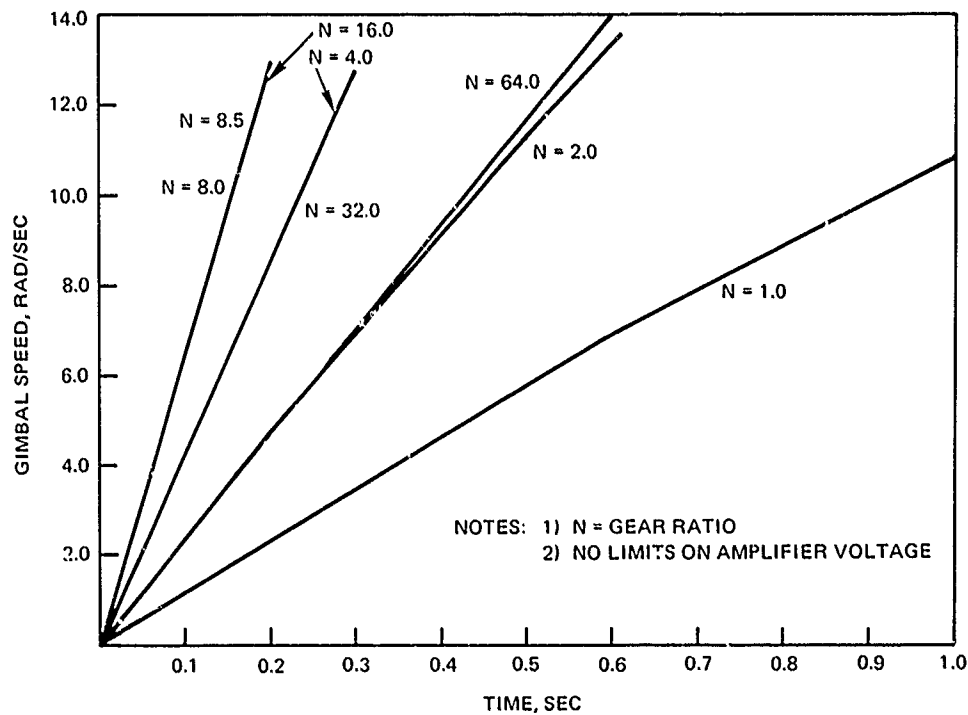


Figure F-5. Amplifier/motor/load time response as function of gear ratio (outer gimbal current drive).

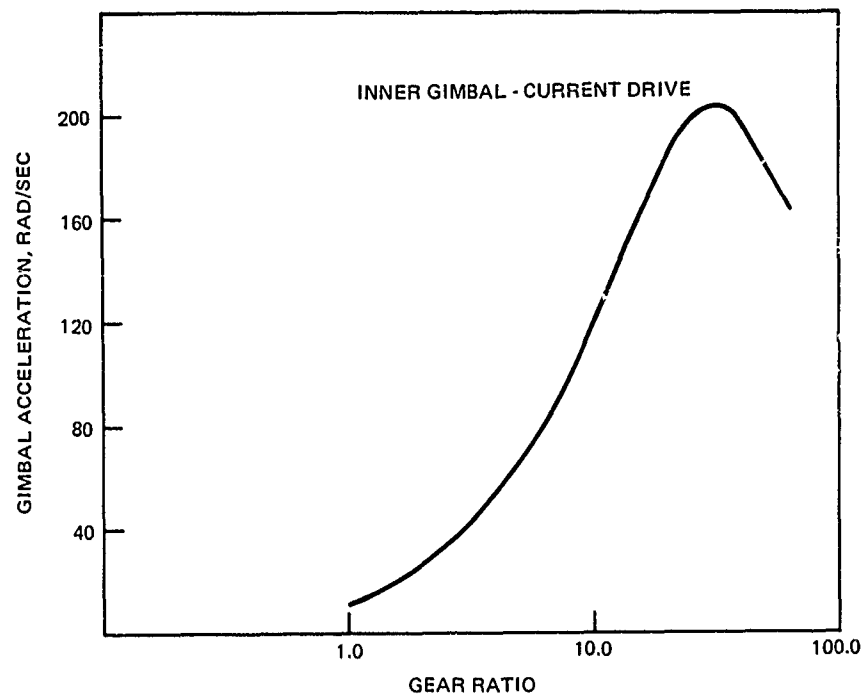


Figure E-6. Gear ratio vs acceleration -- inner gimbal -- current drive.

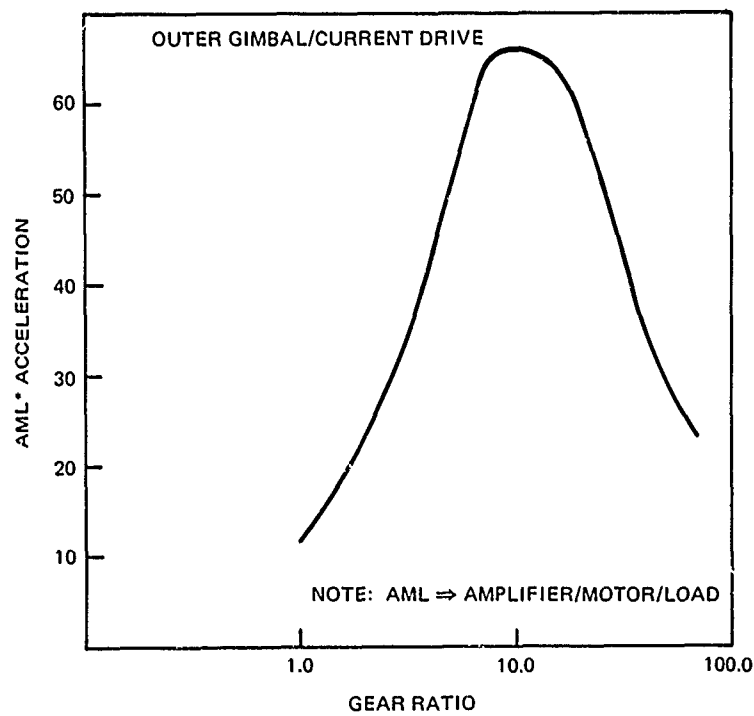


Figure E-7. Gear ratio vs acceleration -- outer gimbal/current drive.

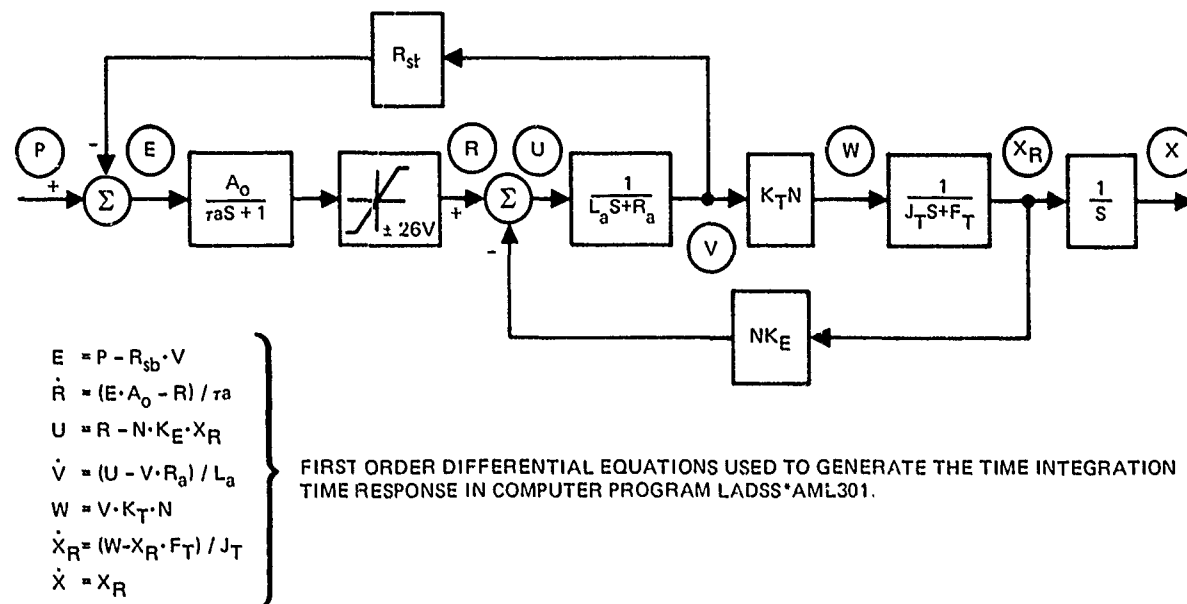


Figure E-8. Block diagram/equations of servo drive system/load for time integration computer program

LADSS* AMLTR

```

BFTN,RODS R.M2 IN
FTN RRI *04/17/80-09:10:16.1)
C.. NAME: LADSS STABILIZED PLATFORM AMPLIFIER/MOTOR/LOAD TIME RESPONSE
1. C..
2. C..
3. C.. USAGE: THE FOLLOWING CONTROL CARDS WILL EXECUTE THIS PROGRAM
4. C.. EXQT LADSS*AMLTR,PROG
5. C.. SAOD LADSS*AMLTR.(APPROPRIATE DATA ELEMENT)
6. C..
7. C..
8. C.. PURPOSE: THIS PROGRAM MODELS (IN THE TIME DOMAIN)
9. C.. THE AMPLIFIER/MOTOR/LOAD PORTION OF THE LADSS
10. C.. STABILIZED PLATFORM. THE TIME RESPONSE IS OBTAINED
11. C.. BY CALCULATING THE INVERSE LAPLACE TRANSFORM OF THE
12. C.. A/H/L TRANSFER FUNCTION.
13. C.. LIMITATIONS: NONE
14. C..
15. C.. WARNINGS: NONE
16. C..
17. C.. SUBPROGRAMS REQUIRED:
18. C.. CUBIC - COMPUTES THE ROOTS OF A CUBIC POLYNOMIAL
19. C..
20. C.. ARGUMENTS: NONE
21. C..
22. C.. NOTES:
23. C.. 1. THIS PROGRAM RUNS ON THE UNIVAC 1110 IN ASCII FORTRAN
24. C.. CAU TIME IS APPROXIMATELY ( NUM / 100 ) SECONDS
25. C.. NO. OF PAGES OF OUTPUT IS APPROXIMATELY 1.06 * NUM
26. C.. 2. EACH INPUT VARIABLE MUST BE ON A SEPARATE LINE WITH 7 SPACES
27. C.. AVAILABLE AT THE BEGINNING OF THE LINE FOR THE VARIABLE NAME
28. C.. 3. THE INPUT TO THE A/M/L IS A UNIT STEP FUNCTION.
29. C.. THIS IS DUE TO THE CHOICE OF LAPLACE TRANSFORM PAIRS
30. C.. THAT ARE USED.
31. C.. 4. TWO TYPES OF SYSTEMS CAN BE MODELED BY THIS PROGRAM.
32. C.. A) A VOLTAGE DRIVEN MOTOR
33. C.. B) A CURRENT DRIVEN MOTOR
34. C.. THE CURRENT DRIVEN VERSION IS OBTAINED BY
35. C.. SETTING INPUT VARIABLE RSB TO THE SENSING RESISTOR VALUE.
36. C.. TO GET THE VOLTAGE DRIVEN RESPONSE SET RSB TO 0.0
37. C.. AND ADJUST INPUT PARAMETERS A & TAU AS INDICATED IN WRITE UP
38. C.. 5. THE AMPLIFIER IS A CURRENT OR VOLTAGE DRIVEN AMPLIFIER.
39. C.. THE DC TORQUE MOTOR IS A PERMANENT MAGNET, ARMATURE
40. C.. CONTROLLED DEVICE.
41. C.. THE LOAD IS THE ANTENNA PLUS MOTOR INERTIA REFERENCED
42. C.. TO THE GIMBAL SHAFT.
43. C..
44. C.. PROGRAMMER/ORGANIZATION: DARYL E. SMITH CSC DEPT 551
45. C..
46. C.. ALGORITHM:
47. C.. 1. READ AND ECHO INPUTS
48. C.. 2. COMPUTE COEFFICIENTS OF CUBIC POLYNOMIAL
49. C.. 3. CALL CUBIC TO FIND ROOTS
50. C.. 4. COMPUTE VARIABLES USED IN INVERSE LAPLACE TRANSFORM
51. C.. EVALUATION
52. C.. 5. DO FOR 'NUM' TIME INCREMENTS
53. C.. EVALUATE INVERSE LAPLACE TRANSFORMS
54. C.. OUTPUT
55. C.. END DO

```

56.	C..	6. STOP
57.	C..	
58.	C..	RECORD OF MODIFICATIONS
59.	C..	START EDIT PAGE
60.		

61.	REAL	A	AMPLIFIER GAIN V/V
62.	REAL+8	ALPHA	REAL PART OF CUBIC ROOT
63.	REAL+8	BE12	IMAGINARY PART OF CUBIC ROOT
64.	REAL	D	MOTOR FRICTION 02-IN-SEC
65.	REAL+8	GAIN	COMPLETE TRANSFER FUNCTION GAIN
66.	INTEGER	I	LOOP COUNTER
67.	INTEGER	ITER	MAX. NO. ITERATIONS ALLOWED IN CUBIC
68.	C		ON RETURN FROM CUBIC, IF ITER=0, NEWTON'S
69.	C		METHOD DID NOT CONVERGE & NO ROOTS WERE FOUND
70.	C		
71.	REAL	JL	LOAD INERTIA 02-IN-SEC**2
72.	REAL	JM	MOTOR INERTIA 02-IN-SEC**2
73.	REAL	JT	TOTAL INERTIA 02-IN-SEC**2
74.	REAL	KE	BACK EMF V/RAD/SEC
75.	INTEGER	KFLG	FLAG RETURNED FROM SUBROUTINE CUBIC
76.	C		KFLG = 0 => 3 REAL ROOTS
77.	C		KFLG = 1 => 1 REAL, 2 COMPLEX ROOTS
78.	REAL	KY	TORQUE SENSITIVITY 02-IN/AMP
79.	REAL	LA	MOTOR INDUCTANCE HENRIES
80.	REAL	N	GEAR RATIO (G:HBAL-TO-MOTOR)
81.	INTEGER	NUM	NUMBER OF TIMES TO EVALUATE
82.	REAL+8	OMEGA	SEE DOCUMENTATION
83.	REAL+8	OMEGA2	SEE DOCUMENTATION
84.	REAL+8	OMF2	SEE DOCUMENTATION
85.	REAL+8	P	COEFFICIENT OF SQUARE TERM IN CUBIC
86.	REAL+8	PMIP	SEE DOCUMENTATION
87.	REAL+8	PMIR	SEE DOCUMENTATION
88.	REAL+8	POSTN	POSITION OUTPUT RAD
89.	REAL+8	Q	COEFFICIENT OF S TERM IN CUBIC
90.	REAL+8	R	CONSTANT TERM IN CUBIC
91.	REAL	RA	ARMATURE RESISTANCE OHMS
92.	REAL+8	RATE	RATE OUTPUT RAD/SEC
93.	REAL+8	RMZ2	SEE DOCUMENTATION
94.	REAL+8	RR	REAL ROOT OF CUBIC
95.	REAL+8	RR1	ROOTS OF CUBIC. IF KFLG = 0,
96.	REAL+8	RR2	THERE ARE 3 REAL ROOTS. IF KFLG = 1,
97.	REAL+8	RR3	THERE ARE 1 REAL & 2 COMPLEX
98.	REAL	R58	SENSING RESISTOR VALUE OHMS
99.	REAL	STOPT	STOP TIME (SIMULATED)
100.	REAL	T	SIMULATED TIME
101.	REAL	TAVA	AMPLIFIER TIME CONSTANT SEC
102.	REAL	TIME	TIME INCREMENT
103.	REAL+8	TRM1	STORAGE FOR INTERMEDIATE VALUES
104.	REAL+8	TRM2	STORAGE FOR INTERMEDIATE VALUES
105.	REAL+8	TRM3	STORAGE FOR INTERMEDIATE VALUES
106.	REAL+8	TRM4	STORAGE FOR INTERMEDIATE VALUES
107.	REAL+8	TRM5	STORAGE FOR INTERMEDIATE VALUES
108.	REAL+8	TRM6	STORAGE FOR INTERMEDIATE VALUES
109.	REAL+8	TRM7	STORAGE FOR INTERMEDIATE VALUES
110.	REAL+8	TRM8	STORAGE FOR INTERMEDIATE VALUES
111.	REAL+8	TT	SEE DOCUMENTATION
112.	REAL+8	TT1	1.0 / 1 - RR1
113.	REAL+8	TT2	1.0 / 1 - RR2
114.	REAL+8	TT3	1.0 / 1 - RR3
115.	REAL+8	TT5Q	TT**2
116.	REAL+8	7ETA	SEE DOCUMENTATION
117.	REAL	START	FD11 PAGE

```

118. READ ( 5,100 ) A,TAUA,RA,RSR,KT,N,JM,JL,D,KE
119. FORMAT ( 7X,F10.0 )
120. READ ( 5,200 ) HUM,TINC,IIEK
121. FORMAT ( 15,F10.0,15 )
122. JT = N*HUM + JL
123. WRITE ( 6,300 ) A,TAUA,RA,RSR,KT,N,JM,JL,JT,D,KE
124. FORMAT ( 11A,10F10.5,10F10.5,10F10.5,10F10.5,10F10.5,10F10.5,10F10.5,10F10.5,10F10.5,10F10.5,10F10.5,10F10.5 )
125. RA = RA
126. RS = RS
127. KT = KT
128. N = N
129. P = ( LA*TAUA + JT*LA + JT*TAUA*RA ) / ( LA*JT*TAUA )
130. Q = ( D*LA + TAUA*D*RA + JT*RA + A*RSB*JT + N*KE*KT*TAUA ) /
131. ( LA*JT*TAUA )
132. R = ( RA*D + A*RSB*D + N*KE*KT ) / ( LA*JT*TAUA )
133. WRITE ( 6,400 ) P,Q,R
134. FORMAT ( 10F10.5,10F10.5,10F10.5 )
135. CALL CURIC ( P,Q,R,IIEK,KFLG,RR1,RR2,RR3 )
136. IF ( IIEK.EQ.0 ) THEN
137. NUM = 0
138. END IF
139. IF ( KFLG.EQ.1 ) THEN
140. C ONE REAL, TWO COMPLEX ROOT CASE
141. C
142. ALPHA = RR2
143. BETA = RR3
144. RR = RR1
145. WRITE ( 6,500 ) RR,ALPHA,BETA
146. FORMAT ( 10F10.5,10F10.5,10F10.5 )
147. TT = 1.000 / ( -RR )
148. TTQ = TT * TT
149. OMEGA2 = ALPHA*ALPHA + BETA*BETA
150. OMEGA = DSQRT ( OMEGA2 )
151. ZETA = - ( ALPHA / OMEGA )
152. OMZ2 = 1.000 - ZETA*ZETA
153. OMZ = DSQRT ( OMZ2 )
154. TRM1 = 1.000 - 2.000*TT*ZETA*OMEGA + TTQ*OMEGA2
155. TRM2 = DSQRT ( TRM1 )
156. TRM3 = ( TT*OMEGA*OMZ2 ) / ( 1.000 - TT*ZETA*OMEGA )
157. PHIR = DATAN ( OMZ2 / ( -ZETA ) ) + DATAN ( TRM3 )
158. PHIP = 2.000*DATAN ( OMZ2 / ( -ZETA ) ) + DATAN ( TRM3 )
159. GAIN = ( A*KT*N*TT ) / ( LA*JT*TAUA*OMEGA2 )
160. WRITE ( 6,600 ) TT,OMEGA,TRM1,TRM2,TRM3,GAIN,ZETA
161. FORMAT ( 10F10.5,10F10.5,10F10.5,10F10.5,10F10.5,10F10.5,10F10.5 )
162. OMEGA = TRM1, TRM2, TRM3
163. GAIN = GAIN
164. ZETA = ZETA
165. STOPT = ELQAT ( HUM ) * TINC
166. WRITE ( 6,700 ) HUM,TINC,STOPT,IIEK
167. FORMAT ( 10F10.5,10F10.5,10F10.5,10F10.5 )
168. JIER = 15
169. WRITE ( 6,800 ) PHIR,PHIP
170. FORMAT ( 10F10.5,10F10.5 )
171. DQ LOQD L=1,HUM
172. Y = TINC * FLOAT ( I )
173. TRM4 = DEXP ( ( -I ) / TT )
174. TRM5 = DEXP ( -ZETA*OMEGA*I )

```

E-18

56.	REAL*8	B0	R ALL P'S AND C'S ARE INTERMEDIATE
57.	REAL*8	B1	R STORAGE FOR NEWTONS METHOD ITERATION.
58.	REAL*8	B2	
59.	REAL*8	B3	
60.	REAL*8	C1	
61.	REAL*8	C2	
62.	REAL*8	C3	
63.	REAL*8	DESC	D DISCRIMINANT OF RESOLVED QUADRATIC
64.	REAL*8	DX	D CHANGE IN X AT EACH ITERATION DX=FIX)/F'(X)
65.	INTEGER	I	D COUNTS NO. OF ITERATIONS
66.	INTEGER	ITER	D MAX NO. OF ITERATIONS TO PERFORM.
67.	C		IF ITERATION SCHEME DOES NOT
68.	C		CONVERGE, SET ITER TO 0
69.	INTEGER	KFLG	D INDICATES TYPE OF ROOTS
70.	REAL*8	P	D COEFF. OF SQUARE TERM IN CUBIC
71.	REAL*8	Q	D COEFF. OF X TERM IN CUBIC
72.	REAL*8	R	D CONSTANT TERM IN CUBIC
73.	REAL*8	RR1	D REAL ROOT
74.	REAL*8	RR2	D REAL ROOT OR REAL PART OF COMPLEX ROOT
75.	REAL*8	RR3	D REAL ROOT OR IMAG PART OF COMPLEX ROOT
76.	REAL*8	X	D UNKNOWN VARIABLE
77.			START EDIT PAGE
78.			

```

79.      I = 0
80.      X = -2.0D-1
81.      B3 = 1.0D0
82.      C3 = B3
83.      I0 = 1
84.      B2 = P + X*B3
85.      C2 = B2 + X*C3
86.      B1 = Q + X*B2
87.      C1 = B1 + X*C2
88.      B0 = R + X*B1
89.      DX = R0 / C1
90.      X = X - DX
91.      WRITE (6,20) X,DX,B0,B1,B2,C1,C2
92.      FORMAT (1X,DX,B0,3(1D20,12,3X),/,
93.      6, B1,B2,C1,C2,/,4(1D20,12,3X))
94.      C
95.      C CHECK FOR END OF ITERATION
96.      C
97.      IF (ABS (DX) .GE. 1.0D-10) ,AND. (1.LE. ITER) ) GO TO 10
98.      C
99.      C CHECK FOR CONVERGENCE
100.     C
101.     IF (1.LE. ITER) THEN
102.     C
103.     C CONVERGENCE: FIND ROOTS
104.     C
105.     RR1 = X - DX
106.     DESC = B2*B2 - 4.0D0*B1
107.     C
108.     C CHECK FOR POSITIVE DISCRIMINANT
109.     C
110.     IF (DESC .GE. 0.0D0) THEN
111.     C
112.     C THREE REAL ROOTS
113.     C
114.     RR2 = (-B2 + DSQRT (DESC)) / 2.0D0
115.     RR3 = (-B2 - DSQRT (DESC)) / 2.0D0
116.     KFLG = 0
117.     ELSE
118.     C
119.     C ONE REAL & TWO COMPLEX
120.     C
121.     RR2 = -B2 / 2.0D0
122.     RR3 = DSQRT (-DESC) / 2.0D0
123.     KFLG = 1
124.     END IF
125.     ELSE
126.     C
127.     C NO CONVERGENCE
128.     C
129.     C
130.     30 WRITE (6,30)
131.     FORMAT (10D20,12,3X) CURRIC ITERATION .GT. ITER ' )
132.     END IF
133.     RETURN
134.     END

```

LADSS-AHLTR (1)-OVLTR			
1	A	1.0	
2	TAUA	.00001	
3	LA	.0014	
4	RA	3.0	
5	RSU	0.0	
6	KT	24.8	
7	N	8.5	
8	JM	.016	
9	IL	3.30	
10	D	.706	
11	FE	.177	
12	10U	.01	20
JXUT R.PHOG			

A 1.000
 TAU 0.000
 LA 0.0140
 KA 3.00000
 RSL 0.0000
 KT 2.00000
 N 1.50000
 JM 0.1000
 JL 3.30000
 JT 4.45000
 D 7.0000
 KE 1.7700

F, W, R: 10021.50000+007 .21306678400+010 .511776409600+011
 X, D, B, C: 238850117656+002 .236250117656+002 .507490676889+011
 U1, B2, C1, C2: 2126635544+010 .100214260000+007 .100214260000+007
 X, D, B, C: 24153327595+002 .26831293900+000 .562168338611+009
 U1, B2, C1, C2: 211913115715+010 .100211911499+007 .209519610079+010
 X, D, B, C: 241533592000+002 .344034436633+004 .721408633617+005
 U1, B2, C1, C2: 211886228205+010 .100211886228205+010 .209465836348+010
 X, D, B, C: 241533592000+002 .56748892734+012 .118869543076+002
 U1, B2, C1, C2: 211886224754+010 .10021188624754+010 .209465829446+010

TANEE REAL ROOTS

RM1, RM2, RM3: -2.153359200+002 -.211886228067+004 -.999999984360+006

T1, T2, T3: 414021085730-001 .471951390663-003 .100000001564-005

IM1, IM2, IM3: 409301571823-001 .514011085730-001 .70951390653-003

GAIN = .660263203648+000

TIME = .0100 TAN4, TMS, TMS: .73569+000 POSITION = .67270-003
 TAN4, TMS, TMS: .78542+000 .62791-009 .00000

TIME = .0200 TAN4, TMS, TMS: .24825+000 POSITION = .26150-002
 TAN4, TMS, TMS: .61689+000 .39427-018 .00000

TIME = .0300 TAN4, TMS, TMS: .33664+000 POSITION = .55573-002
 TAN4, TMS, TMS: .49452+000 .24757-027 .00000

TIME = .0400 TAN4, TMS, TMS: .40610+000 POSITION = .92850-002
 TAN4, TMS, TMS: .38055+000 .15545-036 .00000

TIME = .0500 TAN4, TMS, TMS: .46063+000 POSITION = .13630-001
 TAN4, TMS, TMS: .29869+000 .97609-046 .00000

TIME = .0600 TAN4, TMS, TMS: .50347+000 POSITION = .18459-001
 TAN4, TMS, TMS: .23472+000 .61290-055 .00000

TIME = .0700 TAN4, TMS, TMS: .53711+000 POSITION = .23668-001
 TAN4, TMS, TMS: .18458+000 .36465-064 .00000

TIME = .0800 TAN4, TMS, TMS: .56354+000 POSITION = .29177-001
 TAN4, TMS, TMS: .14482+000 .24165-073 .00000

TIME = .0500	RATE = .38424+000	POSITION = .34920-001
TIME = .1000	RATE = .11374+000	POSITION = .15175-082
TIME = .1500	RATE = .00060+000	POSITION = .40848-001
TIME = .2000	RATE = .89337-001	POSITION = .95275-092
TIME = .2500	RATE = .01340+000	POSITION = .46921-001
TIME = .3000	RATE = .70168-001	POSITION = .59824-101
TIME = .3500	RATE = .02345+000	POSITION = .53107-001
TIME = .4000	RATE = .55111-001	POSITION = .37564-110
TIME = .4500	RATE = .03135+000	POSITION = .59383-001
TIME = .5000	RATE = .43266-001	POSITION = .23587-119
TIME = .5500	RATE = .03750+000	POSITION = .65728-001
TIME = .6000	RATE = .33997-001	POSITION = .14811-128
TIME = .6500	RATE = .04243+000	POSITION = .72129-001
TIME = .7000	RATE = .26702-001	POSITION = .92998-138
TIME = .7500	RATE = .04626+000	POSITION = .76373-001
TIME = .8000	RATE = .20973-001	POSITION = .58394-147
TIME = .8500	RATE = .04926+000	POSITION = .85052-001
TIME = .9000	RATE = .16472-001	POSITION = .36666-156
TIME = .9500	RATE = .05162+000	POSITION = .91557-001
TIME = .1000	RATE = .12938-001	POSITION = .23023-165
TIME = .1500	RATE = .05345+000	POSITION = .98082-001
TIME = .2000	RATE = .10162-001	POSITION = .14457-174
TIME = .2500	RATE = .05493+000	POSITION = .10462+000
TIME = .3000	RATE = .79812-002	POSITION = .90774-184
TIME = .3500	RATE = .05608+000	POSITION = .11118+000
TIME = .4000	RATE = .62666-002	POSITION = .56998-193
TIME = .4500	RATE = .05667+000	POSITION = .11775+000
TIME = .5000	RATE = .49235-002	POSITION = .35790-202
TIME = .5500	RATE = .05768+000	POSITION = .12432+000
TIME = .6000	RATE = .38670-002	POSITION = .22473-211
TIME = .6500	RATE = .05823+000	POSITION = .13090+000
TIME = .7000	RATE = .30372-002	POSITION = .14111-220
TIME = .7500	RATE = .05867+000	POSITION = .13748+000
TIME = .8000	RATE = .23855-002	POSITION = .58604-230
TIME = .8500	RATE = .05901+000	POSITION = .14407+000
TIME = .9000	RATE = .18736-002	POSITION = .55635-239
TIME = .9500	RATE = .05928+000	POSITION = .15066+000
TIME = .1000	RATE = .14111-002	POSITION = .34934-248

TIME = .2800	RATE = .6594+000	POSITION = .15726+000
TRM4,TRM5,TRM6 = .11555-002	POSITION = .21955-257	.00000
TIME = .2900	RATE = .65966+000	POSITION = .16385+000
TRM4,TRM5,TRM6 = .90761-003	POSITION = .13773-266	.00000
TIME = .3000	RATE = .65979+000	POSITION = .17045+000
TRM4,TRM5,TRM6 = .71302-003	POSITION = .06466-276	.00000
TIME = .3100	RATE = .65989+000	POSITION = .17705+000
TRM4,TRM5,TRM6 = .56002-003	POSITION = .54505-285	.00000
TIME = .3200	RATE = .65997+000	POSITION = .18365+000
TRM4,TRM5,TRM6 = .43965-003	POSITION = .34099-294	.00000
TIME = .3300	RATE = .66005+000	POSITION = .19025+000
TRM4,TRM5,TRM6 = .34547-003	POSITION = .21411-303	.00000
TIME = .3400	RATE = .66006+000	POSITION = .19685+000
TRM4,TRM5,TRM6 = .27134-003	POSITION = .00000	.00000
TIME = .3500	RATE = .66012+000	POSITION = .20345+000
TRM4,TRM5,TRM6 = .21312-003	POSITION = .00000	.00000
TIME = .3600	RATE = .66015+000	POSITION = .21005+000
TRM4,TRM5,TRM6 = .16739-003	POSITION = .00000	.00000
TIME = .3700	RATE = .66016+000	POSITION = .21665+000
TRM4,TRM5,TRM6 = .13147-003	POSITION = .00000	.00000
TIME = .3800	RATE = .66019+000	POSITION = .22325+000
TRM4,TRM5,TRM6 = .10326-003	POSITION = .00000	.00000
TIME = .3900	RATE = .66021+000	POSITION = .22986+000
TRM4,TRM5,TRM6 = .81101-004	POSITION = .00000	.00000
TIME = .4000	RATE = .66022+000	POSITION = .23646+000
TRM4,TRM5,TRM6 = .63699-004	POSITION = .00000	.00000
TIME = .4100	RATE = .66023+000	POSITION = .24306+000
TRM4,TRM5,TRM6 = .50031-004	POSITION = .00000	.00000
TIME = .4200	RATE = .66024+000	POSITION = .24966+000
TRM4,TRM5,TRM6 = .39295-004	POSITION = .00000	.00000
TIME = .4300	RATE = .66024+000	POSITION = .25627+000
TRM4,TRM5,TRM6 = .30863-004	POSITION = .00000	.00000
TIME = .4400	RATE = .66025+000	POSITION = .26287+000
TRM4,TRM5,TRM6 = .24241-004	POSITION = .00000	.00000
TIME = .4500	RATE = .66025+000	POSITION = .26947+000
TRM4,TRM5,TRM6 = .19039-004	POSITION = .00000	.00000
TIME = .4600	RATE = .66025+000	POSITION = .27607+000
TRM4,TRM5,TRM6 = .14954-004	POSITION = .00000	.00000

TIME = .4700	RATE = .66026+000	POSITION = .25268+000
TRM4,TRM5,TRM6 =	.11745-004	.00000
TIME = .4800	RATE = .66026+000	POSITION = .26928+000
TRM4,TRM5,TRM6 =	.92246-005	.00000
TIME = .4900	RATE = .66026+000	POSITION = .29588+000
TRM4,TRM5,TRM6 =	.72454-005	.00000
TIME = .5000	RATE = .66026+000	POSITION = .30248+000
TRM4,TRM5,TRM6 =	.56507-005	.00000
TIME = .5100	RATE = .66026+000	POSITION = .30909+000
TRM4,TRM5,TRM6 =	.44596-005	.00000
TIME = .5200	RATE = .66026+000	POSITION = .31569+000
TRM4,TRM5,TRM6 =	.35105-005	.00000
TIME = .5300	RATE = .66026+000	POSITION = .32229+000
TRM4,TRM5,TRM6 =	.27572-005	.00000
TIME = .5400	RATE = .66026+000	POSITION = .32889+000
TRM4,TRM5,TRM6 =	.21056-005	.00000
TIME = .5500	RATE = .66026+000	POSITION = .33550+000
TRM4,TRM5,TRM6 =	.17009-005	.00000
TIME = .5600	RATE = .66026+000	POSITION = .34210+000
TRM4,TRM5,TRM6 =	.13359-005	.00000
TIME = .5700	RATE = .66026+000	POSITION = .34870+000
TRM4,TRM5,TRM6 =	.10495-005	.00000
TIME = .5800	RATE = .66026+000	POSITION = .35530+000
TRM4,TRM5,TRM6 =	.82412-006	.00000
TIME = .5900	RATE = .66026+000	POSITION = .36191+000
TRM4,TRM5,TRM6 =	.64728-006	.00000
TIME = .6000	RATE = .66026+000	POSITION = .36851+000
TRM4,TRM5,TRM6 =	.50839-006	.00000
TIME = .6100	RATE = .66026+000	POSITION = .37511+000
TRM4,TRM5,TRM6 =	.39350-006	.00000
TIME = .6200	RATE = .66026+000	POSITION = .38171+000
TRM4,TRM5,TRM6 =	.31362-006	.00000
TIME = .6300	RATE = .66026+000	POSITION = .38832+000
TRM4,TRM5,TRM6 =	.24032-006	.00000
TIME = .6400	RATE = .66026+000	POSITION = .39492+000
TRM4,TRM5,TRM6 =	.19347-006	.00000
TIME = .6500	RATE = .66026+000	POSITION = .40152+000
TRM4,TRM5,TRM6 =	.15195-006	.00000

TIME = .6600	RATE = .66026+000	POSITION = .42813+000
TIME = .6700	RATE = .66026+000	POSITION = .41473+000
TIME = .6800	RATE = .66026+000	POSITION = .42133+000
TIME = .6900	RATE = .66026+000	POSITION = .42793+000
TIME = .7000	RATE = .66026+000	POSITION = .43454+000
TIME = .7100	RATE = .66026+000	POSITION = .44114+000
TIME = .7200	RATE = .66026+000	POSITION = .44774+000
TIME = .7300	RATE = .66026+000	POSITION = .45434+000
TIME = .7400	RATE = .66026+000	POSITION = .46095+000
TIME = .7500	RATE = .66026+000	POSITION = .46755+000
TIME = .7600	RATE = .66026+000	POSITION = .47415+000
TIME = .7700	RATE = .66026+000	POSITION = .48075+000
TIME = .7800	RATE = .66026+000	POSITION = .48736+000
TIME = .7900	RATE = .66026+000	POSITION = .49396+000
TIME = .8000	RATE = .66026+000	POSITION = .50056+000
TIME = .8100	RATE = .66026+000	POSITION = .50716+000
TIME = .8200	RATE = .66026+000	POSITION = .51377+000
TIME = .8300	RATE = .66026+000	POSITION = .52037+000
TIME = .8400	RATE = .66026+000	POSITION = .52697+000

TIME = .6500	RATE = .6026+000	POSITION = .53358+000
TIME = .6600	RATE = .6026+000	POSITION = .54018+000
TIME = .6700	RATE = .6026+000	POSITION = .54672+000
TIME = .6800	RATE = .6026+000	POSITION = .55338+000
TIME = .6900	RATE = .6026+000	POSITION = .55999+000
TIME = .7000	RATE = .6026+000	POSITION = .56659+000
TIME = .7100	RATE = .6026+000	POSITION = .57319+000
TIME = .7200	RATE = .6026+000	POSITION = .57979+000
TIME = .7300	RATE = .6026+000	POSITION = .58640+000
TIME = .7400	RATE = .6026+000	POSITION = .59300+000
TIME = .7500	RATE = .6026+000	POSITION = .59960+000
TIME = .7600	RATE = .6026+000	POSITION = .60620+000
TIME = .7700	RATE = .6026+000	POSITION = .61281+000
TIME = .7800	RATE = .6026+000	POSITION = .61941+000
TIME = .7900	RATE = .6026+000	POSITION = .62601+000
TIME = .8000	RATE = .6026+000	POSITION = .63261+000

STOI 5999

SPRT M-JUL164
LUPUR 2783A

E36 SL74R1 04/17/50 13:54:55

LADSS*AMLIN(1)*JGVLDH			
1	4	1.0	
2	TAUA	.000001	
3	LA	.00276	
4	RA	9.317	
5	RSB	0.0	
6	KT	19.75	
7	h	12.8	
8	JP	.0015	
9	JL	2.47	
10	C	.622	
11	AE	.141	
12	100	.01	.0

*XGT R-P406

TIME = .0000	RATE = .44174+000	POSITION = .25018-001
TIME = .1000	RATE = .45940+000	POSITION = .27526-001
TIME = .1100	RATE = .47412+000	POSITION = .34196-001
TIME = .1200	RATE = .48630+000	POSITION = .35001-001
TIME = .1300	RATE = .49656+000	POSITION = .43917-001
TIME = .1400	RATE = .50504+000	POSITION = .43926-001
TIME = .1500	RATE = .51210+000	POSITION = .54013-001
TIME = .1600	RATE = .51797+000	POSITION = .59164-001
TIME = .1700	RATE = .52286+000	POSITION = .64369-001
TIME = .1800	RATE = .52693+000	POSITION = .69619-001
TIME = .1900	RATE = .53032+000	POSITION = .74905-001
TIME = .2000	RATE = .53314+000	POSITION = .80223-001
TIME = .2100	RATE = .53549+000	POSITION = .85567-001
TIME = .2200	RATE = .53744+000	POSITION = .90932-001
TIME = .2300	RATE = .53906+000	POSITION = .96314-001
TIME = .2400	RATE = .54042+000	POSITION = .10171+000
TIME = .2500	RATE = .54154+000	POSITION = .10712+000
TIME = .2600	RATE = .54243+000	POSITION = .11254+000
TIME = .2700	RATE = .54326+000	POSITION = .11797+000

E-32

TIME = .4700	RATE = .54705+000	POSITION = .22719+000
TRM4,TRMS,TRM6 = .17220-003		.00000
TIME = .4700	RATE = .54705+000	POSITION = .23266+000
TRM4,TRMS,TRM6 = .14221-003		.00000
TIME = .4700	RATE = .54706+000	POSITION = .23813+000
TRM4,TRMS,TRM6 = .12385-003		.00000
TIME = .5000	RATE = .54707+000	POSITION = .24360+000
TRM4,TRMS,TRM6 = .10307-003		.00000
TIME = .5100	RATE = .54706+000	POSITION = .24907+000
TRM4,TRMS,TRM6 = .85724-004		.00000
TIME = .5200	RATE = .54709+000	POSITION = .25454+000
TRM4,TRMS,TRM6 = .71392-004		.00000
TIME = .5300	RATE = .54710+000	POSITION = .26002+000
TRM4,TRMS,TRM6 = .59420-004		.00000
TIME = .5400	RATE = .54710+000	POSITION = .26549+000
TRM4,TRMS,TRM6 = .49454-004		.00000
TIME = .5500	RATE = .54711+000	POSITION = .27096+000
TRM4,TRMS,TRM6 = .41159-004		.00000
TIME = .5600	RATE = .54711+000	POSITION = .27643+000
TRM4,TRMS,TRM6 = .34255-004		.00000
TIME = .5700	RATE = .54711+000	POSITION = .28190+000
TRM4,TRMS,TRM6 = .28509-004		.00000
TIME = .5800	RATE = .54712+000	POSITION = .28737+000
TRM4,TRMS,TRM6 = .23727-004		.00000
TIME = .5900	RATE = .54712+000	POSITION = .29284+000
TRM4,TRMS,TRM6 = .19747-004		.00000
TIME = .6000	RATE = .54712+000	POSITION = .29831+000
TRM4,TRMS,TRM6 = .16435-004		.00000
TIME = .6100	RATE = .54712+000	POSITION = .30378+000
TRM4,TRMS,TRM6 = .13672-004		.00000
TIME = .6200	RATE = .54712+000	POSITION = .30926+000
TRM4,TRMS,TRM6 = .11384-004		.00000
TIME = .6300	RATE = .54712+000	POSITION = .31473+000
TRM4,TRMS,TRM6 = .94747-005		.00000
TIME = .6400	RATE = .54712+000	POSITION = .32020+000
TRM4,TRMS,TRM6 = .78654-005		.00000
TIME = .6500	RATE = .54712+000	POSITION = .32567+000
TRM4,TRMS,TRM6 = .65028-005		.00000

TIME = .6600	RATE = .54713+000	POSITION = .33114+000
TRM4,TRM5,TRM6 = .54620-005		.00000
TIME = .6700	RATE = .54713+000	POSITION = .33661+000
TRM4,TRM5,TRM6 = .45450-005		.00000
TIME = .6800	RATE = .54713+000	POSITION = .34208+000
TRM4,TRM5,TRM6 = .37834-005		.00000
TIME = .6900	RATE = .54713+000	POSITION = .34755+000
TRM4,TRM5,TRM6 = .31488-005		.00000
TIME = .7000	RATE = .54713+000	POSITION = .35303+000
TRM4,TRM5,TRM6 = .26206-005		.00000
TIME = .7100	RATE = .54713+000	POSITION = .35850+000
TRM4,TRM5,TRM6 = .21211-005		.00000
TIME = .7200	RATE = .54713+000	POSITION = .36397+000
TRM4,TRM5,TRM6 = .18152-005		.00000
TIME = .7300	RATE = .54713+000	POSITION = .36944+000
TRM4,TRM5,TRM6 = .15107-005		.00000
TIME = .7400	RATE = .54713+000	POSITION = .37491+000
TRM4,TRM5,TRM6 = .12573-005		.00000
TIME = .7500	RATE = .54713+000	POSITION = .38038+000
TRM4,TRM5,TRM6 = .10464-005		.00000
TIME = .7600	RATE = .54713+000	POSITION = .38585+000
TRM4,TRM5,TRM6 = .87093-006		.00000
TIME = .7700	RATE = .54713+000	POSITION = .39132+000
TRM4,TRM5,TRM6 = .72484-006		.00000
TIME = .7800	RATE = .54713+000	POSITION = .39680+000
TRM4,TRM5,TRM6 = .60326-006		.00000
TIME = .7900	RATE = .54713+000	POSITION = .40227+000
TRM4,TRM5,TRM6 = .50208-006		.00000
TIME = .8000	RATE = .54713+000	POSITION = .40774+000
TRM4,TRM5,TRM6 = .41786-006		.00000
TIME = .8100	RATE = .54713+000	POSITION = .41321+000
TRM4,TRM5,TRM6 = .34777-006		.00000
TIME = .8200	RATE = .54713+000	POSITION = .41868+000
TRM4,TRM5,TRM6 = .28944-006		.00000
TIME = .8300	RATE = .54713+000	POSITION = .42415+000
TRM4,TRM5,TRM6 = .24089-006		.00000
TIME = .8400	RATE = .54713+000	POSITION = .42962+000
TRM4,TRM5,TRM6 = .20649-006		.00000

TIME = .8500	TMM4, TMM5, TRMC = .56713+000	RATE = .16652-000	POSITION = .42509+000	.00000
TIME = .8600	TMM4, TMM5, TRMC = .56713+000	RATE = .13087-000	POSITION = .44057+000	.00000
TIME = .8700	TMM4, TMM5, TRMC = .56713+000	RATE = .11558-000	POSITION = .44804+000	.00000
TIME = .8800	TMM4, TMM5, TRMC = .56713+000	RATE = .96191-007	POSITION = .45151+000	.00000
TIME = .8900	TMM4, TMM5, TRMC = .56713+000	RATE = .80057-007	POSITION = .45698+000	.00000
TIME = .9000	TMM4, TMM5, TRMC = .56713+000	RATE = .66829-007	POSITION = .46245+000	.00000
TIME = .9100	TMM4, TMM5, TRMC = .56713+000	RATE = .55453-007	POSITION = .46792+000	.00000
TIME = .9200	TMM4, TMM5, TRMC = .56713+000	RATE = .46152-007	POSITION = .47339+000	.00000
TIME = .9300	TMM4, TMM5, TRMC = .56713+000	RATE = .38411-007	POSITION = .47887+000	.00000
TIME = .9400	TMM4, TMM5, TRMC = .56713+000	RATE = .31900-007	POSITION = .48434+000	.00000
TIME = .9500	TMM4, TMM5, TRMC = .56713+000	RATE = .26606-007	POSITION = .48981+000	.00000
TIME = .9600	TMM4, TMM5, TRMC = .56713+000	RATE = .22143-007	POSITION = .49528+000	.00000
TIME = .9700	TMM4, TMM5, TRMC = .56713+000	RATE = .18425-007	POSITION = .50075+000	.00000
TIME = .9800	TMM4, TMM5, TRMC = .56713+000	RATE = .15358-007	POSITION = .50622+000	.00000
TIME = .9900	TMM4, TMM5, TRMC = .56713+000	RATE = .12765-007	POSITION = .51169+000	.00000
TIME = 1.0000	TMM4, TMM5, TRMC = .56713+000	RATE = .10624-007	POSITION = .51716+000	.00000

STOP 5999

PRINT NO. 0601010
FURPUR 2783A E30 SL74K1 04/17/80 13:54:59

LADES*AXLR(13).0UCNTD*

1	A	100000.0
2	T/UA	.02
3	LA	.0014
4	RA	3.0
5	RSB	1.0
6	KT	24.8
7	h	4.5
8	JF	.016
9	JL	5.30
10	D	.706
11	KE	.177
12	100	.61

*XCT R.PAG

A 100000-000
 TAU A -0.000
 LA -00140
 RA 2.00000
 KSH 1.00000
 KT 24.00000
 K 2.50000
 JM -0.100
 JL 2.30000
 JT 4.45000
 D -70.00
 KE -17700

I, Q, K: -219301556396+004 -357155688000+010 -568409096000+009
 X, D, B, C: -159147506971+000 -408524920292-001 -145908192287+009
 B1, E2, C1, C2: -357155664414+010 -219221556396+004 -357158600291+010
 X, D, B, C: -159147506971+000 -102448820757-008 -365904792584+001
 B1, E2, C1, C2: -357155663310+010 -219221556396+004 -357158618205+010
 X, D, B, C: -159147506971+000 -260752813532-016 -931322574615-009
 B1, E2, C1, C2: -357155663310+010 -219221556396+004 -357158618205+010

ONE REAL ROOT, TWO COMPLEX ROOTS

PH, ALPHA, BEIA: -159147506971+000 -109642820823+004 -597526934639+005

IT: -622347884674+001

OMEGA, IRM1, IRM2, IRM3: -597627520368+005 -141013745719+012 -375517969901+006 -545055001595+002

G, IN: -29723387338+003 ZETA: -183463473629-001

NUM = 100 IINC = 0.1000 STOP = 1.00000

ITER = 20

IMR = -310490026270+001 PHIP = -465734931278+001

TIME = 0.100 RATE = 0.7264+000 POSITION = 23637-002
 IMM4, IMM5, IRM6: -998611+000 -17302-004 -5975232903

TIME = 0.200 RATE = 0.94457+000 POSITION = 94504-002
 IMM4, IMM5, IRM6: -998611+000 -29960-009 -11951+004

TIME = 0.300 RATE = 1.4157+001 POSITION = 21252-001
 IMM4, IMM5, IRM6: -998611+000 -51858-014 -17926+004

TIME = 0.400 RATE = 1.8662+001 POSITION = 37763-001
 IMM4, IMM5, IRM6: -998611+000 -89762-019 -23901+004

TIME = 0.500 RATE = 2.3550+001 POSITION = 58973-001
 IMM4, IMM5, IRM6: -998611+000 -15537-023 -29876+004

TIME = 0.700 RATE = 2.8248+001 POSITION = 84877-001
 IMM4, IMM5, IRM6: -998611+000 -26893-028 -35852+004

TIME = 0.700 RATE = 3.2929+001 POSITION = 11547+000
 IMM4, IMM5, IRM6: -998611+000 -46549-033 -41827+004

TIME = .2700	RATE = .12502+002	POSITION = .16998+001
TRM4, TRM5, TRM6:	.95794+000	.27125-126
TIME = .2800	RATE = .12955+002	POSITION = .16731+005
TRM4, TRM5, TRM6:	.95604+000	.46950-133
TIME = .2900	RATE = .13407+002	POSITION = .19589+001
TRM4, TRM5, TRM6:	.95490+000	.51266-138
TIME = .3000	RATE = .13858+002	POSITION = .20952+001
TRM4, TRM5, TRM6:	.95338+000	.14066-142
TIME = .3100	RATE = .14309+002	POSITION = .22361+001
TRM4, TRM5, TRM6:	.95166+000	.24348-147
TIME = .3200	RATE = .14759+002	POSITION = .23814+001
TRM4, TRM5, TRM6:	.95035+000	.42143-152
TIME = .3300	RATE = .15208+002	POSITION = .25312+001
TRM4, TRM5, TRM6:	.94884+000	.72946-157
TIME = .3400	RATE = .15656+002	POSITION = .26856+001
TRM4, TRM5, TRM6:	.94753+000	.12626-161
TIME = .3500	RATE = .16104+002	POSITION = .28444+001
TRM4, TRM5, TRM6:	.94582+000	.21855-166
TIME = .3600	RATE = .16551+002	POSITION = .30076+001
TRM4, TRM5, TRM6:	.94452+000	.37829-171
TIME = .3700	RATE = .16997+002	POSITION = .31754+001
TRM4, TRM5, TRM6:	.94282+000	.65478-176
TIME = .3800	RATE = .17443+002	POSITION = .33476+001
TRM4, TRM5, TRM6:	.94152+000	.11334-180
TIME = .3900	RATE = .17888+002	POSITION = .35242+001
TRM4, TRM5, TRM6:	.93982+000	.19617-185
TIME = .4000	RATE = .18332+002	POSITION = .37053+001
TRM4, TRM5, TRM6:	.93832+000	.33956-190
TIME = .4100	RATE = .18776+002	POSITION = .38909+001
TRM4, TRM5, TRM6:	.93683+000	.58774-195
TIME = .4200	RATE = .19219+002	POSITION = .40809+001
TRM4, TRM5, TRM6:	.93534+000	.10173-199
TIME = .4300	RATE = .19661+002	POSITION = .42752+001
TRM4, TRM5, TRM6:	.93386+000	.17609-204
TIME = .4400	RATE = .20102+002	POSITION = .44741+001
TRM4, TRM5, TRM6:	.93237+000	.30479-209
TIME = .4500	RATE = .20543+002	POSITION = .46773+001
TRM4, TRM5, TRM6:	.93089+000	.52757-214

TIME = .4600	TRM4, TRM5, TRM6 =	RATE = .20263+000	POSITION =	-48849+001
		.92941+000	.51317-219	.27486+005
TIME = .4700	TRM4, TRM5, TRM6 =	RATE = .21422+002	POSITION =	.50969+001
		.92793+000	.15806-223	.28084+005
TIME = .4800	TRM4, TRM5, TRM6 =	RATE = .21861+002	POSITION =	.53134+001
		.92665+000	.27355-228	.28681+005
TIME = .4900	TRM4, TRM5, TRM6 =	RATE = .22299+002	POSITION =	.55342+001
		.92498+000	.47355-233	.29279+005
TIME = .5000	TRM4, TRM5, TRM6 =	RATE = .22736+002	POSITION =	.57593+001
		.92351+000	.81967-238	.29876+005
TIME = .5100	TRM4, TRM5, TRM6 =	RATE = .23172+002	POSITION =	.59859+001
		.92204+000	.14188-242	.30474+005
TIME = .5200	TRM4, TRM5, TRM6 =	RATE = .23608+002	POSITION =	.62228+001
		.92058+000	.24558-247	.31071+005
TIME = .5300	TRM4, TRM5, TRM6 =	RATE = .24043+002	POSITION =	.64610+001
		.91911+000	.42507-252	.31669+005
TIME = .5400	TRM4, TRM5, TRM6 =	RATE = .24478+002	POSITION =	.67036+001
		.91765+000	.73575-257	.32266+005
TIME = .5500	TRM4, TRM5, TRM6 =	RATE = .24912+002	POSITION =	.69506+001
		.91619+000	.12735-261	.32864+005
TIME = .5600	TRM4, TRM5, TRM6 =	RATE = .25345+002	POSITION =	.72019+001
		.91473+000	.22043-266	.33462+005
TIME = .5700	TRM4, TRM5, TRM6 =	RATE = .25777+002	POSITION =	.74575+001
		.91328+000	.38153-271	.34059+005
TIME = .5800	TRM4, TRM5, TRM6 =	RATE = .26209+002	POSITION =	.77174+001
		.91183+000	.60042-276	.34657+005
TIME = .5900	TRM4, TRM5, TRM6 =	RATE = .26640+002	POSITION =	.79816+001
		.91038+000	.11431-280	.35254+005
TIME = .6000	TRM4, TRM5, TRM6 =	RATE = .27070+002	POSITION =	.82502+001
		.90893+000	.19787-285	.35852+005
TIME = .6100	TRM4, TRM5, TRM6 =	RATE = .27500+002	POSITION =	.85230+001
		.90746+000	.34248-290	.36449+005
TIME = .6200	TRM4, TRM5, TRM6 =	RATE = .27928+002	POSITION =	.88002+001
		.90604+000	.59281-295	.37047+005
TIME = .6300	TRM4, TRM5, TRM6 =	RATE = .28357+002	POSITION =	.90816+001
		.90460+000	.10261-299	.37644+005
TIME = .6400	TRM4, TRM5, TRM6 =	RATE = .28784+002	POSITION =	.93673+001
		.90316+000	.17761-304	.38242+005

TIME = .6500	RATE = .29211+002	POSITION = .90573+001
TRM4,TRM5,TRM6 = .90174+000		.38839+005
TIME = .6600	RATE = .29037+002	POSITION = .90515+001
TRM4,TRM5,TRM6 = .90029+000		.39437+005
TIME = .6700	RATE = .30063+002	POSITION = .10250+002
TRM4,TRM5,TRM6 = .89836+000		.40034+005
TIME = .6800	RATE = .30428+002	POSITION = .10553+002
TRM4,TRM5,TRM6 = .89743+000		.40632+005
TIME = .6900	RATE = .30912+002	POSITION = .10860+002
TRM4,TRM5,TRM6 = .89600+000		.41229+005
TIME = .7000	RATE = .31336+002	POSITION = .11171+002
TRM4,TRM5,TRM6 = .89458+000		.41827+005
TIME = .7100	RATE = .31758+002	POSITION = .11487+002
TRM4,TRM5,TRM6 = .89316+000		.42424+005
TIME = .7200	RATE = .32181+002	POSITION = .11806+002
TRM4,TRM5,TRM6 = .89174+000		.43022+005
TIME = .7300	RATE = .32602+002	POSITION = .12130+002
TRM4,TRM5,TRM6 = .89032+000		.43619+005
TIME = .7400	RATE = .33023+002	POSITION = .12458+002
TRM4,TRM5,TRM6 = .88890+000		.44217+005
TIME = .7500	RATE = .33443+002	POSITION = .12791+002
TRM4,TRM5,TRM6 = .88749+000		.44815+005
TIME = .7600	RATE = .33863+002	POSITION = .13127+002
TRM4,TRM5,TRM6 = .88608+000		.45412+005
TIME = .7700	RATE = .34281+002	POSITION = .13458+002
TRM4,TRM5,TRM6 = .88467+000		.46010+005
TIME = .7800	RATE = .34700+002	POSITION = .13813+002
TRM4,TRM5,TRM6 = .88326+000		.46607+005
TIME = .7900	RATE = .35117+002	POSITION = .14162+002
TRM4,TRM5,TRM6 = .88186+000		.47203+005
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TRM4,TRM5,TRM6 = .87905+000		.48400+005
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TRM4,TRM5,TRM6 = .87766+000		.48997+005
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TRM4,TRM5,TRM6 = .87626+000		.49595+005

TIME = .8400	TAM4, TAM5, TAM6 =	RATE = .3719+002	POSITION =	-15970+002
		.37467+000	.0000	.50192+005
TIME = .8500	TAM4, TAM5, TAM6 =	RATE = .37609+002	POSITION =	-16344+002
		.87358+000	.0000	.50790+005
TIME = .8600	TAM4, TAM5, TAM6 =	RATE = .38021+002	POSITION =	-16722+002
		.87209+000	.0000	.51387+005
TIME = .8700	TAM4, TAM5, TAM6 =	RATE = .38433+002	POSITION =	-17104+002
		.87070+000	.0000	.51985+005
TIME = .8800	TAM4, TAM5, TAM6 =	RATE = .38845+002	POSITION =	-17490+002
		.86931+000	.0000	.52582+005
TIME = .8900	TAM4, TAM5, TAM6 =	RATE = .39256+002	POSITION =	-17881+002
		.86793+000	.0000	.53180+005
TIME = .9000	TAM4, TAM5, TAM6 =	RATE = .39668+002	POSITION =	-18276+002
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TIME = .9100	TAM4, TAM5, TAM6 =	RATE = .40075+002	POSITION =	-18674+002
		.86517+000	.0000	.54375+005
TIME = .9200	TAM4, TAM5, TAM6 =	RATE = .40484+002	POSITION =	-19077+002
		.86380+000	.0000	.54972+005
TIME = .9300	TAM4, TAM5, TAM6 =	RATE = .40893+002	POSITION =	-19484+002
		.86242+000	.0000	.55570+005
TIME = .9400	TAM4, TAM5, TAM6 =	RATE = .41300+002	POSITION =	-19895+002
		.86105+000	.0000	.56168+005
TIME = .9500	TAM4, TAM5, TAM6 =	RATE = .41707+002	POSITION =	-20310+002
		.85966+000	.0000	.56765+005
TIME = .9600	TAM4, TAM5, TAM6 =	RATE = .42114+002	POSITION =	-20729+002
		.85832+000	.0000	.57363+005
TIME = .9700	TAM4, TAM5, TAM6 =	RATE = .42519+002	POSITION =	-21152+002
		.85695+000	.0000	.57960+005
TIME = .9800	TAM4, TAM5, TAM6 =	RATE = .42924+002	POSITION =	-21579+002
		.85559+000	.0000	.58558+005
TIME = .9900	TAM4, TAM5, TAM6 =	RATE = .43329+002	POSITION =	-22011+002
		.85423+000	.0000	.59155+005
TIME = 1.0000	TAM4, TAM5, TAM6 =	RATE = .43733+002	POSITION =	-22446+002
		.85287+000	.0000	.59753+005

STOP 5999

APR 11 1980 04/17/80 13:55:03
PURPUN 2763A

1	LADSS+AKLIK (1) - JUCNTDR	1000000.0
2	TAUA	.02
3	LA	.00276
4	HA	9.317
5	RSU	1.0
6	KT	19.75
7	KA	12.8
8	JF	.0013
9	JL	2.47
10	D	.022
11	KE	.141
12	100	.01 .0

WGT R-PROG

NAME	DATE	TIME	LOCATION	STATUS	REMARKS
1. J. A. Smith	1978-07-10	10:00	1000000000	0000000000	0000000000
2. B. C. Jones	1978-07-10	10:00	1000000000	0000000000	0000000000
3. D. E. Brown	1978-07-10	10:00	1000000000	0000000000	0000000000
4. F. G. White	1978-07-10	10:00	1000000000	0000000000	0000000000
5. H. I. Black	1978-07-10	10:00	1000000000	0000000000	0000000000
6. K. L. Green	1978-07-10	10:00	1000000000	0000000000	0000000000
7. M. N. Blue	1978-07-10	10:00	1000000000	0000000000	0000000000
8. P. Q. Yellow	1978-07-10	10:00	1000000000	0000000000	0000000000
9. R. S. Purple	1978-07-10	10:00	1000000000	0000000000	0000000000
10. T. U. Pink	1978-07-10	10:00	1000000000	0000000000	0000000000
11. V. W. Grey	1978-07-10	10:00	1000000000	0000000000	0000000000
12. X. Y. Brown	1978-07-10	10:00	1000000000	0000000000	0000000000
13. Z. A. Green	1978-07-10	10:00	1000000000	0000000000	0000000000
14. B. C. Blue	1978-07-10	10:00	1000000000	0000000000	0000000000
15. D. E. Yellow	1978-07-10	10:00	1000000000	0000000000	0000000000
16. F. G. Purple	1978-07-10	10:00	1000000000	0000000000	0000000000
17. H. I. Pink	1978-07-10	10:00	1000000000	0000000000	0000000000
18. K. L. Grey	1978-07-10	10:00	1000000000	0000000000	0000000000
19. M. N. Brown	1978-07-10	10:00	1000000000	0000000000	0000000000
20. P. Q. Blue	1978-07-10	10:00	1000000000	0000000000	0000000000
21. R. S. Yellow	1978-07-10	10:00	1000000000	0000000000	0000000000
22. T. U. Purple	1978-07-10	10:00	1000000000	0000000000	0000000000
23. V. W. Pink	1978-07-10	10:00	1000000000	0000000000	0000000000
24. X. Y. Grey	1978-07-10	10:00	1000000000	0000000000	0000000000
25. Z. A. Brown	1978-07-10	10:00	1000000000	0000000000	0000000000
26. B. C. Blue	1978-07-10	10:00	1000000000	0000000000	0000000000
27. D. E. Yellow	1978-07-10	10:00	1000000000	0000000000	0000000000
28. F. G. Purple	1978-07-10	10:00	1000000000	0000000000	0000000000
29. H. I. Pink	1978-07-10	10:00	1000000000	0000000000	0000000000
30. K. L. Grey	1978-07-10	10:00	1000000000	0000000000	0000000000
31. M. N. Brown	1978-07-10	10:00	1000000000	0000000000	0000000000
32. P. Q. Blue	1978-07-10	10:00	1000000000	0000000000	0000000000
33. R. S. Yellow	1978-07-10	10:00	1000000000	0000000000	0000000000
34. T. U. Purple	1978-07-10	10:00	1000000000	0000000000	0000000000
35. V. W. Pink	1978-07-10	10:00	1000000000	0000000000	0000000000
36. X. Y. Grey	1978-07-10	10:00	1000000000	0000000000	0000000000
37. Z. A. Brown	1978-07-10	10:00	1000000000	0000000000	0000000000
38. B. C. Blue	1978-07-10	10:00	1000000000	0000000000	0000000000
39. D. E. Yellow	1978-07-10	10:00	1000000000	0000000000	0000000000
40. F. G. Purple	1978-07-10	10:00	1000000000	0000000000	0000000000
41. H. I. Pink	1978-07-10	10:00	1000000000	0000000000	0000000000
42. K. L. Grey	1978-07-10	10:00	1000000000	0000000000	0000000000
4					

ONE MEAL KCOI, TWO COMPLEX LOOTS

KK, ALPHA, BETA: -.230705c11655+u60 -.170071857053+004 -.423780211385+005

100+579R2R257E57- 11:

CPYLA, IRM1, IRM2, IRM3: .424121341042+005 .337956789346+011 .183836554946+006 --.249210938662+002

GA1N - .4034559J4261+003
ZETA = .400998112087-001

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UR = 100          TINC = .01000  STOPT = 1.00000

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1166 = 4311

$$\text{PHIP} = -.459206271850+001$$

TIME = -010 RATE = .52950+000 POSITION = .46483-002

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TIME =	.02UC	RATE =	.1857U+001	POSITION =	.18583-001
		YOMS =	YRMS =		.16895-014
					.24756+003

DATE - 11/2/68
PAGE - 2782/4001
POSITION - 41782-001

YAM4, IAMS, IIRMG:	•99310+00G	•04462-022	•12713+004
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IIPI =	.040C	RATE =	.37057+CU1	POSITION =	.74224-001
					.16951+004

[illegible]

YANKS, YAMS, YIMOS	98053+000	11732-036	21189+004
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TIME =	.060C	RATE =	.5545R+CG1	POSITION =	.16675+000
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IMM4	IMM5	IMM6	19820-051	29665+006

[illegible]

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TIME = .0000	RATE = .73775+001 TMM4,TMMS,TMM6 = .92171+000	POSITION = .21600+000 .11462-059
TIME = .0000	RATE = .02902+001 TMM4,TMMS,TMM6 = .77545+000	POSITION = .37434+000 .33466-066
TIME = .1000	RATE = .92007+001 TMM4,TMMS,TMM6 = .97719+000	POSITION = .46160+000 .13764-073
TIME = .1100	RATE = .10109+002 TMM4,TMMS,TMM6 = .97494+000	POSITION = .55835+000 .56572-061
TIME = .1100	RATE = .11016+002 TMM4,TMMS,TMM6 = .97270+000	POSITION = .60397+000 .23253-088
TIME = .1100	RATE = .11920+002 TMM4,TMMS,TMM6 = .97045+000	POSITION = .77865+000 .95576-096
TIME = .1600	RATE = .12822+002 TMM4,TMMS,TMM6 = .96622+000	POSITION = .90236+000 .39265-103
TIME = .1100	RATE = .13722+002 TMM4,TMMS,TMM6 = .96594+000	POSITION = .10351+001 .16147-110
TIME = .1600	RATE = .14620+002 TMM4,TMMS,TMM6 = .96376+000	POSITION = .11768+001 .66370-116
TIME = .1700	RATE = .15510+002 TMM4,TMMS,TMM6 = .96154+000	POSITION = .13275+001 .27260-125
TIME = .1800	RATE = .16410+002 TMM4,TMMS,TMM6 = .95932+000	POSITION = .14871+001 .11211-132
TIME = .1900	RATE = .17302+002 TMM4,TMMS,TMM6 = .95711+000	POSITION = .16557+001 .46082-140
TIME = .2000	RATE = .18192+002 TMM4,TMMS,TMM6 = .95491+000	POSITION = .18332+001 .18944-147
TIME = .2100	RATE = .19080+002 TMM4,TMMS,TMM6 = .95271+000	POSITION = .20195+001 .77864-155
TIME = .2200	RATE = .19965+002 TMM4,TMMS,TMM6 = .95051+000	POSITION = .22147+001 .32004-162
TIME = .2300	RATE = .20849+002 TMM4,TMMS,TMM6 = .94832+000	POSITION = .24188+001 .13155-169
TIME = .2400	RATE = .21731+002 TMM4,TMMS,TMM6 = .94614+000	POSITION = .26317+001 .54070-177
TIME = .2500	RATE = .22610+002 TMM4,TMMS,TMM6 = .94396+000	POSITION = .28534+001 .22224-184
TIME = .2600	RATE = .23486+002 TMM4,TMMS,TMM6 = .94176+000	POSITION = .30839+001 .91349-192

TIME = -2700	TRM4,IRMS,IRMS6:	RATE =	-4365+002	POSITION =	-3522+001
			-93901+000		-11442+005
TIME = -2800	TRM4,IRMS,IRMS6:	RATE =	-25237+002	POSITION =	-35712+001
			-93744+000		-11866+005
TIME = -2900	TRM4,IRMS,IRMS6:	RATE =	-26106+002	POSITION =	-38279+001
			-93528+000		-12290+005
TIME = -3000	TRM4,IRMS,IRMS6:	RATE =	-25976+002	POSITION =	-40933+001
			-93513+000		-12713+005
TIME = -3100	TRM4,IRMS,IRMS6:	RATE =	-27845+002	POSITION =	-43674+001
			-93098+000		-13157+005
TIME = -3200	TRM4,IRMS,IRMS6:	RATE =	-28711+002	POSITION =	-46503+001
			-92883+000		-13561+005
TIME = -3300	TRM4,IRMS,IRMS6:	RATE =	-29574+002	POSITION =	-49416+001
			-92665+000		-13985+005
TIME = -3400	TRM4,IRMS,IRMS6:	RATE =	-30636+002	POSITION =	-52417+001
			-92456+000		-14409+005
TIME = -3500	TRM4,IRMS,IRMS6:	RATE =	-31295+002	POSITION =	-55504+001
			-92243+000		-14832+005
TIME = -3600	TRM4,IRMS,IRMS6:	RATE =	-32153+002	POSITION =	-58676+001
			-92030+000		-15256+005
TIME = -3700	TRM4,IRMS,IRMS6:	RATE =	-33009+002	POSITION =	-61934+001
			-91618+000		-15680+005
TIME = -3800	TRM4,IRMS,IRMS6:	RATE =	-33862+002	POSITION =	-65278+001
			-91606+000		-16104+005
TIME = -3900	TRM4,IRMS,IRMS6:	RATE =	-34714+002	POSITION =	-68706+001
			-91395+000		-16527+005
TIME = -4000	TRM4,IRMS,IRMS6:	RATE =	-35563+002	POSITION =	-72220+001
			-91165+000		-16951+005
TIME = -4100	TRM4,IRMS,IRMS6:	RATE =	-36411+002	POSITION =	-75819+001
			-90975+000		-17375+005
TIME = -4200	TRM4,IRMS,IRMS6:	RATE =	-37257+002	POSITION =	-79503+001
			-90765+000		-17799+005
TIME = -4300	TRM4,IRMS,IRMS6:	RATE =	-38101+002	POSITION =	-83270+001
			-90556+000		-18223+005
TIME = -4400	TRM4,IRMS,IRMS6:	RATE =	-38943+002	POSITION =	-87123+001
			-90347+000		-18646+005
TIME = -4500	TRM4,IRMS,IRMS6:	RATE =	-39783+002	POSITION =	-91059+001
			-90139+000		-19070+005

TIME = .4600	RATE = .4023+002 TRM4,TRM5,TRM6 = .59531+000	POSITION = .95079+001 .00000	.19494+005
TIME = .4700	RATE = .41457+002 TRM4,TRM5,TRM6 = .59724+000	POSITION = .99123+001 .00000	.19918+005
TIME = .4800	RATE = .42291+002 TRM4,TRM5,TRM6 = .59517+000	POSITION = .10337+002 .00000	.20341+005
TIME = .4900	RATE = .43123+002 TRM4,TRM5,TRM6 = .89211+000	POSITION = .10764+002 .00000	.20765+005
TIME = .5000	RATE = .43953+002 TRM4,TRM5,TRM6 = .89103+000	POSITION = .11199+002 .00000	.21189+005
TIME = .5100	RATE = .44784+002 TRM4,TRM5,TRM6 = .68400+000	POSITION = .11643+002 .00000	.21613+005
TIME = .5200	RATE = .45608+002 TRM4,TRM5,TRM6 = .88695+000	POSITION = .12093+002 .00000	.22037+005
TIME = .5300	RATE = .46433+002 TRM4,TRM5,TRM6 = .88491+000	POSITION = .12553+002 .00000	.22460+005
TIME = .5400	RATE = .47255+002 TRM4,TRM5,TRM6 = .88407+000	POSITION = .13024+002 .00000	.22884+005
TIME = .5500	RATE = .48076+002 TRM4,TRM5,TRM6 = .88063+000	POSITION = .13500+002 .00000	.23308+005
TIME = .5600	RATE = .48895+002 TRM4,TRM5,TRM6 = .87880+000	POSITION = .13983+002 .00000	.23732+005
TIME = .5700	RATE = .49712+002 TRM4,TRM5,TRM6 = .87678+000	POSITION = .14478+002 .00000	.24155+005
TIME = .5800	RATE = .50527+002 TRM4,TRM5,TRM6 = .87476+000	POSITION = .14980+002 .00000	.24579+005
TIME = .5900	RATE = .51340+002 TRM4,TRM5,TRM6 = .87274+000	POSITION = .15489+002 .00000	.25003+005
TIME = .6000	RATE = .52152+002 TRM4,TRM5,TRM6 = .87073+000	POSITION = .16006+002 .00000	.25427+005
TIME = .6100	RATE = .52961+002 TRM4,TRM5,TRM6 = .86872+000	POSITION = .16532+002 .00000	.25851+005
TIME = .6200	RATE = .53769+002 TRM4,TRM5,TRM6 = .86672+000	POSITION = .17066+002 .00000	.26274+005
TIME = .6300	RATE = .54575+002 TRM4,TRM5,TRM6 = .86472+000	POSITION = .17607+002 .00000	.26698+005
TIME = .6400	RATE = .55379+002 TRM4,TRM5,TRM6 = .86273+000	POSITION = .18157+002 .00000	.27122+005

TIME = .6500	TAM4, TAM5, TRM6:	RATE = .5611+002	POSITION = .12715+002
			.00000
TIME = .6600	TAM4, TAM5, TRM6:	RATE = .56981+002	POSITION = .17261+002
			.00000
TIME = .6700	TAM4, TAM5, TRM6:	RATE = .57779+002	POSITION = .19654+002
			.00000
TIME = .6800	TAM4, TAM5, TRM6:	RATE = .58576+002	POSITION = .20436+002
			.00000
TIME = .6900	TAM4, TAM5, TRM6:	RATE = .59370+002	POSITION = .21026+002
			.00000
TIME = .7000	TAM4, TAM5, TRM6:	RATE = .60163+002	POSITION = .21624+002
			.00000
TIME = .7100	TAM4, TAM5, TRM6:	RATE = .60954+002	POSITION = .22229+002
			.00000
TIME = .7200	TAM4, TAM5, TRM6:	RATE = .61744+002	POSITION = .22843+002
			.00000
TIME = .7300	TAM4, TAM5, TRM6:	RATE = .62531+002	POSITION = .23464+002
			.00000
TIME = .7400	TAM4, TAM5, TRM6:	RATE = .63316+002	POSITION = .24093+002
			.00000
TIME = .7500	TAM4, TAM5, TRM6:	RATE = .64100+002	POSITION = .24750+002
			.00000
TIME = .7600	TAM4, TAM5, TRM6:	RATE = .64882+002	POSITION = .25375+002
			.00000
TIME = .7700	TAM4, TAM5, TRM6:	RATE = .65662+002	POSITION = .26028+002
			.00000
TIME = .7800	TAM4, TAM5, TRM6:	RATE = .66441+002	POSITION = .26689+002
			.00000
TIME = .7900	TAM4, TAM5, TRM6:	RATE = .67217+002	POSITION = .27357+002
			.00000
TIME = .8000	TAM4, TAM5, TRM6:	RATE = .67992+002	POSITION = .28033+002
			.00000
TIME = .8100	TAM4, TAM5, TRM6:	RATE = .68765+002	POSITION = .28717+002
			.00000
TIME = .8200	TAM4, TAM5, TRM6:	RATE = .69536+002	POSITION = .29408+002
			.00000
TIME = .8300	TAM4, TAM5, TRM6:	RATE = .70306+002	POSITION = .30107+002
			.00000

TIME = .0400	RATE = .7107+002	POSITION = .30214+002
TIME4, TIME5, TIME6 =	.7107+002	.30214+002
TIME = .0500	RATE = .7153+002	POSITION = .31529+002
TIME4, TIME5, TIME6 =	.7153+002	.31529+002
TIME = .0600	RATE = .7200+002	POSITION = .32251+002
TIME4, TIME5, TIME6 =	.7200+002	.32251+002
TIME = .0700	RATE = .7336+002	POSITION = .32981+002
TIME4, TIME5, TIME6 =	.7336+002	.32981+002
TIME = .0800	RATE = .7412+002	POSITION = .33718+002
TIME4, TIME5, TIME6 =	.7412+002	.33718+002
TIME = .0900	RATE = .7488+002	POSITION = .34463+002
TIME4, TIME5, TIME6 =	.7488+002	.34463+002
TIME = .1000	RATE = .7564+002	POSITION = .35216+002
TIME4, TIME5, TIME6 =	.7564+002	.35216+002
TIME = .1100	RATE = .7639+002	POSITION = .35976+002
TIME4, TIME5, TIME6 =	.7639+002	.35976+002
TIME = .1200	RATE = .7715+002	POSITION = .36744+002
TIME4, TIME5, TIME6 =	.7715+002	.36744+002
TIME = .1300	RATE = .7790+002	POSITION = .37519+002
TIME4, TIME5, TIME6 =	.7790+002	.37519+002
TIME = .1400	RATE = .7865+002	POSITION = .38302+002
TIME4, TIME5, TIME6 =	.7865+002	.38302+002
TIME = .1500	RATE = .7940+002	POSITION = .39092+002
TIME4, TIME5, TIME6 =	.7940+002	.39092+002
TIME = .1600	RATE = .8016+002	POSITION = .39890+002
TIME4, TIME5, TIME6 =	.8016+002	.39890+002
TIME = .1700	RATE = .8093+002	POSITION = .40695+002
TIME4, TIME5, TIME6 =	.8093+002	.40695+002
TIME = .1800	RATE = .8163+002	POSITION = .41508+002
TIME4, TIME5, TIME6 =	.8163+002	.41508+002
TIME = .1900	RATE = .8237+002	POSITION = .42328+002
TIME4, TIME5, TIME6 =	.8237+002	.42328+002
TIME = .2000	RATE = .8311+002	POSITION = .43156+002
TIME4, TIME5, TIME6 =	.8311+002	.43156+002

STOP 1995

APCA R. 130.307481 04/17/80 13:55:00

LADSS* AML30I

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      1. COMMON /SIASTZ/ Y1001,Y01301
      2. COMP-01 / STEP/ DT,MIT,MSYS,M024
      3. EQUIVALENCE (Y111),P1,(Y011),M01
      4. EQUIVALENCE (Y121),V1,(Y012),V01
      5. EQUIVALENCE (Y131),X1,(Y013),X01
      6. EQUIVALENCE (Y141),X1,(Y014),X01
      7. MSIS = 4
      8. READ(5,90) DT
      9. FORMAT(7X,E10.0)
     10. READ (5,100) STPTM,ST,DP,P1M
     11. M024 = DT/24.0
     12. DO 10 I = 1,30
     13.   Y111 = P1*0
     14.   Y011 = 0.0
     15. CONTINUE
     16. READ(5,100) A0,FLA,PA,PSB,ENT,EM,EJM,EJL,FM,FL,EKE,TAUA
     17. FORMAT(7X,F10.0)
     18. P = 0.0
     19. T = 0.0
     20. MIT = 0
     21. IF = T + DF
     22. WRITE(5,300) DT,STPTM,ST,DP,A0,FLA,PA,PSB,ENT,EM,EJM,EJL,FM,FL,
      EKE,TAUA
     23.
     24. 300
     25.   FORMAT('DT,STPTM,ST,DP = ',4F10.6,'/
      'A0,LA,PA,PSB: ',G10.5,3(3X,F10.5),
      'L/
      'C,RT,H,UM,UL: ',4F10.5,3X),
     26.   'C,FM,FL,EKE,TAUA: ',4F10.5,3X),
     27.   'C,O',FX,TIME',17X,F',14X,'H',13X,'XR',
     28.   '13X,'Y')
     29.
     30.   EJT = EM*EN*EJM + EJL
     31.   ET = E*EN*EJM + FL
     32. 20
     33.  C
     34.   SYMMETRIC LIMITER
     35.   P = AMIN1(MAX1(P, 24.0),26.0)
     36.   PD = (E*AC - P)/TAUA
     37.   U = P - EN*EKE*XP
     38.   YD = .5*(U + V*0.5/ELA
     39.   W = V*FT*EN
     40.   XRD = (W - YR*FT)/FJT
     41.   YD = YP
     42.   CALL EQINT
     43.   T = T + DT
     44.   MIT = MIT + 1
     45.   IF (T .GE. STPTM) P = P1M
     46.   IF (T .GE. ST) GO TO 30
     47.   IF (T .GT. DT) .LT. TP1 .AND. (MIT .GE. 101) GO TO 20
     48.   WRITE(6,200) T,P,R,XP,X, U,V,W,XD,XRD
     49.   200
     50.   FORMAT('O',5G15.5,' ',10Y,'U,V,W,XD,XRD: ',5G15.5)
     51.   IP = IP + DM
     52.   IF (T .LT. ST) GO TO 20
     53.   STOP
     54.   END

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END FTH 114 TRANS 190 DBANK 64 COMMON

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      DTN,S L.EQNT
      FTH DRJ 04/17/80-14:03(3,1)
      SUBROUTINE EQINT
      COMMON /STATO/ Y(30),YD(36)
      COMMON /STEP/ DT,NT,MSYS,N024
      DIMENSION C(4),FSAV(30,4)
      DATA C/-9.0,37.0,-59.0,55.0/
      DATA FSAV/120*0.0/
      IFINIT .GE. 31 GO TO 20
      8. C
      9. C USE EULERS METHOD TO START
      10. C
      11. DO 10 I=1,MSYS
      12. FSAV(I,1) = FSAV(I,2)
      13. FSAV(I,2) = FSAV(I,3)
      14. FSAV(I,3) = FSAV(I,4)
      15. FSAV(I,4) = YD(I)
      16. Y(I) = Y(I) + DT*FSAV(I,4)
      17. 10 CONTINUE
      18. GO TO 40
      19. C
      20. C ADAMS -BASHFORTH
      21. C
      22. 20 DO 30 I=1,MSYS
      23. SUM = 0.0
      24. FSAV(I,1) = FSAV(I,2)
      25. FSAV(I,2) = FSAV(I,3)
      26. FSAV(I,3) = FSAV(I,4)
      27. FSAV(I,4) = YD(I)
      28. SUM = SUM + C(1)*FSAV(I,1)
      29. SUM = SUM + C(2)*FSAV(I,2)
      30. SUM = SUM + C(3)*FSAV(I,3)
      31. SUM = SUM + C(4)*FSAV(I,4)
      32. Y(I) = Y(I) + H024*SUM
      33. 30 CONTINUE
      34. 40 RETURN
      35. END
      END FIN 68 IRANK.131 DBANK.64 CPMQM

```

1	OT	50E-4
2	STPM	0.0
3	ST	1.0
4	DP	.01
5	PTH	1.0
6	AO	20000.0
7	LA	.0014
8	PA	3.0
9	ASB	1.0
10	KT	24.8
11	M	8.5
12	JN	.016
13	JL	3.30
14	FL	0.2
15	FL	.70%
16	KE	.177
17	TAUA	.02

EXOT L. PROG

TIME				P				R				X			
50000-006				1.0000				.00000				.00000			
U,V,W,XD,XRD:															
10000-005				1.0000				2.5000				.00000			
U,V,W,XD,XRD:															
15000-005				1.0000				4.9999				.00000			
U,V,W,XD,XRD:															
20000-005				1.0000				9.4322				.48398-007			
U,V,W,XD,XRD:															
25000-005				1.0000				10.921				.55456-013			
U,V,W,XD,XRD:															
30000-005				1.0000				13.397				.37968-006			
U,V,W,XD,XRD:															
35000-005				1.0000				15.867				.45602-012			
U,V,W,XD,XRD:															
40000-005				1.0000				19.317				.85127-012			
U,V,W,XD,XRD:															
45000-005				1.0000				20.753				.15951-011			
U,V,W,XD,XRD:															
10000+000				1.0000				10.061				.23540			
U,V,W,XD,XRD:															
11000				1.0000				10.761				.28471			
U,V,W,XD,XRD:															
12000				1.0000				11.460				.33867			
U,V,W,XD,XRD:															
13000				1.0000				12.158				.39729			
U,V,W,XD,XRD:															
14000				1.0000				12.855				.46054			
U,V,W,XD,XRD:															
15000				1.0000				13.550				.52842			
U,V,W,XD,XRD:															
16000				1.0000				14.245				.60090			
U,V,W,XD,XRD:															
17000				1.0000				14.938				.67800			
U,V,W,XD,XRD:															

.18000	U,V,W,XD,XRD:	1.0000	15.631	.99983	8.1949	210.76	.75971	8.3949	45.969
.19000	U,V,W,XD,XRD:	1.0000	16.319	.99982	9.2534	210.76	.84602	8.8534	45.896
.20000	U,V,W,XD,XRD:	1.0000	17.009	.99982	9.3119	210.75	.93592	9.3119	45.823
.21000	U,V,W,XD,XRD:	1.0000	17.698	.99981	9.7696	210.76	1.0324	9.7695	45.750
.22000	U,V,W,XD,XRD:	1.0000	18.384	.99980	10.226	210.76	1.1324	10.226	45.678
.23000	U,V,W,XD,XRD:	1.0000	19.070	.99980	10.682	210.76	1.2369	10.682	45.605
.24000	U,V,W,XD,XRD:	1.0000	19.756	.99979	11.138	210.76	1.3461	11.138	45.532
.25000	U,V,W,XD,XRD:	1.0000	20.439	.99978	11.591	210.75	1.4597	11.591	45.460
.26000	U,V,W,XD,XRD:	1.0000	21.121	.99978	12.045	210.75	1.5780	12.045	45.388
.27000	U,V,W,XD,XRD:	1.0000	21.804	.99977	12.499	210.75	1.7007	12.499	45.316
.28000	U,V,W,XD,XRD:	1.0000	22.484	.99976	12.951	210.75	1.8280	12.951	45.244
.29000	U,V,W,XD,XRD:	1.0000	23.163	.99975	13.402	210.75	1.9599	13.402	45.172
.30000	U,V,W,XD,XRD:	1.0000	23.842	.99975	13.853	210.75	2.0961	13.853	45.100
.31000	U,V,W,XD,XRD:	1.0000	24.519	.99974	14.304	210.75	2.2368	14.304	45.029
.32000	U,V,W,XD,XRD:	1.0000	25.195	.99973	14.753	210.74	2.3821	14.753	44.957
.33000	U,V,W,XD,XRD:	1.0000	25.870	.99973	15.202	210.74	2.5318	15.202	44.886
.34000	U,V,W,XD,XRD:	1.0000	26.545	.84185	15.620	177.46	2.6859	15.620	37.351
.35000	U,V,W,XD,XRD:	1.0000	26.815	.67384	15.952	142.05	2.8438	15.952	29.350
.36000	U,V,W,XD,XRD:	1.0000	27.143	.54238	16.211	114.33	3.0046	16.211	23.090

.55000	1.0000	28.331	17.147	6.3909	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		
.57000	1.0000	28.331	17.147	6.5616	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		
.58000	1.0000	28.331	17.147	6.7324	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		
.59000	1.0000	28.331	17.147	6.9031	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		
.60000	1.0000	28.331	17.147	7.0739	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		
.61000	1.0000	28.331	17.147	7.2446	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		
.62000	1.0000	28.331	17.147	7.4154	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		
.63000	1.0000	28.331	17.147	7.5861	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		
.64000	1.0000	28.331	17.147	7.7569	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		
.65000	1.0000	28.331	17.147	7.9276	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		
.66000	1.0000	28.331	17.147	8.0977	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		
.67000	1.0000	28.331	17.147	8.2672	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		
.68000	1.0000	28.331	17.147	8.4368	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		
.69000	1.0000	28.331	17.147	8.6063	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		
.70000	1.0000	28.331	17.147	8.7759	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		
.71000	1.0000	28.331	17.147	8.9454	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		
.72000	1.0000	28.331	17.147	9.1150	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		
.73000	1.0000	28.331	17.147	9.2845	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		
.74000	1.0000	28.331	17.147	9.4541	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001	14.207		

.75000	1.0000	28.331	17.147	14.207	9.6236	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				
.76000	1.0000	28.331	17.147	14.207	9.6236	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				
.77000	1.0000	28.331	17.147	14.207	9.6236	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				
.78000	1.0000	28.331	17.147	14.207	10.132	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				
.79000	1.0000	28.331	17.147	14.207	10.302	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				
.80000	1.0000	28.331	17.147	14.207	10.471	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				
.81000	1.0000	28.331	17.147	14.207	10.641	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				
.82000	1.0000	28.331	17.147	14.207	10.811	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				
.83000	1.0000	28.331	17.147	14.207	10.980	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				
.84000	1.0000	28.331	17.147	14.207	11.150	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				
.85000	1.0000	28.331	17.147	14.207	11.319	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				
.86000	1.0000	28.331	17.147	14.207	11.489	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				
.87000	1.0000	28.331	17.147	14.207	11.658	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				
.88000	1.0000	28.331	17.147	14.207	11.828	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				
.89000	1.0000	28.331	17.147	14.207	11.997	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				
.90000	1.0000	28.331	17.147	14.207	12.167	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				
.91000	1.0000	28.331	17.147	14.207	12.336	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				
.92000	1.0000	28.331	17.147	14.207	12.506	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				
.93000	1.0000	28.331	17.147	14.207	12.676	17.147	.47158
U,V,W,XD,XRD:	.20219		.67397-001				

.94000	1.0000	28.331	17.147	14.207	12.845	17.147	.47158
U, V, W, X, Y, Z		.20219	.67397-001				
.95000	1.0000	28.331	17.147	14.207	13.015	17.147	.47158
U, V, W, X, Y, Z		.20219	.67397-001				
.96000	1.0000	28.331	17.147	14.207	13.184	17.147	.47158
U, V, W, X, Y, Z		.20219	.67397-001				
.97000	1.0000	28.331	17.147	14.207	13.354	17.147	.47158
U, V, W, X, Y, Z		.20219	.67397-001				
.98000	1.0000	28.331	17.147	14.207	13.523	17.147	.47158
U, V, W, X, Y, Z		.20219	.67397-001				
.99000	1.0000	28.331	17.147	14.207	13.693	17.147	.47158
U, V, W, X, Y, Z		.20219	.67397-001				
1.0000	1.0000	28.331	17.147	14.207	13.862	17.147	.47158
U, V, W, X, Y, Z		.20219	.67397-001				
1.0000	1.0000	28.331	17.147	14.207	13.862	17.147	.47158
U, V, W, X, Y, Z		.20219	.67397-001				

PART 1.16CINTOR
 FURFUR 27R31 E36 502481 04/17/80 J4212137

1	DT	SDE-4
2	STPM	0.0
3	ST	1.1
4	OP	.01
5	PM	1.1
6	AO	100000.0
7	LA	.00273
8	RA	2.317
9	RSR	1.6
10	KT	19.75
11	Y	12.4
12	JH	.0015
13	JL	2.47
14	FM	0.0
15	FL	.622
16	CE	.141
17	TAUA	.02

0201 L. PROC

18000	1.0000	27.047	13.054	45.447	1.3896	13.066	21.291
U,V,W,XD,XRD;							
19000	1.0000	27.242	13.259	56.409	1.5213	13.259	17.734
U,V,W,XD,XRD;							
20000	1.0000	28.020	13.421	48.473	1.6548	13.421	14.775
U,V,W,XD,XRD;							
21000	1.0000	28.085	13.555	41.971	1.7898	13.555	12.313
U,V,W,XD,XRD;							
22000	1.0000	28.140	13.666	36.377	1.9260	13.666	10.265
U,V,W,XD,XRD;							
23000	1.0000	28.185	13.759	31.806	2.0631	13.759	8.5604
U,V,W,XD,XRD;							
24000	1.0000	28.222	13.836	28.003	2.2010	13.836	7.1424
U,V,W,XD,XRD;							
25000	1.0000	28.254	13.901	24.837	2.3397	13.901	5.9626
U,V,W,XD,XRD;							
26000	1.0000	28.280	13.954	22.206	2.4789	13.954	4.9808
U,V,W,XD,XRD;							
27000	1.0000	28.301	13.998	20.019	2.6186	13.998	4.1652
U,V,W,XD,XRD;							
28000	1.0000	28.319	14.035	18.196	2.7587	14.035	3.4856
U,V,W,XD,XRD;							
29000	1.0000	28.334	14.066	16.680	2.8990	14.066	2.9204
U,V,W,XD,XRD;							
30000	1.0000	28.347	14.092	15.457	3.0399	14.092	2.4503
U,V,W,XD,XRD;							
31000	1.0000	28.357	14.113	14.371	3.1808	14.113	2.0593
U,V,W,XD,XRD;							
32000	1.0000	28.366	14.131	13.498	3.3219	14.131	1.7338
U,V,W,XD,XRD;							
33000	1.0000	28.373	14.146	12.768	3.4634	14.146	1.4616
U,V,W,XD,XRD;							
34000	1.0000	28.379	14.158	12.166	3.6048	14.158	1.2371
U,V,W,XD,XRD;							
35000	1.0000	28.384	14.168	11.670	3.7463	14.168	1.0524
U,V,W,XD,XRD;							
36000	1.0000	28.388	14.177	11.250	3.8878	14.177	.89558
U,V,W,XD,XRD;							

.17000	1.0000	28.392	14.184	4.0292	14.184	.76475
U,V,W,XD,XRD:		.40130	.43114-001	10.899		
.38000	1.0000	28.394	14.189	4.1709	14.189	.65976
U,V,W,XD,XRD:		.39105	.42000-001	10.818		
.39000	1.0000	28.397	14.194	4.3130	14.194	.57254
U,V,W,XD,XRD:		.38243	.41074-001	10.384		
.40000	1.0000	28.399	14.199	4.4551	14.199	.48533
U,V,W,XD,XRD:		.37381	.40149-001	10.150		
.41000	1.0000	28.400	14.202	4.5972	14.202	.43618
U,V,W,XD,XRD:		.36908	.39628-001	10.018		
.42000	1.0000	28.401	14.204	4.7393	14.204	.39258
U,V,W,XD,XRD:		.36477	.39165-001	9.9010		
.43000	1.0000	28.403	14.206	4.8814	14.206	.34897
U,V,W,XD,XRD:		.36046	.38703-001	9.7840	14.206	
.44000	1.0000	28.404	14.209	5.0235	14.209	.30536
U,V,W,XD,XRD:		.35615	.38240-001	9.6671		
.45000	1.0000	28.405	14.211	5.1656	14.211	.26175
U,V,W,XD,XRD:		.35184	.37777-001	9.5501		
.46000	1.0000	28.406	14.212	5.3076	14.212	.23715
U,V,W,XD,XRD:		.34954	.37516-001	9.4841		
.47000	1.0000	28.406	14.212	5.4497	14.212	.23715
U,V,W,XD,XRD:		.34954	.37516-001	9.4841		
.48000	1.0000	28.406	14.212	5.5918	14.212	.23715
U,V,W,XD,XRD:		.34954	.37516-001	9.4841		
.49000	1.0000	28.406	14.212	5.7339	14.212	.23715
U,V,W,XD,XRD:		.34954	.37516-001	9.4841		
.50000	1.0000	28.406	14.212	5.8760	14.212	.23715
U,V,W,XD,XRD:		.34954	.37516-001	9.4841		
.51000	1.0000	28.406	14.212	6.0181	14.212	.23715
U,V,W,XD,XRD:		.34954	.37516-001	9.4841		
.52000	1.0000	28.406	14.212	6.1602	14.212	.23715
U,V,W,XD,XRD:		.34954	.37516-001	9.4841		
.53000	1.0000	28.406	14.212	6.3023	14.212	.23715
U,V,W,XD,XRD:		.34954	.37516-001	9.4841		
.54000	1.0000	28.406	14.212	6.4444	14.212	.23715
U,V,W,XD,XRD:		.34954	.37516-001	9.4841		
.55000	1.0000	28.406	14.212	6.5864	14.212	.23715
U,V,W,XD,XRD:		.34954	.37516-001	9.4841		

.56000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	6.7285	14.212	.23715
	U,V,W,XD,XRD:								
.57000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	6.7285	14.212	.23715
	U,V,W,XD,XRD:								
.58000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	7.0127	14.212	.23715
	U,V,W,XD,XRD:								
.59000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	7.1548	14.212	.23715
	U,V,W,XD,XRD:								
.60000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	7.2969	14.212	.23715
	U,V,W,XD,XRD:								
.61000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	7.4390	14.212	.23715
	U,V,W,XD,XRD:								
.62000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	7.5811	14.212	.23715
	U,V,W,XD,XRD:								
.63000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	7.7232	14.212	.23715
	U,V,W,XD,XRD:								
.64000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	7.8652	14.212	.23715
	U,V,W,XD,XRD:								
.65000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	8.0073	14.212	.23715
	U,V,W,XD,XRD:								
.66000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	8.1492	14.212	.23715
	U,V,W,XD,XRD:								
.67000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	8.2891	14.212	.23715
	U,V,W,XD,XRD:								
.68000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	8.4300	14.212	.23715
	U,V,W,XD,XRD:								
.69000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	8.5709	14.212	.23715
	U,V,W,XD,XRD:								
.70000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	8.7118	14.212	.23715
	U,V,W,XD,XRD:								
.71000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	8.8526	14.212	.23715
	U,V,W,XD,XRD:								
.72000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	8.9935	14.212	.23715
	U,V,W,XD,XRD:								
.73000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	9.1344	14.212	.23715
	U,V,W,XD,XRD:								
.74000	1.0000	28.406	.34954	.37516-001	14.212	9.4841	9.2753	14.212	.23715
	U,V,W,XD,XRD:								

.75000	1.0000	28.406	14.212	9.4841	9.4162	.23715
U,V,W,XD,XRD:		.34954	.37516-001			
.76000	1.0000	28.406	14.212	9.4841	9.5571	.23715
U,V,W,XD,XRD:		.34954	.37516-001			
.77000	1.0000	28.406	14.212	9.4841	9.6980	.23715
U,V,W,XD,XRD:		.34954	.37516-001			
.78000	1.0000	28.406	14.212	9.4841	9.8389	.23715
U,V,W,XD,XRD:		.34954	.37516-001			
.79000	1.0000	28.406	14.212	9.4841	9.9798	.23715
U,V,W,XD,XRD:		.34954	.37516-001			
.80000	1.0000	28.406	14.212	9.4841	10.121	.23715
U,V,W,XD,XRD:		.34954	.37516-001			
.81000	1.0000	28.406	14.212	9.4841	10.262	.23715
U,V,W,XD,XRD:		.34954	.37516-001			
.82000	1.0000	28.406	14.212	9.4841	10.403	.23715
U,V,W,XD,XRD:		.34954	.37516-001			
.83000	1.0000	28.406	14.212	9.4841	10.543	.23715
U,V,W,XD,XRD:		.34954	.37516-001			
.84000	1.0000	28.406	14.212	9.4841	10.684	.23715
U,V,W,XD,XRD:		.34954	.37516-001			
.85000	1.0000	28.406	14.212	9.4841	10.825	.23715
U,V,W,XD,XRD:		.34954	.37516-001			
.86000	1.0000	28.406	14.212	9.4841	10.966	.23715
U,V,W,XD,XRD:		.34954	.37516-001			
.87000	1.0000	28.406	14.212	9.4841	11.107	.23715
U,V,W,XD,XRD:		.34954	.37516-001			
.88000	1.0000	28.406	14.212	9.4841	11.248	.23715
U,V,W,XD,XRD:		.34954	.37516-001			
.89000	1.0000	28.406	14.212	9.4841	11.389	.23715
U,V,W,XD,XRD:		.34954	.37516-001			
.90000	1.0000	28.406	14.212	9.4841	11.530	.23715
U,V,W,XD,XRD:		.34954	.37516-001			
.91000	1.0000	28.406	14.212	9.4841	11.671	.23715
U,V,W,XD,XRD:		.34954	.37516-001			
.92000	1.0000	28.406	14.212	9.4841	11.811	.23715
U,V,W,XD,XRD:		.34954	.37516-001			
.93000	1.0000	28.406	14.212	9.4841	11.952	.23715
U,V,W,XD,XRD:		.34954	.37516-001			

.94000	1.0000	28.406	.37516-001	14.212	9.4841	12.093	14.212	.23715
U,V,W,XD,XRD:		.34954						
.95000	1.0000	28.406	.37516-001	14.212	9.4841	12.234	14.212	.23715
U,V,W,XD,XRD:		.34954						
.96000	1.0000	28.406	.37516-001	14.212	9.4841	12.375	14.212	.23715
U,V,W,XD,XRD:		.34954						
.97000	1.0000	28.406	.37516-001	14.212	9.4841	12.516	14.212	.23715
U,V,W,XD,XRD:		.34954						
.98000	1.0000	28.406	.37516-001	14.212	9.4841	12.657	14.212	.23715
U,V,W,XD,XRD:		.34954						
.99000	1.0000	28.406	.37516-001	14.212	9.4841	12.798	14.212	.23715
U,V,W,XD,XRD:		.34954						
1.0000	1.0000	28.406	.37516-001	14.212	9.4841	12.939	14.212	.23715
U,V,W,XD,XRD:		.34954						
1.0000	1.0000	28.406	.37516-001	14.212	9.4841	12.939	14.212	.23715
U,V,W,XD,XRD:		.34954						

SPACK L.
 PURPUR 2783A E36 SL74R1.04/17/80 14110:20
 END PACK, TEX=3,TOC=1,SYH=10,REL=2,ARS=1

6Fin

APPENDIX F FREQUENCY RESPONSE ANALYSIS

Figure F-1 presents the fundamental block diagram on which the frequency domain analysis will be based.

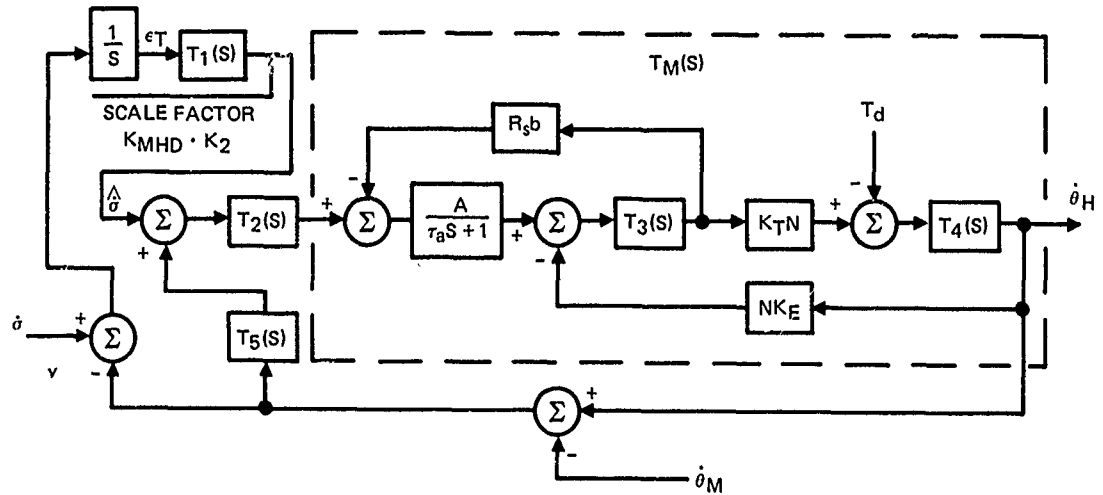


Figure F-1. Stabilized platform block diagram.

where

$$T_1(s) = \frac{K_4 K_5}{\tau_7 s + 1}$$

$$T_2(s) = \frac{K_3 (\tau_2 s + 1)^2 (\tau_5 s + 1)}{s (\tau_3 s + 1)^2 (\tau_6 s + 1)}$$

$$T_3(s) = \frac{1}{L_a s + R_a}$$

$$T_4(s) = \frac{1}{J_T s + D}$$

$$T_5(s) = \frac{K_{MHD} K_2}{(\tau_4 s + 1)^3}$$

Also let

$$T_m(s) = \frac{AK_T N}{(\tau_a s + 1) (L_a s + R_a) (J_T s + D) + AR_s b (J_T s + D) + (\tau_a s + 1) N^2 K_E K_T}$$

which is the full torque motor transfer function. Six transfer functions will be derived for the frequency analysis:

$$1) \frac{\hat{\sigma}}{\sigma}, \quad 2) \frac{\hat{\sigma}}{T_d}, \quad 3) \frac{\hat{\sigma}}{\theta_M}, \quad 4) \frac{\hat{\sigma}}{\theta_H}, \quad 5) \frac{\epsilon_T}{\theta_M}, \quad \text{and} \quad 6) \frac{\epsilon_T}{T_d}.$$

All of these transfer functions are derived as per the conical form of figure F-2.

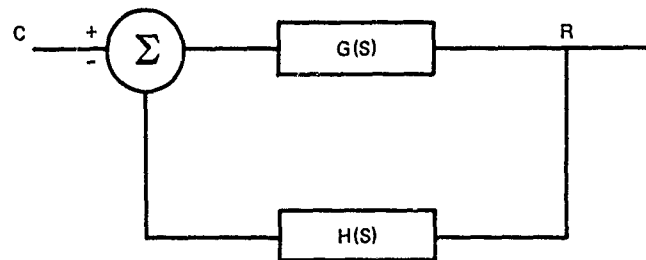


Figure F-2. Conical form block diagram.

where the transfer function of input to output is

$$\frac{R}{C} = \frac{G(S)}{1 + G(S) H(S)} \quad (1)$$

For the first transfer function, $\hat{\sigma}/\sigma$, the block diagram of figure F-1 is rearranged as illustrated in figure F-3.

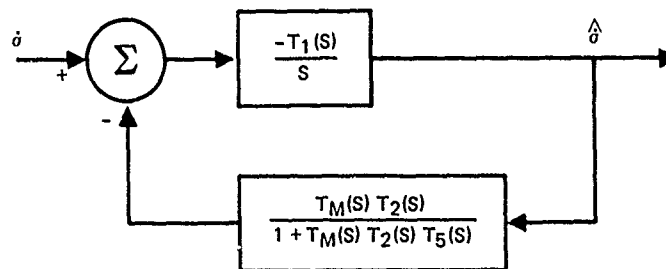


Figure F-3. Block diagram for $\hat{\sigma}/\sigma$ transfer function.

where

$$G_1(S) = \frac{-T_1(S)}{S} \quad (2)$$

$$H_1(S) = \frac{T_M(S) T_2(S)}{1 + T_M(S) T_2(S) T_S(S)} \quad (3)$$

$$\frac{\hat{\theta}}{\hat{\sigma}} = \frac{1}{SF} \cdot \frac{G_1(S)}{1 + G_1(S) H_1(S)} \quad (4)$$

When the scale factor is incorporated into Eq. 4 $\hat{\theta}$ is in the units of rad/sec. The scale factor is

$$SF = K_{MHD} \cdot K_2. \quad (5)$$

For the second transfer function, $\hat{\theta}/T_d$, the block diagram of figure F-1 is rearranged as illustrated in figure F-4.

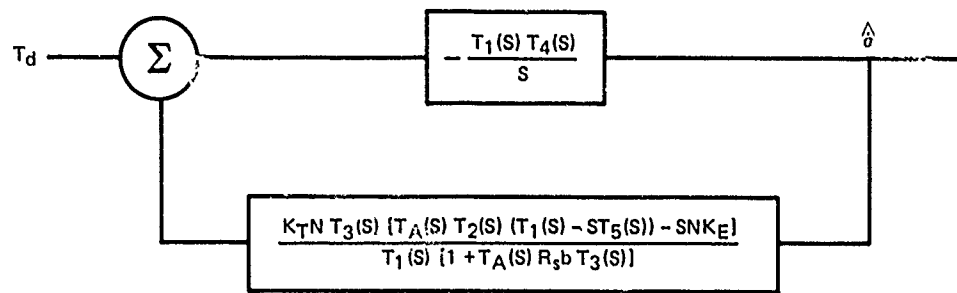


Figure F-4. Block diagram for $\hat{\theta}/T_d$ transfer function.

where

$$G_2(S) = \frac{-T_1(S) T_4(S)}{S}, \quad (6)$$

$$H_2(S) = \frac{K_T N T_3(S) [T_A(S) T_2(S) (T_1(S) - S T_5(S)) - S N K_E]}{T_1(S) [1 + T_A(S) R_s b T_3(S)]} \quad (7)$$

and

$$\frac{\hat{\theta}}{T_d} = \frac{1}{SF} \cdot \frac{G_2(S)}{1 + G_2(S) H_2(S)}. \quad (8)$$

For the third transfer function, $\hat{\theta}/\theta_M$, the block diagram of figure F-1 is rearranged as illustrated in figure F-5.

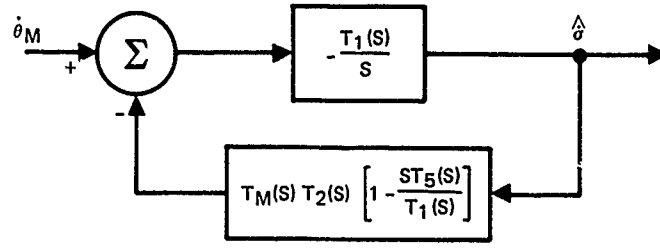


Figure F-5. Block diagram for $\hat{\sigma}/\dot{\theta}_M$ transfer function.

where

$$G_3(S) = \frac{-T_1(S)}{S}, \quad (9)$$

$$H_3(S) = T_M(S) T_2(S) \left[1 - \frac{ST_5(S)}{T_1(S)} \right], \quad (10)$$

and

$$\frac{\hat{\sigma}}{\dot{\theta}_M} = \frac{1}{SF} \cdot \frac{G_3(S)}{1 + G_3(S) H_3(S)} \quad (11)$$

For the fourth transfer function, $\hat{\sigma}/\dot{\theta}_H$, the block diagram of figure F-1 is rearranged as illustrated in figure F-6.

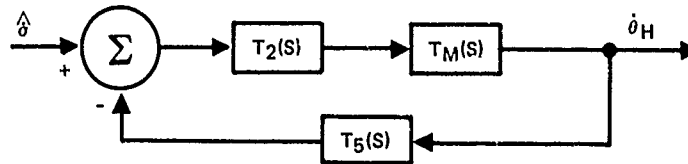


Figure F-6. Block diagram for $\hat{\sigma}/\dot{\theta}_H$ transfer function.

where

$$G_4(S) = T_2(S) T_M(S), \quad (12)$$

$$H_4(S) = T_5(S), \quad (13)$$

and

$$\frac{\hat{\sigma}}{\dot{\theta}_H} = \frac{1}{SF} \cdot \frac{G_4(S)}{1 + G_4(S) H_4(S)} \quad (14)$$

For the fifth transfer function, $\epsilon_T/\dot{\theta}_M$, the block diagram of figure F-1 is rearranged as illustrated in figure F-7.

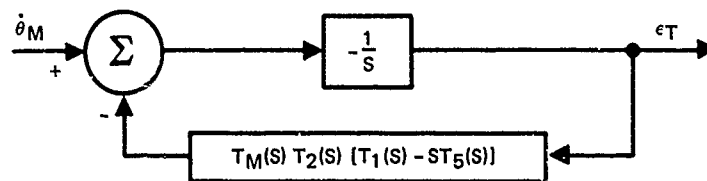


Figure F-7. Block diagram of $\epsilon_T/\dot{\theta}_M$ transfer function.

where

$$G_5(S) = \frac{-1}{S}, \quad (15)$$

$$H_5(S) = T_M(S) T_2(S) [T_1(S) - ST_5(S)], \quad (16)$$

and

$$\frac{\epsilon_T}{\dot{\theta}_M} = \frac{G_5(S)}{1 + G_5(S) H_5(S)} \quad (17)$$

For the sixth transfer function, ϵ_T/T_d , the block diagram of figure F-1 is rearranged as illustrated in figure F-8.

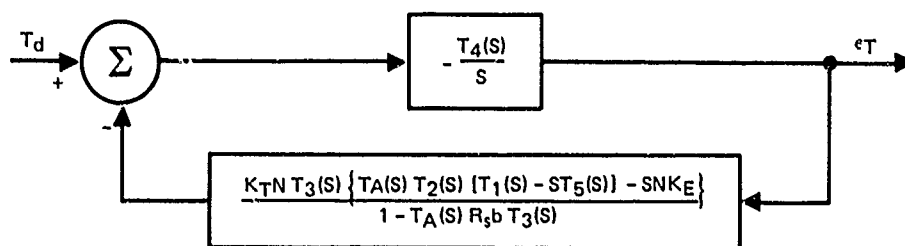


Figure F-8 Block diagram of ϵ_T/T_d transfer function.

where

$$G_6(S) = \frac{-T_4(S)}{S}, \quad (18)$$

$$H_6(S) = \frac{K_T N T_3(S) \{T_A(S) T_2(S) [T_1(S) - ST_5(S)] - SNK_E\}}{1 - T_A(S) R_s b T_3(S)} \quad (19)$$

and

$$\frac{\epsilon_T}{T_d} = \frac{G_6(S)}{1 + G_6(S) H_6(S)} \quad (20)$$

```

0FTN,RODS L,MAIN
SYN ARI 04/16/80-14:14(2,1)
1. C COMPLEX S,YFRECT,LOOPG,G,M,TEMP1,TEMP2
2. C THIS PROGRAM COMPUTES THE FREQUENCY RESPONSES OF THE
3. C LADS PLATFORM. SEVEN DIFFERENT RESPONSES CAN BE
4. C CHOSEN AS LISTED IN THE COMMENTS OF SUBROUTINES G & H.
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      RPTH,RQDS L,INPUT
      FTN BR1 04/16/80-14:1811,1
1.  SUBROUTINE INPUT
2.  IMPLICIT REAL ( J,K,L,N )
3.  COMMON /CONST/ K5,K4,TAU7,K3,TAU2,TAU2P,TAU3,TAU3P,TAU5,
4.  TAUA,A,TAUA,L,RA,RSB,KT,N,JT,D,KE,KMHD,K2,KF,TAU4
5.  COMMON /RANGE/ WHIN,NOCY
6.  COMMON /SCALE/ SF
7.  C 1.0/SE IS THE SCALE FACTOR FOR SIGMA DOT HAT FOR CONVERSION
8.  C FROM VOLTS TOROIDIANS PER SECOND.
9.  READ ( 5,100 ) K5,K4,TAU7,K3,TAU2,TAU2P,TAU3,TAU3P,TAU5,
10. TAUA,A,TAUA
11. 6 100 FORMAT ( 6X,F10.0 )
12. READ ( 5,100 ) LA,RA,RSB,KT,N,JM,JL,D,KE,KMHD,K2,KF,TAU4
13. READ ( 5,100 ) WHIN,NOCY,ISCLF
14. 300 FORMAT ( 5X,F10.0,2I2 )
15. SF = K2 * KMHD
16. IF ( ISCLF .EQ. 0 ) SF = 1.0
17. JT = N*N*JM + JL
18. RETUCH
19. END

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9FTF,ROD5 L.G
FTN 8R1 04/16/80-14:18(4,1)
1. C COMPLEX FUNCTION G ( S )
2. C THIS FUNCTION COMPUTES G FOR CANDIDICAL FORM OF THE CONTROL
3. C SUBSYSTEMS LISTED IN COMMENTS. CHOICE OF SUBSYSTEMS IS
4. C INDICATED BY VARIABLE I IN COMMON AREA GHTYPE.
5. C
6. C IMPLICIT REAL ( J,K,L,N )
7. C COMPLEX S.O.E.II,I2,I3,I4,I5,I6,TC1,TC2
8. C COMMON /CONST/ K5,K4,TAU7,K3,TAU2,TAU2P,TAU3,TAU3P,TAU5,TAU6,
9. C A,TAUA,LA,RA,RSB,KT,N,JT,D,KE,KHD,K2,KF,TAU4
10. C COMMON /GHTYPE/ I
11. C DATA ONE / ( 1.0,0.0 ) /
12. C GO TO ( 10,20,30,40,50,60,70 ) , I
13. C
14. C COMPLETE PLATFORM SIGMA DOT -TO- SIGMA DOT HAT.
15. C
16. C G = T1 ( S ) / S
17. C RETURN
18. C
19. C TORQUE DISTURBANCE -TO- SIGMA DOT HAT.
20. C
21. C G = ( -T1 ( S ) + T4 ( S ) ) / S
22. C RETURN
23. C
24. C BODY MOTION (THETA DOT H) -TO- SIGMA DOT HAT.
25. C
26. C G = T1 ( S ) / S
27. C RETURN
28. C
29. C TORQUE DISTURBANCE -TO- POINTING ERROR.
30. C
31. C G = ( -T4 ( S ) ) / S
32. C RETURN
33. C
34. C BODY MOTION (THETA DOT H) -TO- POINTING ERROR.
35. C
36. C G = ( -ONE ) / S
37. C RETURN
38. C
39. C STABILIZATION LOOP (SIGMA DOT HAT -TO- THETA DOT H).
40. C
41. C G = T2 ( S ) + TH ( S )
42. C RETURN
43. C
44. C SLAVE LOOP
45. C
46. C TC1 = ( TAUA + S + ONE ) * ( TAU2P + S + ONE )
47. C TC2 = ( TAUA + S + ONE ) * ( TAU3P + S + ONE )
48. C TC1 = ( TC1 / TC2 ) * ( ONE / ( TAU6 + S + ONE ) )
49. C G = K3 * TC1 - TH ( S ) - ONE / S
50. C RETURN
51. C END

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56. C SLAVE LOOP
57. C
58. 70 H = K*HD + K2 * KF
59. RETURN
60. END

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QFTH,RODS I,TI
FTN 8R1 04/16/80-14:1A(1,1)
1. COMPLEX FUNCTION TI ( S )
2. IMPLICIT REAL ( J,K,L,M )
3. COMPLEX S,ONE
4. COMMON /CONST/ K5,K4,TAU7,K3,TAU2,TAU2P,TAU3,TAU3P,TAU5,TAU6,
5. 6. A,TAUA,LA,RA,RSB,KT,N,JT,D,KE,KMHD,K2,KF,TAU4
6. DATA ONE / ( 1.0,0.0 ) /
7. I1=K3+K5 / ( TAU7+5+ONE )
8. RETURN
9. END

```

```

      BFTN,RODS L,T2
      FTV BR1 04/16/80-14:18(1,1)
1.    COMPLEX FUNCTION T2 ( S )
2.    IMPLICIT REAL ( J,K,L,N )
3.    COMPLEX S,ONE,C1,C2,T2N,T2D
4.    COMMON /CONST/ K5,K4,TAU7,K3,TAU2,TAU2P,TAU3,TAU3P,TAU5,TAU6,
5.    A,TAUA,LA,RA,RSB,KT,N,JT,D,KE,KHND,K2,KF,TAUH
6.    DATA ONE / ( 1.0,0.0 ) /
7.    C1 = (TAU2 - S * ONE) * (TAU2P * S + ONE)
8.    C2 = (TAU3 * S + ONE) * (TAU3P * S + ONE)
9.    T2N = K3 * C1 * (TAU5 * S + ONE)
10.   T2D = S * C2 * (TAU6 * S + ONE)
11.   T2 = T2N / T2D
12.   RETURN
13.   END

```

```

QFTN,RODS L,T3
FTN 8R1 04/16/80-14:1810.)
1. COMPLEX FUNCTION T3 ( S )
2. IMPLICIT REAL ( J,K,L,N )
3. COMPLEX S,ONE
4. COMMON /CONST/ K5,K4,TAU7,K3,TAU2,TAU2P,TAU3,TAU3P,TAU5,TAU6,
5. A,TAUA,LA,RA,RSD,KI,N,JT,D,KE,KHHD,K2,KF,TAU4
6. DATA ONE / ( 1.0,0.0 ) /
7. T3 = ONE / ( LA * S + RA )
8. RETURN
9. END

```

```

      DFTU,RODS L,T4
      FTYN 8R] 04/16/80-14:18(0,1
1.    COMPLEX FUNCTION T4 ( S )
2.    IMPLICIT REAL ( J,K,L,M )
3.    COMPLEX S,ORE
4.    COMMON /CONST/ K5,K4,TAU7,K3,TAU2,TAU2P,TAU3,TAU3P,TAU5,TAU6,
5.    6 A,TAUA,LA,RA,RSB,KT,N,JT,D,KE,KHMD,K2,KF,TAU4
6.    DATA ONE / ( 1.0,0.0 1 /
7.    I4=ONE / (JT 5,5,1,0)
8.    RETURN
9.    END

```

```

      GFTN,RODS L,T5
      FTN BRJ  .04/16/80-14:1810.)
1.     COMPLEX FUNCTION TS ( S )
2.     IMPLICIT REAL ( J,K,L,N )
3.     COMPLEX S,ONE,C1
4.     COMMON /CONST/ K5,K4,TAU7,K3,TAU2,TAU2P,TAU3,TAU3P,TAU5,TAU6,
5.     A,TAUA,LA,RA,RSN,KT,N,JT,D,KE,KHHD,K2,KF,TAU4
6.     DATA ONE / ( 1.0,0.0 ) /
7.     C1 = TAU4 * S * ONE
8.     TS = KHHD * K2 / (C1 * C1)
9.     RETURN
10.    END

```

```

DETH,RQ05 L,TM
FTN 8K1 04/16/R0-14:1810,1
1. COMPLEX FUNCTION TM ( S )
2. IMPLICIT REAL ( J,K,L,N )
3. COMPLEX S,ONE,C1,C2,C3
4. COMMON /CONST/ K5,K4,TAU7,K3,TAU2,TAU2P,TAU3,TAU3P,TAU5,TAU6,
5. 6 A,TAUA,LA,RA,RSB,KT,N,JT,D,KE,KMC2,K2,KF,TAU4
6. DATA ONE / ( 1.0,0.0 ) /
7. C1 = JI - S + P
8. C2 = TAUA * S + ONE
9. C3 = LA * S + RA
10. TM = A*KT*N / ( C1*C2*C3 + A*PSB*C1 + N*KE*KT*C2 )
11. RETURN
12. END

```

```

LADSS=THPFR(11,OGDATA/NEWJL
1  K5  * 7.0
2  K4  * 7.0
3  TAU7 * .025
4  K3  * 84.720
5  TAU2 * .01
6  TAU2P * .01
7  TAU3 * .0005
8  TAU3P * .0005
9  TAU5 * 0.1
10 TAU6 * 0.80
11 A * 100000.0
12 TAU4 * .02
13 LA * .0014
14 RA * 3.0
15 RSB * 1.0
16 KT * 24.6
17 H * 8.5
18 JH * .016
19 JL * 3.30
20 D * .706
21 KE * .177
22 KMH0 * .8595
23 K2 * 14.0
24 KF * 1.0
25 TAU4 * .0015
26 .01 A L- SIG DT H 1
27 SIG DT - SIG DT H 2
28 TRQ DIS - SIG DT H 3
29 RND MOT - SIG DT H 4
30 TRQ DIS - PNT ERROR 5
31 RND MOT - PNT ERROR 6
32 STABILIZATION LOOP 6

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9X0T L.PROG

SIG DOT - SIG DT H I LADSS PLATFORM

FREQUENCY RADIAN	DR	LOOP GAIN DB	DR	RESPONSE DEGREES	G		H	
					REAL	IMAG	REAL	IMAG
.010	52.196	-90.012	.000	-1.143	-1.2250	-4900.0	.83105-001	.37369-005
.020	46.176	-90.023	.000	-1.287	-1.2250	-2450.0	.83105-001	.74738-005
.030	42.654	-90.035	.000	-1.430	-1.2250	-1633.3	.83105-001	.11211-004
.040	40.155	-90.047	.000	-1.573	-1.2250	-1225.0	.83105-001	.14948-004
.050	38.217	-90.059	.000	-1.716	-1.2250	-980.00	.83105-001	.18685-004
.060	36.633	-90.070	.000	-1.860	-1.2250	-816.66	.83105-001	.22422-004
.070	35.294	-90.082	.000	-1.003	-1.2250	-700.00	.83105-001	.26159-004
.080	34.135	-90.094	.000	-1.146	-1.2250	-612.50	.83105-001	.29896-004
.090	33.112	-90.106	.000	-1.289	-1.2250	-544.44	.83105-001	.33633-004
.100	32.196	-90.117	.000	-1.433	-1.2250	-490.00	.83105-001	.37370-004
.200	26.176	-90.235	.009	-2.864	-1.2250	-244.79	.83105-001	.74748-004
.300	22.654	-90.352	.020	-4.293	-1.2249	-163.32	.83105-001	.11214-003
.400	20.155	-90.470	.035	-5.718	-1.2249	-122.49	.83105-001	.14955-003
.500	18.216	-90.587	.054	-7.138	-1.2248	-97.985	.83105-001	.18699-003
.600	16.633	-90.705	.078	-8.552	-1.2247	-81.648	.83105-001	.22447-003
.700	15.293	-90.822	.106	-9.958	-1.2246	-69.279	.83105-001	.26199-003
.800	14.133	-90.939	.138	-11.357	-1.2245	-61.226	.83106-001	.29955-003
.900	13.110	-91.056	.174	-12.745	-1.2244	-54.417	.83106-001	.33718-003
1.000	12.194	-91.174	.213	-14.124	-1.2242	-48.769	.83106-001	.37486-003
2.000	6.166	-92.341	.799	-27.148	-1.2219	-24.439	.83112-001	.75840-003
3.000	2.633	-93.497	1.631	-38.457	-1.2181	-16.242	.83127-001	.11499-002
4.000	.119	-94.637	2.592	-47.967	-1.2129	-12.129	.83156-001	.15584-002
5.000	-1.837	-95.760	3.590	-55.892	-1.2062	-9.692	.83204-001	.19826-002
6.000	-3.441	-96.866	4.575	-62.833	-1.1986	-7.9870	.83279-001	.24211-002
7.000	-4.802	-97.954	5.525	-68.168	-1.1880	-6.7920	.83382-001	.28713-002
8.000	-5.986	-99.027	6.428	-73.021	-1.1779	-5.8994	.83518-001	.33298-002
9.000	-7.033	-100.085	7.282	-77.267	-1.1660	-5.1821	.83688-001	.37935-002
10.000	-7.924	-101.130	8.1090	-81.034	-1.1529	-4.6118	.83893-001	.42591-002
20.000	-14.268	-111.030	14.329	-105.584	-1.0800	-1.9500	.87870-001	.85150-002
30.000	-18.048	-120.376	18.773	-120.292	-1.0450	-1.0453	.95198-001	.10835-001
40.000	-20.766	-130.019	22.352	-130.739	-1.0250	-1.0250	.91784-002	.11824-002
50.000	-22.985	-140.755	25.389	-138.822	-1.0154	-.38744	.11584	.11584
60.000	-25.105	-152.569	28.049	-144.768	-1.0097	-.25128	.11946	.11946
70.000	-27.379	-164.286	30.429	-149.563	-1.0054	-.17231	.12250	.12250
80.000	-29.829	-174.373	32.572	-153.248	-1.0026	-.09805-001	.98384-001	.48017-001
90.000	-32.321	-177.947	34.502	-156.088	-1.0006	-.07586-001	.88087-001	.49304-001
100.000	-34.718	-172.565	36.247	-158.537	-1.0001	-.05923-001	.5923-001	.31228-001
200.000	-49.771	-163.785	47.947	-168.742	-.07115-001	-.28330-002	.60827-001	.30265-001
300.000	-56.674	-161.142	54.912	-172.433	-.12129-001	.12129-002	.58478-001	.39421-001
400.000	-61.314	-151.726	59.881	-174.313	-.17791-002	.62321-003	.46242-001	.47286-001
500.000	-65.549	-140.147	63.745	-175.445	-.34204-002	.36136-003	.36788-001	.48684-001
600.000	-69.595	-130.913	66.906	-176.200	-.39870-002	.22283-003	.28314-001	.46588-001
700.000	-73.242	-124.560	69.579	-176.740	-.30549-002	.15374-003	.22514-001	.43876-001
800.000	-76.430	-120.026	71.896	-177.145	-.24150-002	.10733-003	.18322-001	.41416-001
900.000	-79.213	-116.409	73.940	-177.461	-.19563-002	.7875-001	.15027-001	.39334-001
1000.000	-81.675	-113.200	75.762	-177.714	-.18980-003	.97661-005	-.27843-002	.24625-001
2000.000	-98.315	84.695	87.805	-178.855	-.21774-003	.29032-005	-.68891-002	.13681-001
3000.000	-109.537	64.036	94.848	-179.236	-.12249-003	.12149-005	-.64166-002	.76491-002
4000.000	-118.252	50.581	99.845	-179.427	-.18395-004	.62716-006	-.52072-002	.45331-002
5000.000	-125.332	41.499	103.721	-179.542	-.15442-004	.28595-006	-.41295-002	.28595-002
6000.000	-131.266	35.050	106.889	-179.618	-.19999-004	.22856-006	-.32958-002	.18979-002
7000.000	-136.356	30.263	109.566	-179.673				

TRQ DIS - SIG DT M 2 LADSS PLATFORM

FREQUENCY RADIAN	LOOP GAIN DB	RESPONSE DB	DEGREES	G		H	
				REAL	IMAG	REAL	IMAG
.010	187.736	-4.157	70.531	438.05	6912.9	-4104.8	-44284.006
.020	177.643	-8.285	91.062	432.90	3415.1	-4104.1	-22137.006
.030	170.513	-12.358	91.062	424.57	2233.1	-4102.8	-114753.006
.040	165.392	-16.350	92.124	413.44	1630.7	-4101.1	-11059.006
.050	161.376	-20.240	93.654	399.96	1261.9	-4098.8	-88418.
.060	158.037	-24.012	93.184	384.63	1011.1	-4096.0	-73624.
.070	155.163	-27.651	93.714	367.97	828.93	-4092.8	-63048.
.080	152.428	-31.149	94.244	350.44	690.61	-4089.0	-55109.
.090	150.350	-34.500	94.772	332.50	582.29	-4084.8	-48727.
.100	148.273	-37.203	95.301	314.50	495.54	-4080.1	-43975.
.200	133.478	-62.442	100.542	169.57	132.96	-4006.8	-21531.
.300	123.843	-78.258	105.668	95.909	4.736	-3890.7	-13872.
.400	116.626	-89.596	110.631	59.636	22.934	-3739.5	-9932.4
.500	110.839	-98.528	115.394	40.124	12.165	-3562.2	-7504.1
.600	105.992	-105.997	119.929	28.661	7.1103	-3368.1	-5850.3
.700	101.811	-112.470	124.220	21.426	4.4570	-3165.5	-4654.2
.800	98.125	-118.205	128.261	16.532	2.9428	-2961.4	-3755.0
.900	94.824	-123.355	132.050	13.213	2.0208	-2761.3	-3061.3
1.000	91.831	-128.023	135.593	10.741	1.4305	-2569.1	-2516.4
2.000	71.385	-158.468	160.129	2.7359	1.9628	-1274.4	-460.45
3.000	52.289	-173.577	174.304	1.2184	-2.6882	-750.40	-101.31
4.000	50.973	-178.322	178.183	.68210	-4.0372	-517.8	-16.456
5.000	49.782	-179.231	179.508	.43437	-4.0372	-397.51	3.1819
6.000	39.922	-172.411	179.352	.29971	-3.6896	-328.20	3.2728
7.000	35.965	-172.033	177.466	.21850	-3.3160	-284.33	3.2894
8.000	32.652	-172.568	177.433	.16580	-2.9758	-254.46	12.194
9.000	29.819	-173.685	174.854	.12969	-2.6791	-232.85	-21.832
10.000	27.356	-175.172	171.916	.10388	-2.4228	-216.26	-31.564
20.000	17.693	-165.359	134.926	.22079	-1.0823	-132.84	-114.47
30.000	5.251	-147.691	82.647	.78584	-0.021	-67.491	-174.49
40.000	.561	-133.486	26.263	.34499	-0.021	4.9309	-219.44
50.000	-2.680	-122.742	-5.450	.17233	-0.021	84.455	-253.63
60.000	-5.079	-114.973	-22.710	.94358	-0.031	170.31	-281.37
70.000	-8.962	-107.584	-33.679	.55460	-0.031	262.46	-305.77
80.000	-10.508	-102.954	-41.405	.34500	-0.031	361.34	-339.00
90.000	-12.820	-102.954	-47.201	.22432	-0.031	467.51	-352.52
100.000	-10.951	-101.080	-51.735	.15228	-0.031	581.53	77.25
200.000	-17.979	-97.755	-71.395	.10615	-0.041	2211.6	-76.28
300.000	-21.886	-97.788	-77.778	.21426	-0.051	4755.5	-1491.5
400.000	-24.629	-102.032	-80.941	.68317	-0.091	8171.9	-2319.3
500.000	-26.746	-104.213	-82.826	.28083	-0.061	12413.	-4226.8
600.000	-28.473	-104.370	-84.077	.13569	-0.061	17414.	-6406.6
700.000	-29.941	-108.547	-84.970	.73330	-0.071	2308.3	-9247.0
800.000	-31.230	-110.741	-85.641	.43017	-0.071	29310.	-12814.
900.000	-32.389	-112.929	-86.166	.26870	-0.071	35972.	-17145.
1000.000	-33.448	-115.088	-86.587	.17636	-0.071	42952.	-22252.
2000.000	-41.310	-133.008	-88.487	.11036	-0.081	11224.006	-10899.006
3000.000	-46.822	-144.456	-89.081	.21803	-0.091	15945.006	-22989.006
4000.000	-51.125	-151.818	-89.349	.68973	-0.101	18733.006	-35823.006
5000.000	-54.638	-156.799	-89.498	.28281	-0.101	20368.006	-48594.006
6000.000	-57.594	-160.344	-89.591	.13639	-0.101	21387.006	-61152.006
7000.000	-60.139	-162.978	-89.655	.72567	-0.111	22043.006	-73505.006

BOO NOT - SIG DT H 3 LADSS PLATFORM

FREQUENCY RADIAN	LOOP GAIN		RESPONSE		G		H	
	OR	DEGREES	OR	DEGREES	REAL	IMAG	REAL	IMAG
.010	201.738	175.859	-19.542	94.126	-1.2250	-4900.0	-1.7939	006.24845+007
.020	189.646	171.747	-13.470	78.225	-1.2250	-2450.0	-1.7726	006.12254+007
.030	182.517	167.689	-13.863	102.268	-1.2250	-1633.3	-1.7382	006.79937+006
.040	172.403	163.711	-13.298	106.232	-1.2250	-1225.0	-1.6922	006.58116+006
.050	173.382	159.833	-13.515	110.095	-1.2250	-980.00	-1.6365	006.44730+006
.060	170.044	156.073	-13.410	113.841	-1.2250	-816.66	-1.5730	006.35597+006
.070	167.172	152.449	-13.187	117.455	-1.2250	-700.00	-1.5040	006.28947+006
.080	164.638	148.955	-13.0504	120.930	-1.2250	-612.50	-1.4314	006.23888+006
.090	162.361	145.611	-12.9250	124.260	-1.2250	-544.44	-1.3570	006.19923+006
.100	160.286	142.414	-12.8090	127.443	-1.2250	-490.00	-1.2823	006.16746+006
.200	145.503	117.685	-11.9328	152.028	-1.2250	-244.99	-1.07930	-36076
.300	135.875	101.853	-11.3221	167.718	-1.2249	-163.32	-1.0008	-8100.8
.400	128.662	90.498	-10.8507	178.929	-1.2249	-122.49	-1.1364	-413.64
.500	122.876	81.553	-10.4659	182.269	-1.2248	-97.985	-1.4081	1911.5
.600	118.030	74.074	-10.1398	184.933	-1.2247	-81.648	-9425.9	2537.4
.700	113.850	67.592	-9.8557	186.595	-1.2246	-69.979	-6552.6	2568.6
.800	110.164	61.850	-9.6032	187.996	-1.2245	-61.223	-4683.9	2389.5
.900	106.864	56.693	-9.3754	189.981	-1.2244	-54.417	-3433.0	2146.7
1.000	103.871	52.018	-9.1678	193.449	-1.2242	-48.969	-2560.9	1898.5
2.000	83.430	21.462	-7.7265	114.323	-1.2219	-24.439	-249.84	552.71
3.000	71.349	6.132	-6.6722	100.419	-1.2181	-16.242	-41.018	223.03
4.000	63.063	-2.243	-6.2258	93.669	-1.2122	-12.129	-7.0598	116.52
5.000	56.912	-6.816	-5.8775	90.319	-1.2062	-8.6492	-38906	72.068
6.000	52.101	-9.139	-5.5595	89.444	-1.1980	-7.9870	52940	49.865
7.000	49.175	-10.085	-5.3084	89.880	-1.1986	-6.7920	10310	37.254
8.000	44.934	-10.173	-5.1018	91.194	-1.1779	-5.8894	58312	29.380
9.000	42.154	-9.724	-4.9324	93.032	-1.1660	-5.1821	-1.2444	24.093
10.000	39.242	-8.939	-4.7896	95.188	-1.1529	-4.6119	-1.8151	20.337
20.000	25.440	2.830	-40.685	119.251	-98000	-1.9600	-4.1902	7.4380
30.000	18.103	13.366	-38.382	130.766	-78400	-1.0453	-4.7284	3.9345
40.000	13.313	22.261	-37.771	153.361	-61250	-6.1250	-4.9308	2.0665
50.000	9.881	29.930	-37.948	164.136	-47005	-38244	-5.0362	77330
60.000	7.292	36.554	-38.525	172.058	-37692	-25128	-5.1089	-25555
70.000	5.298	42.233	-39.413	177.890	-30154	-17231	-5.1734	-25555
80.000	3.710	47.052	-40.210	177.808	-24500	-12250	-5.2422	-1.9586
90.000	2.429	51.091	-41.160	174.619	-20206	-89805-001	-5.3233	-2.7274
100.000	1.377	54.429	-42.131	172.258	-16897	-67586-001	-5.4228	-3.4717
200.000	3.708	63.113	-51.019	167.112	-47115-001	-94231-002	-8.3976	-10.673
300.000	6.139	51.868	-57.601	171.032	-21397-001	-28530-002	-16.360	-15.950
400.000	8.286	35.283	-67.366	179.108	-12129-002	-12129-002	-27.491	-15.587
500.000	-10.470	17.762	-85.951	179.493	-77701-002	-62331-003	-37.323	-7.458
600.000	-12.712	9.922	-88.716	175.359	-54204-002	-36136-003	-42.547	2.142
700.000	-14.782	14.724	-70.968	174.517	-39870-002	-22783-003	-42.439	13.785
800.000	-17.248	-29.055	-72.897	173.731	-30549-002	-15274-003	-38.095	23.728
900.000	-19.486	-42.112	-73.682	173.682	-24150-002	-10733-003	-31.218	30.846
1000.000	-21.680	-54.000	-76.198	173.071	-19597-002	-7825-004	-23.353	35.004
2000.000	-40.465	-130.780	-87.752	178.440	-48980-003	-97961-005	12.928	14.395
3000.000	-54.503	-169.203	-94.832	179.216	-21774-003	-29032-005	8.5151	1.5065
4000.000	-65.457	168.272	-99.841	179.433	-12249-003	12249-005	4.3554	-92789
5000.000	-74.352	153.670	-103.720	179.521	-78395-004	12276-006	2.1818	-1.1015
6000.000	-81.800	143.503	-106.868	179.621	-54442-004	36225-006	1.1942	-89537
7000.000	-88.188	136.040	-109.566	179.674	-39999-004	22856-006	.69724	-68011

TRQ DIS - PHIT ERROR 4 LADSS PLATFORM				RESPONSE		G		H	
FREQUENCY RADIAN	LOOP GAIN DB	DFGREFS	DR	DEGREES	REAL	IMAG	REAL	IMAG	REAL
.010	195.757	-4.157	-152.750	90.546	8.9045	141.08	-41328+006-	43398+008	-41328+006-
.020	183.663	-8.286	-146.729	91.091	8.2997	69.711	-41320+006-	42169+008	-41320+006-
.030	176.534	-12.358	-143.206	91.637	9.6305	45.580	-41307+006-	41458+008	-41307+006-
.040	171.312	-16.351	-140.205	92.182	8.9043	32.289	-41289+006-	40838+008	-41289+006-
.050	167.997	-20.241	-138.765	92.727	8.1303	25.763	-41266+006-	40664+007	-41266+006-
.060	164.057	-24.013	-137.178	93.271	7.8187	20.646	-41239+006-	40214+007	-41239+006-
.070	161.184	-27.552	-135.836	93.816	7.4799	16.930	-41206+006-	40180+007	-41206+006-
.080	158.649	-31.150	-134.673	94.360	7.1237	14.108	-41168+006-	40398+007	-41168+006-
.090	156.370	-34.502	-133.446	94.903	6.7590	11.899	-41125+006-	40793+007	-41125+006-
.100	154.294	-37.705	-132.226	95.446	6.3932	10.129	-41077+006-	40855+007	-41077+006-
.200	139.458	-62.446	-126.634	100.832	3.4471	2.7308	-40335+006-	21080+007	-40335+006-
.300	129.883	-78.264	-122.995	106.104	1.9497	1.0297	-39160+006-	13564+007	-39160+006-
.400	122.646	-89.604	-120.340	111.212	1.2124	.48022	-37628+006-	96952+006	-37628+006-
.500	115.858	-98.538	-118.212	116.120	.81576	.25849	-35833+006-	73081+006	-35833+006-
.600	112.012	-106.009	-116.409	120.800	.58274	.15388	-33868+006-	56812+006	-33868+006-
.700	107.830	-112.484	-114.830	125.237	.43567	.98610-001	-31816+006-	45040+006	-31816+006-
.800	104.144	-118.221	-113.414	129.423	.33742	.66824-001	-29750+006-	36104+006	-29750+006-
1.000	100.843	-123.373	-112.124	133.357	.26873	.47308-001	-27724+006-	29361+006	-27724+006-
1.500	97.899	-128.043	-110.936	137.046	.21592	.34685-001	-25778+006-	24000+006	-25778+006-
2.000	77.395	-158.508	-102.441	163.035	.14004-001	.55469-003	-12671+006-	36648	-12671+006-
3.000	65.385	-173.637	-97.356	176.656	.55754-001	.44132-002	-73675	-4299.9	-73675
4.000	56.952	-178.300	-94.098	176.028	.24866-001	.13132-002	-50117	3476.7	-50117
5.000	50.738	-174.132	-91.655	170.740	.89877-002	.26416-003	-38026	5129.6	-38026
6.000	45.851	-172.292	-89.915	170.534	.62294-002	.16450-003	-31066	5042.6	-31066
7.000	41.860	-171.896	-88.576	170.534	.45776-002	.10361-003	-26693	4419.3	-26693
8.000	38.510	-172.413	-87.512	171.187	.35051-002	.69418-004	-23750	3443.6	-23750
9.000	35.636	-173.511	-86.642	172.394	.27697-002	.48759-004	-21655	2849.9	-21655
10.000	33.127	-174.981	-85.914	173.960	.22436-002	.35547-004	-20091	2085.8	-20091
15.000	17.829	-165.694	-81.701	164.073	.56101-003	.44442-005	-13478	-323.5	-13478
20.000	9.597	-148.109	-79.042	134.728	.24934-003	.13169-005	-10313	-6341.7	-10313
30.000	4.140	-133.937	-78.393	96.018	.14026-003	.55556-006	-8050.9	-8237.3	-8050.9
40.000	.241	-123.200	-80.628	63.252	.89766-004	.28445-006	-6301.9	-9564.1	-6301.9
50.000	-2.693	-115.419	-83.687	44.185	.62337-004	.16461-006	-5078.4	-10613	-5078.4
60.000	-4.999	-109.910	-84.483	33.316	.45799-004	.10366-006	-4207.9	-11536	-4207.9
70.000	-6.879	-106.043	-88.902	26.569	.35065-004	.69445-007	-3594.6	-12408	-3594.6
80.000	-8.454	-103.334	-91.010	22.037	.27706-004	.48774-007	-3168.4	-13264	-3168.4
90.000	-9.804	-101.437	-92.875	18.804	.22442-004	.35556-007	-2880.4	-14122	-2880.4
100.000	-17.642	-97.963	-104.936	7.584	.56104-005	.44445-008	-3257.8	-23156	-3257.8
200.000	-21.733	-99.930	-111.969	4.709	.24935-005	.13169-008	-5682.0	-32356	-5682.0
300.000	-24.523	-102.145	-116.667	3.381	.14026-005	.55556-009	-8906.5	-41308	-8906.5
400.000	-26.692	-104.297	-120.847	2.616	.89767-006	.28445-009	-12748	-49958	-12748
500.000	-28.436	-106.438	-124.017	2.117	.62338-006	.16461-009	-17203	-58249	-62338-006
600.000	-29.915	-108.604	-126.698	1.764	.45799-006	.10366-009	-22260	-66078	-45799-006
700.000	-31.210	-110.789	-129.020	1.499	.35065-006	.69446-010	-27860	-73339	-35065-006
800.000	-32.373	-112.971	-131.069	1.291	.27706-006	.48774-010	-33907	-79955	-27706-006
900.000	-33.437	-115.124	-132.902	.937	.22442-006	.35556-011	-40293	-85885	-22442-006
1000.000	-41.308	-133.020	-144.269	.357	.56104-007	.44445-011	-10461+006-	11209+006	-56104-007
2000.000	-46.822	-144.461	-152.031	.155	.24935-007	.13169-011	-14880+006-	10628+006	-24935-007
3000.000	-51.125	-151.820	-157.040	.078	.14026-007	.55556-012	-17460+006-	93534	-14026-007
4000.000	-54.638	-156.800	-160.923	.044	.89767-008	.28445-012	-18984+006-	81358	-89767-008
5000.000	-57.594	-160.345	-164.054	.027	.62338-008	.16461-012	-19729+006-	71173	-62338-008
6000.000	-60.139	-162.978	-166.775	.018	.45799-008	.10366-012	-20546+006-	62893	-45799-008

800 HQT - PH1 ERRQR 5 LADSS PLATFORM

FREQUENCY RADIAN	LOOP GAIN DB	DEGREES	RESPONSE		G		H	
			DB	DEGREES	REAL	IMAG	REAL	IMAG
.010	201.738	-4.141	-161.736	94.141	.00000	100.000	-.88206+007	-.12184+009
.020	189.646	-8.253	-155.666	98.253	.00000	50.000	-.87159+007	-.60088+008
.030	182.517	-12.311	-152.059	102.311	.00000	33.333	-.85467+007	-.39163+008
.040	172.403	-16.289	-149.445	106.289	.00000	25.000	-.83203+007	-.28473+008
.050	173.382	-20.167	-147.361	110.167	.00000	20.000	-.80460+007	-.21908+008
.060	170.044	-23.927	-145.607	113.927	.00000	16.667	-.77339+007	-.17431+008
.070	167.172	-27.554	-144.074	117.554	.00000	14.286	-.73944+007	-.14171+008
.080	164.638	-31.045	-142.700	121.045	.00000	12.500	-.70373+007	-.11691+008
.090	162.361	-34.389	-141.446	124.389	.00000	11.111	-.66712+007	-.97471+007
.100	160.286	-37.586	-140.286	127.586	.00000	10.000	-.63039+007	-.81899+007
.200	145.503	-62.315	-131.524	152.315	.00000	5.0000	-.32373+007	-.17510+007
.300	135.875	-78.147	-125.418	168.147	.00000	3.3333	-.18241+007	-.38324+006
.400	128.662	-89.502	-120.703	179.502	.00000	2.5000	-.10842+007	-.9426.0
.500	122.876	-98.447	-116.855	171.553	.00000	2.0000	-.68868+006	-.10227+006
.600	118.030	-105.926	-113.593	164.074	.00000	1.6667	-.45990+006	-.13123+006
.700	113.850	-112.405	-110.752	152.592	.00000	1.4286	-.31878+006	-.13144+006
.800	110.164	-118.150	-108.226	142.018	.00000	1.2500	-.22732+006	-.12163+006
.900	106.864	-123.307	-105.949	146.693	.00000	1.1111	-.16577+006	-.10892+006
1.000	103.871	-127.982	-103.871	142.018	.00000	1.0000	-.12308+006	-.96102.
2.000	83.430	-158.538	-89.450	111.463	.00000	.50000	-.10861.	27626.
3.000	71.349	-173.868	-80.889	96.133	.00000	.33333	-.1183.6	11017.
4.000	63.063	-172.757	-75.099	87.755	.00000	.25000	22.779	5687.2
5.000	56.912	-173.184	-70.879	83.175	.00000	.20000	415.86	3478.4
6.000	52.101	-170.861	-67.642	80.838	.00000	.16667	383.81	2385.8
7.000	48.195	-169.915	-65.063	79.876	.00000	.14286	314.87	1770.4
8.000	44.934	-169.827	-62.948	79.769	.00000	.12500	249.37	1389.7
9.000	42.154	-170.276	-61.172	80.200	.00000	.11111	194.79	1136.7
10.000	39.742	-171.061	-59.653	80.968	.00000	.10000+000	150.83	959.70
20.000	25.440	-177.170	-50.984	92.989	.00000	.50000-001	-18.471	373.70
30.000	18.103	-166.634	-46.529	105.240	.00000	.33333-001	-55.743	234.60
40.000	13.313	-157.739	-43.463	118.099	.00000	.25000-001	-70.175	171.43
50.000	9.881	-150.070	-41.241	132.419	.00000	.20000-001	-77.818	135.16
60.000	7.299	-143.446	-39.790	148.028	.00000	.16667-001	-82.806	111.69
70.000	5.298	-137.767	-38.107	163.664	.00000	.14286-001	-86.585	95.379
80.000	3.710	-132.948	-36.069	177.733	.00000	.12500-001	-89.763	83.553
90.000	2.429	-128.909	-33.451	170.658	.00000	.11111-001	-92.625	74.763
100.000	1.377	-125.571	-30.042	161.529	.00000	.10000-001	-95.310	68.163
200.000	-.3708	-116.887	-25.241	129.543	.00000	.50000-002	-116.40	59.017
300.000	-.6.139	-128.132	-27.564	119.156	.00000	.33333-002	-116.39	91.367
400.000	-.8.286	-144.737	-29.196	107.975	.00000	.25000-002	-88.957	125.81
500.000	-10.470	-162.238	-31.132	97.287	.00000	.20000-002	-45.696	142.85
600.000	-12.712	-179.078	-33.277	90.278	.00000	.16667-002	-2.2351	138.84
700.000	-14.982	-165.276	-35.272	88.868	.00000	.14286-002	31.704	120.64
800.000	-17.248	-150.945	-36.976	85.668	.00000	.12500-002	53.333	95.998
900.000	-19.486	-137.888	-38.399	85.584	.00000	.11111-002	64.029	70.833
1000.000	-21.680	-125.000	-39.590	85.992	.00000	.10000-002	66.671	58.737
2000.000	-40.445	49.220	-66.074	89.591	.00000	.50000-003	14.355	12.382
3000.000	-54.503	10.797	-69.558	89.980	.00000	.33333-003	1.0582	-5.5491
4000.000	-65.457	-11.728	-72.046	90.006	.00000	.25000-003	-.43377	-2.0895
5000.000	-74.152	-26.130	-73.981	90.005	.00000	.20000-003	-.43493	-.5865
6000.000	-81.800	-36.497	-75.564	90.003	.00000	.16667-003	-.29207	-.39205
7000.000	-88.188	-53.960	-76.902	90.002	.00000	.14286-003	-.18931	-.19631

STABILIZATION LOOP 6 LADSS PLATFORM

FREQUENCY RADIAN	LOOP GAIN		RESPONSE DEGREES	G		H	
	DB	DEGREES	DB	REAL	IMAG	REAL	IMAG
.010	149.542	-92.988	-21.607	-17328.008	24870.007	12.033	-54148.003
.020	141.470	-97.948	-21.607	-17123.008	12272.007	12.033	-10830.002
.030	139.883	-101.454	-21.607	-16792.006	80060.006	12.033	-16245.002
.040	137.235	-102.879	-21.607	-16349.006	58286.006	12.033	-21659.002
.050	135.164	-109.405	-21.607	-15813.006	44924.006	12.033	-27074.002
.060	133.409	-113.012	-21.607	-15202.006	35820.006	12.033	-32489.002
.070	131.076	-116.469	-21.607	-14538.006	29196.006	12.033	-37904.002
.080	130.502	-119.926	-21.607	-13839.006	24159.006	12.033	-43319.002
.090	129.247	-123.017	-21.607	-13123.006	20212.006	12.033	-48734.002
.100	128.087	-126.032	-21.607	-12404.006	17050.006	12.033	-54148.002
.200	119.316	-149.249	-21.607	-65986.0	-39309.0	12.033	-10830.001
.300	113.174	-153.533	-21.607	-21856.0	-2558.5	12.033	-16245.001
.400	108.458	-157.426	-21.607	-14085.0	181.76	12.033	-21659.001
.500	104.584	-179.132	-21.607	-9574.3	1124.6	12.033	-27074.001
.600	101.289	-173.146	-21.607	-6776.6	1400.2	12.033	-32489.001
.700	98.402	-168.145	-21.607	-4950.4	1411.4	12.033	-37904.001
.800	95.840	-163.870	-21.607	-3709.9	1321.3	12.033	-43319.001
.900	93.513	-160.164	-21.607	-2840.1	1194.9	12.033	-48734.001
1.000	91.382	-156.924	-21.607	-410.61	344.03	12.032	-54148.001
2.000	76.186	-139.526	-21.506	-126.70	123.99	12.032	-10829
3.000	66.580	-134.847	-21.604	-57.255	55.705	12.030	-16243
4.000	59.656	-131.759	-21.601	-32.038	28.986	12.029	-21657
5.000	54.317	-136.573	-21.595	-20.412	16.463	12.027	-27069
6.000	50.022	-139.228	-21.586	-14.154	10.274	12.025	-32480
7.000	46.462	-142.221	-21.573	-10.406	6.626	12.023	-37890
8.000	43.443	-145.307	-21.557	-7.9823	4.4837	12.020	-43298
9.000	40.839	-148.357	-21.538	-6.2230	3.0997	12.017	-48704
10.000	39.558	-151.307	-21.514	-1.4412	.26555-001	12.017	-54108
20.000	24.772	-173.785	-21.083	-60933	-17396	11.968	-1.0797
30.000	17.618	-171.796	-20.372	-60933	-17396	11.888	-1.6135
40.000	12.949	-161.009	-19.518	-32358	-18152	11.775	-2.1401
50.000	9.602	-152.299	-18.722	-19229	-16463	11.633	-2.6573
60.000	7.082	-145.056	-18.227	-12125	-14642	11.460	-3.1627
70.000	5.126	-138.987	-18.193	-78515-001	13065	11.259	-3.6543
80.000	3.573	-133.909	-18.581	-50836-001	11759	11.030	-4.1501
90.000	2.317	-129.690	-19.214	-31897-001	10483	10.775	-4.5883
100.000	1.285	-126.224	-19.718	-18380-001	9713-001	10.496	-5.0272
200.000	-3.727	-117.115	-23.405	-24043-001	5688-001	6.7829	-8.1116
300.000	-6.143	-128.265	-23.357	-30539-001	44571-001	2.7162	-8.7117
400.000	-8.294	-144.828	-23.033	-31310-001	39984-001	-38269	-7.5773
500.000	-10.465	-162.504	-23.407	-30158-001	38178-001	-2.1686	-5.7666
600.000	-12.706	-179.126	-24.295	-28097-001	37510-001	-2.9018	-3.9997
700.000	-14.975	-195.240	-25.269	-25548-001	37267-001	-2.9875	-2.5795
800.000	-17.241	-150.920	-26.840	-22741-001	37104-001	-2.7501	-1.5506
900.000	-19.478	-137.022	-26.140	-19829-001	36849-001	-2.3908	-85068
1000.000	-21.672	-125.922	-27.513	-16924-001	36424-001	-2.0155	-39435
2000.000	-40.456	49.263	-32.117	-26244-002	24798-001	-3.1286	-21659
3000.000	-54.494	10.878	-36.296	-68970-002	13708-001	-74928-001	97342-001
4000.000	-55.448	-11.612	-40.014	-54208-002	76525-002	-25419-001	47036-001
5000.000	-74.342	-26.180	-43.218	-52085-002	45334-002	-10757-001	25611-001
6000.000	-81.791	-36.314	-45.984	-11299-002	28559-002	-52814-002	15320-001
7000.000	-88.178	-51.745	-48.397	-32959-002	18978-002	-2.29818-002	98415-002

1	LADSS	TMFPR	11	IGDATA/MF-JUL
2	K5	.	7.0	
3	K4	.	7.0	
4	TAU7	.	.025	
5	K3	.	46.68	
6	TAU2	.	.01	
7	TAU2P	.	.01	
8	TAU3	.	.0005	
9	TAU3P	.	.0005	
10	TAU5	.	0.1	
11	TAU6	.	0.80	
12	A	.	190000.0	
13	TAUA	.	.02	
14	LA	.	.00278	
15	RA	.	9.317	
16	RSR	.	1.0	
17	KT	.	19.75	
18	N	.	12.9	
19	JM	.	.0015	
20	JL	.	2.47	
21	D	.	.622	
22	KF	.	.141	
23	KHND	.	.8595	
24	K2	.	14.0	
25	KF	.	1.0	
26	TAU4	.	.0015	
27	SIG DOT	-	SIG DT H	1
28	TRQ DIS	-	SIG DT H	2
29	ROD HOT	-	SIG DT H	3
30	TRQ DIS	-	PNT ERROR	4
31	ROD HOT	-	PNT ERROR	5
32	STABILIZATION LOOP	-		6

RXOT L, PROG

SIG OUT - SIG DT H I LADSS PLATFORM

FREQUENCY RADIAN	LOOP GAIN DB	DEGREES	NR	RESPONSE DEGREES	G				H			
					REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG
.010	52.196	-90.012	.000	.143	-1.2250	-4900.0	.83105-001	.37360-005	.83105-001	.37360-005	.83105-001	.37360-005
.020	46.176	-90.023	.000	.287	-1.2250	-2450.0	.83105-001	.74720-005	.83105-001	.74720-005	.83105-001	.74720-005
.030	42.654	-90.035	.000	.430	-1.2250	-1633.3	.83105-001	.11208-004	.83105-001	.11208-004	.83105-001	.11208-004
.040	40.155	-90.047	.000	.573	-1.2250	-1225.0	.83105-001	.19944-004	.83105-001	.19944-004	.83105-001	.19944-004
.050	38.217	-90.059	.001	.716	-1.2250	-980.00	.83105-001	.16880-004	.83105-001	.16880-004	.83105-001	.16880-004
.060	36.633	-90.070	.001	.860	-1.2250	-816.66	.83105-001	.22416-004	.83105-001	.22416-004	.83105-001	.22416-004
.070	35.294	-90.082	.001	1.003	-1.2250	-700.00	.83105-001	.26153-004	.83105-001	.26153-004	.83105-001	.26153-004
.080	34.135	-90.094	.001	1.146	-1.2250	-612.50	.83105-001	.29889-004	.83105-001	.29889-004	.83105-001	.29889-004
.090	33.112	-90.106	.002	1.289	-1.2250	-544.44	.83105-001	.33625-004	.83105-001	.33625-004	.83105-001	.33625-004
.100	32.196	-90.117	.002	1.433	-1.2250	-490.00	.83105-001	.37361-004	.83105-001	.37361-004	.83105-001	.37361-004
.200	25.176	-90.235	.009	2.864	-1.2250	-244.99	.83105-001	.74729-004	.83105-001	.74729-004	.83105-001	.74729-004
.300	22.654	-90.352	.020	4.293	-1.2249	-163.32	.83105-001	.11211-003	.83105-001	.11211-003	.83105-001	.11211-003
.400	20.155	-90.470	.035	5.718	-1.2249	-122.49	.83105-001	.19511-003	.83105-001	.19511-003	.83105-001	.19511-003
.500	18.216	-90.587	.054	7.138	-1.2248	-97.985	.83105-001	.18694-003	.83105-001	.18694-003	.83105-001	.18694-003
.600	16.633	-90.705	.078	8.552	-1.2247	-81.648	.83105-001	.22439-003	.83105-001	.22439-003	.83105-001	.22439-003
.700	15.293	-90.822	.106	9.958	-1.2246	-67.979	.83105-001	.26189-003	.83105-001	.26189-003	.83105-001	.26189-003
.800	14.133	-90.939	.138	11.357	-1.2245	-61.226	.83106-001	.29943-003	.83106-001	.29943-003	.83106-001	.29943-003
.900	13.110	-91.057	.174	12.745	-1.2244	-54.417	.83106-001	.33702-003	.83106-001	.33702-003	.83106-001	.33702-003
1.000	12.194	-91.174	.213	14.124	-1.2242	-48.969	.83106-001	.37466-003	.83106-001	.37466-003	.83106-001	.37466-003
2.000	6.166	-92.342	.799	27.148	-1.2219	-24.439	.83112-001	.75559-003	.83112-001	.75559-003	.83112-001	.75559-003
3.000	2.633	-93.199	1.632	38.457	-1.2181	-16.242	.83135-001	.11470-002	.83135-001	.11470-002	.83135-001	.11470-002
4.000	.118	-94.641	3.591	57.966	-1.2129	-12.129	.83152-001	.15522-002	.83152-001	.15522-002	.83152-001	.15522-002
5.000	-1.838	-95.767	5.589	75.873	-1.2052	-9.6492	.83176-001	.19716-002	.83176-001	.19716-002	.83176-001	.19716-002
6.000	-3.443	-96.977	7.574	92.535	-1.1980	-7.9870	.83254-001	.24039-002	.83254-001	.24039-002	.83254-001	.24039-002
7.000	-5.805	-97.970	9.523	108.172	-1.1896	-6.7920	.83359-001	.28468-002	.83359-001	.28468-002	.83359-001	.28468-002
8.000	-8.990	-99.048	11.426	123.029	-1.1779	-5.8894	.83483-001	.32972-002	.83483-001	.32972-002	.83483-001	.32972-002
9.000	-12.039	-100.112	13.280	137.279	-1.1660	-5.1821	.83638-001	.37521-002	.83638-001	.37521-002	.83638-001	.37521-002
10.000	-15.981	-101.162	15.087	151.050	-1.1539	-4.6118	.83825-001	.42086-002	.83825-001	.42086-002	.83825-001	.42086-002
20.000	-31.313	-111.075	31.329	305.644	-1.0800	-1.9600	.93982-001	.10865-001	.93982-001	.10865-001	.93982-001	.10865-001
30.000	-46.158	-120.275	46.781	458.374	-1.0453	-1.0453	.99408-002	.38263-002	.99408-002	.38263-002	.99408-002	.38263-002
40.000	-60.957	-129.483	61.250	608.804	-1.0292	-.61250	.10292	.77422-002	.10292	.77422-002	.10292	.77422-002
50.000	-75.245	-139.390	75.769	757.741	-1.1235	-.38244	.11235	.33195-001	.11235	.33195-001	.11235	.33195-001
60.000	-89.044	-150.044	89.944	904.944	-1.1863	-.25128	.11863	.40043-001	.11863	.40043-001	.11863	.40043-001
70.000	-102.578	-160.618	102.945	1059.427	-1.2311	-.17231	.11211	.42567-001	.11211	.42567-001	.11211	.42567-001
80.000	-116.890	-169.928	117.548	1214.314	-1.2250	-.12250	.11211	.43312-001	.11211	.43312-001	.11211	.43312-001
90.000	-132.237	-177.277	134.500	1377.277	-1.2026	-.89805-001	.10303	.44043-001	.10303	.44043-001	.10303	.44043-001
100.000	-148.511	-177.371	148.511	1485.249	-1.16897	-.67586-001	.94124-001	.42567-001	.94124-001	.42567-001	.94124-001	.42567-001
200.000	-29.140	-167.448	36.242	158.249	-1.1515-001	.94231-002	.66450-001	.29394-001	.66450-001	.29394-001	.66450-001	.29394-001
300.000	-55.835	-164.419	47.944	168.734	-1.1397-001	.94231-002	.68786-001	.29448-001	.68786-001	.29448-001	.68786-001	.29448-001
400.000	-80.284	-154.049	58.910	172.430	-1.1219-001	.94231-002	.67581-001	.41677-001	.67581-001	.41677-001	.67581-001	.41677-001
500.000	-104.466	-141.077	69.745	175.448	-1.1054-002	.62321-003	.55504-001	.52667-001	.55504-001	.52667-001	.55504-001	.52667-001
600.000	-128.576	-130.876	80.906	176.202	-1.0898-003	.97961-005	.41353-001	.54715-001	.41353-001	.54715-001	.41353-001	.54715-001
700.000	-152.303	-124.145	92.579	176.741	-1.0759-002	.36136-003	.31171-001	.52135-001	.31171-001	.52135-001	.31171-001	.52135-001
800.000	-176.377	-119.502	104.845	177.146	-1.0649-002	.15274-003	.24464-001	.48768-001	.24464-001	.48768-001	.24464-001	.48768-001
900.000	-200.865	-112.724	117.714	177.714	-1.0549-002	.10733-003	.19764-001	.45784-001	.19764-001	.45784-001	.19764-001	.45784-001
1000.000	-225.539	-84.513	130.876	178.855	-1.0459-002	.28275-004	.16145-001	.43312-001	.16145-001	.43312-001	.16145-001	.43312-001
2000.000	-451.745	63.8-5	269.645	179.236	-1.0370-002	.97961-005	.31300-002	.26917-001	.31300-002	.26917-001	.31300-002	.26917-001
3000.000	-677.442	50.294	398.845	179.427	-1.0289-002	.29032-005	.76043-002	.14957-001	.76043-002	.14957-001	.76043-002	.14957-001
4000.000	-902.500	41.128	529.721	179.542	-1.0214-002	.12249-005	.70865-002	.83602-002	.70865-002	.83602-002	.70865-002	.83602-002
5000.000	-1124.407	34.601	654.889	179.618	-1.0142-002	.36295-006	.57621-002	.49514-002	.57621-002	.49514-002	.57621-002	.49514-002
6000.000	-1340.407	29.234	784.566	179.673	-1.0073-002	.22856-006	.45831-002	.31169-002	.45831-002	.31169-002	.45831-002	.31169-002
7000.000	-1554.465	24.234	919.566	179.673	-1.0010-002	.20690-002	.36710-002	.20690-002	.36710-002	.20690-002	.36710-002	.20690-002

TRO DIS - SIG DT M 2 LADSS PLATFORM

FREQUENCY RADIAN	LOOP DB	GAIN DEGREES	DR	RESPONSE DEGREES	G		H	
					REAL	IMAG	REAL	IMAG
.010	179.087	-3.045	-122.774	90.531	345.227	7862.7	-1060.1	-11437.006
.020	147.020	-6.081	-116.753	91.062	343.331	3908.9	-1059.9	-57174.
.030	159.934	-9.098	-111.230	91.593	340.009	2581.4	-1059.5	-38103.
.040	154.878	-12.087	-110.729	92.124	335.69	1910.8	-1059.1	-28561.
.050	150.928	-15.041	-108.789	92.654	330.19	1503.5	-1058.5	-22838.
.060	147.672	-17.950	-107.203	93.184	323.71	1228.2	-1057.8	-19015.
.070	144.892	-20.809	-105.861	93.714	316.37	1028.7	-1057.0	-16284.
.080	142.456	-23.612	-104.697	94.243	308.31	877.03	-1056.0	-14233.
.090	140.282	-26.354	-103.670	94.772	299.66	757.56	-1054.9	-12436.
.100	138.313	-29.030	-102.750	95.300	290.54	660.92	-1053.7	-11398.
.200	124.497	-51.956	-96.658	100.541	196.26	222.50	-1034.8	-5561.0
.300	115.460	-68.736	-93.021	105.666	127.37	95.739	-1004.8	-3582.8
.400	105.571	-81.406	-90.366	110.628	85.403	47.773	-965.71	-2565.4
.500	102.970	-91.494	-88.238	115.388	59.987	26.576	-919.92	-1938.3
.600	99.238	-99.888	-86.437	119.921	43.985	16.039	-869.78	-1511.3
.700	94.130	-107.095	-84.858	124.209	33.442	10.238	-817.45	-1202.4
.800	90.495	-113.416	-83.443	128.244	26.195	6.9358	-764.74	-970.21
.900	87.229	-119.041	-82.155	132.028	21.029	4.8507	-713.06	-791.10
1.000	84.262	-124.092	-80.968	135.564	17.4231	3.4957	-663.42	-650.41
2.000	63.903	-156.302	-72.468	159.958	4.4666	.28653	-329.00	-119.92
3.000	51.817	-171.791	-67.411	171.846	1.9933	.26648-002	-193.59	-27.664
4.000	43.492	-179.752	-64.055	177.317	1.1192	.47556-001	-133.30	-6.246
5.000	37.282	-176.430	-61.679	179.117	.71318	.56158-001	-102.21	-1.6637
6.000	32.400	-175.106	-59.901	178.670	.49225	.54734-001	-84.145	-2.1305
7.000	28.423	-173.346	-58.510	176.785	.35894	.50780-001	-72.524	-4.3123
8.000	25.098	-171.589	-57.380	173.942	.27241	.46417-001	-64.692	-7.0952
9.000	22.261	-178.479	-56.433	170.425	.21309	.42281-001	-58.863	-10.063
10.000	20.802	-174.217	-55.615	168.403	.17070	.38544-001	-54.331	-13.051
20.000	5.796	-152.255	-50.771	102.713	.38288-001	.17627-001	-28.631	-38.910
30.000	-530	-131.749	-55.513	25.545	.12903-001	.95243-002	-5.4357	-58.409
40.000	-4.267	-118.415	-62.562	-7.468	.56705-002	.56059-002	21.480	-73.664
50.000	-6.856	-105.936	-68.053	-24.277	.28325-002	.35076-002	52.094	-86.215
60.000	-8.838	-104.507	-72.502	-35.043	.15509-002	.23073-002	86.305	-97.262
70.000	-10.449	-100.280	-76.287	-42.705	.91157-003	.15932-002	124.22	-107.65
80.000	-11.810	-98.654	-79.545	-48.481	.56706-003	.11261-002	166.03	-117.92
90.000	-12.988	-97.103	-82.455	-53.003	.36953-003	.82576-003	211.95	-128.42
100.000	-14.026	-96.064	-85.074	-56.644	.25029-003	.62159-003	263.13	-139.36
200.000	-20.589	-94.569	-102.646	-73.263	.17448-004	.86724-004	1015.6	-290.16
300.000	-24.304	-95.959	-113.105	-78.872	.35218-005	.26261-004	2234.9	-540.58
400.000	-26.918	-97.477	-120.555	-81.682	.11229-005	.11644-004	3912.0	-919.04
500.000	-28.937	-98.975	-126.343	-83.367	.46159-006	.57368-005	6036.1	-1457.5
600.000	-30.584	-100.476	-131.105	-84.490	.22304-006	.33264-005	8592.8	-2192.4
700.000	-31.940	-102.001	-135.117	-85.293	.12053-006	.20772-005	11560.	-3160.5
800.000	-33.197	-103.543	-138.594	-85.896	.70707-007	.14061-005	14911.	-4394.9
900.000	-34.280	-105.094	-141.661	-86.367	.44165-007	.98804-006	18414.	-5923.5
1000.000	-35.261	-106.642	-144.405	-86.754	.29987-007	.72055-006	22633.	-7769.0
2000.000	-42.224	-127.816	-162.469	-88.465	.18139-008	.90178-007	72811.	-45441.
3000.000	-46.978	-131.827	-173.042	-89.040	.35838-009	.26725-007	12335.006	-11340.006
4000.000	-50.767	-140.038	-180.595	-89.317	.11340-009	.11276-007	16292.006	-19844.006
5000.000	-53.945	-146.164	-186.364	-89.475	.46451-010	.57733-008	19132.006	-29043.006
6000.000	-56.680	-150.811	-191.118	-89.575	.22402-010	.33411-008	21134.006	-38436.006
7000.000	-57.075	-154.419	-195.137	-89.643	.12092-010	.21041-008	22558.006	-47814.006

ROD NOT - SIG DT M 3 LADSS PLATFORM

FREQUENCY RADIAN	LOOP GAIN DB	DEGREES	DB	RESPONSE DEGREES	G		H	
					REAL	IMAG	REAL	IMAG
.010	199.294	176.973	-147.097	93.013	-1.2250	-4900.0	-9886.6	-18788+007
.020	187.227	173.955	-141.051	96.0016	-1.2250	-24500.0	-98312.6	-93283+006
.030	180.142	170.956	-137.488	99.001	-1.2250	-1633.3	-97370.6	-61468+006
.040	175.087	167.984	-134.932	101.959	-1.2250	-1225.0	-96081.6	-45362+006
.050	171.138	165.047	-132.921	104.882	-1.2250	-900.00	-94470.6	-35551+006
.060	167.883	162.153	-131.250	107.761	-1.2250	-816.66	-92571.6	-28900+006
.070	165.104	159.308	-129.809	110.591	-1.2250	-700.00	-90419.6	-24067+006
.080	162.670	156.519	-127.386	113.367	-1.2250	-612.50	-88054.6	-20381+006
.090	160.497	153.789	-125.334	116.082	-1.2250	-544.44	-85512.6	-17469+006
.100	158.530	151.124	-123.334	118.733	-1.2250	-490.00	-82834.6	-15109+006
.200	144.731	128.253	-118.555	141.460	-1.2250	-244.99	-55040.6	-41843.6
.300	135.706	111.469	-113.052	159.101	-1.2249	-163.32	-34651.6	-13929.6
.400	128.824	98.778	-108.669	170.650	-1.2249	-122.49	-22248.6	-3663.4
.500	123.228	88.667	-105.012	179.383	-1.2248	-97.985	-14798.6	159.40
.600	118.498	80.251	-101.866	171.111	-1.2247	-81.648	-10178.6	1591.9
.700	114.332	73.025	-99.032	163.029	-1.2246	-68.979	-7202.6	2061.5
.800	110.758	66.686	-96.625	157.831	-1.2245	-61.226	-5218.2	2126.1
.900	107.493	61.042	-94.383	152.331	-1.2244	-54.417	-3855.3	2021.4
1.000	104.526	55.966	-92.333	147.398	-1.2243	-48.969	-2896.0	1852.2
2.000	84.172	23.492	-78.007	116.353	-1.2219	-24.439	-293.27	591.96
3.000	72.107	7.492	-69.480	101.780	-1.2181	-16.242	-50.527	242.25
4.000	63.828	-1.221	-63.721	94.490	-1.2129	-12.129	-9.780	127.08
5.000	57.679	-5.997	-59.511	91.136	-1.2062	-6.642	-1.5494	78.706
6.000	52.869	-8.457	-56.352	90.093	-1.1980	-7.9870	-70312-001	54.480
7.000	48.964	-9.500	-53.831	90.460	-1.1886	-6.7920	-130280	40.703
8.000	45.704	-9.661	-51.784	91.698	-1.1779	-5.8894	-92380	32.095
9.000	42.924	-9.269	-50.088	93.477	-1.1660	-5.1821	-1.5686	26.316
10.000	40.512	-8.530	-48.600	95.586	-1.1529	-4.6118	-2.1511	22.211
20.000	26.212	3.033	-41.419	119.457	-98000	-1.9600	-4.6082	8.125
30.000	18.874	13.501	-39.073	139.000	-78400	-1.0453	-5.1778	4.2879
40.000	14.085	22.361	-36.415	153.724	-61250	-6.1250	-5.3928	2.2491
50.000	10.653	30.009	-34.547	164.676	-47805	-38244	-5.5053	.83761
60.000	8.071	36.618	-39.085	172.788	-37592	-25128	-5.5833	-28552
70.000	6.082	42.287	-39.836	178.798	-30154	-17231	-5.6529	-1.2575
80.000	4.482	47.098	-40.700	176.738	-24500	-12250	-5.7276	-2.1452
90.000	3.200	51.130	-41.620	173.417	-20206	-89805-001	-5.8159	-2.9848
100.000	2.149	54.462	-42.565	170.947	-16897	-67586-001	-5.9245	-3.7977
200.000	-2.336	63.119	-45.622	165.622	-47115-001	-94231-002	-9.1768	-11.666
300.000	-5.367	51.860	-57.838	169.950	-21397-001	-28530-002	-17.883	-17.130
400.000	-7.514	35.243	-62.595	175.463	-12129-001	-12129-002	-30.952	-17.026
500.000	-9.697	17.733	-66.132	179.774	-77701-002	-62321-003	-40.798	-9.5388
600.000	-11.939	.885	-68.866	176.365	-54204-002	-36136-003	-46.503	2.3792
700.000	-14.289	-14.770	-71.087	174.337	-39870-002	-22783-003	-46.376	15.105
800.000	-16.475	-29.108	-72.985	173.445	-30549-002	-15274-003	-41.617	25.976
900.000	-18.713	-42.173	-74.679	173.354	-24150-002	-10733-003	-34.091	33.757
1000.000	-20.906	-54.062	-76.238	173.746	-19569-002	-7825-004	-25.584	38.298
2000.000	-39.684	-130.924	-87.746	178.402	-48980-003	-97961-005	-14.184	15.714
3000.000	-53.710	-169.423	-94.830	179.214	-21774-003	-29032-005	9.3356	1.6148
4000.000	-64.647	167.977	-99.840	179.434	-12449-003	-12249-005	4.6661	-1.0426
5000.000	-73.520	153.299	-103.720	179.546	-78395-004	-62716-006	2.3932	-1.2278
6000.000	-80.941	143.054	-106.888	179.621	-54442-004	-36295-006	1.3105	-9.9939
7000.000	-87.297	135.510	-109.566	179.674	-32999-004	-22856-006	.76555	-7.6067

TRQ DIS - PNT ERROR 4 LADSS PLATFORM

FREQUENCY RADIAN	LOOP GAIN DB	DEGREES	DB	RESPONSE DEGREES	G		H	
					REAL	IMAG	REAL	IMAG
.010	180.958	-3.045	-136.843	90.545	7.0062	160.47	-66177.	-69517.007
.020	168.692	-6.081	-130.821	91.091	6.9644	79.778	-66164.	-69522.007
.030	161.806	-9.098	-127.298	91.636	6.9012	52.687	-66144.	-69530.007
.040	156.1750	-12.088	-124.798	92.181	6.8118	39.003	-66115.	-69536.007
.050	152.800	-15.041	-122.657	92.726	6.7002	30.692	-66079.	-69549.007
.060	149.544	-17.950	-121.271	93.270	6.5688	25.074	-66034.	-69557.007
.070	146.763	-20.809	-119.929	93.814	6.4197	21.005	-65981.	-69565.006
.080	144.328	-23.612	-118.765	94.358	6.2563	17.911	-65920.	-69570.006
.090	142.154	-26.354	-117.738	94.901	6.0806	15.474	-65852.	-69573.006
.100	140.185	-29.031	-116.817	95.444	5.8957	13.503	-65775.	-69578.006
.200	126.369	-51.957	-110.726	100.828	3.9826	4.5608	-64586.	-69589.006
.300	117.331	-68.737	-107.089	106.097	2.5848	1.9734	-62706.	-69730.006
.400	110.442	-81.407	-104.434	111.202	1.7332	.99238	-60255.	-69833.006
.500	104.842	-91.196	-102.306	116.106	1.2174	.55767	-57382.	-69910.006
.600	100.109	-99.890	-100.504	120.783	.89275	.34078	-54235.	-91041.
.700	96.001	-107.097	-98.925	125.214	.67880	.22210	-50951.	-72189.
.800	92.366	-113.419	-97.509	129.393	.53176	.15224	-47644.	-58014.
.900	89.100	-119.045	-96.220	133.321	.42694	.10865	-44401.	-47081.
1.000	86.133	-124.103	-95.033	137.001	.34987	.80132-001	-41286.	-38496.
2.000	65.772	-156.310	-86.543	162.831	.90654-001	10.405-001	-20305.	-6268.8
3.000	53.682	-171.802	-81.452	176.151	.40676-001	3.1054-002	-11817.	-791.80
4.000	45.352	-179.767	-78.080	176.957	.22939-001	1.3134-002	-8048.5	428.02
5.000	39.135	176.412	-75.684	173.749	.14698-001	.67327-003	-6115.9	665.57
6.000	34.245	175.084	-73.886	172.801	.10213-001	.38987-003	-5005.3	623.65
7.000	30.259	175.320	-72.475	173.298	.75067-002	2.9561-003	-3209.4	495.08
8.000	26.922	176.560	-71.327	174.758	.57487-002	1.6458-003	-3842.8	341.60
9.000	24.074	178.447	-70.363	176.885	.45430-002	1.1561-003	-3512.4	184.75
10.000	21.683	179.252	-69.531	179.503	.36803-002	.84291-004	-3267.4	32.183
20.000	7.408	-152.319	-64.429	135.333	.92043-003	10.540-004	-2270.6	-1158.2
30.000	.844	-131.831	-66.481	72.548	.40911-003	.31233-005	-1811.7	-1993.2
40.000	-3.129	-118.505	-71.903	42.906	.23013-003	.13177-005	-1461.7	-2555.2
50.000	-5.923	-110.028	-76.224	30.142	.14729-003	.67467-006	-1190.5	-3220.0
60.000	-8.073	-104.597	-79.612	23.206	.10228-003	.39043-006	-986.93	-3731.1
70.000	-9.819	-101.067	-82.395	18.853	.75146-004	2.9587-006	-838.52	-4214.0
80.000	-11.286	-98.737	-84.765	15.869	.57539-004	1.6472-006	-733.35	-4662.8
90.000	-12.548	-97.181	-86.833	13.700	.45459-004	.11569-006	-661.61	-5145.3
100.000	-13.553	-96.137	-88.672	12.054	.36822-004	.84335-007	-615.75	-5605.6
200.000	-20.480	-94.612	-100.692	5.495	.92055-005	10.542-007	-838.17	-10245.
300.000	-24.254	-95.989	-107.723	3.6553	.40913-005	.31235-008	-1573.9	-14894.
400.000	-26.890	-97.500	-112.718	2.616	.23014-005	.13177-008	-3576.8	-19487.
500.000	-28.919	-98.993	-116.593	2.063	.14729-005	.67468-009	-3811.7	-24014.
600.000	-30.572	-100.492	-119.761	1.698	.10228-005	.39044-009	-52.11	-28460.
700.000	-31.971	-102.014	-122.439	1.438	.75147-006	2.9587-009	-6991.3	-32801.
800.000	-33.190	-103.554	-124.759	1.243	.57535-006	1.6472-009	-8932.5	-37006.
900.000	-34.275	-105.103	-126.805	1.089	.45459-006	.11569-009	-11090.	-41052.
1000.000	-35.257	-106.650	-128.636	.965	.36822-006	.84335-010	-13445.	-44317.
2000.000	-42.223	-120.819	-140.685	.389	.92055-007	10.542-010	-43096.	-72221.
3000.000	-46.977	-131.829	-147.737	.196	.40913-007	.31235-011	-73008.	-81560.
4000.000	-50.767	-140.039	-152.741	.110	.23014-007	.13177-011	-9428.	-80792.
5000.000	-53.945	-146.164	-156.622	.067	.14729-007	.67468-012	-11324.006	-75904.
6000.000	-56.680	-150.811	-159.793	.043	.10228-007	.39044-012	-12509.006	-69872.
7000.000	-59.075	-154.414	-162.473	.022	.75147-008	2.9587-012	-13351.006	-63924.

BOD MOT - PNT ERROR S LADSS PLATFORM:

FREQUENCY RADIAN	LOOP GAIN		RESPONSE		G		H	
	DB	DEGREES	DB	DEGREES	REAL	IMAG	REAL	IMAG
.010	199.294	-3.027	-15.294	93.027	.00000	100.00	-48684.007	.92060+008
.020	187.227	-6.045	-15.248	96.045	.00000	50.000	-48402.007	.45706+008
.030	180.142	-9.064	-14.685	99.044	.00000	33.333	-47937.007	.30116+008
.040	175.087	-12.016	-14.128	102.016	.00000	25.000	-47302.007	.22222+008
.050	171.138	-14.953	-14.517	104.953	.00000	20.000	-46508.007	.17414+008
.060	167.883	-17.847	-14.344	107.847	.00000	16.667	-45572.007	.14154+008
.070	165.004	-20.692	-14.006	110.692	.00000	14.286	-44512.007	.11785+008
.080	162.670	-23.481	-14.732	113.481	.00000	12.500	-43346.007	.99278+007
.100	160.497	-26.211	-13.582	116.211	.00000	11.111	-42093.007	.85505+007
.120	158.530	-28.876	-13.530	118.876	.00000	10.000	-40774.007	.73233+007
.140	144.731	-51.747	-13.751	141.747	.00000	5.0000	-37076.007	.21348+007
.160	135.706	-68.531	-12.524	158.531	.00000	3.3333	-31702.007	.66973+006
.180	128.824	-81.222	-12.865	171.222	.00000	2.5000	-24109.007	.16859+006
.200	123.228	-91.333	-11.7208	178.667	.00000	2.0000	-22488.006	16871.
.250	118.498	-99.749	-11.4061	170.251	.00000	1.6667	-19743.006	85466.
.300	114.392	-106.975	-11.294	163.025	.00000	1.4286	-173105.006	.10716+006
.400	107.758	-113.314	-10.620	156.686	.00000	1.2500	-153505.006	.10925+006
.500	104.526	-124.034	-10.578	151.043	.00000	1.0000	-13955.006	.10325+006
.600	101.172	-136.508	-9.5192	145.967	.00000	.50000	-12888.	29650.
.700	94.107	-156.508	-8.1648	113.494	.00000	.33333	-1576.7	11988.
.800	86.828	-172.508	-7.8643	89.778	.00000	.25000	132.44	6213.6
.900	81.679	-174.003	-7.1647	83.995	.00000	.20000	397.91	3806.8
1.000	57.669	174.003	-6.412	81.524	.00000	.16667	388.24	2611.3
2.000	52.869	171.543	-6.5835	80.466	.00000	.14286	324.26	1937.7
3.000	48.964	170.500	-6.3722	80.289	.00000	.12500	258.91	1520.9
4.000	45.704	170.339	-6.1948	80.645	.00000	.11111	202.99	1243.8
5.000	42.924	170.731	-6.0431	81.335	.00000	.10000	157.34	1043.0
6.000	40.512	171.470	-5.797	93.189	.00000	.50000	-21.637	408.33
7.000	38.212	176.967	-4.7402	105.212	.00000	.33333	-61.523	256.25
8.000	36.274	166.499	-4.410	117.616	.00000	.25000	-77.020	187.23
9.000	34.085	157.63	-4.252	131.134	.00000	.20000	-85.250	147.61
10.000	31.653	149.99	-4.0811	145.642	.00000	.16667	-90.636	121.96
20.000	3.071	143.38	-4.060	160.174	.00000	.14286	-94.727	104.15
30.000	4.482	132.71	-3.897	173.470	.00000	.12500	-98.176	91.238
40.000	3.200	128.670	-4.0141	175.282	.00000	.11111	-101.29	81.641
50.000	2.143	125.538	-4.0612	166.216	.00000	.10000	-104.21	74.335
60.000	2.035	116.881	-4.5384	133.192	.00000	.50000	-127.22	64.489
70.000	5.367	128.140	-4.7500	122.439	.00000	.33333	-127.19	99.877
80.000	2.4514	144.756	-4.8939	110.318	.00000	.25000	-97.181	137.54
90.000	2.697	162.267	-5.0823	98.247	.00000	.20000	-43.867	155.94
100.000	11.933	179.115	-5.3030	90.300	.00000	.16667	-2.3448	151.75
200.000	14.209	165.230	-5.5106	86.499	.00000	.14286	34.759	131.84
300.000	16.475	150.892	-5.6872	85.198	.00000	.12500	58.396	104.88
400.000	18.713	137.827	-5.8336	85.131	.00000	.11111	70.076	77.356
500.000	20.906	125.931	-5.9554	85.596	.00000	.10000	73.950	52.866
600.000	39.684	49.076	-6.6080	89.554	.00000	.50000	15.672	-13.587
700.000	53.710	10.577	-6.560	89.978	.00000	.33333	1.1361	-6.0841
800.000	64.647	-12.023	-7.046	90.007	.00000	.25000	-48.797	-2.2913
900.000	73.520	-26.701	-7.3981	90.005	.00000	.20000	-47.376	-9.4191
1000.000	80.941	-36.946	-7.5564	90.003	.00000	.16667	-32.360	-4.4307
2000.000	87.297	-44.490	-7.6902	90.002	.00000	.14286	-2.2176	-2.21556

STABILIZATION LOOP 6 LADSS PLATFORM

FREQUENCY RAD/SEC	LOOP GAIN		RESPONSE		G		H	
	DR	DEGREES	DR	DEGREES	REAL	IMAG	REAL	IMAG
.010	147.097	-92.875	-21.607	.003	-94272.	-18790.007	12.033	-54148.003
.020	141.051	-95.740	-21.607	.005	-93728.	-93328.006	12.033	-10330.002
.030	137.488	-98.587	-21.607	.008	-92837.	-61536.006	12.033	-16245.002
.040	134.921	-101.407	-21.607	.010	-91615.	-45451.006	12.033	-21650.002
.050	132.920	-104.191	-21.607	.013	-90098.	-35661.006	12.033	-27071.002
.060	131.248	-106.933	-21.607	.015	-88292.	-29029.006	12.033	-32489.002
.070	129.808	-109.625	-21.607	.018	-86255.	-24214.006	12.033	-37901.002
.080	128.533	-112.262	-21.607	.021	-84015.	-20545.006	12.033	-43319.002
.090	127.383	-114.839	-21.607	.023	-81608.	-17649.006	12.033	-48731.002
.100	126.331	-117.352	-21.607	.026	-79072.	-15303.006	12.033	-54148.002
.200	118.543	-138.701	-21.607	.052	-52749.	-46425.	12.033	-10830.001
.300	113.025	-153.967	-21.607	.077	-33429.	-16384.	12.033	-16245.001
.400	108.621	-165.147	-21.607	.103	-21662.	-5786.6	12.033	-21650.001
.500	104.936	-173.755	-21.607	.129	-14579.	-1628.7	12.033	-27071.001
.600	101.757	-179.323	-21.607	.155	-10174.	92.700	12.033	-32489.001
.700	98.952	-173.578	-21.607	.181	-7322.2	800.82	12.033	-37901.001
.800	96.433	-168.706	-21.607	.206	-5409.0	1060.0	12.033	-43319.001
.900	94.142	-164.514	-21.607	.232	-4084.8	1114.0	12.033	-48731.001
1.000	92.037	-160.873	-21.607	.258	-3144.1	1074.6	12.033	-54148.001
2.000	76.927	-141.557	-21.606	.521	-460.21	358.62	12.032	-10829
3.000	67.339	-136.208	-21.605	.791	-141.44	131.98	12.032	-16243
4.000	60.420	-135.777	-21.601	1.062	-53.595	59.723	12.030	-21657
5.000	55.084	-137.392	-21.595	1.358	-35.444	31.159	12.029	-27069
6.000	50.790	-139.910	-21.587	1.654	-22.515	17.937	12.027	-32480
7.000	47.231	-142.804	-21.576	1.956	-15.578	11.066	12.025	-37890
8.000	44.213	-145.818	-21.561	2.262	-11.435	7.1783	12.023	-43298
9.000	41.609	-148.811	-21.543	2.569	-8.7611	4.8301	12.020	-48704
10.000	39.4329	-151.716	-21.522	2.874	-6.9335	3.3378	12.017	-54108
20.000	25.543	-173.989	-21.127	5.490	-1.5752	.23535-001	11.968	-1.0797
30.000	18.390	-171.662	-20.481	6.595	-6.6599	-19.168	11.888	-1.6135
40.000	13.720	-160.910	-19.710	5.517	-35.330	-1.9900	11.775	-2.1401
50.000	10.373	-152.220	-18.983	1.950	-20991	-1.8022	11.633	-2.6573
60.000	7.854	-144.993	-18.498	-3.734	-13233	-1.6017	11.460	-3.1627
70.000	5.898	-138.733	-18.389	-10.360	-85677-001	-1.4287	11.259	-3.6543
80.000	4.344	-133.863	-18.642	-16.493	-55458-001	-1.2856	11.030	-4.1301
90.000	3.088	-129.651	-19.130	-21.239	-34781-001	-1.1678	10.775	-4.5883
100.000	2.056	-126.190	-19.711	-24.430	-20025-001	-1.0702	10.496	-5.0272
200.000	-2.055	-117.109	-22.774	-23.862	-26283-001	-1.953-001	6.7829	-8.1116
300.000	-5.371	-128.274	-22.519	-23.176	-33370-001	-1.48718-001	2.7162	-8.7117
400.000	-7.4512	-134.842	-22.004	-31.662	-34207-001	-1.3713-001	2.38269	-7.5773
500.000	-9.693	-162.332	-22.325	-43.497	-32941-001	-1.1745-001	-2.1866	-5.7666
600.000	-11.933	-179.163	-23.275	-52.918	-30684-001	-1.019-001	-2.9018	-3.9997
700.000	-14.202	-165.195	-24.330	-59.126	-27893-001	-1.40757-001	-2.9875	-2.5795
800.000	-16.468	-150.867	-25.263	-63.360	-24820-001	-1.40582-001	-2.7501	-1.5506
900.000	-18.705	-137.811	-26.044	-66.651	-21634-001	-1.40305-001	-2.3908	-85068
1000.000	-20.898	-125.922	-26.703	-69.557	-18454-001	-1.39842-001	-2.0155	-37735
2000.000	-39.675	-49.119	-31.341	-96.633	-29400-002	-1.2712-001	-3.1286	-21659
3000.000	-53.700	-10.659	-35.505	-116.949	-76140-002	-1.4990-001	-7.4926-001	97342-001
4000.000	-64.638	-11.906	-39.204	-130.286	-70916-002	-1.6364-002	-25419-001	47036-001
5000.000	-73.510	-42.386	-42.386	-139.330	-57643-002	-1.49518-002	-10757-001	25611-001
6000.000	-80.932	-36.764	-45.126	-145.781	-45836-002	-1.1169-002	-52814-002	15320-001
7000.000	-87.288	-44.274	-47.506	-150.594	-36712-002	-1.20690-002	-28818-002	98415-002

APPENDIX G TIME-DOMAIN ANALYSIS

TIME-DOMAIN ANALYSIS DERIVATION

The time-domain analysis was carried out using time integration computer programs. The advantage of using this program is that nonlinearities can very easily be incorporated into the computer model. The approach is straightforward. First the transfer functions are broken down into first order. This is illustrated in figures G-1 and G-2, the slave and track loops respectively. Each of the first order blocks can then be equated to a first order differential equation. These first order differential equations are listed on figures G-1 and G-2. Once the system of first order differential equations has been defined, they are incorporated into a computer program that uses an integration routine for a step by step time integration of a system of first order differential equations.

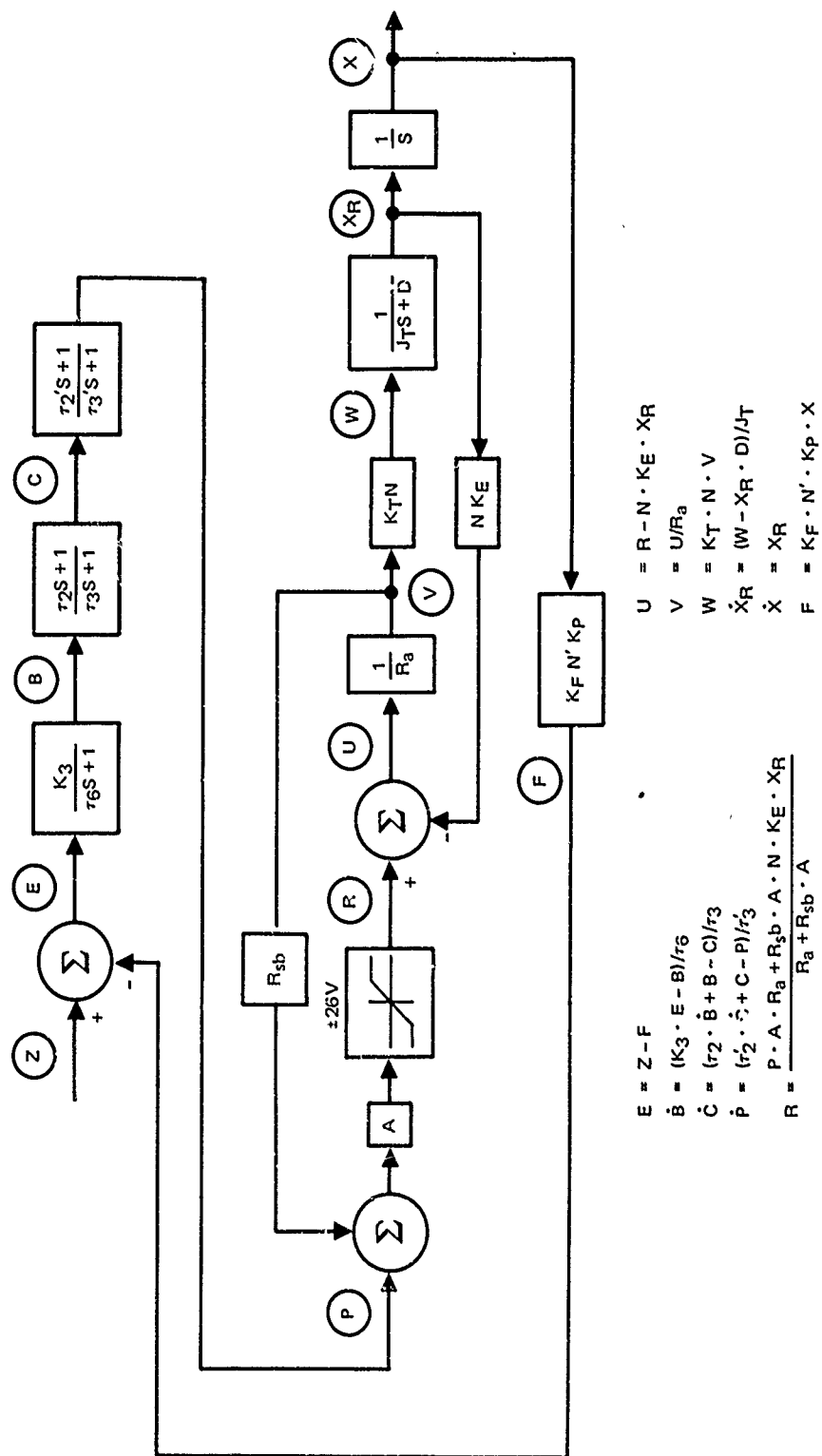


Figure G-1. Time-domain analysis block diagram of slave loop.

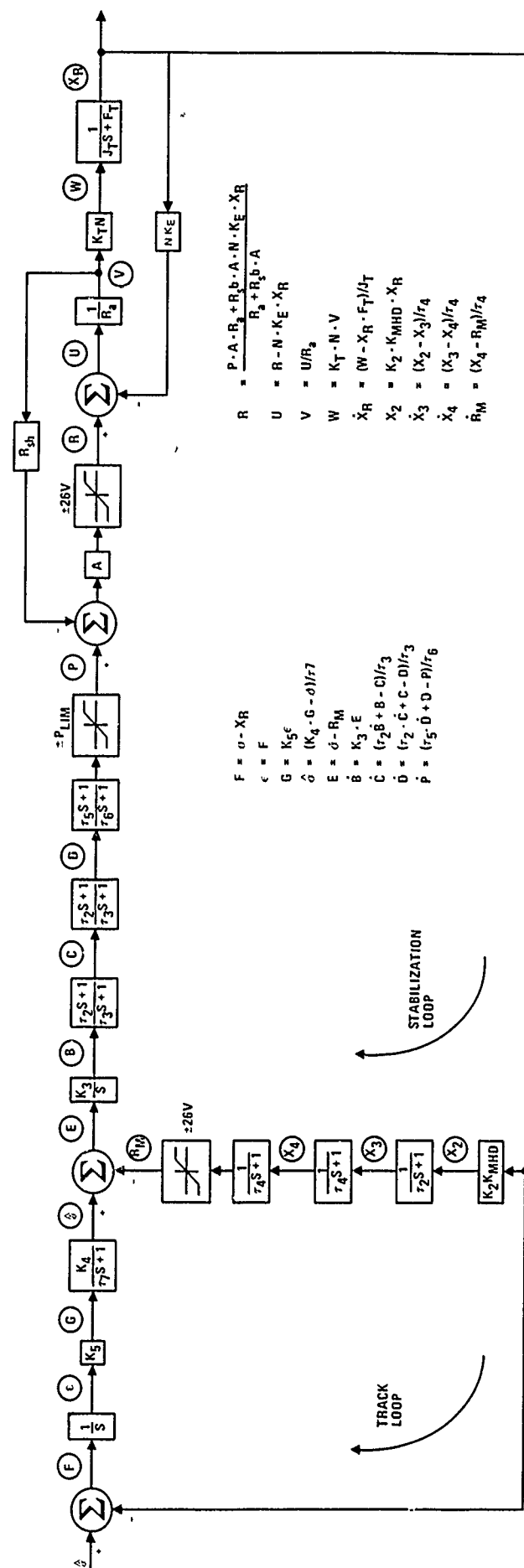


Figure G-2. Time-domain analysis block diagram of track loop.

LADSS*TRKLPTR

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#FIN.RODS R-MAIN
FTN ORT 00-14-12(10,2)
1. C** NAME=LADSS-STABILIZED-PLATFORM-TRACK LOOP TIME RESPONSE
2. C**
3. C** USAGE: THE FOLLOWING CONTROL CARDS WILL EXECUTE THIS PROGRAM
4. C**
5. C**
6. C**
7. C**
8. C**
9. C**
10. C**
11. C**
12. C**
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51. C**
52. C**
53. C**

PURPOSE: THIS PROGRAM MODELS (IN THE TIME DOMAIN) THE TRACK
LOOP OF THE LADSS GIMBALED PLATFORM BY NUMERICAL INTEGRATION
OF THE DIFFERENTIAL EQUATIONS THAT MODEL THE SYSTEM.
THAT IS, IT COMPUTES THE TIME RESPONSE OF THE TRACK LOOP
TO A GIVEN INPUT SIGNAL.

LIMITATIONS: THE FOLLOWING LIMITATIONS ARE MODELED AS A STREIGHT
GAIN (A), AND THE ARMATURE INDUCTANCE (LA) IS OMITTED.

WARNINGS: THIS PROGRAM MAY USE CONSIDERABLE COMPUTER TIME IF THE
INPUTS STOP AND DT ARE CHOSEN INCORRECTLY.

SUBPROGRAMS REQUIRED:
EQUINT - PERFORMS THE NUMERICAL INTEGRATION
ARGUMENTS: NONE

NOTES:
1. THIS PROGRAM RUNS ON THE UNIVAC-1110 IN ASCII FORTRAN.
CAU TIME IS APPROXIMATELY .00038 * (DT/STOPT).
NUMBER OF PAGES OF OUTPUT IS APPROXIMATELY .09 * (DP/STOPT).
2. EACH INPUT VARIABLE IS ON A SEPARATE LINE WITH 2 SPACES
AVAILABLE AT THE BEGINNING OF THE LINE FOR THE VARIABLE NAME.
3. OUTPUT IS GENERATED EVERY DP SECONDS OF SIMULATED TIME
4. THE INPUT SIGNAL (SIGD) IS CHOSEN AS EITHER:
A) A STEP FUNCTION WHOSE VALUE IS GIVEN BY INPUT STPA
B) A SINUSOID WHOSE FREQUENCY & AMPLITUDE ARE GIVEN BY
INPUT-VARIABLES SIF AND SINA RESPECTIVELY.
THE CHOICE IS MADE BY SETTING LOGICAL VARIABLE SIGF PROPERLY
SIGF = .TRUE. YIELDS A SINUSOID WHILE
SIGF = .FALSE. YIELDS A STEP FUNCTION.

PROGRAMMER/ORGANIZATION: DARYL E. SMITH CSC DEPT 551

ALGORITHM:
1. READ AND ECHO INPUTS
2. INITIALIZE CONTROL VARIABLES
3. DO WHILE I .LE. STOPT
COMPUTE VALUE OF DIFFERENTIALS
CALL EQUINT
CHECK FOR OUTPUT
4. END DO
5. STOP

RECORD OF MODIFICATIONS:
START EDIT PAGE

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54.	REAL	U	OPEN LOOP AMPLIFIER GAIN V/V
55.	REAL	U	SEE BLOCK DIAGRAM
56.	REAL	U	DERIVATIVE OF U
57.	REAL	C	SEE BLOCK DIAGRAM
58.	REAL	CD	DERIVATIVE OF C
59.	REAL	D	SEE BLOCK DIAGRAM
60.	REAL	DD	DERIVATIVE OF D
61.	REAL	DP	PRINT INTERVAL
62.	REAL	DT	INTEGRATION INTERVAL
63.	REAL	E	OUTPUT OF STAB LOOP SUMMER
64.	REAL	EPS	POINTING ERROR DEG
65.	REAL	EPSD	POINTING ERROR RATE DEG
66.	REAL	F	OUTPUT OF TRACK LOOP SUMMER
67.	REAL	FT	TOTAL FRICTION
68.	REAL	G	SEE BLOCK DIAGRAM
69.	INTEGER	HEADER (20)	DATA IDENTIFICATION LABEL DUFFER
70.	INTEGER	I	1/0 IMPLIED LOOP COUNTER
71.	INTEGER	IPRINT	LO. OF DT'S BETWEEN OUTPUTS
72.	REAL	JL	LOAD INERTIA 02-IN-SEC**2
73.	REAL	JM	MOTOR INERTIA 02-IN-SEC**2
74.	REAL	I	LOCAL INERTIA 02-IN-SEC**2
75.	REAL	K2	DATE SENS FILT GAIN VDC/VHMS
76.	REAL	K3	COMPENSATION GAIN V/V
77.	REAL	K4	GUIDANCE SIGNAL FILT GAIN V/V
78.	REAL	K5	SENSOR GAIN VDC/RAD/SEC
79.	REAL	KE	BACK EMF CONSTANT V/RAD/SEC
80.	REAL	KMD	DATE-SENSOR-GAIN-VHMS/RAD/SEC
81.	REAL	KT	TRQ SENSITIVITY CONST 02-IN/AMP
82.	REAL	N	GEAR RATIO GYBAL-TO-MOTOR
83.	INTEGER	NI	LOOP COUNTER-COUNTS NO. OF DT'S
84.	INTEGER	NDTS	TOTAL # OF DT'S TO PERFORM
85.	INTEGER	NTS	NO. OF EQUATIONS IN SYSTEM
86.	REAL	P	OUTPUT-OF-COMPENSATION-BLOCK-V
87.	REAL	PD	DERIVATIVE OF P
88.	REAL	PLIN	LIMIT ON P
89.	REAL	RA	AMPLIFIER OUTPUT
90.	REAL	RA	ARMATURE RESISTANCE OHMS
91.	REAL	RM	MEASURED RATE FEEDBACK
92.	REAL	RMD	DERIVATIVE-OF RM
93.	REAL	RSB	CURRENT FEEDBACK CONSTANT OHMS
94.	REAL	SIGD	TRACK LOOP INPUT
95.	REAL	SIGDH	ESTIMATED-LINE-OF-SIGHT
96.	REAL	SIGDHD	DERIVATIVE OF SIGDH
97.	REAL	SIGDHO	SIGDH SCALED FOR OUTPUT
98.	REAL	SIGDI	TEMP-VARIABLE
99.	LOGICAL	SIGF	INPUT SIGNAL FLAG
100.	REAL	SIVA	AMPLITUDE OF SINUSOID INPUT
101.	REAL	SIVF	FREQUENCY OF SINUSOID INPUT
102.	REAL	STOPT	STOP TIME
103.	REAL	SIPA	AMPLITUDE OF STEP INPUT
104.	REAL	T	SIMULATED-TIME
105.	REAL	TAU2	ALL TAU'S ARE TIME CONSTANTS
106.	REAL	TAU3	
107.	REAL	TAU4	
108.	REAL	TAU5	
109.	REAL	TAU6	
110.	REAL	TAU7	

111.	REAL	U	SEE CLJCA DIAGRAM
112.	REAL	V	MOTOR CURRENT OUTPUT AMPS
113.	REAL	W	MOTOR TORQUE OUTPUT 01-IN-SEC2
114.	REAL	X2	SEE GLOCK DIAGRAM
115.	REAL	X3	SEE GLOCK DIAGRAM
116.	REAL	X20	DERIVATIVE OF X3
117.	REAL	X4	SEE GLOCK DIAGRAM
118.	REAL	X40	DERIVATIVE OF X4
119.	REAL	X4	STAB-LOOP-OUTPUT
120.	REAL	XRD	DERIVATIVE OF AR
121.	REAL	Y (30)	OUTPUT OF NUMERICAL INTEGRATION
122.	REAL	YD (50)	DERIVATIVES INPUT TO NUM INTG
123.	EQUIVALENCE	(Y (1) , EPS) , (YD (1) , EPSD)	
124.	EQUIVALENCE	(Y (2) , SIGDH) , (YD (2) , SIGDHD)	
125.	EQUIVALENCE	(Y (3) , C) , (YD (3) , BD)	
126.	EQUIVALENCE	(Y (4) , C) , (YD (4) , CD)	
127.	EQUIVALENCE	(Y (5) , D) , (YD (5) , DD)	
128.	EQUIVALENCE	(Y (6) , P) , (YD (6) , PD)	
129.	EQUIVALENCE	(Y (7) , RA) , (YD (7) , XRD)	
130.	EQUIVALENCE	(Y (8) , X3) , (YD (8) , X3D)	
131.	EQUIVALENCE	(Y (9) , Z) , (YD (9) , X4D)	
132.	EQUIVALENCE	(Y (10) , RA) , (YD (10) , RMD)	
133.			START EDIT PAGE
134.	C		
135.	C		RLAD AND ECHO INPUTS.
136.	C		

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1 174.      CD = ( TAU2 * C0 + B - C ) / TAU3
1 175.      DC = ( TAU2 * C0 + C - D ) / TAU3
1 176.      PLIM = APLIM ( APLIM ( P, PLIM ) , PLIM )
1 177.      PD = ( TAU5 * DD + U - P ) / TAU6
1 178.      R = ( P * A * RA + KSC * A * N * KE * XR ) /
1 179.      ( RA + KSC * A * N )
1 200.      X = ANIM1 ( APLIM1 ( K5 - 20.0 ) , 26.0 )
1 201.      U = R - H * KE * AR
1 202.      V = U / RA
1 203.      W = K1 * N * V
1 204.      KND = ( A - X * FT ) / J1
1 205.      X2 = A2 * KND * A * K
1 206.      X50 = ( X2 - X3 ) / TAU4
1 207.      A40 = ( X3 - X4 ) / TAU4
1 208.      KND = ( X4 - XN ) / TAU4
1 209.      CALL LOINT ( DT, N11, MSYS, YD, Y )
1 210.      T = T + DT
1 211.      L
1 212.      C CHECK FOR OUTPUT
1 213.      C
1 214.      IF ( XND - 1.0, IPRINT, 10.0 ) OR ( N11 - 10.0 ) THEN
2 215.          P = ANIM1 ( APLIM1 ( P, PLIM ) , PLIM )
2 216.          NH = ANIM1 ( ANIM1 ( RN, -26.0 ) , 26.0 )
2 217.          SIGDH = SIGDH / ( K2 * KND )
2 218.          WRITE ( 6, 10 ) F, SIGDH, EPS, SIGDH, XR, P, V, W, RM
2 219.          FORMAT ( 'U', 6X, 'TIME', 8A, 'SIGD', 5X, 'EPS', 7X,
2 220.          'SIGDH', 5X, 'XR', 5X, 'V', 5X, 'W', 5X, 'RM', 5X,
2 221.          '0.22X', 5X, '10X', 5X, '10X', 5X, '10X', 5X,
2 222.          '16X', 4X, 'G12.5' )
2 223.          A = ANIM1 ( APLIM1 ( R, -26.0 ) , 26.0 )
2 224.          WRITE ( 6, 100 ) F, SIGDH, SIGDH, K, PD, K, XND, RMD
2 225.          FORMAT ( 'U', 12X, F, SIGDH, SIGDH, E, 4 ( 2X, G12.5 ) ,
2 226.          1X, PD, R, XND, RMD, 5X, 4 ( 2X, G12.5 ) )
2 227.          END IF
1 228.      110 CONTINUE
229.      STOP
250.      END

```

```

06TH,RODS H.EQINT
FIN,PI 0.2/10/30-14.1-1.1(10.)
1.  SUBROUTINE EQINT (DI,
2.  INPUT
3.  INPUT
4.  INPUT
5.  INPUT
6.  OUTPUT
7.  USAGE=CALL EQINT (DI,M1,FMSYS,YD,Y)
8.  C**
9.  C**
10. C** PURPOSE: THIS ROUTINE PERFORMS A NUMERICAL INTEGRATION ON A SYSTEM
11. C** OF FIRST-ORDER LINEAR DIFFERENTIAL EQUATIONS.
12. C**
13. C** LIMITATIONS: THE NUMBER OF EQUATIONS IN THE SYSTEM IS LIMITED TO 30
14. C** BY THE DIMENSION OF Y,S,YD.
15. C**
16. C** WARNINGS: NONE
17. C**
18. C** SUBPROGRAMS REQUIRED: NONE
19. C**
20. C** ARGUMENTS:
21. C** INPUT: DI - REAL *4 INTEGRATION INTERVAL
22. C** M1 - INTEGER COUNTS NUMBER OF TIMES EQINT IS CALLED.
23. C**
24. C** USED TO FLAG SWITCH FROM EULER TO ADAMS-BASHFORTH
25. C** INTEGRATION ALGORITHMS.
26. C**
27. C** MSYS - NO. OF EQUATIONS IN SYSTEM
28. C**
29. C** YD - DERIVATIVES INPUT TO NUMERICAL INTEGRATION
30. C**
31. C** OUTPUT: Y - INTEGRATED OUTPUT FROM NUMERICAL INTEGRATION
32. C**
33. C** NOTES: THE DIFFERENTIAL EQUATIONS MUST BE CALCULATED BEFORE THE
34. C** CALL TO EQINT AND THE RESULTS STORED IN ARRAY YD.
35. C** THE RESULTS OF THE INTEGRATION ARE CALCULATED BY EQINT
36. C** AND STORED IN ARRAY Y. THERE IS A ONE-ONE CORRESPONDENCE
37. C** BETWEEN THE ELEMENTS OF Y & YD; Y(1) IS THE RESULT
38. C** OF INTEGRATING YD(1).
39. C**
40. C** PROGRAMMER/ORGANIZATION: GARYL E. SMITH CSC DEPT 551
41. C**
42. C** ALGORITHM: THE METHOD OF INTEGRATION IS THE STANDARD
43. C** ADAMS-BASHFORTH. FOR THE FIRST THREE CALLS TO EQINT, EULER'S
44. C** METHOD IS USED AND THE RESULTS STORED IN ARRAY FSAV. AFTER THAT
45. C** ADAMS BASHFORTH IS USED.
46. C**
47. C** RECORD OF MODIFICATIONS:
48. C**
49. C** START EDIT PAGE
50. C**

```

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46.      C (4)  /-1.37E-57.55.1  @ ADAMS-BASHFORTH COEFFICIENTS
47.      REAL  DT  / 24.0
48.      REAL  DT024  / 24.0
49.      REAL  FSAV(50,4)  / 120.0
50.      INTEGER  I
51.      INTEGER  NIT
52.      INTEGER  NSYS
53.      REAL  SUM
54.      REAL  Y (50)
55.      REAL  YD (50)
56.      IF (.NOT. LE. 3.) THEN
57.          DT024 = DT / 24.0
58.          DO 10 I=1,NSYS
59.              FSAV(I,1) = FSAV(I,2)
60.              FSAV(I,2) = FSAV(I,3)
61.              FSAV(I,3) = FSAV(I,4)
62.              FSAV(I,4) = YD(I)
63.              Y (I) = Y (I) + DT * FSAV (I,4)
64.          CONTINUE
65.      ELSE
66.          DO 50 I=1,NSYS
67.              SUM = 0.0
68.              FSAV (I,1) = FSAV (I,2)
69.              FSAV (I,2) = FSAV (I,3)
70.              FSAV (I,3) = FSAV (I,4)
71.              FSAV (I,4) = YD (I)
72.              SUM = SUM + C (1) * FSAV (I,1)
73.              SUM = SUM + C (2) * FSAV (I,2)
74.              SUM = SUM + C (3) * FSAV (I,3)
75.              SUM = SUM + C (4) * FSAV (I,4)
76.              Y(I) = Y(I) + DT024 * SUM
77.          CONTINUE
78.      END IF
79.      RETURN
80.      END

```

```

LADSS=INRLPTR(1),OGDATA/NE-JL
1 LADE5 PLA IFORN OUTEN GIALAL, UNIT STEP INPUT.
2 AS 2.0
3 K4 7.0
4 TAU7 0.25
5 AC 54272
6 TAU2 0.010
7 TAU3 0.0005
8 TAU5 0.1
9 TAU6 0.2
10 PLIM 25.0
11 A 100000.0
12 RA 5.0
13 RSU 1.0
14 NT 24.0
15 H 8.5
16 JH 0.16
17 JL 5.30
18 KE 0.177
19 NPHD 0.595
20 K2 14.0
21 TAU4 0.0015
22 IT 0.706
23 GT 0.0001
24 BP 0.1
25 STOPT 1.0
26 SIRE 1.0
27 SIRA 1.0
28 STPA 1.0
29 SIGE REALSE.

```

EXIT R.2406

J	K	L	U	P
KJ	7.0000			
KL	7.0000			
IAU1	52.50			
KJ	94.7200			
IAU2	6.100			
IAU3	6365			
IAU5	1000			
IAU6	8000			
PLIA	20.650			
A	106000.00			
PA	5.0000			
RSU	1.0000			
KI	24.3000			
N	9.5000			
JA	61.50			
JL	3.5300			
KL	17.70			
LAND	2585			
KL	16.0000			
IAU4	0015			
EL	70.00			

----- RUN FOR 1.00 SECONDS, PRINT EVERY .0100 SECONDS -----

```

      INPUT IS A STEP-FUNCTION-OF AMPLITUDE 1.0000 --
      TIME - SIGD - EPS - SIGDH - XR -
      1.0000 1.0000 10.00E-06 .0000 .0000

```

	P	V	W	RM
1	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000
24	0.000	0.000	0.000	0.000
25	0.000	0.000	0.000	0.000
26	0.000	0.000	0.000	0.000
27	0.000	0.000	0.000	0.000
28	0.000	0.000	0.000	0.000
29	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000
31	0.000	0.000	0.000	0.000
32	0.000	0.000	0.000	0.000
33	0.000	0.000	0.000	0.000
34	0.000	0.000	0.000	0.000
35	0.000	0.000	0.000	0.000
36	0.000	0.000	0.000	0.000
37	0.000	0.000	0.000	0.000
38	0.000	0.000	0.000	0.000
39	0.000	0.000	0.000	0.000
40	0.000	0.000	0.000	0.000
41	0.000	0.000	0.000	0.000
42	0.000	0.000	0.000	0.000
43	0.000	0.000	0.000	0.000
44	0.000	0.000	0.000	0.000
45	0.000	0.000	0.000	0.000
46	0.000	0.000	0.000	0.000
47	0.000	0.000	0.000	0.000
48	0.000	0.000	0.000	0.000
49	0.000	0.000	0.000	0.000
50	0.000	0.000	0.000	0.000
51	0.000	0.000	0.000	0.000
52	0.000	0.000	0.000	0.000
53	0.000	0.000	0.000	0.000
54	0.000	0.000	0.000	0.000
55	0.000	0.000	0.000	0.000
56	0.000	0.000	0.000	0.000
57	0.000	0.000	0.000	0.000
58	0.000	0.000	0.000	0.000
59	0.000	0.000	0.000	0.000
60	0.000	0.000	0.000	0.000
61	0.000	0.000	0.000	0.000
62	0.000	0.000	0.000	0.000
63	0.000	0.000	0.000	0.000
64	0.000	0.000	0.000	0.000
65	0.000	0.000	0.000	0.000
66	0.000	0.000	0.000	0.000
67	0.000	0.000	0.000	0.000
68	0.000	0.000	0.000	0.000
69	0.000	0.000	0.00	

TIME	- SIGD -	- EPS -	- SIGD -	- XR -
1 000	1 000	2000-007	1620-007	0000

f,SIGDH,SIGDHD,E:	1.0000	.19600-006	.19600-001	.00000
D-B-X-E-A-D=	00.000	.00000	.00000	.00000

[illegible]

```

F,510H,SIGDIG,E= 1.0000 58792-000 39192-001 19600-006
P,D,N,XND,AND; 32000-005 00000 00000 00000

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TIME .4000-004	- SIGD 1.0000	- EPS .40000-004	- SIGDH .10504-006	- XR .90307-011
	- P .4245-007	- V .5323-005	- RM .17501-005	- RM .00000
F, SIGDH, SIGDH, AE: PD, R, XRD, RND:	1.0000 .24500-002	.12736-005 .24907-007	.58776-001 .59276-006	.58792-006 .00000
TIME .5000-004	- SIGD 1.0000	- EPS .50000-004	- SIGDH .17508-006	- XR .47309-010
	- P .11637-006	- V .44242-007	- RM .93202-005	- RM .00000
F, SIGDH, SIGDH, AE: PD, R, XRD, RND:	1.0000 .52255-002	.21549-005 .13274-006	.78349-001 .20930-005	.12736-005 .00000
TIME .6000-004	- SIGD 1.0000	- EPS .60000-004	- SIGDH .26858-006	- XR .12806-009
	- P .22160-006	- V .11635-006	- RM .24530-004	- RM .00000
F, SIGDH, SIGDH, AE: PD, R, XRD, RND:	1.0000 .86836-002	.52313-005 .4916-006	.97914-001 .55048-005	.21549-005 .00000
TIME .7000-004	- SIGD 1.0000	- EPS .70000-004	- SIGDH .37433-006	- XR .26335-009
	- P .37383-006	- V .22167-006	- RM .46728-004	- RM .38622-015
F, SIGDH, SIGDH, AE: PD, R, XRD, RND:	1.0000 .12041-001	.45043-005 .6521-006	.11747 .10487-004	.52318-005 .16833-010
TIME .8000-004	- SIGD 1.0000	- EPS .80000-004	- SIGDH .49632-006	- XR .48333-009
	- P .57660-006	- V .57382-006	- RM .76801-004	- RM .19280-014
F, SIGDH, SIGDH, AE: PD, R, XRD, RND:	1.0000 .17645-001	.59722-005 .11219-005	.13702 .17684-004	.45043-005 .85358-010
TIME .9000-004	- SIGD 1.0000	- EPS .90000-004	- SIGDH .65454-006	- XR .81992-009
	- P .53730-006	- V .57678-006	- RM .12159-003	- RM .56663-014
F, SIGDH, SIGDH, AE: PD, R, XRD, RND:	1.0000 .23075-001	.76555-005 .17311-005	.15656 .27286-004	.59722-005 .24335-009
TIME .1000-003	- SIGD 1.0000	- EPS .10000-003	- SIGDH .78900-006	- XR .12902-008

F, SIGDH, SIGDH, E:	.3331	1.7514	43.333	58949-002
PD, R, XRD, RMD:	-.34221	.47573	3.7029	45.289
TIME	- SIGD -	- SIGDH -	- XR -	
.7.00-001	1.0000	.06511-001	.17909	.19798
	- P -	- V -	- RM -	
.74770-001	.74759-001	15.761	2.1392	
F, SIGDH, SIGDH, E:	.80226	2.1547	40.262	-54224-001
PD, R, XRD, RMD:	-.42685	.5221	3.5097	45.282
TIME	- SIGD -	- SIGDH -	- XR -	
.0.00J-001	1.0000	.72567-001	.21232	.23202
	- P -	- V -	- RM -	
.70660-001	.70676-001	14.899	2.6097	
F, SIGDH, SIGDH, E:	.76001	2.5540	39.669	-54924-001
PD, R, XRD, RMD:	-.37973	.56106	3.3068	40.841
TIME	- SIGD -	- SIGDH -	- XR -	
.9.00-001	1.0000	.79084-001	.24429	.26423
	- P -	- V -	- RM -	
.67295-001	.67292-001	14.165	3.0368	
F, SIGDH, SIGDH, E:	.73581	2.9467	38.704	-60073-001
PD, R, XRD, RMD:	-.29710	.59935	3.1415	38.654
TIME	- SIGD -	- SIGDH -	- XR -	
.1.00-000	1.0000	.07085-001	.27659	.29497
	- P -	- V -	- RM -	
.64677-001	.64673-001	13.653	3.3843	
F, SIGDH, SIGDH, E:	.70306	3.5282	37.564	-56090-001
PD, R, XRD, RMD:	-.23161	.63775	3.0127	36.915
TIME	- SIGD -	- SIGDH -	- XR -	
.1100	1.0000	.93987-001	.30729	.32455
	- P -	- V -	- RM -	
.62560-001	.62555-001	13.137	3.7463	
F, SIGDH, SIGDH, E:	.67547	3.6976	36.313	-48690-001
PD, R, XRD, RMD:	-.19759	.67591	2.9079	35.541
TIME	- SIGD -	- SIGDH -	- XR -	
.1.00	1.0000	.10060	.33692	.35315
	- P -	- V -	- RM -	
.00657-001	.00632-001	12.781	4.0956	
F, SIGDH, SIGDH, E:	.04098	4.0542	35.005	-41456-001
PD, R, XRD, RMD:	-.19151	.71317	2.8124	34.356

TIME	- SIGD -	- EPS -	- SIGDH -	- AK -
.1200	1.0000	.10693	.30546	.38079
	- P -	- V -		- RM -
	.50697-001	.50691-001	12.372	4.4334
F, SIGDH, SIGDH, E:	.61923	4.3776	33.675	-35880-001
PD, R, XRD, XRD:	-.17304	.74694	2.7162	33.209
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.1400	1.0000	.11295	.37289	.40745
	- P -	- V -		- RM -
	.50664-001	.50650-001	11.944	4.7596
F, SIGDH, SIGDH, E:	.59257	4.7276	32.346	-31996-001
PD, R, XRD, XRD:	-.20341	.76295	2.6158	32.025
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.1500	1.0000	.11378	.41922	.43309
	- P -	- V -		- RM -
	.54550-001	.54544-001	11.493	5.0737
F, SIGDH, SIGDH, E:	.56693	5.0444	31.033	-29234-001
PD, R, XRD, XRD:	-.21350	.81518	2.5117	30.790
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.1600	1.0000	.12432	.44447	.45768
	- P -	- V -		- RM -
	.52411-001	.52404-001	11.047	5.3752
F, SIGDH, SIGDH, E:	.54235	5.3483	29.747	-26958-001
PD, R, XRD, XRD:	-.21321	.64375	2.4066	29.523
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.1700	1.0000	.12963	.46856	.48122
	- P -	- V -		- RM -
	.50305-001	.50295-001	10.603	5.6642
F, SIGDH, SIGDH, E:	.51080	5.6594	28.497	-24745-001
PD, R, XRD, XRD:	-.20718	.87486	2.3032	28.272
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.1800	1.0000	.13470	.49134	.50375
	- P -	- V -		- RM -
	.5274-001	.5267-001	10.175	5.9407
F, SIGDH, SIGDH, E:	.49627	5.9183	27.287	-22440-001
PD, R, XRD, XRD:	-.19331	.90266	2.2036	27.051
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.1900	1.0000	.13956	.51402	.52530

	- P -	- V -	- W -	- RM -
	.46340-001	.46340-001	9.7670	6.2053
F, SIGDH, SIGDH, E:				
PD, R, XRD, RMD:	.47472	.47472	20.120	-20047-001
	.72926	.72926	2.1057	25.481
TIME				
.2600	- SIGD -	- EPS -	- SIGDH -	- XR -
	1.0000	.14420	.53526	.54593
	- P -	- V -	- W -	- RM -
	.44499-001	.44499-001	9.3787	6.4504
F, SIGDH, SIGDH, E:				
PD, R, XRD, RMD:	.45409	.45409	24.998	-17692-001
	.95479	.95479	2.0182	24.769
TIME				
.2100	- SIGD -	- EPS -	- SIGDH -	- XR -
	1.0000	.14464	.53558	.56567
	- P -	- V -	- W -	- RM -
	.42743-001	.42743-001	9.3085	6.7007
F, SIGDH, SIGDH, E:				
PD, R, XRD, RMD:	.43435	.43435	23.921	-15481-001
	.97923	.97923	1.9350	23.709
TIME				
.2200	- SIGD -	- EPS -	- SIGDH -	- XR -
	1.0000	.15283	.57502	.58457
	- P -	- V -	- W -	- RM -
	.41064-001	.41064-001	8.6545	6.9527
F, SIGDH, SIGDH, E:				
PD, R, XRD, RMD:	.41545	.41545	22.887	-13476-001
	.16438	.16438	1.3496	22.698
TIME				
.2300	- SIGD -	- EPS -	- SIGDH -	- XR -
	1.0000	.15245	.59362	.60267
	- P -	- V -	- W -	- RM -
	.39454-001	.39454-001	6.3150	7.1547
F, SIGDH, SIGDH, E:				
PD, R, XRD, RMD:	.39735	.39735	21.895	-11695-001
	.15791	.15791	1.7705	21.728
TIME				
.2400	- SIGD -	- EPS -	- SIGDH -	- XR -
	1.0000	.15023	.61142	.61998
	- P -	- V -	- W -	- RM -
	.37907-001	.37907-001	7.5890	7.3673
F, SIGDH, SIGDH, E:				
PD, R, XRD, RMD:	.38003	.38003	20.945	-10126-001
	.15115	.15115	1.6946	20.798
TIME				
.2500	- SIGD -	- EPS -	- SIGDH -	- XR -
	1.0000	.16455	.62844	.63856
	- P -	- V -	- W -	- RM -
	.36422-001	.36422-001	7.6759	7.5707

F, SIGDH, SIGDH, E:		35340	7.5623	20.035	-07399-002
PD, R, XRD, RMD:		-1455	1.0669	1.6217	19.935
TIME		- SIGD -	- EPS -	- SIGDH -	- XR -
.2600		1.0000	.10510	.6472	.65242
		- P -	- V -	- RM -	- RM -
.36977-001		.34500-001	7.3754	7.7554	7.7554
F, SIGDH, SIGDH, E:		54760	7.7579	17.163	-75108-002
PD, R, XRD, RMD:		-13957	1.0865	1.5518	19.047
TIME		- SIGD -	- EPS -	- SIGDH -	- XR -
.2700		1.0000	.17150	.66029	.66760
		- P -	- V -	- RM -	- RM -
.35631-001		.35021-001	7.0873	7.9517	7.9517
F, SIGDH, SIGDH, E:		53242	7.9453	16.328	-64107-002
PD, R, XRD, RMD:		-13301	1.1052	1.4647	19.224
TIME		- SIGD -	- EPS -	- SIGDH -	- XR -
.2000		1.0000	.17475	.67519	.68212
		- P -	- V -	- RM -	- RM -
.52318-001		.52303-001	6.6105	8.1299	8.1299
F, SIGDH, SIGDH, E:		31790	3.1245	17.530	-54327-002
PD, R, XRD, RMD:		-12505	1.1231	1.4203	17.439
TIME		- SIGD -	- EPS -	- SIGDH -	- XR -
.2500		1.0000	.17786	.60545	.69600
		- P -	- V -	- RM -	- RM -
.31054-001		.31054-001	6.5462	8.3005	8.3005
F, SIGDH, SIGDH, E:		30401	8.2959	16.766	-45532-002
PD, R, XRD, RMD:		-12296	1.1403	1.3588	16.683
TIME		- SIGD -	- EPS -	- SIGDH -	- XR -
.3000		1.0000	.18083	.70305	.70929
		- P -	- V -	- RM -	- RM -
.27865-001		.29655-001	6.2933	8.4636	8.4636
F, SIGDH, SIGDH, E:		29072	3.4590	10.035	-37568-002
PD, R, XRD, RMD:		-11074	1.1567	1.3000	15.960
TIME		- SIGD -	- EPS -	- SIGDH -	- XR -
.3100		1.0000	.18307	.71608	.72200
		- P -	- V -	- RM -	- RM -
.57177-001		.28707-001	6.0513	8.6196	8.6196
F, SIGDH, SIGDH, E:		27031	8.6160	15.335	-30458-002
PD, R, XRD, RMD:		-11270	1.1724	1.2436	15.268

TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.500	1.0000	.1033	.7254	.72416
	- P -	- V -		- RM -
	.27018-001	.27018-001	5.0191	8.7229
	F, SIGDH, SIGDH, E:	.20545	8.7665	14.566
	P, R, XRD, MHD:	-.10735	1.1574	1.1897
				-24183-002
				14.607
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.500	1.0000	.1033	.74045	.74580
	- P -	- V -		- RM -
	.25560-001	.20555-001	5.5076	8.9117
	F, SIGDH, SIGDH, E:	.25421	9.9090	14.025
	P, R, XRD, MHD:	-.10333	1.2017	1.1381
				-18677-002
				13.973
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.500	1.0000	.1033	.75134	.75692
	- P -	- V -		- RM -
	.25555-001	.25547-001	5.5854	9.0483
	F, SIGDH, SIGDH, E:	.24537	9.0459	13.412
	P, R, XRD, MHD:	-.28274-001	1.2154	1.0886
				-15038-002
				13.367
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.500	1.0000	.1033	.76274	.76757
	- P -	- V -		- RM -
	.25594-001	.24582-001	5.1819	9.1790
	F, SIGDH, SIGDH, E:	.23244	9.1780	12.825
	P, R, XRD, MHD:	-.23775-001	1.2235	1.0413
				-96071-003
				12.786
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.500	1.0000	.1033	.77316	.77775
	- P -	- V -		- RM -
	.23070-001	.23057-001	4.972	9.3040
	F, SIGDH, SIGDH, E:	.22220	9.3034	12.264
	P, R, XRD, MHD:	-.20517-001	1.2411	.99599
				-58973-003
				12.230
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.500	1.0000	.1033	.78312	.78749
	- P -	- V -		- RM -
	.22756-001	.22774-001	4.8006	7.4235
	F, SIGDH, SIGDH, E:	.21252	9.4235	11.727
	P, R, XRD, MHD:	-.20915-001	1.2531	.95261
				-26536-003
				11.697
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.500	1.0000	.2037	.77264	.79680

F, SIGDH, SIGDH, E:		15527	10-12-	5-5704	30512-002
PD, R, XRD, RND:		-53644-001	1-5230	69707	8-5603
TIME		- SIGD -	- SIGDH -	- XR -	
-4560		1.0000	- EPS -	- R4 -	
		-21257	-3-200	-85155	
		- P -	- V -	- R4 -	
16950-001		16743-001	3-5716	10-210	
F, SIGDH, SIGDH, E:		14440	10-211	3-1946	11535-002
PD, R, XRD, RND:		-50904-001	1-3320	66660	9-1867
TIME		- SIGD -	- SIGDH -	- XR -	
-4400		1.0000	- EPS -	- R4 -	
		-21402	-85526	-85806	
		- P -	- V -	- R4 -	
16361-001		16349-001	3-5463	10-290	
F, SIGDH, SIGDH, E:		14174	10-291	7-8352	12286-002
PD, R, XRD, RND:		-57710-001	1-3400	63745	7-6287
TIME		- SIGD -	- SIGDH -	- XR -	
-4760		1.0000	- EPS -	- R4 -	
		-21541	-86162	-86429	
		- P -	- V -	- R4 -	
15793-001		15780-001	3-3264	10-367	
F, SIGDH, SIGDH, E:		13571	10-363	7-4915	12877-002
PD, R, XRD, RND:		-57757-001	1-3477	60957	7-4862
TIME		- SIGD -	- SIGDH -	- XR -	
-4799		1.0000	- EPS -	- R4 -	
		-21674	-86770	-87025	
		- P -	- V -	- R4 -	
15249-001		15236-001	3-2116	10-440	
F, SIGDH, SIGDH, E:		12975	10-441	7-1620	13355-002
PD, R, XRD, RND:		-52177-001	1-3550	58291	7-1583
TIME		- SIGD -	- SIGDH -	- XR -	
-4899		1.0000	- EPS -	- R4 -	
		-21601	-87352	-87595	
		- P -	- V -	- R4 -	
14729-001		14716-001	3-1022	10-510	
F, SIGDH, SIGDH, E:		12406	10-511	6-8485	13709-002
PD, R, XRD, RND:		-51755-001	1-3620	55240	6-8456
TIME		- SIGD -	- SIGDH -	- XR -	
-4999		1.0000	- EPS -	- R4 -	
		-21222	-87905	-88140	
		- P -	- V -	- R4 -	
14252-001		14219-001	2-9973	10-577	
F, SIGDH, SIGDH, E:		11101	10-576	6-5480	13662-002
PD, R, XRD, RND:		-49672-001	1-3687	53299	6-5460

TIME .5099	- SIGD - 1.0000	- EPS - -2.235	- SIGDH - -2.440	- XR - -5560
	- P - .13750-001	- V - .11745-001	- W - 2.0509	- RM - 10.541
	F, SIGDH, SIGDH, I: PD, R, XKD, MMD:	- EPS - -11540	- SIGDH - 10.664	- XR - 6.2606
		- EPS - -17249-001	- SIGDH - 1.3751	- XR - 5.0965
				-14123-002 6.2595
TIME .5199	- SIGD - 1.0000	- EPS - -2.2146	- SIGDH - -6.948	- XR - -69158
	- P - .13501-001	- V - .13267-001	- W - 2.5010	- RM - 10.702
	F, SIGDH, SIGDH, I: PD, R, XKD, MMD:	- EPS - -10642	- SIGDH - 10.703	- XR - 5.9658
		- EPS - -44658-001	- SIGDH - 1.3812	- XR - 4.6733
				-14206-002 5.9656
TIME .5299	- SIGD - 1.0000	- EPS - -2.2254	- SIGDH - -6.9434	- XR - -89635
	- P - .12865-001	- V - .12852-001	- W - 2.7092	- RM - 10.760
	F, SIGDH, SIGDH, I: PD, R, XKD, MMD:	- EPS - -10366	- SIGDH - 10.762	- XR - 5.7230
		- EPS - -42430-001	- SIGDH - 1.3871	- XR - 4.6597
				-14215-002 5.7235
TIME .5399	- SIGD - 1.0000	- EPS - -2.2356	- SIGDH - -6.9896	- XR - -90090
	- P - .12449-001	- V - .12436-001	- W - 2.6214	- RM - 10.816
	F, SIGDH, SIGDH, I: PD, R, XKD, MMD:	- EPS - -99106-001	- SIGDH - 10.817	- XR - 5.4712
		- EPS - -40136-001	- SIGDH - 1.3927	- XR - 4.4556
				-14170-002 5.4728
TIME .5499	- SIGD - 1.0000	- EPS - -2.2452	- SIGDH - -9.0343	- XR - -90525
	- P - .12051-001	- V - .12037-001	- W - 2.5375	- RM - 10.870
	F, SIGDH, SIGDH, I: PD, R, XKD, MMD:	- EPS - -94752-001	- SIGDH - 10.871	- XR - 5.2315
		- EPS - -39666-001	- SIGDH - 1.3981	- XR - 4.2603
				-14066-002 5.2327
TIME .5599	- SIGD - 1.0000	- EPS - -2.2545	- SIGDH - -9.0757	- XR - -90941
	- P - .11670-001	- V - .11657-001	- W - 2.4572	- RM - 10.921
	F, SIGDH, SIGDH, I: PD, R, XKD, MMD:	- EPS - -90590-001	- SIGDH - 10.922	- XR - 5.0018
		- EPS - -37466-001	- SIGDH - 1.4032	- XR - 4.0736
				-13938-002 5.0040
TIME .5699	- SIGD - 1.0000	- EPS - -2.2633	- SIGDH - -9.1173	- XR - -91339

	- P -	- J -	- M -	- P -
	.11300-001	.11295-001	2.5805	10.709
	F, SIGDH, SIGDHD, E:	-26610-001	10.971	4.7022
	P, R, XKD, MND:	-34440-001	1.4061	.35951
				.13764-002
				4.7845
TIME	- SIGD -	- LPS -	- SIGDH -	- XR -
.5759	1.0000	-2.718	-91561	.91720
	- P -	- V -	- M -	- RM -
	.10958-001	.10944-001	2.5070	11.016
	F, SIGDH, SIGDHD, E:	-82805-001	11.018	4.5722
	P, R, XKD, MND:	-34511-001	1.4128	.37241
				.13540-002
				4.5752
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.5057	1.0000	.22799	.91932	.92084
	- P -	- V -	- M -	- RM -
	.10625-001	.10611-001	2.2368	11.061
	F, SIGDH, SIGDHD, E:	.79157-001	11.464	4.3714
	P, R, XKD, MND:	-34502-001	1.4172	.35009
				.13297-002
				4.3741
TIME	- SIGD -	- LPS -	- SIGDH -	- XR -
.5599	1.0000	.22876	.92287	.92432
	- P -	- V -	- M -	- RM -
	.10300-001	.10292-001	2.1697	11.104
	F, SIGDH, SIGDHD, E:	.75652-001	11.105	4.1794
	P, R, XKD, MND:	-32350-001	1.4215	.34046
				.13034-002
				4.1875
TIME	- SIGD -	- LPS -	- SIGDH -	- XR -
.6049	1.0000	.22950	.92626	.92764
	- P -	- V -	- M -	- RM -
	.10002-001	.99879-002	2.1055	11.144
	F, SIGDH, SIGDHD, E:	.72302-001	11.146	3.9959
	P, R, XKD, MND:	-28116-001	1.4250	.32552
				.12759-002
				3.9995
TIME	- SIGD -	- LPS -	- SIGDH -	- XR -
.6199	1.0000	.23621	.92950	.93082
	- P -	- V -	- M -	- RM -
	.97104-002	.96964-002	2.0440	11.163
	F, SIGDH, SIGDHD, E:	.69183-001	11.185	3.8204
	P, R, XKD, MND:	-28442-001	1.4295	.31123
				.12457-002
				3.8236
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.6299	1.0000	.23668	.93200	.93386
	- P -	- V -	- M -	- RM -
	.94319-002	.94178-002	1.9853	11.221

TIME	- SIGD -	- LIS -	- SIGDH -	- AR -
.699	1.0000	.2345	.9500	.95171
	- P -	- V -	- M -	- RM -
	.77963-002	.77820-002	1.6404	11.440
	F, SIGDH, SIGDH, E:	.48394-001	11.441	2.6672
	PD, R, XRD, KMD:	-.25079-001	1.4554	.21736
				.98670-003
				2.6704
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.709	1.0000	.25532	.95296	.95383
	- P -	- V -	- M -	- RM -
	.76024-002	.75880-002	1.5995	11.466
	F, SIGDH, SIGDH, E:	.46171-001	11.467	2.5501
	PD, R, XRD, KMD:	-.19064-001	1.4573	.20784
				.95594-003
				2.5540
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.719	1.0000	.23577	.95503	.95586
	- P -	- V -	- M -	- RM -
	.74150-002	.74006-002	1.5600	11.491
	F, SIGDH, SIGDH, E:	.44142-001	11.492	2.4382
	PD, R, XRD, KMD:	-.18338-001	1.4603	.19866
				.92328-003
				2.4419
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.729	1.0000	.23620	.95701	.95780
	- P -	- V -	- M -	- RM -
	.72371-002	.72227-002	1.5225	11.515
	F, SIGDH, SIGDH, E:	.42203-001	11.516	2.3311
	PD, R, XRD, KMD:	-.17785-001	1.4627	.18993
				.89180-003
				2.3347
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.739	1.0000	.23661	.95889	.95965
	- P -	- V -	- M -	- RM -
	.70686-002	.70541-002	1.5870	11.538
	F, SIGDH, SIGDH, E:	.40349-001	11.538	2.2287
	PD, R, XRD, KMD:	-.16461-001	1.4650	.18166
				.86260-003
				2.2332
TIME	- SIGD -	- LPS -	- SIGDH -	- XR -
.749	1.0000	.23701	.96070	.96162
	- P -	- V -	- M -	- RM -
	.69049-002	.66505-002	1.4523	11.559
	F, SIGDH, SIGDH, E:	.38377-001	11.560	2.1309
	PD, R, XRD, KMD:	-.22240-001	1.4671	.17364
				.92982-003
				2.1338
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.759	1.0000	.23735	.96243	.96312

	- P -	- V -	- RX -
	.67500-002	.67501-002	11.580
F, SIGDH, SIGDH, E:	.55042-001	11.581	2.0373
P, R, XRD, RND:	-.17735-001	1.4692	.16007
			.00192-003
			2.0415
TIME	- SIGD -	- SIGDH -	- XR -
.7699	1.0000	.25774	.96474
	- P -	- V -	- RM -
	.00005-002	.65859-002	11.500
F, SIGDH, SIGDH, E:	.55263-001	11.001	1.9479
P, R, XRD, RND:	-.12378-001	1.4712	.15371
			.77236-003
			1.9511
TIME	- SIGD -	- SIGDH -	- XR -
.7747	1.0000	.63007	.96629
	- P -	- V -	- RM -
	.64591-002	.64445-002	11.019
F, SIGDH, SIGDH, E:	.53714-001	11.623	1.8024
P, R, XRD, RND:	-.11040-001	1.4731	.15177
			.74470-003
			1.8655
TIME	- SIGD -	- SIGDH -	- XR -
.7899	1.0000	.25042	.96777
	- P -	- V -	- RM -
	.63227-002	.65000-002	11.037
F, SIGDH, SIGDH, E:	.32234-001	11.030	1.7607
P, R, XRD, RND:	-.10761-001	1.4749	.14508
			.71645-003
			1.7833
TIME	- SIGD -	- SIGDH -	- XR -
.7999	1.0000	.63075	.96918
	- P -	- V -	- RM -
	.61930-002	.61790-002	11.055
F, SIGDH, SIGDH, E:	.30019-001	11.055	1.7025
P, R, XRD, RND:	-.17503-001	1.4767	.13875
			.68891-003
			1.7048
TIME	- SIGD -	- SIGDH -	- XR -
.8099	1.0000	.63503	.97054
	- P -	- V -	- RM -
	.60637-002	.60540-002	11.071
F, SIGDH, SIGDH, E:	.29465-001	11.072	1.6279
P, R, XRD, RND:	-.10670-001	1.4783	.13263
			.66411-003
			1.6311
TIME	- SIGD -	- SIGDH -	- XR -
.8199	1.0000	.63932	.97183
	- P -	- V -	- RM -
	.67499-002	.69352-002	11.067

F, SIGDH, S, GDHD, E:		-2.172-001	11.450	1.5565	-03848-003
PD, R, XRD, RHD:		-0.10259-001	1.4777	-12.330	1.5000
TIME	- SIGD -	- EPS -	- SIGDH -	- AR -	
	1.0000	-0.3359	-0.7256	-0.97507	
	- P -	- V -	- N -	- RM -	
	-0.52373-002	-0.55227-002	1.2274	11.702	
F, SIGDH, S, GDHD, E:		-0.26935-001	11.703	1.4081	-0.1262-003
PD, R, XRD, RHD:		-0.17977-001	1.4814	-12.128	1.4106
TIME	- SIGD -	- EPS -	- SIGDH -	- AR -	
	1.0000	-0.23986	-0.97377	-0.97425	
	- P -	- V -	- N -	- RM -	
	-0.7262-002	-0.57135-002	1.2044	11.717	
F, SIGDH, S, GDHD, E:		-0.25753-001	11.717	1.4229	-0.58937-003
PD, R, XRD, RHD:		-0.78472-002	1.4829	-11.593	1.4272
TIME	- SIGD -	- EPS -	- SIGDH -	- AR -	
	1.0000	-0.24911	-0.97492	-0.97538	
	- P -	- V -	- N -	- RM -	
	-0.56260-002	-0.56112-002	1.1828	11.731	
F, SIGDH, S, GDHD, E:		-0.24623-001	11.731	1.3605	-0.56732-003
PD, R, XRD, RHD:		-0.83982-002	1.4843	-11.091	1.3633
TIME	- SIGD -	- EPS -	- SIGDH -	- AR -	
	1.0000	-0.24035	-0.97602	-0.97646	
	- P -	- V -	- N -	- RM -	
	-0.55753-002	-0.55110-002	1.1617	11.744	
F, SIGDH, S, GDHD, E:		-0.23543-001	11.744	1.3008	-0.54407-003
PD, R, XRD, RHD:		-0.70597-002	1.4856	-10.600	1.3041
TIME	- SIGD -	- EPS -	- SIGDH -	- AR -	
	1.0000	-0.24058	-0.97707	-0.97749	
	- P -	- V -	- N -	- RM -	
	-0.6510-002	-0.54162-002	1.1419	11.757	
F, SIGDH, S, GDHD, E:		-0.22510-001	11.757	1.2439	-0.52333-003
PD, R, XRD, RHD:		-0.75406-002	1.4864	-10.138	1.2485
TIME	- SIGD -	- EPS -	- SIGDH -	- AR -	
	1.0000	-0.24079	-0.97808	-0.97848	
	- P -	- V -	- N -	- RM -	
	-0.3366-002	-0.55259-002	1.1223	11.769	
F, SIGDH, S, GDHD, E:		-0.21522-001	11.769	1.1893	-0.49961-003
PD, R, XRD, RHD:		-0.17571-001	1.4081	-9.6826-001	1.1920

TIME	- SIGD -	- EPS -	- SIGDH -	- AR -
0699	1.0000	0.2103	0.91504	0.97962
	- P -	- V -	- RM -	
	0.2553-002	0.52384-002	1.1043	11.780
	F, SIGDH, SIGDHD, E:	0.20579-001	11.761	1.1372
	P, R, XRD, RHD:	0.60376-002	1.4893	0.92636-001
				0.48101-003
				1.1413
TIME	- SIGD -	- EPS -	- SIGDH -	- AR -
0899	1.0000	0.24120	0.97996	0.98032
	- P -	- V -	- RM -	
	0.51723-002	0.51575-002	1.0872	11.791
	F, SIGDH, SIGDHD, E:	0.19676-001	11.792	1.0874
	P, R, XRD, RHD:	0.70755-002	1.4904	0.83665-001
				0.46480-003
				1.0928
TIME	- SIGD -	- EPS -	- SIGDH -	- AR -
0999	1.0000	0.24140	0.98064	0.98119
	- P -	- V -	- RM -	
	0.50925-002	0.50777-002	1.0704	11.802
	F, SIGDH, SIGDHD, E:	0.18814-001	11.802	1.0398
	P, R, XRD, RHD:	0.58075-002	1.4914	0.84752-001
				0.4584-003
				1.0451
TIME	- SIGD -	- EPS -	- SIGDH -	- AR -
0999	1.0000	0.24158	0.98168	0.98201
	- P -	- V -	- RM -	
	0.50157-002	0.50008-002	1.0542	11.312
	F, SIGDH, SIGDHD, E:	0.17804-001	11.813	0.99426
	P, R, XRD, RHD:	0.48474-002	1.4924	0.80984-001
				0.42558-003
				1.0008
TIME	- SIGD -	- EPS -	- SIGDH -	- AR -
0299	1.0000	0.24175	0.98248	0.98280
	- P -	- V -	- RM -	
	0.9415-002	0.9204-002	1.0365	11.822
	F, SIGDH, SIGDHD, E:	0.17201-001	11.822	0.95071
	P, R, XRD, RHD:	0.30099-002	1.4934	0.77341-001
				0.40603-003
				0.95352
TIME	- SIGD -	- EPS -	- SIGDH -	- AR -
0999	1.0000	0.24192	0.98325	0.98355
	- P -	- V -	- RM -	
	0.60751-002	0.60602-002	1.0245	11.831
	F, SIGDH, SIGDHD, E:	0.16447-001	11.831	0.90911
	P, R, XRD, RHD:	0.53423-002	1.4943	0.74088-001
				0.39160-003
				0.91529
TIME	- SIGD -	- EPS -	- SIGDH -	- AR -
0999	1.0000	0.24208	0.98398	0.98427

	- P -	- V -	- R -	
	.4035-002	.7937-002	1.0105	11.040
	f, SIGDH, SIGDH, E:	.15727-001	11.040	.66924
	P, R, XRD, RMD:	-.14126-001	1.4952	.70031-001
				.37444-003
				.87261
	LINE	- EPS -	- SIGDH -	- XR -
	.9599	1.0000	.90405	.98496
	- P -	- V -	- R -	
	.47408-002	.47260-002	.99623	11.548
	f, SIGDH, SIGDH, E:	.15035-001	11.849	.83133
	P, R, XRD, RMD:	-.78242-002	1.4961	.67515-001
				.55572-003
				.83431
	LINE	- EPS -	- SIGDH -	- XR -
	.9699	1.0000	.90535	.98562
	- P -	- V -	- R -	
	.40801-002	.46652-002	.98341	11.856
	f, SIGDH, SIGDH, E:	.14390-001	11.857	.79502
	P, R, XRD, RMD:	-.36635-002	1.4969	.64535-001
				.34010-003
				.79854
	LINE	- EPS -	- SIGDH -	- XR -
	.9799	1.0000	.96599	.98625
	- P -	- V -	- R -	
	.46224-002	.46075-002	.97125	11.864
	f, SIGDH, SIGDH, E:	.13750-001	11.864	.76025
	P, R, XRD, RMD:	-.79608-002	1.4976	.61706-001
				.32651-003
				.76278
	LINE	- EPS -	- SIGDH -	- XR -
	.9899	1.0000	.96661	.98635
	- P -	- V -	- R -	
	.45729-002	.45580-002	.96084	11.872
	f, SIGDH, SIGDH, E:	.13149-001	11.872	.72685
	P, R, XRD, RMD:	-.95526-002	1.4984	.59272-001
				.32032-003
				.73179
	LINE	- EPS -	- SIGDH -	- XR -
	.9999	1.0000	.96719	.98743
	- P -	- V -	- R -	
	.45207-002	.45058-002	.94981	11.879
	f, SIGDH, SIGDH, E:	.12574-001	11.879	.69527
	P, R, XRD, RMD:	-.67941-002	1.4991	.56708-001
				.30923-003
				.70318
STUF	999			

PRI R.IGDATA/NE.JL
 CURRUR-27854-86-862441-04446430-14-1-209

LADSS+TRALPT+(1).L0DATA/NEWJL
 1 LADSS PLATFORM INHER GLIAL, UNIT STLP ILM RESPONSE

2	45	A	7.0
3	44	A	7.0
4	TAU7	A	.025
5	43	A	46.66
6	TAU2	A	.01
7	TAU3	A	.0005
8	TAU5	A	.01
9	TAU6	A	0.0
10	FLIM	A	20.0
11	A	A	100000.0
12	RA	A	9.317
13	RSU	A	1.0
14	AI	A	19.75
15	N	A	12.0
16	JM	A	.0015
17	JL	A	2.42
18	KE	A	1.1
19	KHD	A	.5595
20	K2	A	14.0
21	TAU4	A	.0015
22	FT	A	.622
23	OT	A	.0001
24	OP	A	.01
25	STOP1	A	1.0
26	SINF	A	1.0
27	SINA	A	1.0
28	STPA	A	1.0
29	SIG	A	FALSE

XXXX-R-PR06

I.A.C.A.	L	U.O.P.
K2	7.0000	
K6	7.0000	
IAU1	0.0250	
K3	46.6800	
IAU2	0.0100	
IAU3	0.0005	
IAU5	0.1000	
IAU6	0.5000	
PL1H	20.0000	
A	100000.00	
R4	9.3170	
R5H	1.6000	
K1	19.7500	
H	12.0000	
J3	0.015	
J4	2.0700	
KL	0.1410	
K4H6	0.5925	
K2	14.0000	
IAU4	0.015	
FI	0.6250	

PRINT FOR 1.0 SECONDS, PRINT EVERY .0100 SECONDS

[illegible]

1111 - SIGD - 547 - 0000 - 0000 - XR -

	- P -	- V -	- W -	- RM -
F 21 00H, SUDHO, E:	1.0000	0.0000	0.0000	0.0000
P 0. R 250. 450.	0.0000	0.0000	0.0000	0.0000

1141	- SIGD -	- LPS -	- SIGDH -	- XR -
2500-00	1.3000	2500-00	1.0209-007	.00000
	- P -	- V -	- Q -	- PH -
00000	00000	00000	00000	00000

F,SI,CH,SGDHP,E=	1.00J0	19600-001	.00000
PD,R,XKD,MDI	-----00000	.00000	.00000
TIME	- S1G0 -	- S1G0H -	- XR -
1 00-000	1 0000	1 0000-000	00000

	- P -	- V -	- - -	- 84 -
-----	.5746-008-----	.00000-----	-- .0000-----	-.00000-----
f, 100H, SIGDHD, E:	1.00J00	.58792-006	.39192-001	.19600-006
0.00000	.65711-007	.00000	.00000	.00000

TIME	- SIGD -	- EPS -	- SIGDH -	- AR -
.4000-004	1.0000	.00000-000	.10000-000	.97570-011
	- P -	- V -	-	- RY -
	.00000-000	.00000-000	.11000-000	.00000
	- SIGD -	- EPS -	- SIGDH -	- AR -
f, SIGDH, SIGDH, E:	1.0000	.00000-000	.10000-000	.58792-000
PD, R, XRD, KAD:	.13000-000	.00000-000	.00000-000	.00000
TIME	- SIGD -	- EPS -	- SIGDH -	- AR -
.5000-004	1.0000	.00000-000	.10000-000	.51288-010
	- P -	- V -	-	- RM -
	.00000-000	.00000-000	.10000-000	.00000
	- SIGD -	- EPS -	- SIGDH -	- AR -
f, SIGDH, SIGDH, E:	1.0000	.00000-000	.10000-000	.12736-005
PD, R, XRD, KAD:	.28700-000	.00000-000	.00000-000	.00000
TIME	- SIGD -	- EPS -	- SIGDH -	- AR -
.6000-004	1.0000	.00000-000	.10000-000	.13034-009
	- P -	- V -	-	- RM -
	.00000-000	.00000-000	.10000-000	.00000
	- SIGD -	- EPS -	- SIGDH -	- AR -
f, SIGDH, SIGDH, E:	1.0000	.00000-000	.10000-000	.21549-005
PD, R, XRD, KAD:	.47000-000	.00000-000	.00000-000	.00000
TIME	- SIGD -	- EPS -	- SIGDH -	- AR -
.7000-004	1.0000	.00000-000	.10000-000	.28504-009
	- P -	- V -	-	- RM -
	.00000-000	.00000-000	.10000-000	.00000
	- SIGD -	- EPS -	- SIGDH -	- AR -
f, SIGDH, SIGDH, E:	1.0000	.00000-000	.10000-000	.32318-005
PD, R, XRD, KAD:	.70750-000	.00000-000	.11369-004	.18271-010
TIME	- SIGD -	- EPS -	- SIGDH -	- AR -
.8000-004	1.0000	.00000-000	.10000-000	.52941-009
	- P -	- V -	-	- RM -
	.00000-000	.00000-000	.10000-000	.00000
	- SIGD -	- EPS -	- SIGDH -	- AR -
f, SIGDH, SIGDH, E:	1.0000	.00000-000	.10000-000	.45043-005
PD, R, XRD, KAD:	.97225-000	.00000-000	.19172-004	.92539-010
TIME	- SIGD -	- EPS -	- SIGDH -	- AR -
.9000-004	1.0000	.00000-000	.10000-000	.88569-009
	- P -	- V -	-	- RM -
	.00000-000	.00000-000	.10000-000	.00000
	- SIGD -	- EPS -	- SIGDH -	- AR -
f, SIGDH, SIGDH, E:	1.0000	.00000-000	.10000-000	.59722-005
PD, R, XRD, KAD:	.12710-000	.00000-000	.29581-004	.26382-009
TIME	- SIGD -	- EPS -	- SIGDH -	- AR -
.1000-005	1.0000	.00000-000	.10000-000	.13987-008

	- P -	- V -	- RM -
	.63472-006	.11702-003	.15141-013
F, SIGDH, SIGDH, E:	1.0000	.74940-005	.17509
PD, R, XKD, RMD:	.16042-001	.42990-005	.42941-004
			.76355-005
			.61553-009
TIME	- SIGD -	- EPS -	- XR -
.1000-001	1.0000	.77635-002	.71532-002
			.55331-002
	- P -	- V -	- RM -
	.13224-001	.13409-001	.53292
			.21576-001
F, SIGDH, SIGDH, E:	.99448	.66074-001	16.112
PD, R, XKD, RMD:	1.5045	.13303	1.2283
			.64413-001
			7.0007
TIME	- SIGD -	- EPS -	- XR -
.2000-001	1.0000	.19340-001	.25279-001
			.23857-001
	- P -	- V -	- RM -
	.25891-001	.25077-001	6.5416
			.17517
F, SIGDH, SIGDH, E:	.97017	.30413	26.723
PD, R, XKD, RMD:	1.1391	.28411	2.4033
			.12897
			22.760
TIME	- SIGD -	- EPS -	- XR -
.3000-001	1.0000	.27472-001	.50511-001
			.52478-001
	- P -	- V -	- RM -
	.35010-001	.35005-001	8.8492
			.46755
F, SIGDH, SIGDH, E:	.94755	.63780	33.447
PD, R, XKD, RMD:	.67631	.42079	3.2465
			.14027
			34.975
TIME	- SIGD -	- EPS -	- XR -
.4000-001	1.0000	.30776-001	.80123-001
			.87369-001
	- P -	- V -	- RM -
	.39595-001	.39587-001	10.008
			.85505
F, SIGDH, SIGDH, E:	.91267	.6413	37.432
PD, R, XKD, RMD:	.25626	.52643	3.6050
			.10612
			42.259
TIME	- SIGD -	- EPS -	- XR -
.5000-001	1.0000	.47110-001	.11221
			.12467
	- P -	- V -	- RM -
	.40017-001	.40011-001	10.266
			1.2974
F, SIGDH, SIGDH, E:	.87537	1.3502	39.515
PD, R, XKD, RMD:	.24623-001	.60331	3.7518
			.52835-001
			44.952
TIME	- SIGD -	- EPS -	- XR -
.6000-001	1.0000	.55282-001	.14545
			.16177
	- P -	- V -	- RM -
	.39595-001	.39590-001	10.008
			1.7469

f, SIGDH, SIGDH, E:		- 0300		1.7500		40.007		- 52073-002	
P, R, X, R, M, D:		- 015001		0.0070		3.6482		44.587	
f, SIGDH, SIGDH, E:		- 115		- SIGDH		- AR			
P, R, X, R, M, D:		- 0445-001		0.1767		0.1940			
f, SIGDH, SIGDH, E:		- V		9.5559		- RM			
P, R, X, R, M, D:		- 5700-001		0.0000		2.1543			
f, SIGDH, SIGDH, E:		- EPS		- SIGDH		- XR			
P, R, X, R, M, D:		- 0200		2.1535		40.251		- 50784-001	
f, SIGDH, SIGDH, E:		- 1275		0.7039		3.4735		42.768	
f, SIGDH, SIGDH, E:		- EPS		- SIGDH		- XR			
P, R, X, R, M, D:		- 7230-001		0.2120		0.2312			
f, SIGDH, SIGDH, E:		- V		9.1021		- RM			
P, R, X, R, M, D:		- 3001-001		0.0000		2.6012			
f, SIGDH, SIGDH, E:		- 7007		2.5533		39.053		- 47801-001	
P, R, X, R, M, D:		- 1000		0.7527		3.2966		40.616	
f, SIGDH, SIGDH, E:		- EPS		- SIGDH		- XR			
P, R, X, R, M, D:		- 7005-001		0.2478		0.2536			
f, SIGDH, SIGDH, E:		- V		8.7207		- RM			
P, R, X, R, M, D:		- 5403-001		0.0000		2.9973			
f, SIGDH, SIGDH, E:		- 7207		2.7454		38.720		- 51930-001	
P, R, X, R, M, D:		- 1300		0.7984		3.1508		38.681	
f, SIGDH, SIGDH, E:		- EPS		- SIGDH		- XR			
P, R, X, R, M, D:		- 3707-001		0.2769		0.2934			
f, SIGDH, SIGDH, E:		- V		8.4114		- RM			
P, R, X, R, M, D:		- 5520-001		0.0000		3.3759			
f, SIGDH, SIGDH, E:		- 7050		3.3270		37.585		- 48863-001	
P, R, X, R, M, D:		- 11175		0.4110		3.0299		37.089	
f, SIGDH, SIGDH, E:		- EPS		- SIGDH		- XR			
P, R, X, R, M, D:		- 5500-001		0.3072		0.3210			
f, SIGDH, SIGDH, E:		- V		8.1443		- RM			
P, R, X, R, M, D:		- 3224-001		0.0000		3.7599			
f, SIGDH, SIGDH, E:		- 6750		3.6967		36.336		- 45238-001	
P, R, X, R, M, D:		- 10140		0.8505		2.9247		35.752	
f, SIGDH, SIGDH, E:		- EPS		- SIGDH		- XR			
P, R, X, R, M, D:		- 1005		0.3506		0.35285			
f, SIGDH, SIGDH, E:		- V		7.0901		- RM			
P, R, X, R, M, D:		- 5121-001		0.0000		4.0912			
f, SIGDH, SIGDH, E:		- 04710		4.0535		35.027		- 57744-001	
P, R, X, R, M, D:		- 10121		0.4275		2.8245		34.579	

[illegible]

	- P -	- V -	- R -	
	.11703-001	.11740-001	.2.747	- R -
				9.5303
F, SIGDH, SIGDH, E:	.20317	9.535	11.212	-25511-004
PD, R, XRD, MMD:	-.41455-001	1.5470	.71110	11.188
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.3900	1.0000	.0337	.03179	.80574
	- P -	- V -	- R -	
	.11350-001	.11543-001	2.0675	- RM -
				9.6477
F, SIGDH, SIGDH, E:	.19426	9.6474	10.721	.20289-003
PD, R, XRD, MMD:	-.39430-001	1.5595	.87135	10.700
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.4100	1.0000	.20420	.81049	.81426
	- P -	- V -	- R -	
	.10971-001	.10550-001	2.7696	- RM -
				9.7523
F, SIGDH, SIGDH, E:	.16575	9.7527	10.251	.40114-003
PD, R, XRD, MMD:	-.37610-001	1.5716	.83333	10.233
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.4100	1.0000	.20600	.81682	.82241
	- P -	- V -	- R -	
	.10600-001	.10585-001	2.6758	- RM -
				9.8523
F, SIGDH, SIGDH, E:	.17760	9.8524	9.8021	.57077-003
PD, R, XRD, MMD:	-.56535-001	1.5624	.79694	9.7864
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.4400	1.0000	.20782	.82678	.83020
	- P -	- V -	- R -	
	.10240-001	.10230-001	2.5861	- R -
				9.9479
F, SIGDH, SIGDH, E:	.16901	9.7457	9.3724	.71561-003
PD, R, XRD, MMD:	-.54235-001	1.5930	.76213	9.3593
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.4300	1.0000	.20947	.83439	.83765
	- P -	- V -	- R -	
	.72062-002	.75905-002	2.5003	- RM -
				10.039
F, SIGDH, SIGDH, E:	.10236	10.040	6.9015	.63816-003
PD, R, XRD, MMD:	-.53361-001	1.6039	.72882	8.9503
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.4400	1.0000	.21106	.84167	.84677
	- P -	- V -	- R -	
	.75817-002	.75059-002	2.4183	- RA -
				10.127

F, SIGDH, SIGDH, E:	.15224	1.0120	5.5086	.94199-005
PD, R, XRD, RMD:	-.52735-001	1.0130	.09098	8.5591
TIME				
.4500	- SIGD -	- LPS -	- SIGDH -	- RM -
	1.0000	.21250	.84863	.85158
	- P -	- V -	- RM -	- RM -
	.92712-002	.92553-002	2.5397	10.211
F, SIGDH, SIGDH, E:	.14340	10.212	8.1923	.10282-002
PD, R, XRD, RMD:	-.50012-001	1.6232	.66650	8.1855
TIME				
.4600	- SIGD -	- EPS -	- SIGDH -	- XR -
	1.0000	.21403	.85528	.85910
	- P -	- V -	- RM -	- RM -
	.69742-002	.69581-002	2.6646	10.291
F, SIGDH, SIGDH, E:	.14171	10.272	7.8334	.10985-002
PD, R, XRD, RMD:	-.26312-001	1.6321	.63735	7.8277
TIME				
.4700	- SIGD -	- LPS -	- SIGDH -	- XR -
	1.0000	.21542	.80164	.86433
	- P -	- V -	- RM -	- RM -
	.66999-002	.66736-002	2.1927	10.367
F, SIGDH, SIGDH, E:	.13568	10.368	7.4398	.11538-002
PD, R, XRD, RMD:	-.27942-001	1.5407	.60945	7.4849
TIME				
.4799	- SIGD -	- EPS -	- SIGDH -	- XR -
	1.0000	.21674	.80772	.87028
	- P -	- V -	- RM -	- RM -
	.64185-002	.64020-002	2.1240	10.440
F, SIGDH, SIGDH, E:	.12972	10.441	7.1612	.11982-002
PD, R, XRD, RMD:	-.26593-001	1.6490	.58279	7.1574
TIME				
.4899	- SIGD -	- EPS -	- SIGDH -	- XR -
	1.0000	.21801	.87354	.87598
	- P -	- V -	- RM -	- RM -
	.61582-002	.61419-002	2.0543	10.510
F, SIGDH, SIGDH, E:	.12403	10.511	6.8469	.12319-002
PD, R, XRD, RMD:	-.26152-001	1.6560	.55727	6.8441
TIME				
.4999	- SIGD -	- EPS -	- SIGDH -	- XR -
	1.0000	.21922	.87910	.88142
	- P -	- V -	- RM -	- RM -
	.79096-002	.78932-002	1.9954	10.577
F, SIGDH, SIGDH, E:	.11054	10.578	6.5464	.12560-002
PD, R, XRD, RMD:	-.24962-001	1.6643	.53287	6.5446

TIME .5679	- SIGD - 1.0000	- LPS - .2253	- SIGDH - .2344	- AR - .58503
	- P - .70717-002	- V - .70552-002	- SIGDH - 1.2752	- RM - 10.041
F, SIGDH, SIGDH, E: PD, R, XRD, RMD:	-11337 -23113-001	10.642 1.6715	6.2591 .50953	.12717-002 6.2581
TIME .5179	- SIGD - 1.0000	- LPS - .22149	- SIGDH - .85949	- AR - .89101
	- P - .74442-002	- V - .74276-002	- SIGDH - 1.8777	- RM - 10.702
F, SIGDH, SIGDH, E: PD, R, XRD, RMD:	-10339 -21932-001	10.703 1.6784	5.9344 .48720	.12801-002 5.9840
TIME .5279	- SIGD - 1.0000	- EPS - .22255	- SIGDH - .89435	- AR - .89637
	- P - .72266-002	- V - .72100-002	- SIGDH - 1.6227	- RM - 10.760
F, SIGDH, SIGDH, E: PD, R, XRD, RMD:	-10363 -21523-001	10.762 1.6649	5.7416 .46585	.12822-002 5.7217
TIME .5379	- SIGD - 1.0000	- LPS - .22356	- SIGDH - .89900	- XR - .90092
	- P - .70165-002	- V - .70013-002	- SIGDH - 1.7701	- RM - 10.816
F, SIGDH, SIGDH, E: PD, R, XRD, RMD:	-99062-001 -20334-001	10.816 1.6912	5.4704 .44563	.12786-002 5.4711
TIME .5479	- SIGD - 1.0000	- EPS - .22453	- SIGDH - .90344	- XR - .90527
	- P - .65196-002	- V - .65022-002	- SIGDH - 1.7198	- RM - 10.570
F, SIGDH, SIGDH, E: PD, R, XRD, RMD:	-94730-001 -19783-001	10.371 1.6972	5.2303 .42591	.12710-002 5.2313
TIME .5579	- SIGD - 1.0000	- LPS - .22545	- SIGDH - .90768	- XR - .90944
	- P - .66293-002	- V - .66124-002	- SIGDH - 1.6716	- RM - 10.921
F, SIGDH, SIGDH, E: PD, R, XRD, RMD:	-90509-001 -18306-001	10.924 1.7029	5.0006 .40724	.12593-002 5.0024
TIME .5679	- SIGD - 1.0000	- LPS - .22634	- SIGDH - .91174	- XR - .91341

	- P -	- V -	- RM -	
	.447-002	.5505-002	1.5256	10.970
F, SIGDH, SIGDH, E:	.06570-001	1.0971	4.7610	.12439-002
PD, R, XRD, RMD:	-.17109-001	1.7084	.38939	4.7831
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.5799	1.0000	.22718	.91562	.91722
	- P -	- V -	- RM -	
	.62733-002	.62563-002	1.5816	11.016
F, SIGDH, SIGDH, E:	.82782-001	11.016	4.5711	.12246-002
PD, R, XRD, RMD:	-.16582-001	1.7137	.37231	4.5741
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.5899	1.0000	.22799	.91933	.92086
	- P -	- V -	- RM -	
	.61069-002	.60988-002	1.5395	11.061
F, SIGDH, SIGDH, E:	.79149-001	11.064	4.3704	.12028-002
PD, R, XRD, RMD:	-.16774-001	1.7187	.35598	4.5732
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.5999	1.0000	.22876	.92288	.92433
	- P -	- V -	- RM -	
	.59477-002	.59306-002	1.4793	11.104
F, SIGDH, SIGDH, E:	.75671-001	11.105	4.1785	.11792-002
PD, R, XRD, RMD:	-.15070-001	1.7235	.34036	4.1814
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.6099	1.0000	.22950	.92627	.92766
	- P -	- V -	- RM -	
	.57955-002	.57784-002	1.4603	11.145
F, SIGDH, SIGDH, E:	.72347-001	11.146	3.9949	.11545-002
PD, R, XRD, RMD:	-.13916-001	1.7281	.32543	3.9984
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.6199	1.0000	.23021	.92951	.93084
	- P -	- V -	- RM -	
	.56495-002	.56327-002	1.4239	11.184
F, SIGDH, SIGDH, E:	.69160-001	11.185	3.8195	.11276-002
PD, R, XRD, RMD:	-.13874-001	1.7324	.31113	3.8224
TIME	- SIGD -	- EPS -	- SIGDH -	- XR -
.6299	1.0000	.23023	.93261	.93387
	- P -	- V -	- RM -	
	.55107-002	.54935-002	1.3688	11.221

TIME .6599	F, SIGDH, SIGDH, E: PD, R, XRD, RMD:	-56127-001 -12741-001	11.224 1.7566	3.6518 .29743	-11004-002 3.6546
	- SIGD - 1.0000	- EPS - .23152	- SIGDH - .93557	- AR - .93078	
	- P - .5280-002	- V - .5300-002	- J - 1.5552	- RM - 11.257	
TIME .6479	F, SIGDH, SIGDH, E: PD, R, XRD, RMD:	-5624-001 -13555-001	11.256 1.7406	3.4513 .28446	-10723-002 3.4541
	- SIGD - 1.0000	- EPS - .23215	- SIGDH - .93840	- AR - .93756	
	- P - .52509-002	- V - .5255-002	- J - 1.5250	- RM - 11.291	
TIME .6599	F, SIGDH, SIGDH, E: PD, R, XRD, RMD:	-50446-001 -11063-001	11.292 1.7445	3.3380 .27198	-10448-002 3.3411
	- SIGD - 1.0000	- EPS - .23274	- SIGDH - .94111	- AR - .94221	
	- P - .51289-002	- V - .5116-002	- J - 1.2922	- RM - 11.523	
TIME .6699	F, SIGDH, SIGDH, E: PD, R, XRD, RMD:	-57790-001 -13033-001	11.324 1.7431	3.1914 .26002	-10132-002 3.1945
	- SIGD - 1.0000	- EPS - .23330	- SIGDH - .94370	- AR - .94675	
	- P - .50129-002	- V - .49555-002	- J - 1.2629	- RM - 11.355	
TIME .6799	F, SIGDH, SIGDH, E: PD, R, XRD, RMD:	-55251-001 -10916-001	11.356 1.7516	3.0513 .24864	-98503-003 3.0546
	- SIGD - 1.0000	- EPS - .23384	- SIGDH - .94617	- AR - .94718	
	- P - .49014-002	- V - .48640-002	- J - 1.2347	- RM - 11.384	
TIME .6899	F, SIGDH, SIGDH, E: PD, R, XRD, RMD:	-52623-001 -13111-001	11.385 1.7550	2.9173 .23770	-95356-003 2.9203
	- SIGD - 1.0000	- EPS - .23432	- SIGDH - .94854	- AR - .94950	
	- P - .47954-002	- V - .4777-002	- J - 1.2378	- RM - 11.413	
TIME .6999	F, SIGDH, SIGDH, E: PD, R, XRD, RMD:	-50503-001 -96507-002	11.414 1.7582	2.7892 .22729	-92554-003 2.7928
	- SIGD - 1.0000	- EPS - .23432	- SIGDH - .94854	- AR - .94950	
	- P - .47954-002	- V - .4777-002	- J - 1.2378	- RM - 11.413	

TIME .6599	- SIGD - 1.0000	- EPS - .23455	- SIGDH - .95050	- RM - .35172
	- P - - .6933-002	- V - .46753-002	- RM - 11.440	
	F, SIGDH, SIGDH0, E: PD, R, XRD, XRD:	- EPS - - .48294-001 - .12050-001	11.441 1.7612	2.6667 2.1725
TIME .7099	- SIGD - 1.0000	- EPS - .23532	- SIGDH - .95296	- XR - .95384
	- P - - .45905-002	- V - .45790-002	- RM - 11.466	
	F, SIGDH, SIGDH0, E: PD, R, XRD, XRD:	- EPS - - .46103-001 - .10806-001	11.467 1.7641	2.5496 2.0778
TIME .7199	- SIGD - 1.0000	- EPS - .23577	- SIGDH - .95503	- XR - .95587
	- P - - .45029-002	- V - .44354-002	- RM - 11.491	
	F, SIGDH, SIGDH0, E: PD, R, XRD, XRD:	- EPS - - .44135-001 - .07151-002	11.492 1.7667	2.4377 2.19860
TIME .7299	- SIGD - 1.0000	- EPS - .23620	- SIGDH - .95701	- XR - .95781
	- P - - .4140-002	- V - .43964-002	- RM - 11.515	
	F, SIGDH, SIGDH0, E: PD, R, XRD, XRD:	- EPS - - .42197-001 - .35311-002	11.516 1.7690	2.3307 2.18987
TIME .7399	- SIGD - 1.0000	- EPS - .23661	- SIGDH - .95889	- XR - .95966
	- P - - .43293-002	- V - .43122-002	- RM - 11.538	
	F, SIGDH, SIGDH0, E: PD, R, XRD, XRD:	- EPS - - .40343-001 - .90145-002	11.538 1.7722	2.2283 2.18161
TIME .7499	- SIGD - 1.0000	- EPS - .23701	- SIGDH - .96070	- XR - .96143
	- P - - .42479-002	- V - .42303-002	- RM - 11.559	
	F, SIGDH, SIGDH0, E: PD, R, XRD, XRD:	- EPS - - .38571-001 - .10092-001	11.560 1.7746	2.1306 2.17356
TIME .7599	- SIGD - 1.0000	- EPS - .23738	- SIGDH - .96243	- XR - .96312

F, SIGDH, SIGDH, E:	-25135-001	11.565	1.5563	57850-003
P, R, XMD, RMD:	-25135-002	1.7537	1.2678	1.5594
TIME	- SIGD -	- SIGDH -	- XR -	
.5297	1.0000	.97256	.97307	
	- EPS -	- RM -	- RM -	
	.25135	-	-	
	- V -	-	-	
	.37143-002	.93447	11.702	
F, SIGDH, SIGDH, E:	-26535-001	11.703	1.4890	55456-003
P, R, XMD, RMD:	-26535-002	1.7906	1.2123	1.4900
TIME	- SIGD -	- SIGDH -	- XR -	
.5347	1.0000	.97376	.97425	
	- EPS -	- RM -	- RM -	
	.25585	-	-	
	- V -	-	-	
	.36601-002	.72675	11.717	
F, SIGDH, SIGDH, E:	-25751-001	11.717	1.4226	53465-003
P, R, XMD, RMD:	-25751-002	1.7923	1.1591	1.4267
TIME	- SIGD -	- SIGDH -	- XR -	
.5497	1.0000	.97492	.97538	
	- EPS -	- RM -	- RM -	
	.25011	-	-	
	- V -	-	-	
	.35070-002	.96764	11.731	
F, SIGDH, SIGDH, E:	-24201-001	11.731	1.3203	51463-003
P, R, XMD, RMD:	-24201-002	1.7932	1.1089	1.3627
TIME	- SIGD -	- SIGDH -	- XR -	
.5597	1.0000	.97602	.97646	
	- EPS -	- RM -	- RM -	
	.24035	-	-	
	- V -	-	-	
	.35410-002	.89517	11.744	
F, SIGDH, SIGDH, E:	-23541-001	11.744	1.3007	49317-003
P, R, XMD, RMD:	-23541-002	1.7953	1.0598	1.3016
TIME	- SIGD -	- SIGDH -	- XR -	
.5697	1.0000	.97707	.97749	
	- EPS -	- RM -	- RM -	
	.24057	-	-	
	- V -	-	-	
	.35112-002	.86328	11.757	
F, SIGDH, SIGDH, E:	-22735-001	11.757	1.2436	47457-003
P, R, XMD, RMD:	-22735-002	1.7967	1.0136	1.2481
TIME	- SIGD -	- SIGDH -	- XR -	
.5797	1.0000	.97807	.97848	
	- EPS -	- RM -	- RM -	
	.24079	-	-	
	- V -	-	-	
	.34651-002	.87146	11.769	
F, SIGDH, SIGDH, E:	-21521-001	11.769	1.1892	45288-003
P, R, XMD, RMD:	-21521-002	1.7981	.96787-001	1.1919

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