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R. Larson

PREINSTALLATION G&N TESTING OF THE LUNAR EXCURSION MODULE OPTICAL RENDEZVOUS SYSTEM

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G&N TESTING OF THE LUNAR EXCURSION MODULE

OPTICAL RENDEZVOUS SYSTEM

1. SCOPE

1.1 This document establishes the performance required of the Lunar Excursion Module Optical Rendezvous System (LORS) at the G&N level.

2. APPLICABLE DOCUMENTS

2.1 Unless otherwise indicated, the following documents shall form a part of this document to the extent specified herein.

NASA PROCUREMENT SPECIFICATIONS

PS 2017500	Contract End Item Detail Specification (Part I), Luminous Beacon
PS 6021500	Contract End Item Detail Specification (Part I), Optical Tracker

INTERFACE CONTROL DOCUMENTS

<u>TRACKER</u>

LIS-520-14001	Design Environment
LIS-390-14001	Power
LIS-490-14001	Weight (Design Load)
LIS-510-14001	Thermal
LIS-370-14001	Measurements
LID-280-14000	Installation
LID-390-14000	Wiring and Connectors
LID-280-14001	LORS Field of View
LIS-520-14002	Materials Compatibility

<u>BEACON</u>

MH01-24004-436	GSE

MH01-24003-436 Design Environment

MH01-24001-436 Electrical Requirements

MH01-24005-436 Mechanical and Installation

MH01-24002-436 Thermal Environment

XDE's

34-R-302 LORS-PGNS Electrical Interface Control Document

34-R-301 LORS-PGNS Computer Program Functional (Software) Interface Control Document

DRAWINGS

2017500 Tracking Beacon Assembly

6021500 Optical Tracker Subsystem

3. REQUIREMENTS

3.1 General

The function of LORS is to

a) provide attitude information which can be used for alignment of the Lunar Excursion Module (LEM) Inertial Measurement Unit (IMU), and

b) provide guidance information during the lunar descent phase, during fixed site operations on the lunar surface, and again during the ascent/rendezvous phase of the lunar mission.

LORS consists of an optical tracker mounted on the LEM and a luminous beacon mounted on the Command/Service Module (CSM).

3.2 Detailed Functional Requirements

3.2.1 Tracker

3.2.1.1 Weight - The optical tracker shall weigh 27 pounds or less.

3.2.1.2 Power - The tracker shall meet the requirements of paragraphs 3.2.1.3 through 3.2.1.11 under power supply variations and restrictions listed in LIS-390-14001 and XDE 34-R-302.

3.2.1.2.1 DC Power -

a) Steady State Voltage Limits - 25 to 32 volts DC with a power of 50 watts or less; 24 to 32 volts DC with a power of 80 watts or less.

b) Transient Voltages - Transient voltages superimposed on the DC steady state voltage shall be less than +50 volts, -100 volts for 10 μ sec with a repetition rate of 10 pps.

c) Ripple Voltage - Ripple voltage superimposed on the DC steady state voltage shall not exceed ± 1.5 volts, peak, with frequency components from 20 cps to 20 KC.

d) Power Requirements - At 28 VDC, the maximum power required by the tracker shall be 80 watts, and the average power 40 watts. Minimum power requirements are still to be defined.

3.2.1.2.2 28V, 800~ Resolver Excitation -

a) The 800 cps signal input characteristics under normal conditions (800 cps frequency synchronized by LEM Guidance Computer clock) and under degraded conditions (800 cps frequency not synchronized by LEM Guidance Computer clock) shall be as listed in Table 3.2.1.2.2.

TABLE 3.2.1.2.2

	Normal Conditions	Degraded Conditions
Voltage	28 ± 2% VRMS	28 ± 5% VRMS
Frequency	800 ± 0.5% cps	750 ± 40 cps
Harmonic Content	5% maximum	5% maximum

b) Maximum Load - One watt at 28 VRMS, 800 cps.

c) Turn-On Transient - The voltage at turn-on of the Primary Guidance and Navigation System (PGNS) shall not exceed 45 volts rms, and shall be within tolerance in less than five seconds.

3.2.1.3 Tracking Sensitivity -

a) Star Tracking - The tracker shall be capable of tracking a third magnitude star to within 30° of the sun, 5° of the limb of the sum-illuminated earth, 5° of the edge of any antenna, and 20° of any extended sunlit surface of the CSM or the LEM.

b) CSM Tracking - The tracker shall be capable of tracking a sun-illuminated CSM at ranges of 0.5 to 400 n.mi. under the conditions specified in 3.2.1.3.a.

c) Luminous Beacon Tracking - The tracker shall be capable of tracking a luminous beacon on the CSM at ranges of 0.5 to 400 n.mi. against a star background. The tracker shall also be able to track the luminous beacon at ranges of 0.5 to 40 n.mi. against the sunlit lunar surface. Tracking shall be under the conditions specified in 3.2.1.3.a.

d) Lunar Marker Tracking - The tracker shall be capable of tracking a sunlit marker on the lunar surface (such as a 15 ft. balloon with diffuse reflectance of 0.8) at ranges of 0.5 to 22 n.mi.

3.2.1.4 Tracking Accuracy - The tracker shall be capable of a tracking accuracy of 0.15 milliradian (one sigma random) or the angle subtended by the target, whichever is larger, of target LOS position relative to the tracker mounting axes, as represented by the resolver outputs. This error shall not include alignment errors readily measured during normal ground testing and easily compensated in LEM Guidance Computer (LGC), such as LOS to mounting base errors but not orthogonality errors. The deviation caused when the nutating wedge is stopped in a fixed position will be compensated with a single correction factor in all LGC's. Uncertainties in establishing this correction factor shall be included in the tracking accuracy error analysis. Uncertainty in the determination of these alignment errors and instabilities in all parameters over the life of the instrument shall be included in the tracking uncertainty. The tracking accuracy shall be achieved under the conditions of 3.2.1.3.a, 3.2.1.3.b, and 3.2.1.3.c and be maintained during:

a) A combination of LOS and body rate angular velocities of less than 1°/sec about each body axis simultaneously.

b) LOS angular accelerations of less than 0.01 rad/sec^2 about any body axis.

c) CSM fly-by at a lunar altitude of not less than 80 n.mi. up to a tracker elevation angle of 84°.

3.2.1.5 Tracking During LEM Maneuvers - The tracker shall be capable of tracking during spacecraft accelerations of up to 0.75 rad/sec^2, and angular velocities of up to 10°/sec about any vehicle axis without loss of lock-on. The tracking accuracy need not be maintained during the above conditions but shall be restored:

a) Within 1.0 seconds after cessation of vehicle simultaneous accelerations of 0.75 rad/sec^2 from angular velocities of $\pm$ 10°/sec about any axis to an angular velocity within ±1°/sec.

b) Within 0.5 seconds after cessation of vehicle accelerations of 0.75 rad/sec^2 and velocity changes of 1°/sec about any axis.

3.2.1.6 Multiple Target Discrimination - The tracker shall provide the LOS coordinates of the most brilliant point-source unmodulated target within the field of view to the accuracy specified in 3.2.1.4 when in the star track mode. The brightness difference shall be equivalent to 1 visual magnitude or greater

3.2.1.7 Lunar Marker Tracker Accuracy - The tracker shall be capable of a tracking uncertainty of 5.0 mr, one sigma, or the angle subtended by the target, whichever is greater, of target LOS position relative to the tracker mounting axes as represented by the resolver outputs. Tracker accuracy shall be maintained under conditions indicated in 3.2.1.3.d and during:

a) A combination of LOS and body rate angular velocities of less than 1°/sec about each body axis simultaenously.

b) LOS angular accelerations of less than 0.01 rad/sec^2 about any body axis.

c) During simultaneous angular rates of less than 10°/sec about each body axis and accelerations of 0.75 rad/sec^2.

d) During vibrational environment of LEM descent engine operation.

3.2.1.8 Beacon Lock-On - The tracker shall lock onto the CSM luminous beacon modulated signal in less than 30 sec when directed to a position in a 2° cone containing the target LOS when in the beacon mode. The tracker shall lock on the luminous beacon in the presence of + 1 visual magnitude stars in the field of view with the accuracies specified in 3.2.1.4.

3.2.1.9 Star, CSM Lock-On - The tracker shall lock onto stars or sun-illuminated CSM within 30 sec when directed to a position in a 2° cone containing the target LOS when in the star track mode.

3.2.1.10 Probability of Lock-On - The probability of optical target lock-on shall be greater than 0.99 for the targets defined in this specification.

3.2.1.11 Failure Rate - The tracker operational failure rate shall not exceed 70 failures per million hours.

3.2.2 Luminous Beacon

3.2.2.1 Weight - The luminous beacon shall weigh 25 pounds or less.

3.2.3.2 Power - The beacon shall meet the requirements of paragraphs 3.2.2.3 and 3.2.2.4 under the power supply variations and restrictions listed in MH01-24001-436.

a) Steady State Voltage Limits - 25 to 30 volts DC.

b) Transient Voltages - Transient voltages superimposed on the DC steady-state voltage shall be less than +80 volts, -24 volts for 10 μ sec with a repetition rate of 10 pps.

c) Ripple Voltage - Ripple voltage shall not exceed 1 volt peak-to-peak within the band width of 30 cps to 30 KC.

d) Power Requirements - The power drawn by the beacon shall not exceed 365 watts.

3.2.2.3 Autotrack Mode - The beacon shall be pulsed as required to achieve the tracker performance specified in 3.2.1.3-4-5-8-10. The operational failure rate in this mode shall not exceed 10 failures per million hours.

3.2.2.4 Visual Mode - The beacon shall be modulated with a one-second period and shall appear brighter than a third magnitude star when at a range of 175 n. mi. The operational failure rate in this mode shall not exceed 50 failures per million hours.

3.3 Loop Performance, Logic Characteristics and Test Points

3.3.1 Star Tracker Signal Processing Loop

3.3.1.1 General

Servo error signals for the star track mode will be generated by a signal process which is basically pulse position modulation working into a sample and hold.

Pulse position modulation of the deviation of a target star from the optical centerline is accomplished by optical means that combines image nutation with spatial filtering. Image nutation will be produced by directing incoming star light through a rotating refracting prism. The result will be an image that rotates in the image plane with a diameter of 10 milliradians. Spatial filtering will be accomplished by a four slit reticle mask located in the image plane. As the star image sweeps across each reticle slit, an energy pulse is released into the detection circuitry. When the image is on the tracker optical centerline, four equally spaced pulses will be generated, characterizing a tracker null. Any deviation of the target image from the tracker optical centerline will produce a train of pulses whose repetition period varies as a function of the image displacement.

The in-line component functions of the star tracker signal processing loop are as follows:

a) Light shade assembly for minimizing the effects of stray light.

b) Nutating wedge for rotating the image in the image plane.

c) Reticle mask for pulse position modulation.

d) Sector division optics for separation of azimuth from elevation signals.

e) Photomultiplier tubes for conversion of radiant energy to electrical signals.

f) Pulse conditioning electronics and drive axis logic.

g) Threshold circuitry for rejecting stars weaker than a certain magnitude.

h) Sample and hold phase locked to the nutation drive.

A block diagram of the signal processing for the star track mode is shown in Figure 3.3.1A. The overall functional equivalent of this processing loop is approximated by the illustration in Figure 3.3.1B.

3.3.1.2 Operational Characteristics - The operational characteristics of the star track signal processing loop shall be as follows:

a) Reject all stars whose brightness is less than the target by one visual magnitude.

b) Reject all background originated and tube noise such that the accuracy requirements specified in 3.2.1.4 through 7 are met.

c) Provide an end to end overall gradient of 3000 volts per radian for image displacements to 5.0 milliradians.

d) Provide the gradient factor in c) above without contributing significant dynamic lags or servo break points to the overall system.

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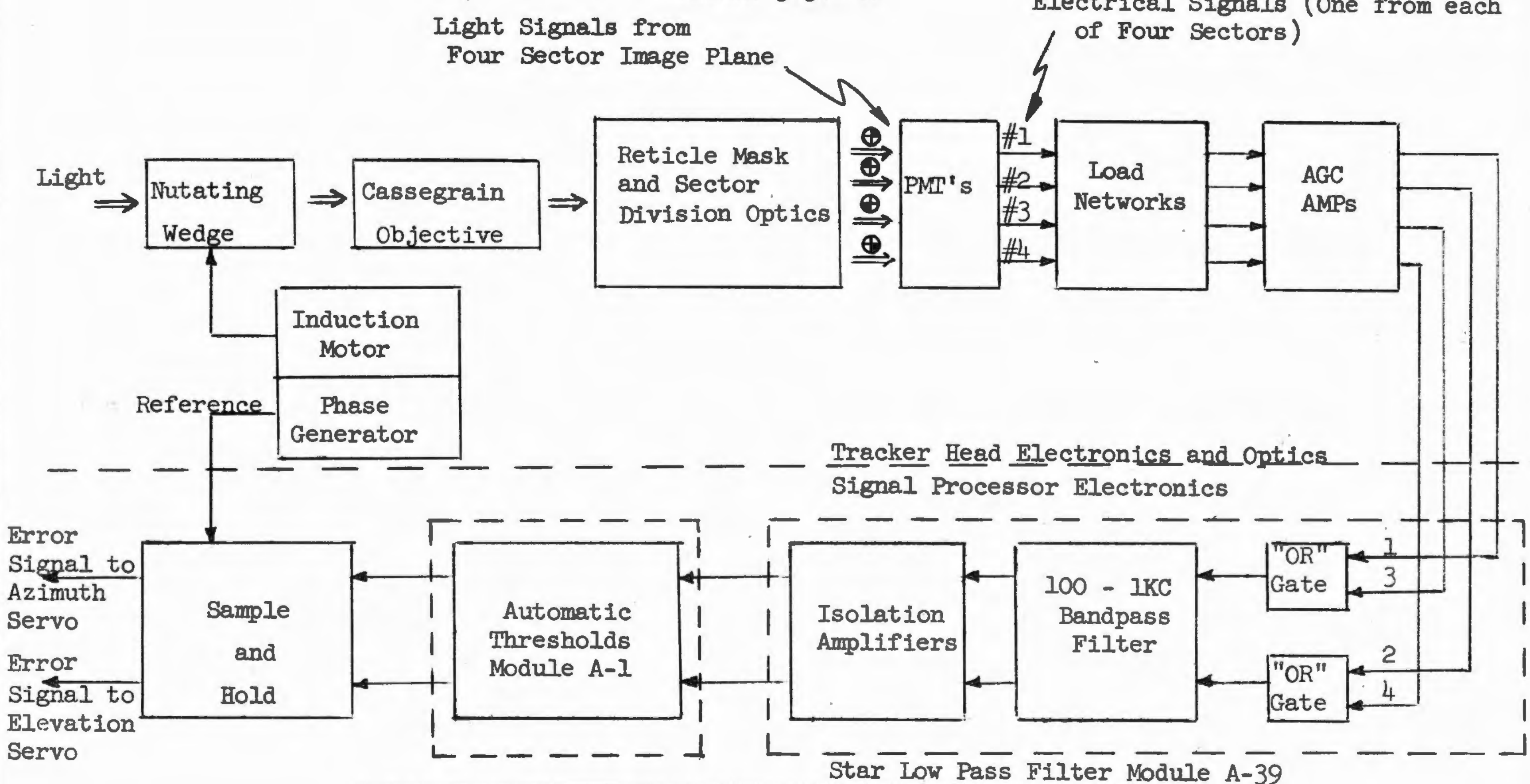
SIGNAL PROCESSING LOOP FOR SERVO ERRORS OF STAR TRACK MODE

FIGURE 3.3.1 A



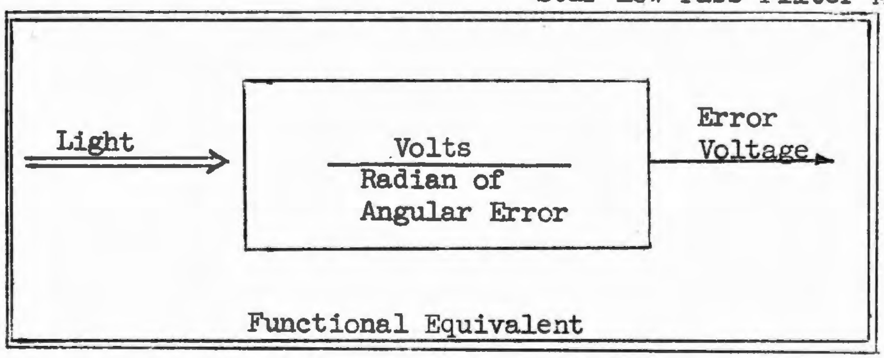


Figure 3.3.1 B

3.3.2 Beacon Track Signal Processing Loop

3.3.2.1 General

Servo error signals for the beacon track mode will be generated by a signal process which is based on detecting energy pulse inputs by an energy balance scheme.

Impulse inputs to the beacon tracker will originate from a flashing beacon mounted on the CSM. The resulting energy pulses are processed by a clear optical path that produces a shaped energy distribution in the sector division plane for detection by the photomultipliers on an energy balance basis.

The optical path for beacon signal processing will differ from that used for star signal processing in two respects:

a) The nutating wedge is held stationary for processing beacon signals. Because of this, a standoff error to the tracker optical centerline of 5 milliradians will occur. This will be compensated for by a single correction factor in the LEM Guidance Computer.

b) The reticle mask will be removed from the optical path for processing beacon signals.

The in-line component of the beacon track signal processing loop are as follows:

a) Light shade assembly for minimizing the effects of stray light.

b) Nutating wedge which introduces a standoff error from the optical centerline of 5 milliradians.

c) Sector division optics for separation of the blur image into four sectors.

d) Photomultiplier tubes for conversion of sector energy to an electrical signal.

e) Pulse conditioning electronics and drive axis logic.

f) Threshold circuitry for accurate gating of the sample and hold.

g) Linearization circuitry to compensate for the nonlinear gradient inherent in the energy balance detection scheme.

h) Sample and hold phase locked to the pulses from each image plane sector.

A block diagram of the signal processing for the beacon track mode is shown in Figure 3.3.2A. The overall functional equivalent of this processing loop is approximated by the illustration in Figure 3.3.2B.

3.3.2.2 Operational Characteristics - The operational characteristics of the beacon track signal processing loop shall be as follows:

a) Provide sufficient predetection high pass filtering such that the tracking requirements specified in 3.2.1.3 are met when there is a sudden change in background irradiance due to the moon sweeping into the field of view.

b) Reject all background originated and tube noise such that the accuracy requirements specified in 3.2.1.4 are met.

c) Provide an end to end overall gradient of 3000 volts per radian for image displacements to 0.2 milliradians from the beacon tracking line.

d) Provide servo error signals with a nonlinear gradient for image displacements greater than 0.2 milliradians but less than 5 milliradians from the beacon tracking line.

e) Provide the gradient factor mentioned in c) above without contributing significant dynamic lags or servo break points to the overall system.

3.3.3 Automatic Gain Control Loop

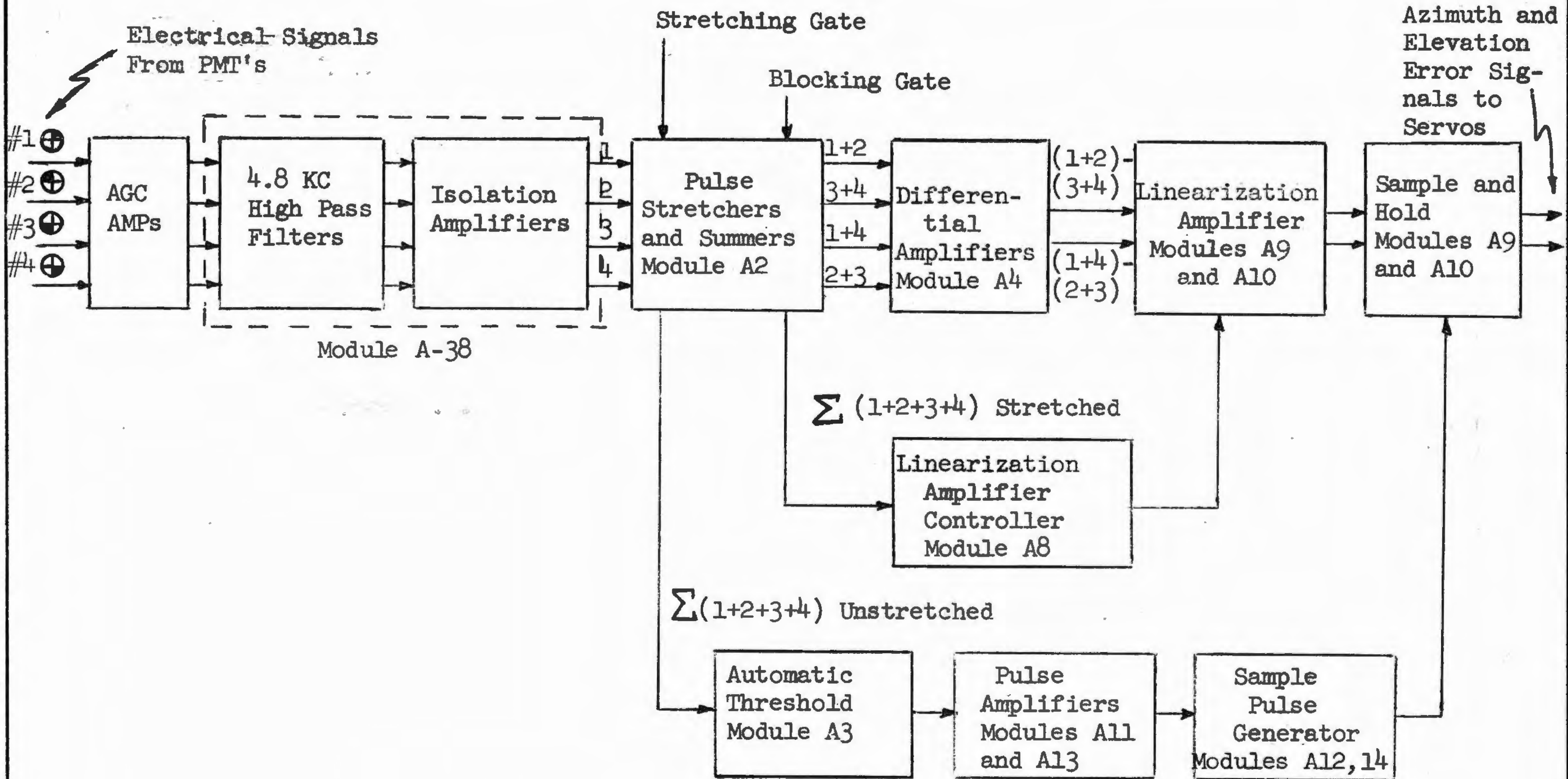
3.3.3.1 General

The Automatic Gain Control Loop for the LEM Optical Tracker is shown in Figure 3.3.3A. AGC will be used for both star track and beacon track. An AGC mode selection scheme will eliminate interfering AGC voltages from the unselected mode.

The functional equivalent of the multiloop dc/ac AGC feedback loop is shown in Figure 3.3.3B.

The primary controlled variable of the AGC system is the current gain of the four photomultipliers. This in turn is controlled by the amount of voltage applied across the phototube dynodes. Large variations in light intensity can be neutralized by making corresponding changes in current gain. In this manner, PMT output can be maintained constant even through the tracker is viewing celestial objects of different brightness. The adverse effects of background irradiance will also be minimized by AGC.

FIGURE 3.3.2 A
SIGNAL PROCESSING LOOP FOR SERVO ERRORS OF
BEACON TRACK MODE



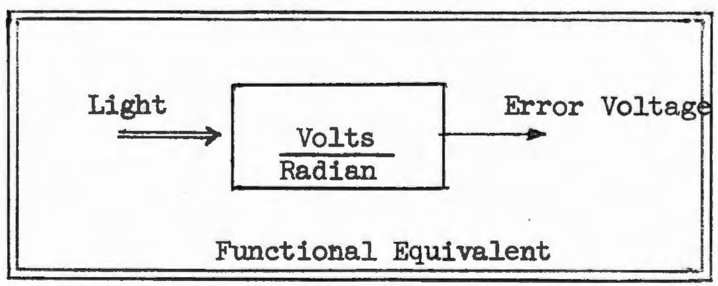


Figure 3.3.2 B

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AUTOMATIC GAIN CONTROL (AGC)

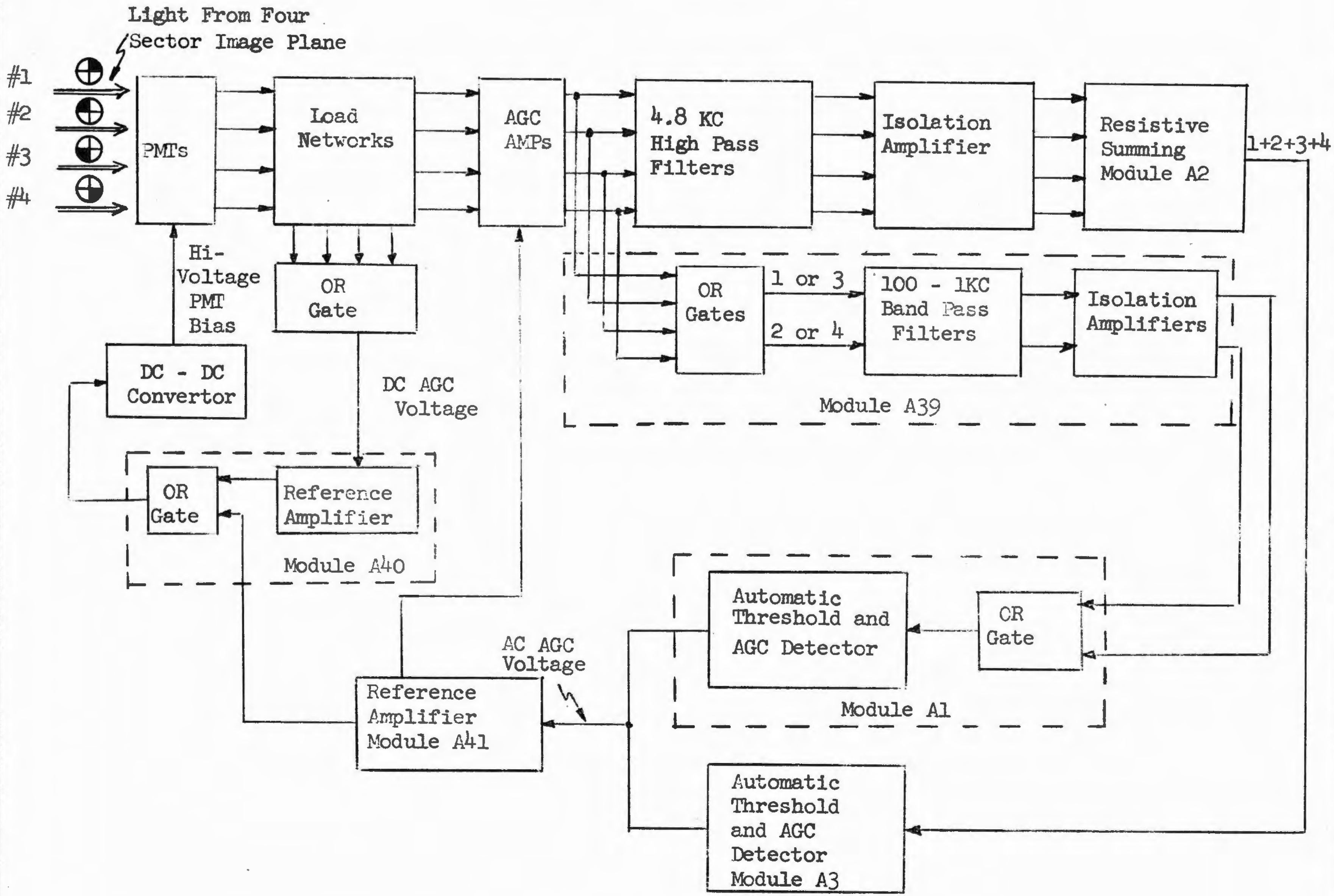

FIGURE 3.3.3 A

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AUTOMATIC GAIN CONTROL (AGC)

FUNCTIONAL EQUIVALENT

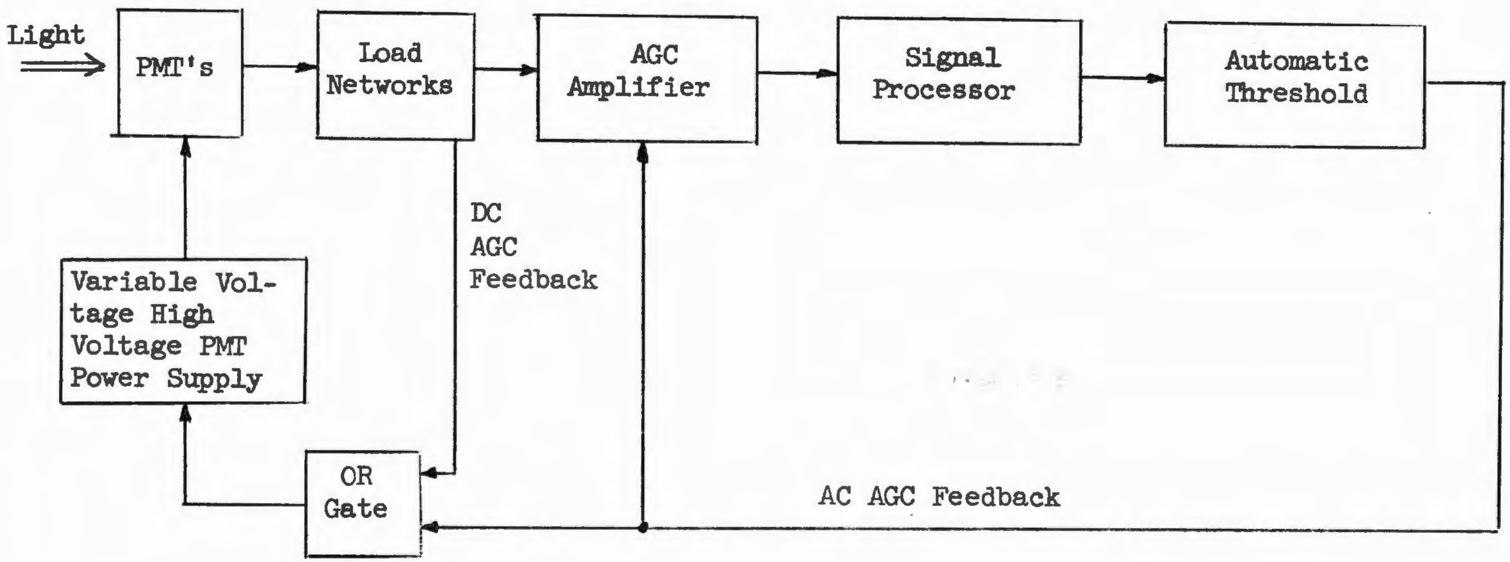

FIGURE 3.3.3 B

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3.3.3.2 Operational Characteristics

a) The Automatic Gain Control Loop shall provide adequate regulation of phototube output such that the tracking requirements specified in 3.3.4 are met.

b) When a star appears suddenly in the field of view, the initial burst of light results in saturation of the signal processor sample and hold output. AGC will take control at the fourth pulse allowing the fourth pulse to be sampled and held at the proper error signal level.

3.3.4 Star Track and Beacon Track Servo Loops

3.3.4.1 General

The servo mechanisms herein defined are common to both the star track and beacon track modes. As shown in Figure 3.3.4A, the block diagrams for star and beacon track differ only because of the signal processing used. The functional equivalent of the star and beacon track servomechanisms is shown in Figure 3.3.4.B.

3.3.4.2 Operational Characteristics

3.3.4.2.1 Integrator Characteristics - By a process of armature current and tachometer feedback, (Figures 3.3.4.2.1A and B), the LEM tracker gimbal drive is made to function as an electromechanical integrator. Thus, a constant input to the drive mechanism will produce a constant velocity output. The gimbal drives are therefore velocity coupled to disturbance inputs as measured by the signal processing loops defined in 3.3.1 and 3.3.2. A system of this kind is generally classified as type 1.

The integrator characteristics of the gimbal drives for the LEM Optical Tracker shall be as listed in Table 3.3.4.2.1.

TABLE 3.3.4.2.1

Integrator Characteristics of Gimbal Drive

Parameter	Elevation	Azimuth
Velocity Constant	$K_{V_E} = .045$ rad/sec/volt	$K_{V_A} = .090$ rad/sec/volt
Parasitic Break Points	$\left(\frac{s}{160} + 1\right)\left(\frac{s}{22K} + 1\right)$	$\left(\frac{s}{180} + 1\right)\left(\frac{s}{18K} + 1\right)$
Total Characteristics	$\frac{.045}{s}\left[\frac{1}{\left(\frac{s}{160}+1\right)\left(\frac{s}{22K}+1\right)}\right]$	$\frac{.090}{s}\left[\frac{1}{\left(\frac{s}{180}+1\right)\left(\frac{s}{18K}+1\right)}\right]$

SERVO CONFIGURATION FOR STAR AND BEACON TRACK MODE

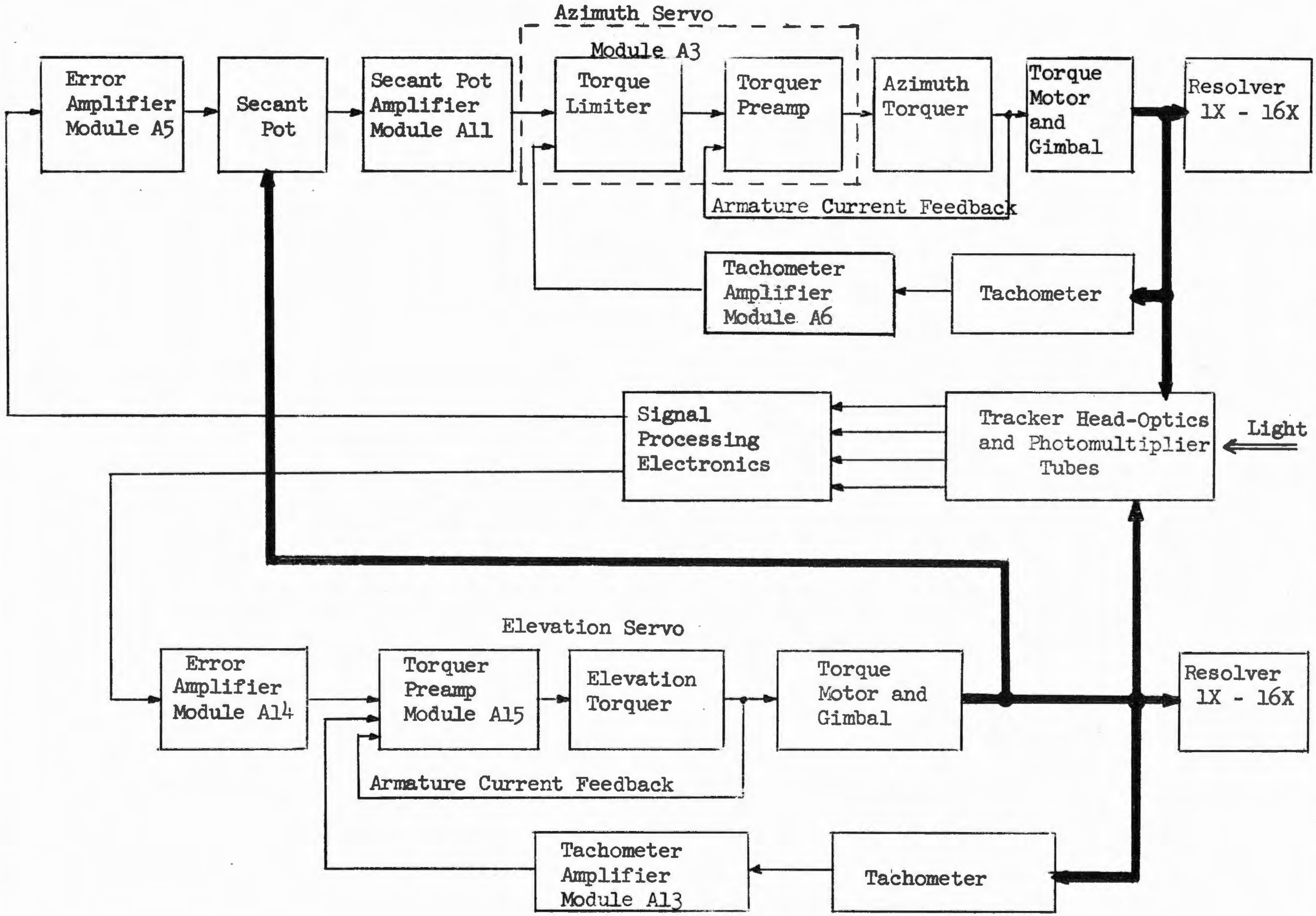

FIGURE 3.3.4 A

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FUNCTIONAL EQUIVALENT OF THE SERVO FOR STAR AND BEACON TRACK MODE

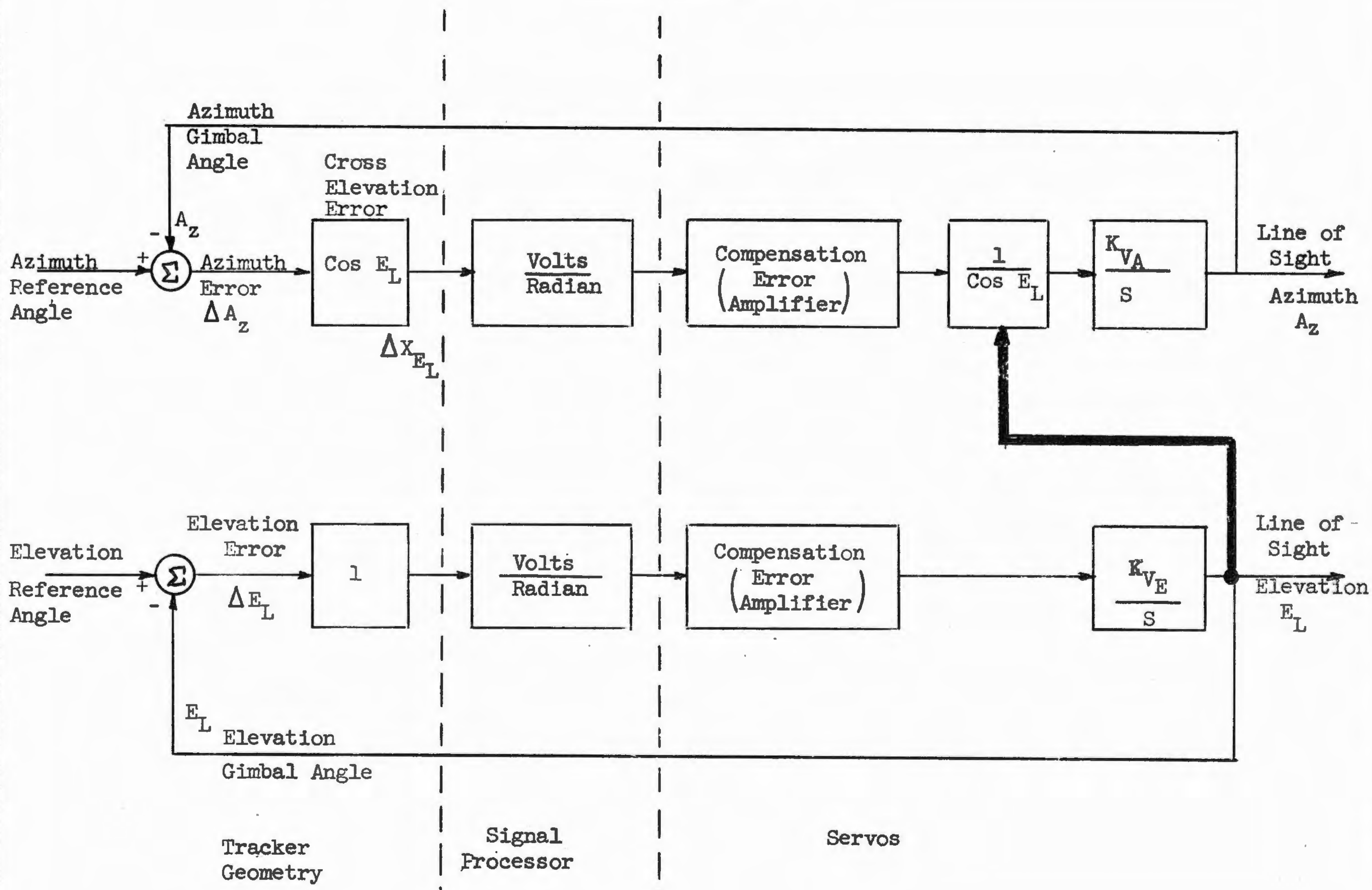

FIGURE 3.3.4 B

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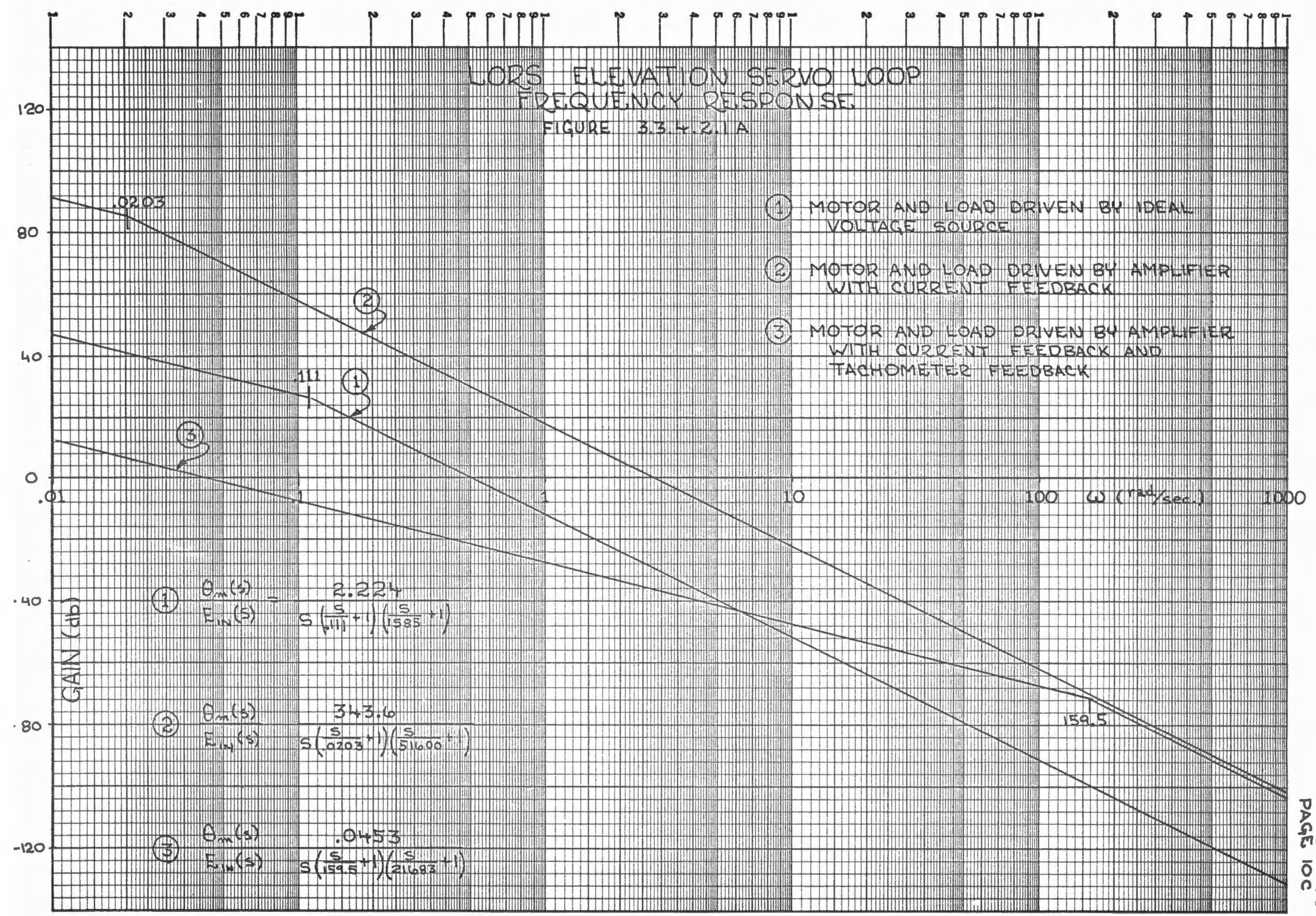
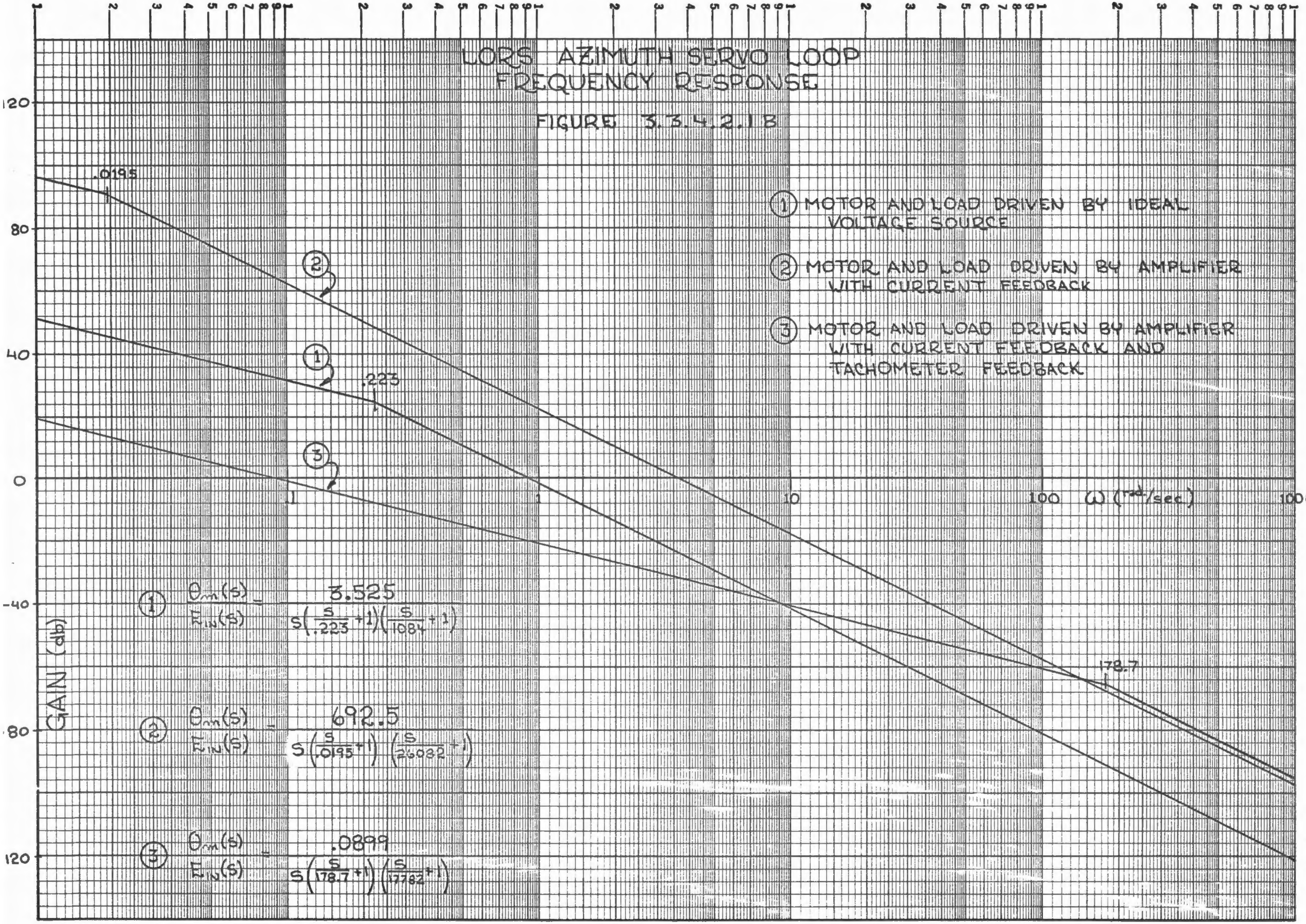


LORS ELEVATION SERVO LOOP
FREQUENCY RESPONSE
FIGURE 3.3.4.2.1A
1 MOTOR AND LOAD DRIVEN BY IDEAL VOLTAGE SOURCE
2 MOTOR AND LOAD DRIVEN BY AMPLIFIER WITH CURRENT FEEDBACK
3 MOTOR AND LOAD DRIVEN BY AMPLIFIER WITH CURRENT FEEDBACK AND TACHOMETER FEEDBACK
.0203
.111
159.5
GAIN (db)
ω (rad/sec.)
.01
.1
1
10
100
1000
120
80
40
0
-40
-80
-120
1 θm(s) / EIN(s) = 2.224 / s(s/.111 + 1)(s/1585 + 1)
2 θm(s) / EIN(s) = 343.6 / s(s/.0203 + 1)(s/51600 + 1)
3 θm(s) / EIN(s) = .0453 / s(s/159.5 + 1)(s/21683 + 1)



(1) $\frac{\theta_m(s)}{E_{in}(s)} = \frac{3.525}{s\left(\frac{s}{.223}+1\right)\left(\frac{s}{1084}+1\right)}$

(2) $\frac{\theta_m(s)}{E_{in}(s)} = \frac{692.5}{s\left(\frac{s}{.0195}+1\right)\left(\frac{s}{26082}+1\right)}$

(3) $\frac{\theta_m(s)}{E_{in}(s)} = \frac{.0899}{s\left(\frac{s}{178.7}+1\right)\left(\frac{s}{17782}+1\right)}$

3.3.4.2.2 Servo Geometry - When the elevation and azimuth gimbals are rotated from the zero-zero position, the error signals generated by signal processing can no longer be directly transmitted to the torquers mounted on the gimbal axis. To do so would give rise to erroneous corrections. As shown in Figure 3.3.4B, errors in elevation are detected on a one-to-one basis. Errors in azimuth, however, are detected by telescope signal processing as errors in cross-elevation. The factor relating detected disturbances to the appropriate corrections of the azimuth gimbal is the secant of the elevation angle. The ability of the mechanized secant function to neutralize the effects on loop performance of gimbal geometry shall be specified in the "Secant Pot" performance section 3.4.4.3.

3.3.4.3.2 Steady State Error - Finite displacements of the target image from the tracker's optical centerline will produce error signals which are nulled by servo action of the gimbal drives. As the error signal is decreased with respect to spurious inputs and random noise, the signal which is necessary to position the telescope is lost in noise. The result is a quiescent condition during which the gimbals, and hence, the tracking line of sight will exhibit random motion. The angular noise of the azimuth and elevation gimbals shall be limited to a value such that a tracking accuracy as specified in 3.2.1.4 is achieved.

3.2.4.3.4 Dynamic Error - One of inherent characteristics of a type 1 servomechanism is the lag error that exists when the system is tracking a constant rate input. In the LEM Optical Tracker this error will produce a fixed displacement in the field of view while the tracker is undergoing a constant angular rate input. The displacement is linearly related to the tracking rate by the velocity constant of the servo. The velocity "error constant" for the elevation and azimuth servos shall be as specified in Table 3.3.4.2.4 below:

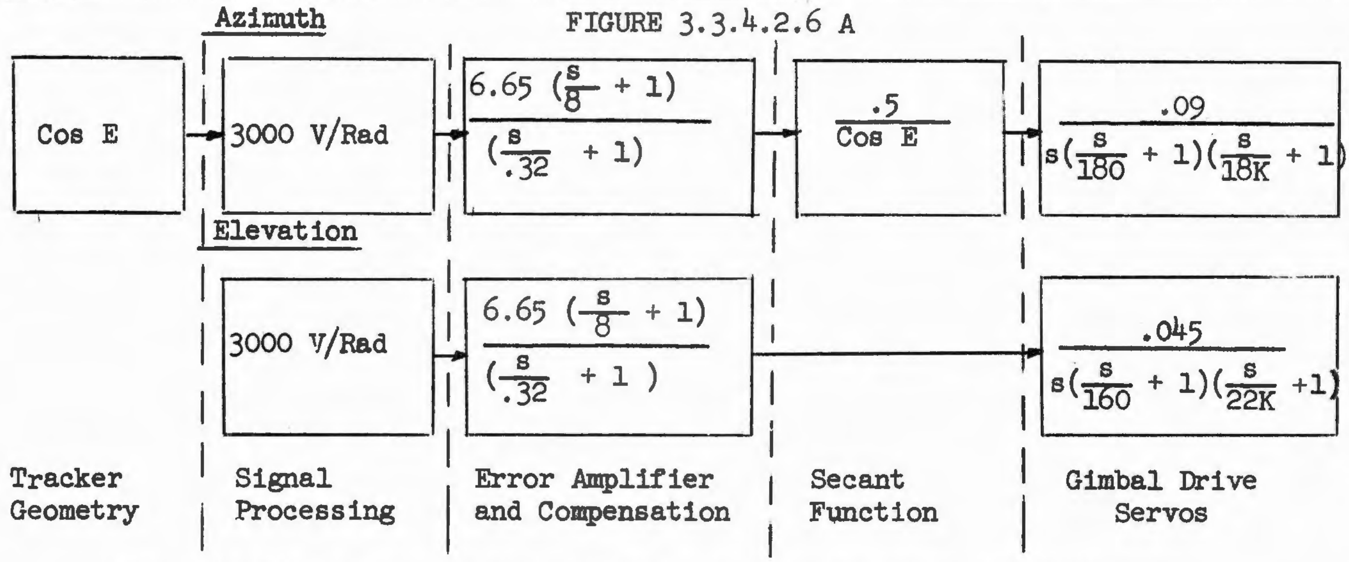
TABLE 3.3.4.3.4

Parameter	Elevation	Azimuth
Velocity "Error Constant" in milliradians/rad/sec.	1.11	1.11

The severest requirements with regard to dynamic tracking capability occur for the azimuth gimbal when the elevation line of sight passes near the zenith pole. Loss of track shall not occur for pole passage up to 84° elevation, and the tracking requirement specified in 3.2.1.3a shall be met.

3.3.4.2.6 Servo Parameters - The overall open loop transfer function of the tracking servo mechanisms shall be as shown in Figure 3.3.4.2.6A.

FIGURE 3.3.4.2.6 A

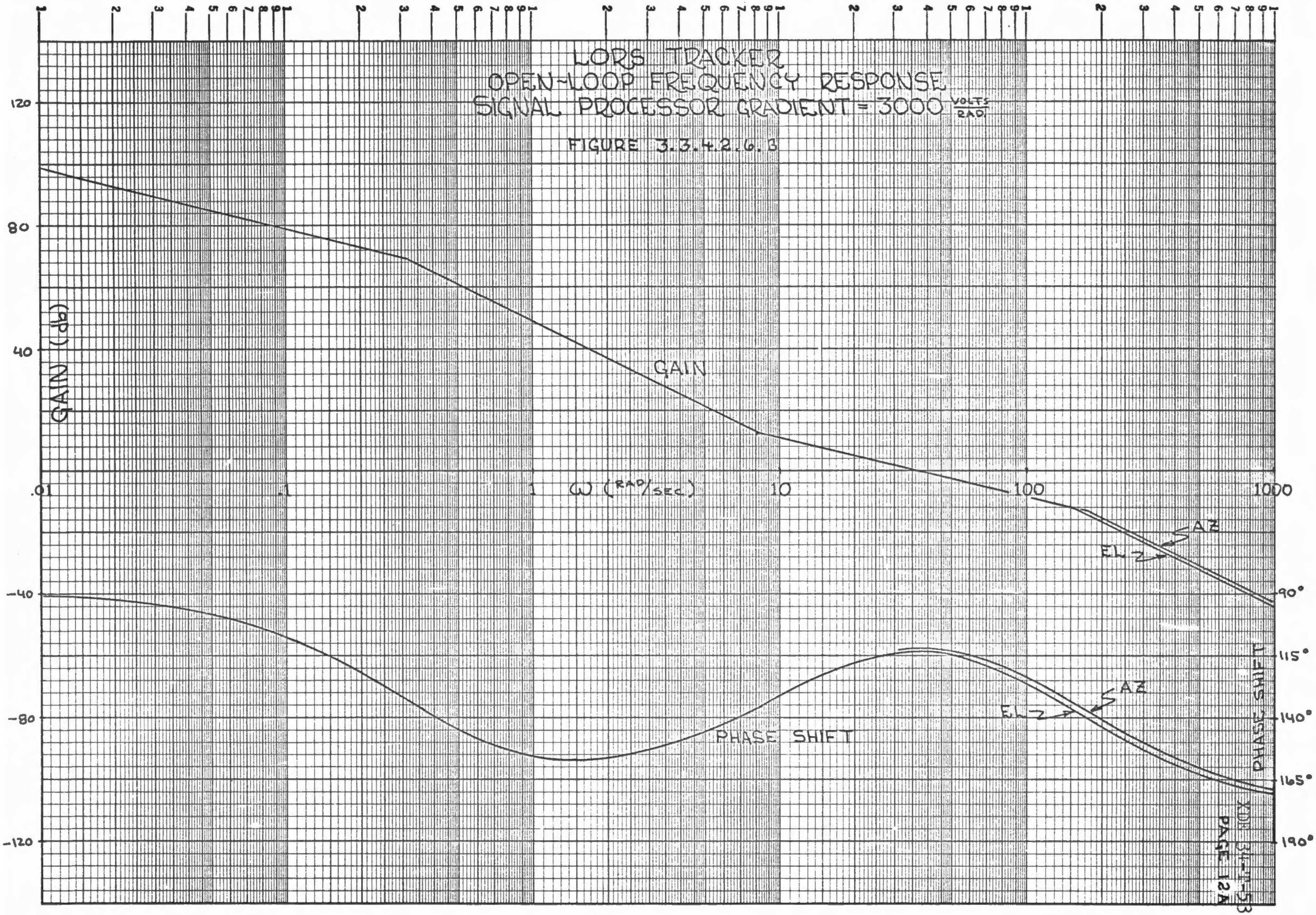


The Bode diagram characterizing open loop performance for both star and beacon track shall be as shown in Figure 3.3.4.2.6B.

The servo characteristics shall apply to both the star track and beacon track modes.

The servo parameters for both loops shall be as shown in Table 3.3.4.2.5.

TABLE 3.3.4.2.5	
Phase Margin	> 60°
Gain Margin	> 40 db
Open Loop Crossover	36 rad./sec.
Velocity Constant	900 rad/sec/volt



LORS TRACKER
OPEN-LOOP FREQUENCY RESPONSE
SIGNAL PROCESSOR GRADIENT = 3000 VOLTS/RAD.
FIGURE 3.3.4.2.6.3
GAIN (db)
120
80
40
-40
-80
-120
GAIN
.01
.1
1
ω (RAD/SEC)
10
100
1000
AZ
EL
PHASE SHIFT
90°
115°
140°
165°
190°
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3.3.5 Acquisition Loop

3.3.5.1 General

The servomechanism used to point the LEM Optical Tracker during the acquisition mode shall be a multiloop system as shown in Figure 3.3.5. Secondary error signals for positioning the Optical Tracker are generated by the LEM Coupling Data Unit. The unit, the gimbal drives and the encoding resolvers constitute the inner loop of the multiloop acquisition system.

The LEM coupling data unit shall provide both digital to analog (D/A) and analog to digital (A/D) interfaces between the LEM Guidance Computer (LGC) and analog section of the acquisition loop. The D/A converter accepts position pulses from the LGC and feedback pulses from a gimbal counter, stores their difference in an error counter and provides an ac signal proportional to this stored information. The A/D converter accepts analog signals from the gimbal resolvers and generates digitized information which is stored in a gimbal counter. The interchange of digitized information between the error counter and the gimbal counter of the Coupling Data Unit allows closed loop slewing of the inner loop.

Feedback to the LEM Guidance Computer is also provided by the CDU gimbal counter. This information will be processed by the LGC such that primary positioning error signals are generated. Primary position commands will be time shared between the elevation and azimuth CDU's. Sequential pulsing between the elevation and azimuth servos will be cycled until positioning is accomplished.

The severest requirements with regard to dynamic tracking capability occurs for the azimuth gimbal when the elevation line of sight passes near the zenith pole. Loss of track is expected during this event for elevation angles greater than 84°. Reacquisition of the target image will be accomplished by the LEM Guidance Computer.

3.3.5.2 Operational Characteristics - The mechanization shown by Figure 3.3.5 shall be capable of the following acquisition characteristics:

a) Position the LEM Optical Tracker to a designated inertial reference such that lock on is achieved as specified in 3.2.1.8 and 3.2.1.9.

b) Remove and restore the tracker to the stow position as programmed in the LGC.

c) Reacquire tracking after lock on is lost due to zenith pole passage.

SERVO CONFIGURATION FOR ACQUISITION MODE

FUNCTIONAL EQUIVALENT

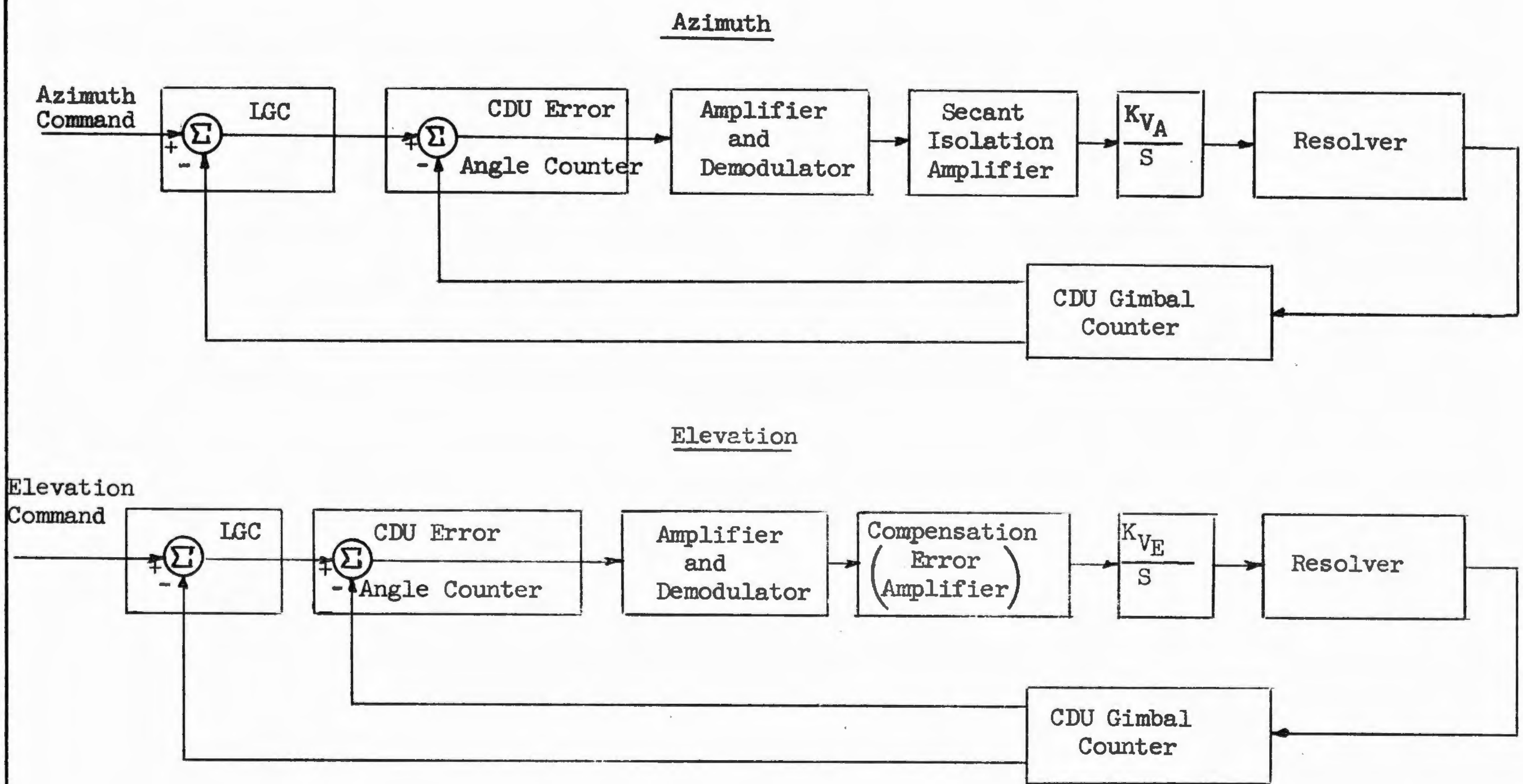

FIGURE 3.3.5

d) Provide adequate isolation from vehicle motion by periodically updating the position of the desired inertial reference.

The acquisition loop parameters shall be as shown in Table 3.3.5.

TABLE 3.3.5

a)	LGC Output Scale Factor	.044°/bit = 160 sec/bit	
b)	LGC Output Repetition Rate	3200 bits/sec	
c)	LGC Maximum bits/burst	384	
d)	CDU Error Counter D/A Scale Factor	13 mv/bit = 300 mv/degree	
e)	CDU Error Counter Output Scale Factor	.044°/bit = 160 sec/bit	
f)	CDU Error Counter gradient factor	16.65 mv ac rms/milliradian	
		Azimuth	**Elevation**
g)	Amplifier and Demodulator gain	3.75 vdc/vrms	5 vdc/vrms
h)	Secant Isolation Amplifier	5 vdc/vdc	
i)	Compensation Amplifier		5 vdc/vdc
j)	Velocity Constant of Integrator	.09 rad/sec/volt	.045 rad/sec/volt
k)	Resolver Gradient	16X - 5 v ac/rad;	1X - 26 v/rad
l)	Feedback scale factor between gimbal counter and error counter	.044°/bit = 160 sec/bit	
m)	Feedback scale factor between gimbal counter and LGC	40 sec/bit	

3.3.6 Acquisition/Scan Loops

3.3.6.1 General

The servomechanism used for the scan mode is shown in Figure 3.3.6. An area scan is produced about the designated angle by superimposing small ramp and staircase commands on the acquisition loop. As shown in Figure 3.3.6, the designated angle is maintained by the LGC during the scan mode.

Both scan commands originate from modular electronics which are free wheeling and not cyclically synchronized to computer moding. Reset and recycling of the scan pattern shall continue for 30 seconds after initiation of this mode or until lock-on occurs. Should lock-on not occur within the 30 second time period, the system will down mode to the acquisition mode.

3.3.6.2 Operational Characteristics - The severest test within specified conditions for the reset accuracy of the scan program occurs for an elevation angle of 84°. Recycling, reset, and reinitiation of acquisition by the LGC shall be such that the performance requirements specified in 3.2.1.8 and 3.2.1.9 are met.

The acquisition/scan loop parameters for the acquisition portion of the system shall be as shown in Table 3.3.5. The scan loop parameters of the scan portion of the system are as listed in Table 3.3.6.

TABLE 3.3.6

a) Azimuth axis staircase Command

Discretes - position levels	8
Quantized weight each step	5 mrad
Step rate	1 level/sec
Total time before reset	8 seconds

b) Elevation axis sawtooth Command

Sawtooth peak to peak amplitude	2°
Sawtooth ramp characteristic	2°/sec
Total time before reset	8 seconds

c) Compensation gain Azimuth Loop	2.0 vdc/vdc
d) Secant gain Azimuth Loop	0.1/Cos E
e) Mixing ratio adjustment elevation axis	0.34 v/v
f) Area scan about the designated angle	2° x 2° square
g) Time for one area scan	8 seconds

SERVO CONFIGURATION FOR SCAN MODE

FUNCTIONAL EQUIVALENT

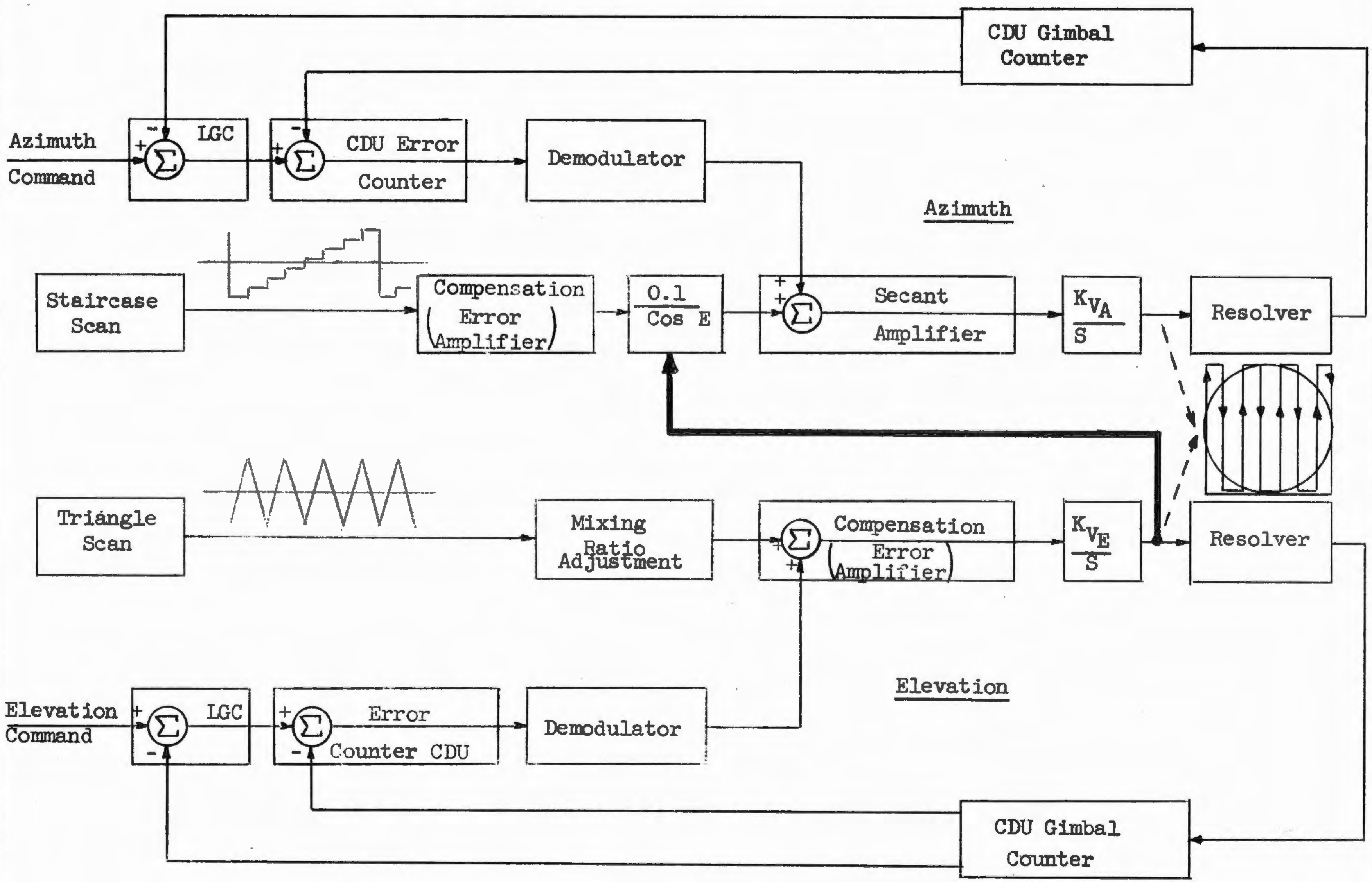

FIGURE 3.3.6

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3.3.7 Sun Shutter

3.3.7.1 General

Direct exposure of the photomultiplier tubes to the sun can seriously damage the tubes. Therefore, a sun shutter shall be used which will rotate a mask into the optical path when incoming irradiance is sufficient to damage the phototubes.

A functional block diagram of the loop used to protect the photomultipliers from over exposure is shown in Figure 3.3.7.

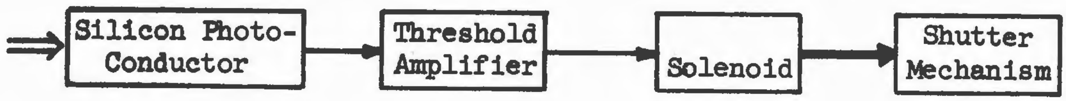

Figure 3.3.7

Sun Shutter Mechanization

3.3.7.2 Operational Characteristics

a) Sun Stop Actuator

1) Power required only when sun protection is required. The power requirements are the same as those for the reticle actuator.
2) Sun protection actuator is identical to reticle actuator.

b) Sun Protection - The shutter shall operate when the edge of the sun is 5° from the optical centerline.

3.3.8 Mode Logic

3.3.8.1 Mode Logic for Input/Output Signals

The LEM Optical Rendezvous System logic input and output signals shall be as follows:

a)	LOCK-ON DISCRETE (TO LGC)	ON (+28 VDC)	The target is the tracker field of view
		OFF (0 V)	There is no target in the tracker field of view.
b)	DATA GOOD DISCRETE (TO LGC)	ON (+ 28 VDC)	The angular error between the target line of sight and the tracker optical centerline is

			less than .1 milliradian
		OFF (0 V)	The angular error between the target line of sight and the tracker optical centerline is greater than .1 milliradian.
c)	MODE-INDICATE DISCRETE (TO LGC)	ON (+28 VDC)	The tracker is in the Star Track Mode
		OFF (0 V)	The tracker is in the Beacon track mode.
d)	TRACK-ENABLE (FROM LGC)	ON (+28 VDC)	The tracker has been designated to the desired angle but the target is not in the field of view, therefore, the scan programs should be connected into the servo loops.
		OFF (0 V)	The scan program should be disconnected from the input to the servo loop.
e)	STAR/BEACON MODE COMMAND	ON (80 ms BURST of 3.2 KPPS)	Switch signal processor mode. If the signal processor is in beacon mode change to star track mode. If it is in the star mode change to beacon track mode.
		OFF (0 V)	Do not change signal processor modes.
f)	SELF-TEST COMMAND (FROM LGC)	ON (80 ms BURST OF 3.2 KPPS)	Change state ofself-test lamp. If it is on, turn it off. If it is off turn it on.
		OFF (0 V)	Leave the self-test lamp in its present state.

The lock-on, data good, and mode indicate signals shall be generated by the tracker.

The lock-on signal shall be used together with the track enable signal from the LGC to control the servo moding as shown in Table 3.3.8.

Signal processor moding shall be controlled by the star/beacon mode command from the LGC. The Star mode shall be selected automatically when tracker power is turned on; from there a command from the computer will switch modes. Tracker moding shall be accomplished by disconnecting power from the beacon track modules when in the star track mode, and by disconnecting power from the star track modules when in the beacon track mode.

SERVO MODE CONTROL LOGIC

MODE		ACQUISITION		SCAN	TRACK
Logic Inputs	TRACK ENABLE	OFF	OFF	ON	ON
	LOCK-ON	OFF	ON	OFF	ON
Controlled Functions	Signal Processor Error Voltages	Disconnected from Servo		Disconnected from Servo	Connected
	Acquisition Command from CDU	Connected		Connected	Disconnected from servo
	Scan Programs	Disconnected from Servo		Connected	Disconnected from servo
	Compensation	Pure Gain		Pure Gain	LAG - Lead
Mode Control Voltages	V_A	+ 5 VDC		+ 5 VDC	- 5 VDC
	V_B	- 21 VDC		+ 21 VDC	- 21 VDC
	V_C	+ 21 VDC		+ 21 VDC	- 21 VDC
	V_D	- 21 VDC		- 21 VDC	+ 21 VDC

TABLE 3.3.8

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3.3.8.2 Mode Logic for The Servomechanism Compensation Amplifier (Error amplifier) - Moding for the compensation amplifier shall be as shown in Figure 3.3.8.2.

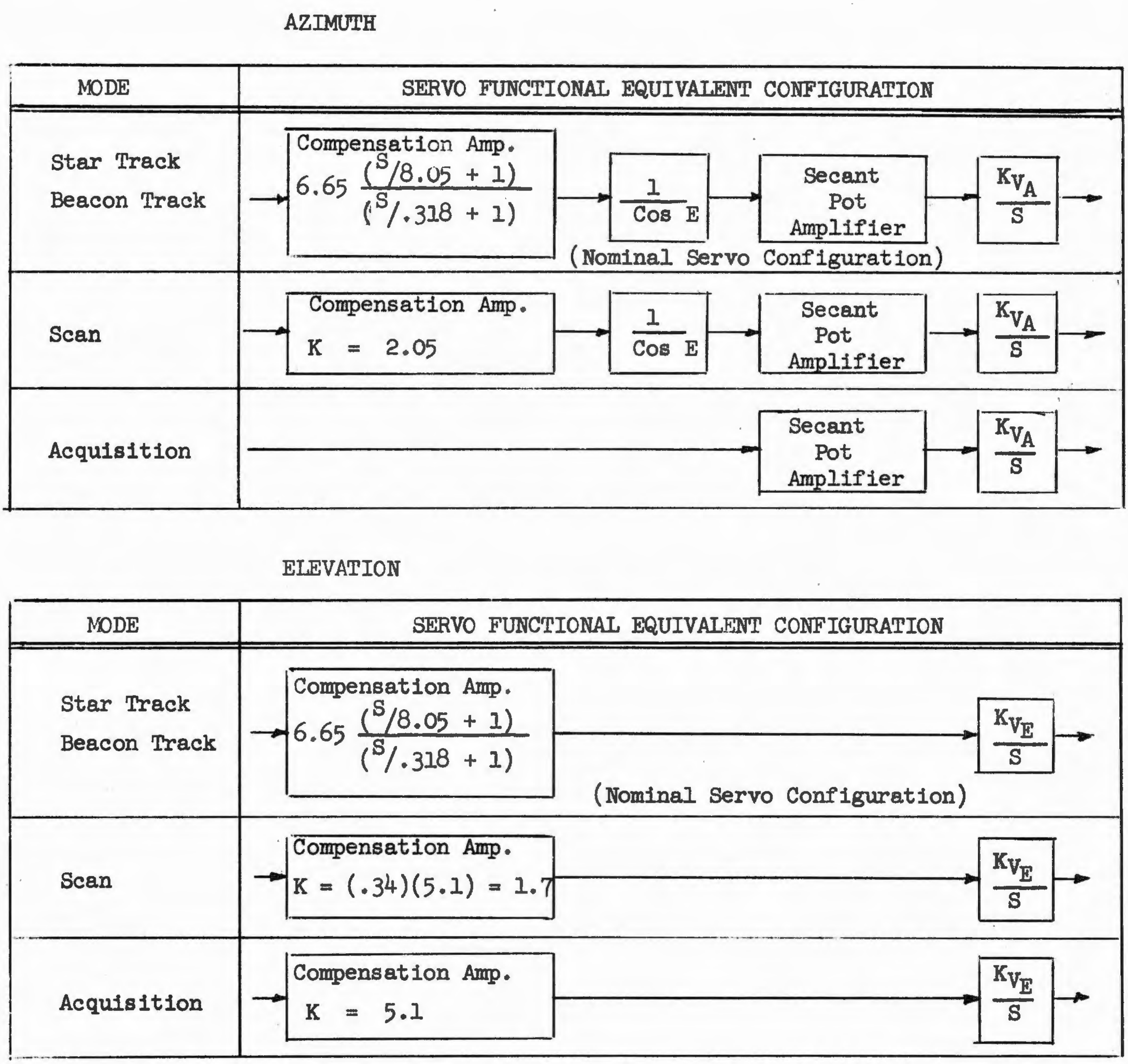


FIGURE 3.3.8.2

3.3.9 G&N Test Signals

Test signals available for G&N testing shall be as defined in Table 3.3.9.

Measurement signals qualified by the notation a), b), or c) shall be as follows:

a) The tracker composite analog signal shall be composed of the following:

DATA GOOD

LOCK ON

STAR/BEACON MODE

SCAN MOTOR OPERATE

LOTS OPERATE

b) The beacon composite analog signal shall show the following conditions:

Both channels functional

One lamp or trigger failed, one channel functional

One charge supply failed, one channel functional

Both lamps or triggers failed

One charge supply and the other lamp or trigger failed

Both charge supplies failed

c) Conditioning of 0 to 5 volts dc shall be available only for the R&D flights.

Test point locations that are available for G&N testing shall be as shown in Figure 3.3.9.

TABLE 3.3.9

Measurement	Display Requirement	Range (Unconditioned Signal)	Conditioning
Operational			
Tracker (OTS) - LEM			
Main Automatic Gain Control (AGC) - A.C.	A, CRT	-10 to 30 V	0 to 5 VDC
Composite Analog	CRT	0 to 5 V	0 to 5 VDC
Sun Shutter	CRT	Discrete	0 to 5 VDC
Beacon (CLBS) - CSM			
Composite Analog	E, CRT	0 to 5 V	0 to 5 VDC
Research and Development Instrumentation (OTS) - LEM			
Automatic Gain Control D.C.	A, CRT	+8 to +30 V	0 to 5 VDC
Photomultiplier Tube Temp	A, CRT	To be deter.	0 to 5 VDC
Azimuth Tachometer Amplifier	A, CRT	0 to ±15 V	0 to 5 VDC
Elevation Tachometer Amplifier	A, CRT	0 to ±15 V	0 to 5 VDC
Azimuth Error Amplifier	A, CRT	0 to ±15 V	0 to 5 VDC
Elevation Error Amplifier	A, CRT	0 to ±15 V	0 to 5 VDC
Automatic Checkout Equipment (OTS) LEM			
PMT Star Mode	Scope		
LOTS Operate +	CRT	0 to +35 V	Available in Unconditioned form
LOTS Operate -	CRT	0 to ±6.4 V	Available in Unconditioned form

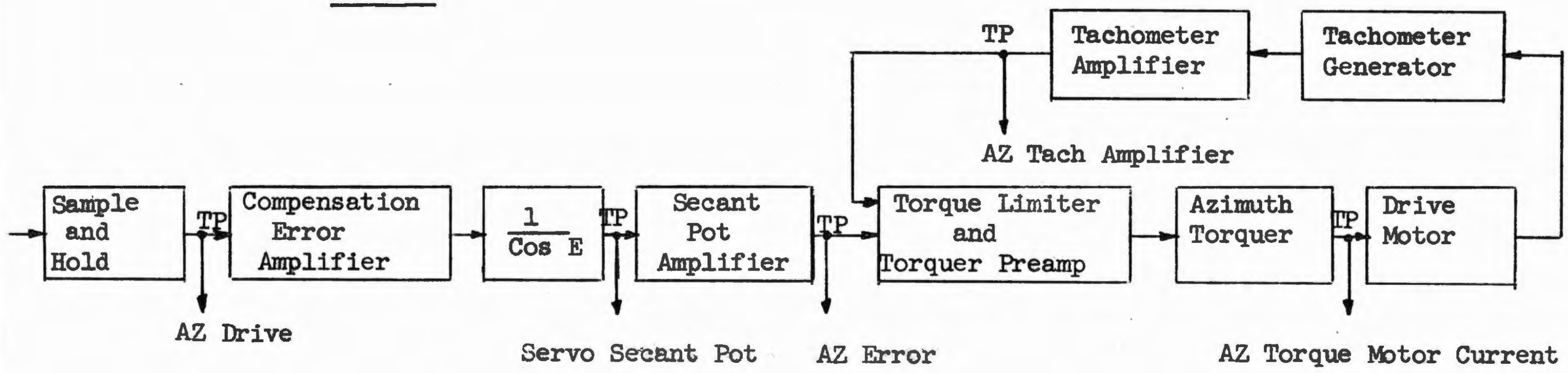
TABLE 3.3.9 (cont)

Measurement	Display Requirement	Range (Unconditioned Signal)	Conditioning
Servo Secant Pot	A, CRT	0 to ±6.4 V	Available in Unconditioned form
Elevation Drive	A, CRT	0 to ±15 V	Available in Unconditioned form
Azimuth Drive	A, CRT	0 to ±15 V	Available in Unconditioned form
Elevation Error	A, CRT	0 to ±15 V	Available in Unconditioned form
Azimuth Error	A, CRT	0 to ±15 V	Available in Unconditioned form
Elevation Torque Motor Current	A, CRT	0 to ±1.6 A	Available in Unconditioned form
Azimuth Torque Motor Current	A, CRT	0 to ±.4 A	Available in Unconditioned form
CDU Test Points			
Azimuth Fine Error	Scope	0 to 5 V rms, 800 cps	Buffer resistor brought to G&N end connector
Azimuth Coarse Error	Scope	0 to 5 V rms, 800 cps	Buffer resistor brought to G&N end connector
Elevation Fine Error	Scope	0 to 5 V rms, 800 cps	Buffer resistor brought to G&N end connector
Elevation Coarse Error	Scope	0 to 5 V rms, 800 cps	Buffer resistor brought to G&N end connector

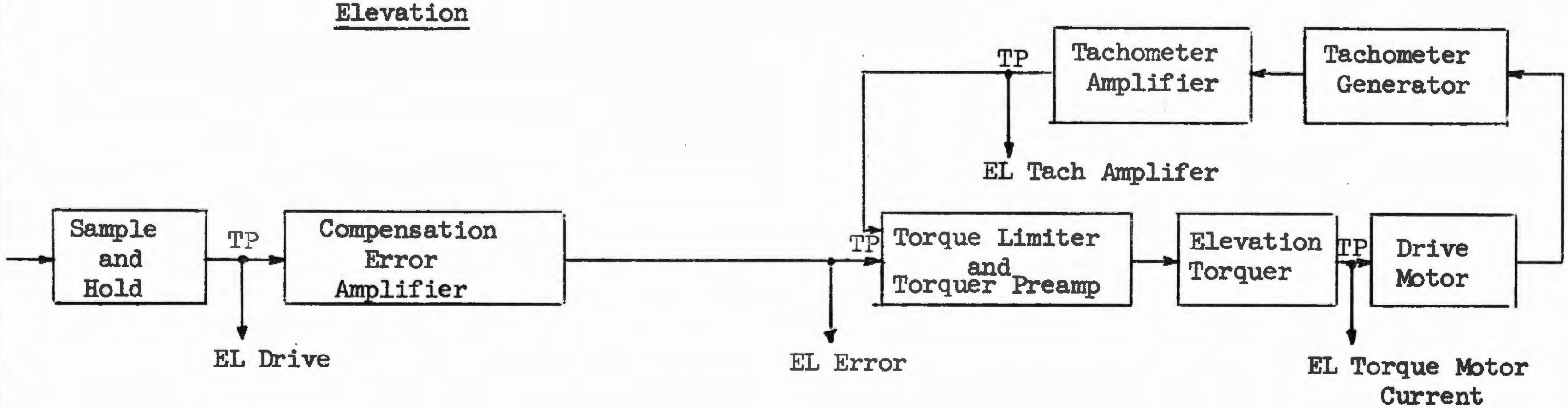
G&N SERVO LOOP TEST POINTS

FIGURE 3.3.9

Azimuth



Elevation



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3.4 Components and Component Performance

3.4.1 Signal Processing for the Star Track Mode - In order to meet the requirements specified in Section 3.3.1, the following components shall be utilized in the star track signal processing loop.

a) Light Shade Assembly

b) Nutating Wedge

c) Cassegrain Objective

d) Induction Motor and Phase Generator

e) Reticle Mask and Sector Division Optics

f) Photomultiplier Tubes

g) Photomultiplier Load Network and Associated Electronics

3.4.1.1 Light Shade Assembly - The light shade assembly consists of two light shades, window housing and window (Figure 3.4.1)

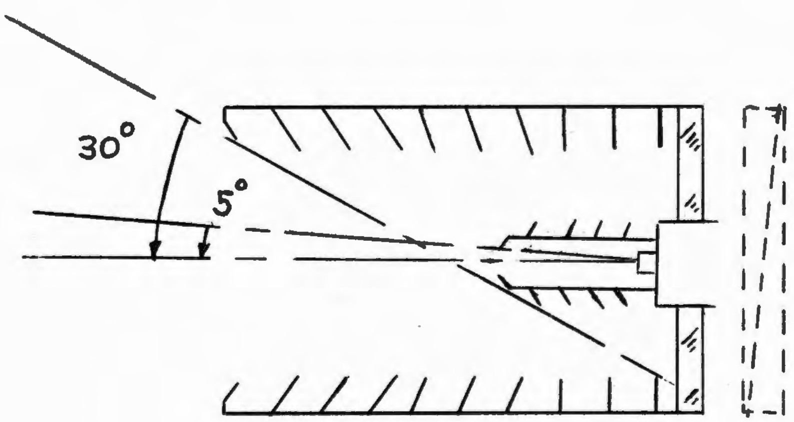


Figure 3.4.1

Light Shade Assembly

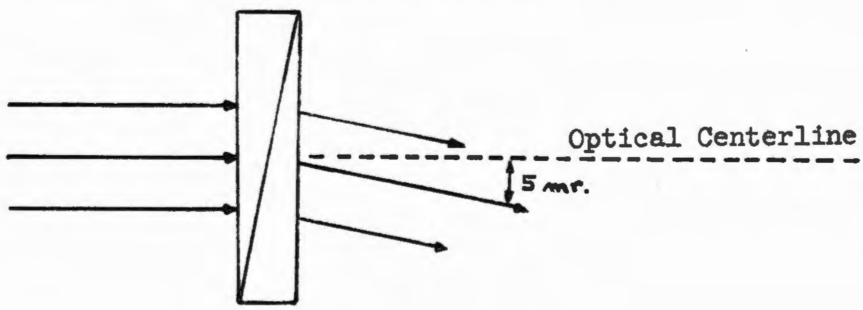
The outer light shade prevents direct light from striking the window face for incidence angles greater than 30° from the optical centerline, and it minimizes scattered light by means of a series of baffles.

The inner shade houses the sun sensor, and prevents direct light from striking the sun-sensing photodiode for incidence angles greater than 5°.

The window housing contains the tracker window and provides the structural support for the nutating wedge, motor, reference signal generator and sun sensor.

Using a window as the forward optical element allows the tracker head to be hermetically sealed and pressurized with inert gas. The window is made of fused silica which extends transmission into the ultraviolet.

3.4.1.2 Nutating Wedge - The nutating wedge shall refract collimated light as shown in Figure 3.4.1.2



Nutation Wedge

Figure 3.4.1.2

After imaging, the star shall be displaced 5 mr from the optical centerline in the image plane. The nutation wedge shall have the following characteristics:

a) Line of sight deviation - 5 mr

b) Material-fused silica/calcium fluoride composite construction

3.4.1.3 Cassegrain Objective - The objective collects and images incoming light, and shall have the characteristics in Table 3.4.1.3.

TABLE 3.4.1.3

	Star Track		Beacon Track
Focal length		12 inches	
Diameter of entrance pupil	2.8 inches		3.1 inches
Obscuration of area due to concentrically mounted scan motor, sun sensor and reference signal generator		25%	
Spectral region		0.25 u = 0.70 u	
Instantaneous field of view	± 5 mrad		± 5 mrad
Blur diameter (including color)	0.0012 inch (0.1 mrad)		80% of energy within within 0.0048-inch diameter circle (0.4 mrad) Remaining 2% of enerby distributed within 0.120-inch diameter circle (10 mrad)
Deviation of wedge		5 mrad	
Diameter of nutation circle	10 mrad		None
Transmission (Total)		>51%	

A shaped energy distribution near the focal plane is necessary to control the sensor gain in the beacon track mode. The required energy distribution is obtained by grinding a conical surface on the perimeter of the secondary mirror. This results in a point source image with a blur diameter of 0.0012 inches (0.1 mr) at the focal plane. Eightly percent of the light energy lies inside this diameter, and the remaining twenty percent is distributed over the remainder of the exit pupil. In the beacon track mode the point source image is deliberately defocused by using the relay prism faces as a reticle, since the prism faces lie 0.014 inches behind the focal plane. At the prism faces, eighty percent of the energy is within a 0.4 mr diameter circle and the remaining twenty percent within 10 mr.

The beacon track mode signal processing utilizes all the light falling on the prism faces. However, the light energy spread over the exit pupil by the conical periphery of the secondary mirror does not contribute to the information content of the signal in the star track mode. Thus, the effective diameter of the collecting area in the star track mode is reduced from 3.1 inches to 2.8 inches.

3.4.1.4 Induction Motor and Phase Generator

Nutation of the star image in the image plane shall be produced by driving the nutating wedge with an induction motor. The induction motor shall have the following characteristics:

a) Induction motor type - 2 phase ac - 12 pole

b) Excitation - 28 volts rms 200 cps from dc to ac power supply

c) Synchronous speed - 33.3 rpm

The phase generator shall be used as a phase reference from which pulse position information of the star detection process is demodulated to anlog form for nulling by the servos. The phase generator shall have the following characteristics:

a) Phase generator type - Permanent magnet - 2 toridal windings 90° apart

b) Output characteristics - $V_o = 10.6 \sin wt$ at 32 rpm

3.4.1.5 Reticle Mask and Sector Division Optics - The reticle mask and sector division optics shall be the mechanism which converts angular displacements of the star image from the optical centerline to pulse position information.

The sector division optics shall be a four prism array which divides the image plane into four sectors as shown in Figure 3.4.1.5A.

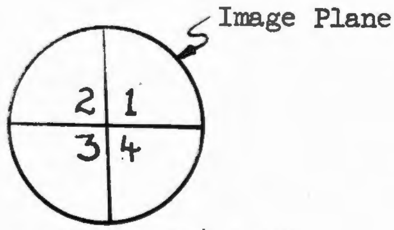


Figure 3.4.1.5A

Incoming light shall be reflected by each relay prism such that the light energy of each image plane sector is directed to a corresponding photomultiplier.

The reticle mask shall be the mechanism which modulates the nutating image in pulse position form.

Pulse position information as a function of image displacement from the optical centerline shall be produced as shown in Figure 3.4.1.5B.

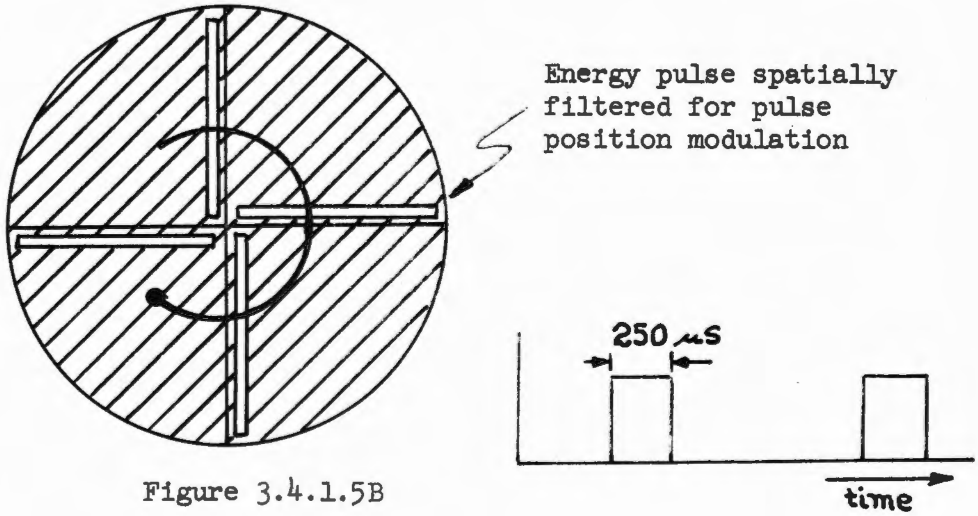


Figure 3.4.1.5B

3.4.1.6 Photomultiplier Tubes

The photomultiplier tube (Figure 3.4.1.6A) converts luminous flux to usable electrical current. This is accomplished in two steps:

1. Incident photons produce electrons at a photomissive surface (photocathode)

2. The photocathode current is amplified by secondary emission occurring at each of the 14 dynodes.

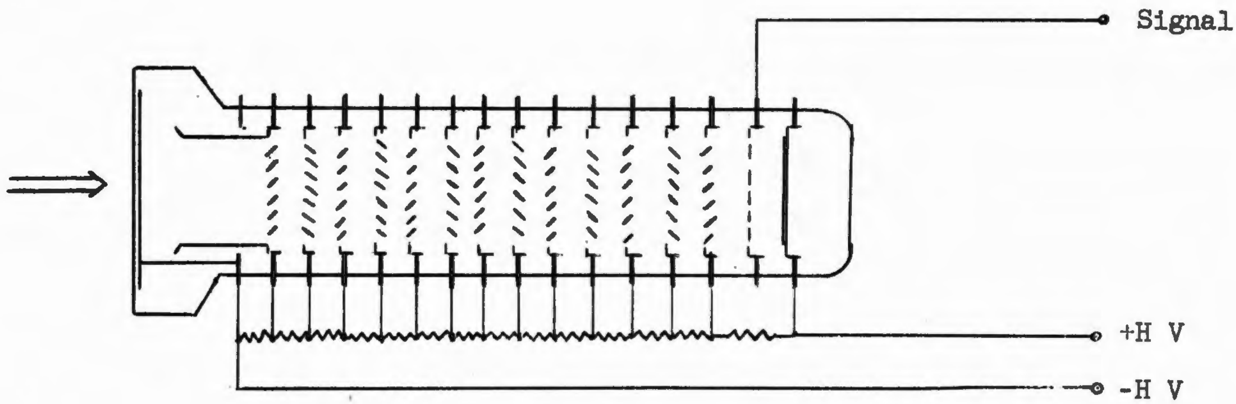


Figure 3.4.1.6A

The efficiency of the photoelectric process occurring at the photocathode is characterized by two parameters:

1. Quantum efficiency Q, which is the number of electrons produced per incident photon of a given wavelength.

2. Spectral response, which is the photocathode current in amps per watt of incident flux at a given wavelength (Figure 3.4.1.6B)

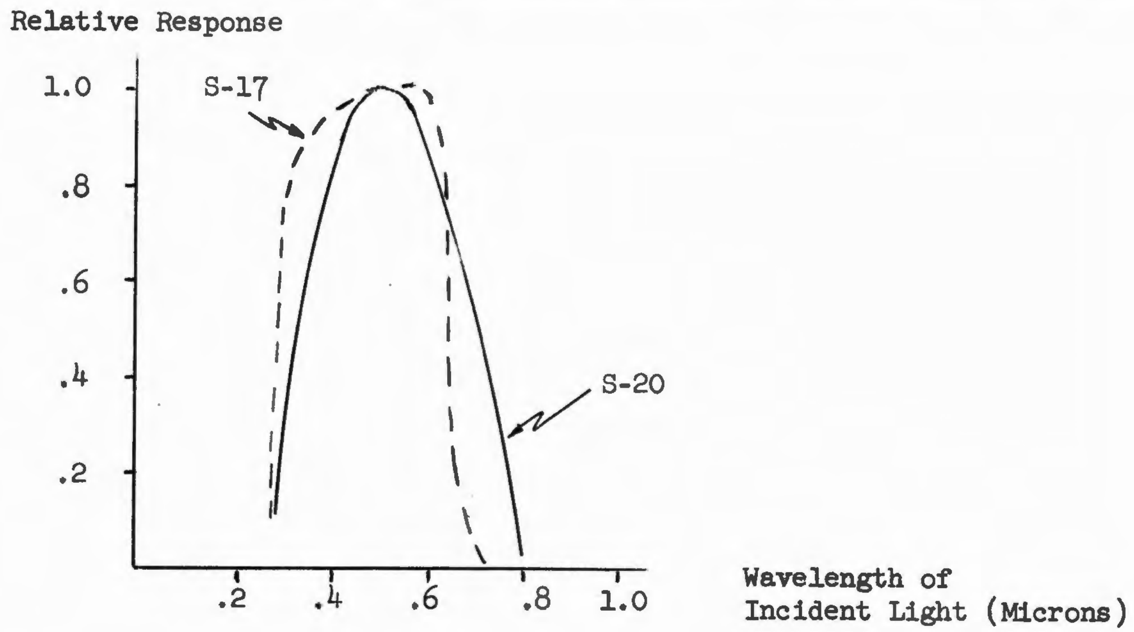


Figure 3.4.1.6B

Spectral Response of Photocathode

Lines of constant quantum efficiency would be straight lines with a positive slope equal to Q.

The electrons produced at the photocathode are accelerated through a potential of approximately 200 V and strike the first dynode. Secondary electrons are ejected from the dynode surface with a typical yield of three - four secondary electrons per primary electron. The secondary electrons are in turn accelerated, striking the second dynode, and the process is repeated at each dynode until the electrons are collected at the anode. Overall current amplifications of 10^6 - 10^8 are typical.

The secondary emission yield at each dynode is proportional to the primary electron energy, which is in turn proportional to the accelerating voltage between dynodes and thus to the supply voltage. Thus current gain is a function of supply voltage (Figure 3.1.4.6 C).

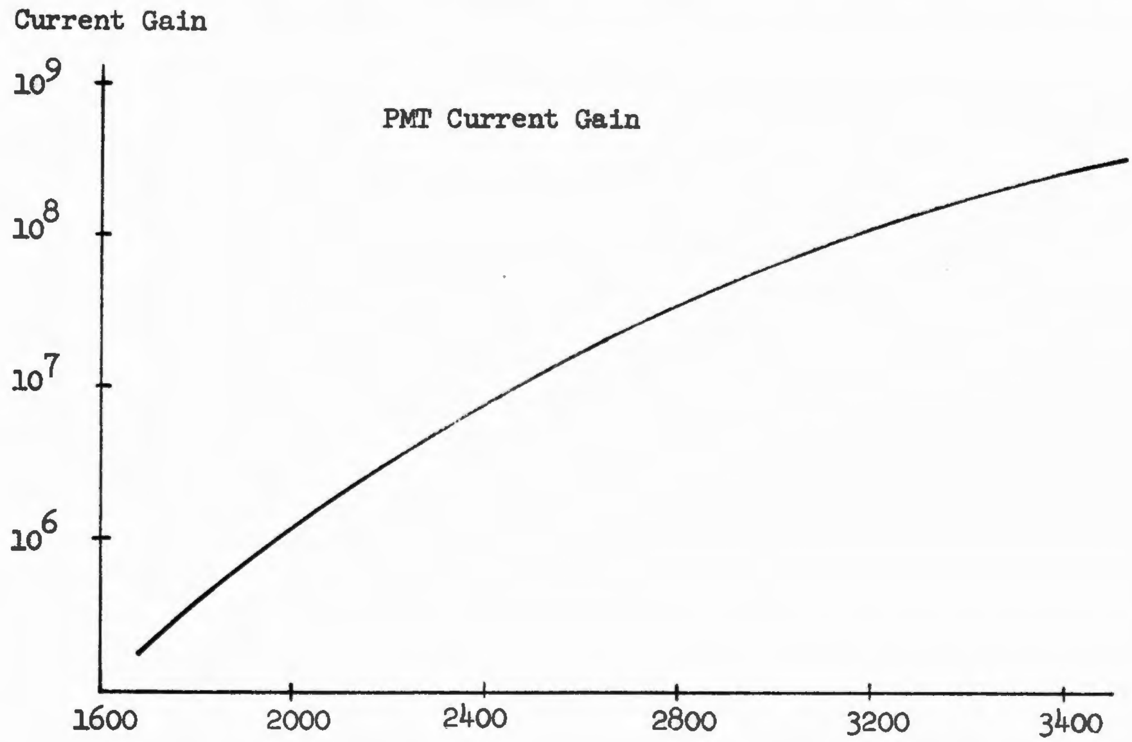


Figure 3.4.1.6 C

Typical Variation of Current Gain with Supply Voltage

Observed dark current is the sum of currents due to three causes:

1. Thermionic emission from the photocathode and dynodes.

2. Ohmic leakage through the glass envelope, supporting members and base.

3. Regenerative effects which occur when the supply voltage becomes too great and which may permanently damage the tube.

Dark current increases rapidly with both temperature and current gain. The equivalent anode dark current input is the luminous flux in either lumens or watts that, if incident on the photocathode, would result in the observed anode dark current. Both temperature and current gain must be specified when the equivalent input is given.

The emission of electrons from the photocathode and dynodes is a statistical process, and resulting current fluctuations contribute to the overall noise of the system. A parameter used to characterize the noise contributions of the tube is equivalent noise input, which is the value of luminous flux which, if incident in square wave pulses produces an rms output current equal to rms noise current within a specified bandwidth.

The typical characteristics of the photomultipliers which may be used for LORS are as shown in Table 3.4.1.6

TABLE 3.4.1.6

		S-20	S-17
A.	Spectral Characteristics	S-20	S-17
B.	Cathode Type	Semitransparent, trialkali	Semi-transparent, antimony-cesium
C.	Dynode Material & Type	$A_g - M_g$ Venetian blind	$A_g - M_g$, Venetian Blind
D.	Window Material	7056 Glass	7056 Glass
E.	Number of Dynodes	14	14
F.	Collecting Area of Cathode	.785 in^2	.785 in^2

	MIN.		TYPICAL		MAX		UNITS
	E	A	E	A	E	A	
G. Quantum Efficiency at 4100°A	12.5	12	19	15			%
H. Cathode Luminous Sensitivity	100	45	150	65			ma/lm
I. Cathode Radiant Sensitivity at Wavelength of Max. Spectral Response	.042	.041	.065	.055			a/lm
J. Voltage Required for Current Amplification of 10^5			1900	1600		1900	V
10^6			2400	2100	2900	2400	V
10^7			3300	2720		3020	V
10^8				3450			V

	MIN. E	MIN. A	TYPICAL E	TYPICAL A	MAX. E	MAX. A	Units
K. Dark Current at +20° C. and Current Amplification of 10^5			$1.5x10^{-10}$	$2.2x10^{-10}$			a
10^6			$1.5x10^{-9}$	$2.0x10^{-9}$	$5x10^{-9}$	$7x10^{-9}$	a
10^7			$1.5x10^{-8}$	$2.0x10^{-8}$			a
10^8				$2.0x10^{-7}$			a
L. Equivalent Anode Dark Current							
Input at +20°C and Current Amplification of 10^6							
Luminous			$1x10^{-11}$	$3x10^{-11}$	$5x10^{-11}$	$1.6x10^{-10}$	lm
Radiant at 4500 A			$2.3x10^{-14}$	$3.7x10^{-14}$	$9x10^{-14}$	$1.6x10^{-13}$	w
M. Equivalent Noise Input at +20°C and Current Amplification of 10^6:							
Luminous			$1.6x10^{-13}$	$3.9x10^{-13}$	$5x10^{-13}$	$1.1x10^{-12}$	lm
Radiant at 4500°A			$3x10^{-16}$	$4.6x10^{-16}$	$7x10^{-16}$	$1.1x10^{-15}$	w
N. Supply Voltage					3600	3600	V
O. Anode Current					1	1	ma
P. Temperature	-55	-55			+75	+75	°C
Q. Anode Pulse Rise Time					--		sec
R. Electron Transit Time					--		sec

3.4.1.7 Photomultiplier Load Network and Associated Electronics

The photomultiplier load network and its associated electronics shall process pulse signals such that the requirements specified in 3.3.1 will be met.

3.4.2 Signal Processing for Beacon Track - In order to meet the requirements specified in Section 3.3.2, the following components shall be utilized in the beacon track signal processing loop.

a) Beacon mounted on the CSM

b) Light Shade Assembly

c) Nutating Wedge

d) Cassegrain Objective

e) Sector Division Optics

f) Photomultiplier Tubes

g) Automatic Gain Control Amplifier and Associated Electronics

3.4.2.1.1 Beacon Mounting - The LEM optical tracker is required to track a flashing beacon mounted on the Command Service Module. The beacon shall be mounted to the CSM as shown in Figure 3.4.2.1.1.

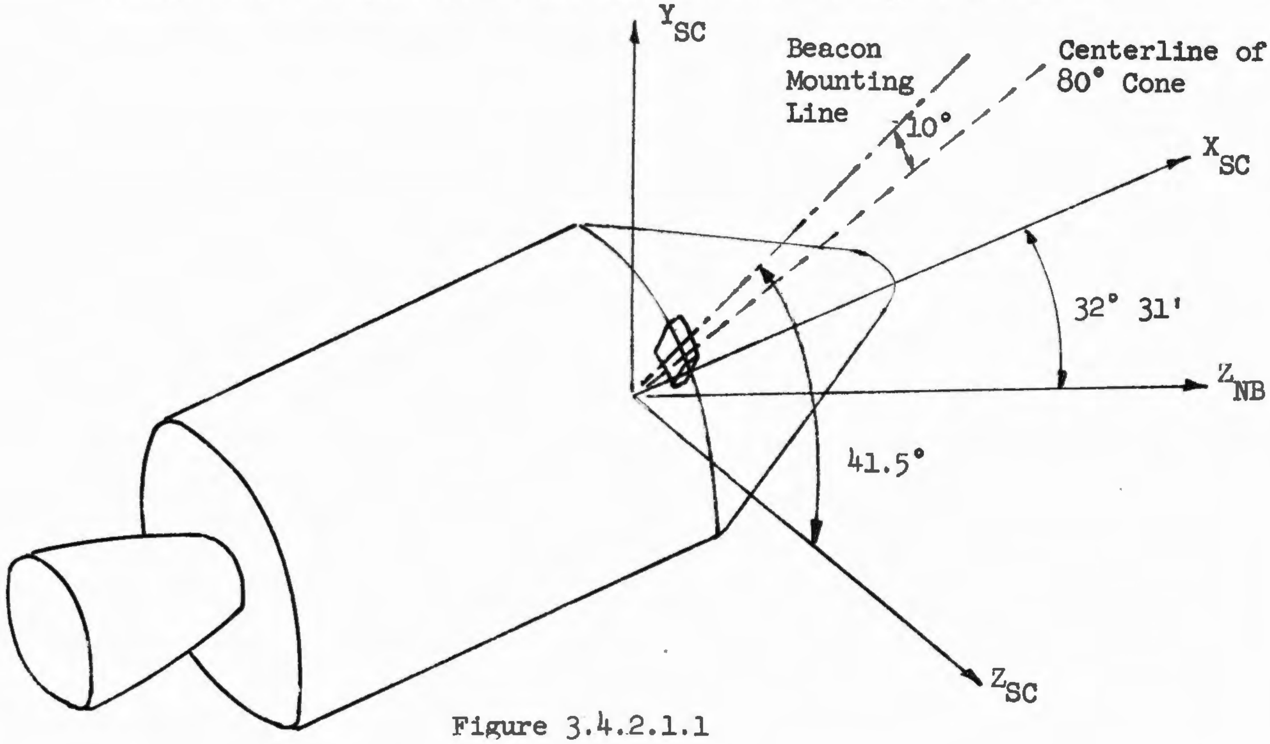
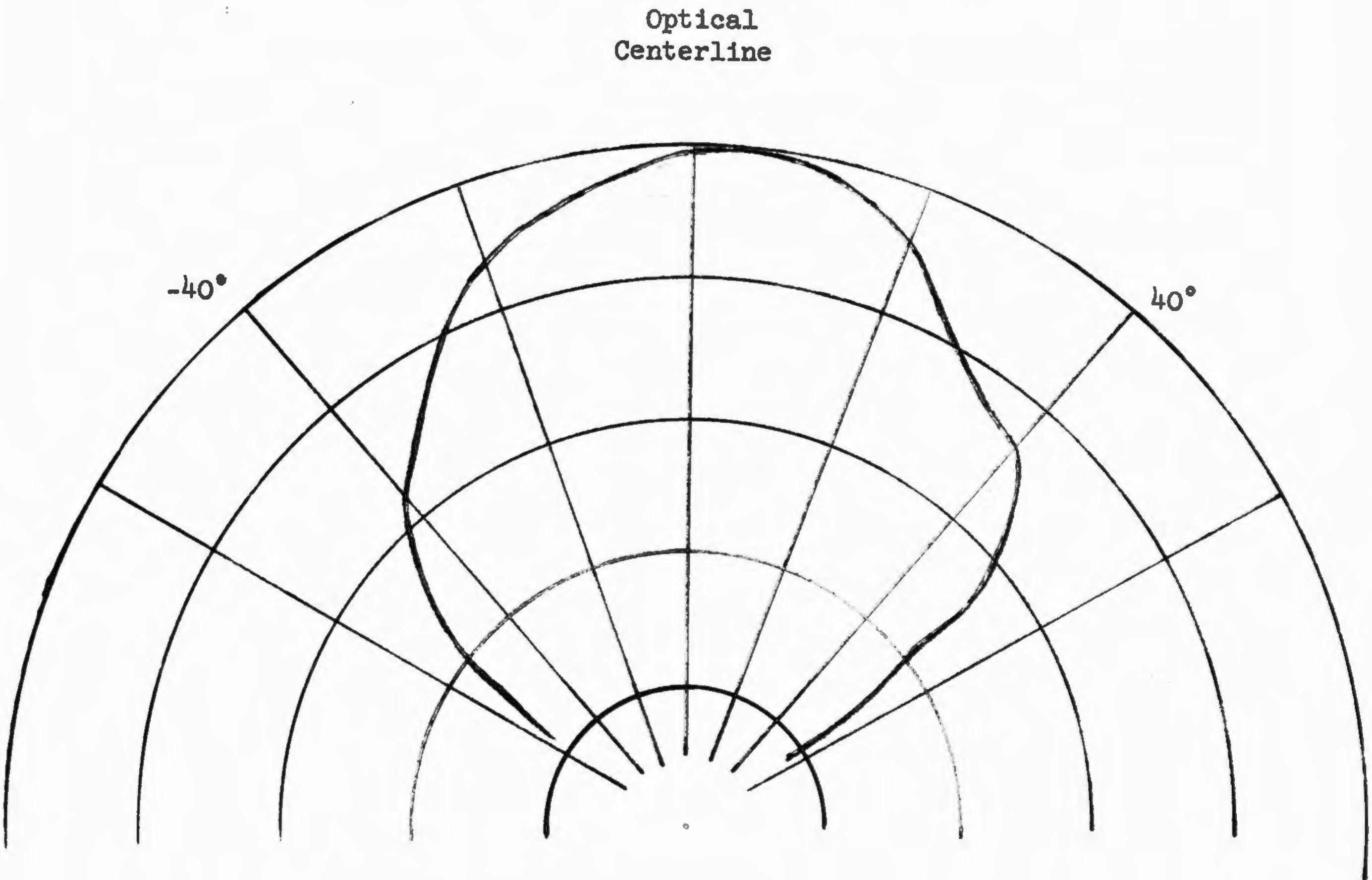


Figure 3.4.2.1.1

The beacon shall be mounted between the CM heat shield and the top of the SM, and shall be rotated -41.5° from $X_{sc} - Z_{nb} - Z_{sc}$ plane about the X_{sc} axis.

3.4.2.1.2 Beacon Radiation Characteristics - The beacon shall produce radiant energy in an 80° cone. The concentration of radiant energy shall be as shown in Figure 3.4.2.1.2.



Typical Beacon Radiation Characteristic

Figure 3.4.2.1.2

3.4.2.1.3 <u>Beacon Circuitry</u> - The control electronics for the two xenon flash lamps shall be as shown in Figure 3.4.2.1.3.

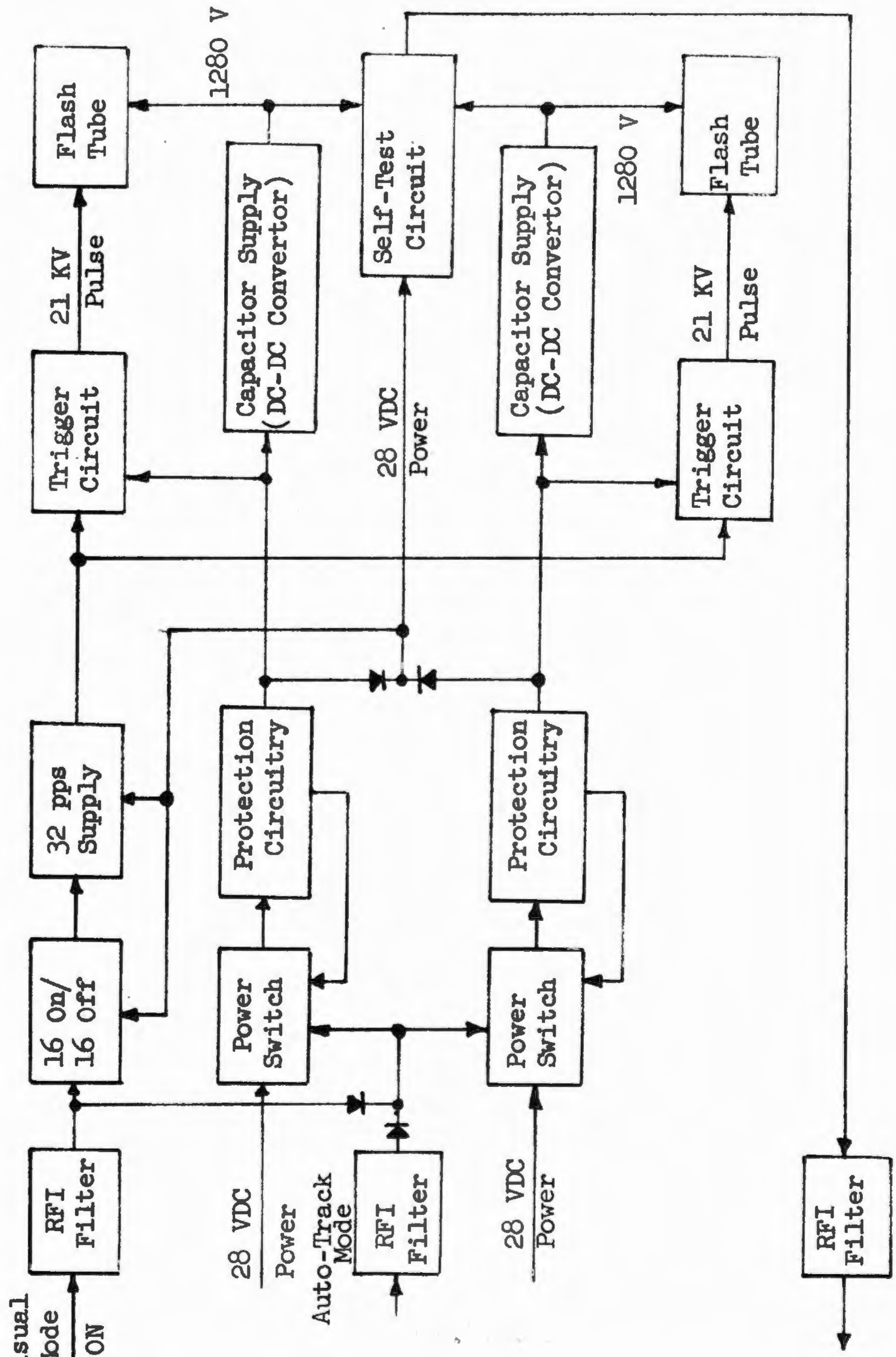


FIGURE 3.4.2.1.3

Beacon Control Electronics

The control electronics for each xenon flash lamp shall consist of a capacitor, a capacitor charging supply and a trigger circuit.

3.4.2.1.4 Beacon Operating Modes - The beacon shall have two operating modes. In the AUTO-TRACK mode, both lamps shall be flashed simultaneously at 32 pps. In the visual mode, the 32 cps oscillator shall be moded to produce a one-second cycle of 16 pulses on 16 pulses off.

3.4.2.1.5 Beacon Operational Characteristics - The beacon shall have the following operational characteristics.

	Symbol	Parameter	Value
a)	f	Frequency	32 cps
b)	t	Pulse Width	10 μ sec
c)	Ω	Beacon Field of View	1.47 steradians (80° cone)

3.4.2.1.5 Beacon Composite TM Output - The same as shown in Table 3.4.2.1.5.

5.0 ± 0.25 VDC	Both channels functional
4.0 + 0.25 VDC	One lamp or trigger failed, one channel functional
3.0 ± 0.25 VDC	One charge supply failed, one channel functional
2.0 ± 0.25 VDC	Both lamps or triggers failed
1.0 ± 0.25 VDC	One charge supply and the other trigger or lamp failed
0 ± 0.25 VDC	Both charge supplies failed

TABLE 3.4.2.1.5

3.4.2.2 Light Shade Assembly - The light shade assembly for beacon track signal processing shall be the same as that described in 3.4.1.1 for the star track mode.

3.4.2.3 Nutating Wedge - The nutating wedge for beacon track signal processing shall be the same as that described in 3.4.1.1 except for the following operational exceptions.

a) The wedge shall be stationary and locked in a known position,

b) A continuous standoff from the optical centerline shall occur in the image plane.

3.4.2.4 Cassegrain Objective - The Cassegrain objective for the beacon track signal processing shall conform to the requirements of 3.4.1.3.

3.4.2.5 Sector Division Optics - The sector division optics for beacon track signal processing shall be the same as those described in 3.[illegible]5 for star track signal processing except for the reticle mask.

During beacon track the reticle mask shall be removed from the optical path by a rotary actuator.

3.4.2.6 Photomultipliers - The photomultipliers for beacon track signal processing shall be the same as those described in 3.4.1.6 for the star track signal processing.

3.4.2.7 Automatic Gain Control Amplifier and Associated Electronics The automatic gain control amplifier and associated electronics shall process beacon originating pulse signals such that the requirements specified in 3.3.2 are met.

3.4.3 Automatic Gain Control - In order to meet the requirements specified in section 3.3.3, the following components shall be utilized for automatic gain control.

a) Light Shade Assembly

b) Nutation wedge (rotating for star track, stationary for beacon track)

c) Cassegrain Objective

d) Induction motor and phase generator (for star track)

e) Reticle mask and sector division optics (reticle mask for star track)

f) Photomultiplier tubes

g) Automatic load network

h) Automatic Gain Amplifier

i) High pass filter and isolation electronics

j) "OR" logic bandpass filter and isolation electronics

k) Resistor summing electronics

l) Automatic threshold and AGC detector electronics

m) Automatic threshold and AGC detector electronics

n) Reference amplifier electronics

o) Load network "OR" Gate

p) "OR" logic and reference amplifier

q) Photomultiplier high voltage DC-DC converter

3.4.4 Servomechanisms - In order to meet the requirements specified in section 3.3.4, the following components shall be utilized for the nominal servo configuration.

	Elevation	Azimuth
a)	Signal processing	Signal processing
b)	Compensation (Error Amplifier)	Compensation (Error Amplifier)
c)		Secant Pot
d)		Secant Pot Amplifier
e)		Torque Limiter
f)	Torquer Preamp & Driver	Torquer Preamp & Driver
g)	Elevation torquer motor	Azimuth torquer motor
h)	Elevation Gimbal	Azimuth Gimbal
i)	Elevation tachometer	Azimuth tachometer
j)	Elevation tachometer Amplifier	Azimuth tachometer Amplifier

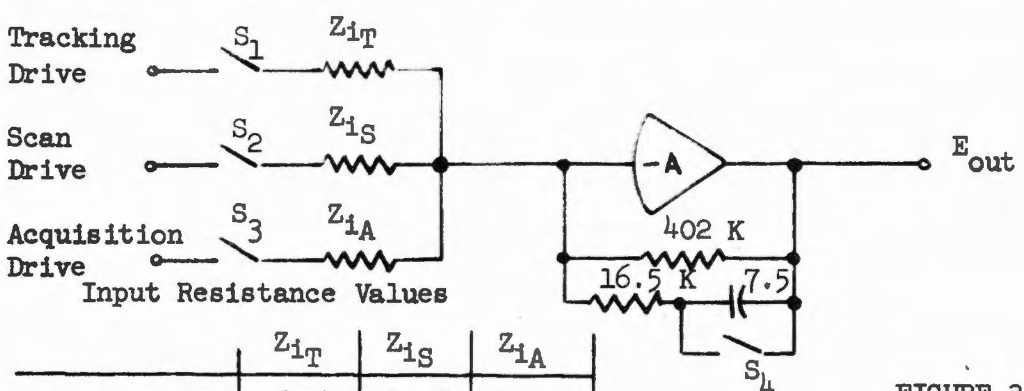
3.4.4.1 Signal Processing - The signal processing for servo operation during specified modes of operation shall be as defined in Table 3.4.4.1.

Servo Mode	Signal Processing
Star Track	Section 3.3.1
Beacon Track	Section 3.3.2
Acquisition	Section 3.3.5
Scan	Section 3.3.6

TABLE 3.4.4.1

3.4.4.2 Compensation Amplifier - The function of the error amplifier is to provide dc gain in the acquisition and scan modes and dc gain and frequency compensation in the tracking modes. In addition to these functions the error amplifier shall provide summing and switching between the various servo drive inputs (except for the azimuth acquisition drive which is summed into the loop at the secant pot amplifier). To accomplish these functions the error amplifier utilizes a high gain operational type amplifier with complex feedback and a number of resistor inputs which may be switched on or off to enable the various tracking modes.

The error amplifier is shown functionally in figure 3.4.4.2.



Input Resistance Values

	Z_{i_T}	Z_{i_S}	Z_{i_A}
Azimuth	60.4	8.06	----
Elevation	60.4	9.76	3.24

FIGURE 3.4.4.2

The switches that are shown are field effect transisters which are opened or closed by voltages generated by the mode control logic as defined in Paragraph 3.3.8. Switch S_1 is closed in the track mode, S_2 in the scan mode and S_3 and S_4 are closed in the acquisition and scan modes. The impedance values for the input and feedback components shall be as shown in the above figure and the corresponding gain and compensation is listed in Table 3.3.4.c. The elevation error amplifier is identical to the azimuth error amplifier except that the AZ error amplifier will not have an acquisition drive input. The input impedances and gains will differ for the scan mode inputs.

Maximum input levels are listed below. These are the maximum levels at each input which will not produce amplifier saturation.

AZ	track input	± 2.2 VDC
AZ	scan input	± 7.3 VDC
EL	track input	± 2.2 VDC
EL	scan input	± 8.8 VDC
EL	acquisition input	± 3.0 VDC

3.4.4.3 Secant Pot - The secant function ahall be generated by using a conductive plastic Secant function potentiometer. The pot track shall be shorted and connected to a trimming resistor for angular positions between plus and minus 28°. This results in a gain of .1 for angles less than ±28°. The secant function shall be good only to +84° at which point the gain of the pot is 1.0. This value of gain will be held for angles greater than 84°.

A sketch of the Secant pot and its gain verses angular position is shown in Figure 3.4.4.3.

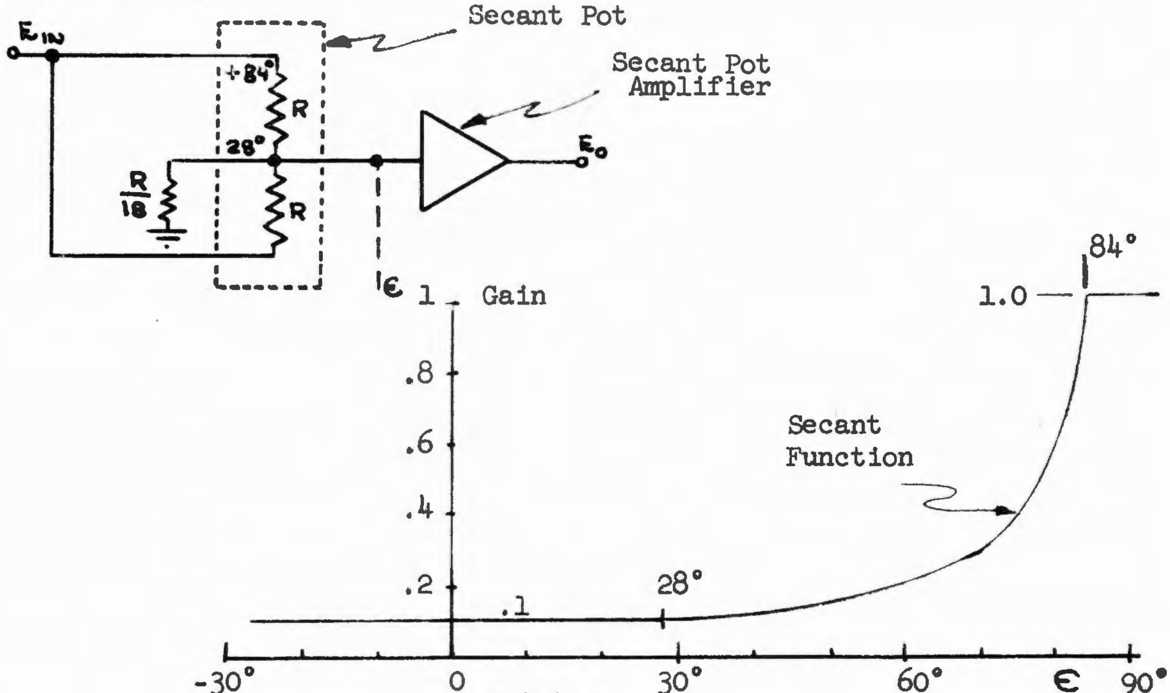


Figure 3.4.4.3

3.4.4.4 Secant Pot Amplifier - The secant pot amplifier shall provide gain for the servo loop and a high input impedance to prevent loading of the secant pot. The amplifier shall also serve as a summing point for the azimuth acquisition command signal. The proper gain for this amplifier is achieved by using feedback resistors around a high gain amplifier.

Maximum input signal that will not produce amplifier saturation

$$V_{max} = \pm 3 \text{ vdc}$$

Gain = 5 V/V (Both inputs)

3.4.4.5 Torque Limiter - Torque limiting shall be provided by diode bridge shown in Figure 3.4.4.1.

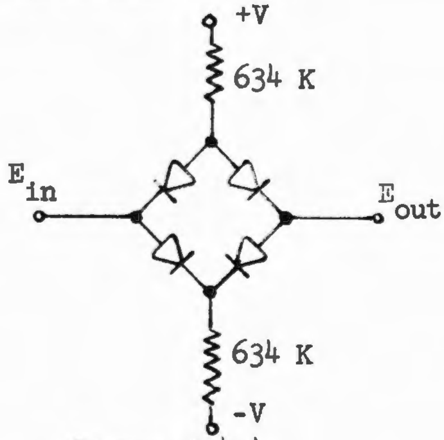


Figure 3.4.4.1

Torque is limited to a value of 60 oz-in by this diode network.

3.4.4.6 Torquer Preamp and Drivers - The torquer preamps and drivers act functionally as one module. Their purpose is to sum the servo error signals and tachometer feedback signals and provide a torque motor current which is proportional to that sum. Constant current output for a given voltage input is achieved through the use of current feedback. The transfer function, as a result of this current feedback, takes the form of current out/voltage in.

Azimuth Torquer Preamp and Driver. The voltage limiter shown in Figure 3.4.4.1 is included in the preamp module. By limiting the voltage into the torquer preamp, the current output is proportionally limited. This is done to prevent torque motor desaturation.

GAIN = 3.33 amps/volt ± 5%

Input Impedance 10K Servo Drive Input
10K Tachometer Input

Max Output Current (with voltage limiting) 1.6 amps

Elevation torquer preamp and driver. The elevation preamp shall not have voltage limiting at its input because full voltage applied to the preamp will not cause the torque motor to desaturate.

GAIN = .33 amps/volt ±5%

Input Impedance 10K Servo Drive Input
10K Tachometer Input

3.4.4.7 Torque Motor Characteristics - Torque motor characteristics shall be as shown in Table 3.4.4.7

Parameter	Azimuth Value	Elevation Value	Units
Inertia (Motor + Gimbal)(J)	3.75	2.3	in-oz-sec^2
Peak Torque (T)	60	35	in-oz
T/J (No Friction)	16	15.2	sec^{-2}
T/J (With Disturbing Torque)	15.6	14.85	sec^{-2}
Torque Constant (K_a)	38.4	54	oz-in/amp
Motor Break Point (R/L)	1080	1580	sec^{-1}
Armature Resistance (R)	13	95	ohms
Armature Inductance (L)	$12x10^{-3}$	$60x10^{-3}$	henries
Volts at Peak Torque Stalled (25°c)	20.3	61.6	volts
Back EMF Constant	.27	.38	volts/rad/sec
Amps at Peak Torque	1.6	.65	amps
Coulomb Friction	1.5	.8	oz-in
Viscous Friction	.81	.21	oz-in/rad/sec

TABLE 3.4.4.7

3.4.4.8 Gimbal Characteristics -

Gimbal Definitions and Conventions - The angles and direction conventions relating to the LEM optical tracker shall be as follows:

a) Azimuth Angle. A_A is defined as the angle between the projection of the LOTS line of sight in the LEM Y-Z plane and the LEM + Z axis.

b) Elevation Angle. A_E is defined as the angle between the LOTS line-of-sight and the projection of the LOTS line-of-sight in the LEM Y-Z plane.

c) Azimuth and Elevation Zero Angles. The 0, 0 coordinates are defined as the position of the LOTS when it is parallel to the LEM Z axis and pointing in the + Z direction.

d) Azimuth Sense. Positive azimuth angles are defined as those angles measured from the zero azimuth coordinate about the LEM +X axis in the right hand sense.

e) Elevation Sense. Positive elevation angles are defined as those angles measured from the zero elevation coordinate about the LEM +Y axis in a right hand sense when the azimuth angle is 0 degrees.

f) Azimuth Limit Stops. The azimuth limit stops are at -270° and $+450^\circ$ yielding $\pm 360^\circ$ of angular freedom from the stow position which is $+90^\circ$.

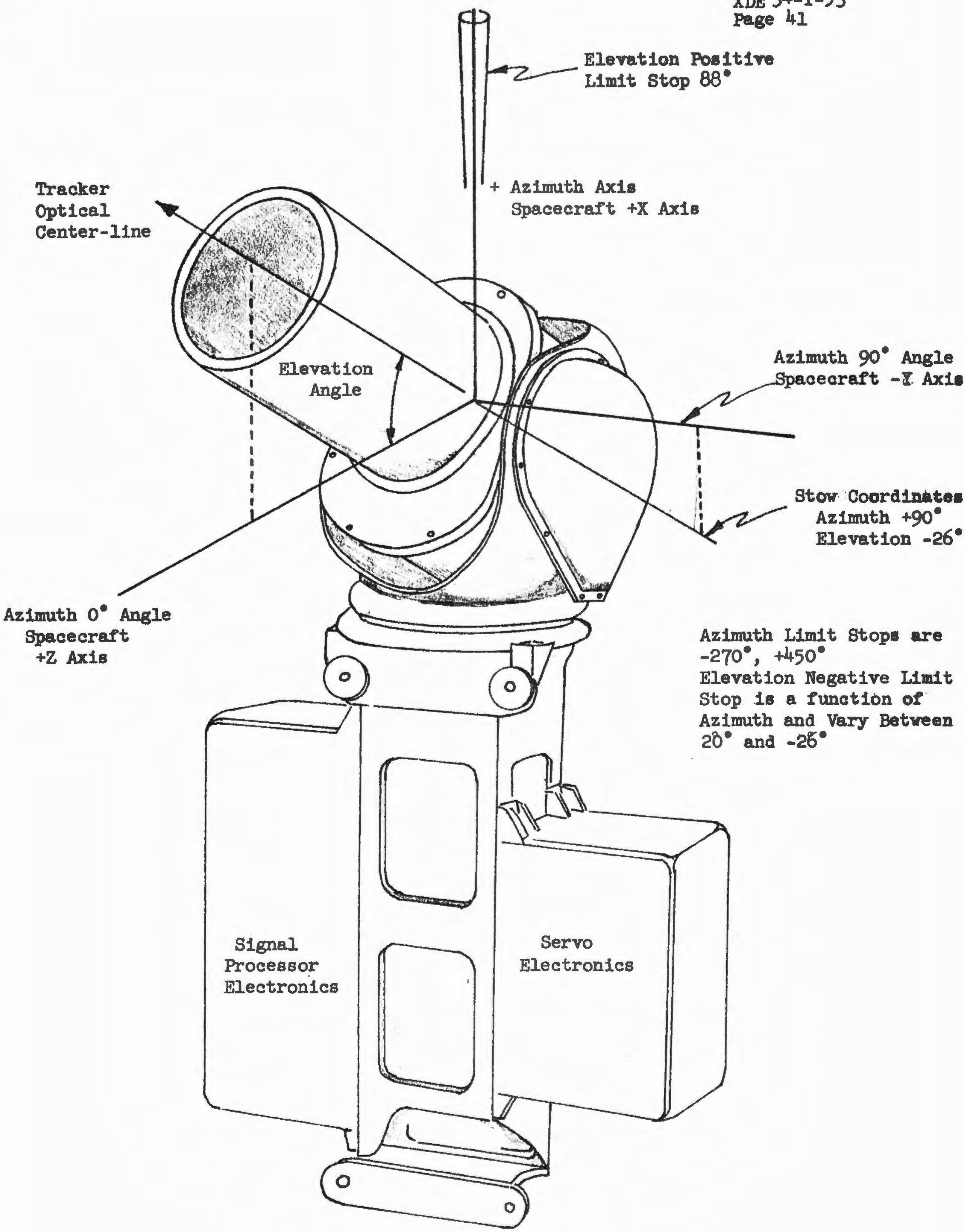
g) Elevation Limit Stops. The positive elevation limit stop is at $+88^\circ$. The negative limit stop is a function of azimuth angle and varies between $+20^\circ$ and -26° of elevation.

h) Stow Coordinates.

Azimuth $+90^\circ$

Elevation -26°

i) Optical Coverage. The overall optical coverage of this gimbal system shall take the form of a hemisphere which is canted from 20° below the LEM +Z axis to 20° above the LEM -Z axis.



GIMBAL CHARACTERISTICS

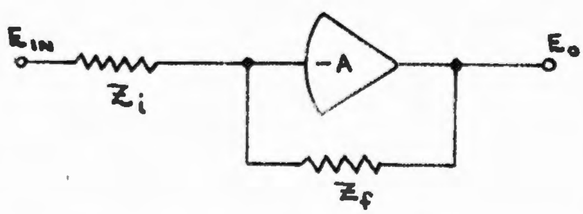
Figure 3.4.4.8.

3.4.4.9 Tachometer Characteristics - The tachometer characteristics shall be as shown in Table 3.4.4.9.

Parameter	Value	Units
Friction Torque	1.2	oz-in
Ripple Voltage (average pk to pk)	5	percent
Ripple (cycles/revolution)	33	cycles/rev
Inertia	.007	oz-in-sec^2
Weight	9	oz
DC Resistance (25°c)	667	ohms
Voltage Sensitivity	1.06	volts/rad/sec
Inductance	.40	henries
Minimum Load Resistance	67K	ohms
Maximum Operating Speed	39	rad/sec
Volts at Max Operating Speed	41.5	volts

TABLE 3.4.4.9

3.4.4.10 Tachometer Amplifier - The tachometer amplifier utilizes a high gain operational type amplifier with feedback to yield the desired gain. The operational amplifier is a three stage differential amplifier and the input and feedback impedances are purely resistive. The circuit is shown functionally below along with a table of paramter values.



Parameter	Azimuth Value	Elevation Value
Z_i	19.09 K	19.31 K
Z_f	200 K	402 K
Gain(E_o/E_{in})	10.5 volts/volt	20.8 volts/volt

AZ Tach Amplifier.- The function of this amplifier is to amplify the output of the azimuth gimbal tachometer by the required gain factor.

Input Impedance:	19.1K
Maximum Input Level:	± 1.5 VDC
Gain:	10.5 v/v
Maximum Output Capability:	±15 VDC

Elevation Tach Amplifier.- This amplifier performs the same function as the azimuth tach amplifier.

Input Impedance:	19.3K
Maximum Input Level:	±.75 VDC
Gain:	20.8 v/v
Gain Tolerance:	±5%

3.4.5. Acquisition.- In order to meet the requirements specified in section 3.3.5, the following components shall be utilized:

a) LEM Guidance Computer (LGC)
b) Elevation and Azimuth CDU's
c) Amplifier and Demodulator
d) Compensation electronics for the elevation axis
e) Elevation and azimuth electromechanical integrators

3.4.5.1 LEM Guidance Computer.

3.4.5.1.1 General. The LEM Guidance Computer will be in primary control during all aspects of the acquisition mode and shall be capable of originating the appropriate commands to accomplish the following tasks:

a) Remove the optical tracker from the stow location and position the azimuth and elevation axes for proper tracking.

b) When use of the tracker is completed, move the tracker to the stow position.

c) Initialize azimuth before each tracker operation to provide unambiguous angle readout.

d) Recover tracking if lock-on is lost during zenith pole passage or encountering an azimuth or elevation limit stop.

e) Point the tracker to within ±1° of the target.

f) Perform self tests of the optical tracker.

g) Decide as to whether or not the optical tracker has failed.

3.4.5.1.2 Angle Designation.- The following functions will be performed by the LGC when an angle is designated:

a) The LGC determines a designation angle.

b) The LGC checks to determine whether designation angle is within OTS gimbal limits; if not, the LGC re-orients the LEM.

c) The LGC sends designation angle through CDU to OTS (the presence of the 800 cps angle error command in excess of 2^{o} operates the latch solenoid through circuitry in the servo electronics.) The scale factor of the analog command is $.044^{o}$/Bit.

d) When the error angle in the CDU goes to zero (indicating the OTS is pointed in the designated direction), the LGC issues the Track Enable discrete.

e) The LGC looks for the Lock On discrete from the OTS. If it doesn't appear in 30 sec the LGC either redesignates the tracker, or initiates the Tracker Warning indication.

f) When acquisition does occur as indicated by the Lock-On discrete the LGC then looks for the Data-Good discrete.

g) When Data-Good occurs, the LGC begins sampling the angle data from the CDU.

3.4.5.1.3 Mode Selection.- The LGC will, after a discrete from the astronaut via the DSKY,

a) determine which optical tracker mode will be used.

b) examine the Star/Beacon Mode discrete to see which mode the tracker is in.

c) if the mode requires changing toggle the optical tracker with 80 millisecond (±5%) burst of 3.2 kpps (±5 %) pulses.

d) check mode discrete for change to proper mode.

3.4.5.1.4 Loss of Data-Good.- When the tracker removes the Data-Good discrete, the LGC stops sampling the angle outputs of the CDU.

3.4.5.1.5 Loss of Lock-On.- When the tracker removes the Data-Good and Lock On discretes

a) LGC removes the Track Enable.

b) LGC checks the last sampled angles for:

1) Relationship of LOS to optical tracker Gimbal Limits

2) Relationship of LOS to no track zones, i.e., near sun, earth or gimbal pole.

If the target angles are outside of the optical tracker azimuth gimbal limits, the LGC returns to the angle designation mode and repositions the LOS (rotate azimuth 360^{o}) so that the Target may be reacquired. If the target angles are outside of the OTS negative elevation limits, the LGC must reposition the LEM vehicle and the OTS so that the target may be reacquired. If the target angles are inside the optical tracker gimbal limits and outside the no-track zones, the LGC returns to the angle designate mode.

If the target angles are within a no-track zone the LGC also returns to the angle designate mode. The LGC must then reposition the OTS gimbals so that the target can be reacquired when it emerges from the no-track zone. If the Lock On discrete is absent for a predetermined time after the computed LOS leaves the no-track zone, the LGC gives a warning.

3.4.5.2 Azimuth and Elevation CDU

3.4.5.2.1 Functions.- The CDU shall perform the following basic functions:

a) Provide the analog to digital conversion link required to read the OTS gimbal angles into the LGC.

b) Provide the digital to analog conversion capability required to allow the LGC to position the OTS gimbals.

c) Provide a feedback path between change in the indicated angle and change in angle commanded by the LGC. This allows the LGC to command a change in OTS gimbal angle by sending to the CDU a number of pulses equal to the desired gimbal change, and then the CDU analog output to the gimbal servo will be proportional to the difference between the present angle and the desired angle.

3.4.5.2.2 Moding.- Mode control of the CDU shall be as follows:

a) CDU Zero.- The CDU Zero discrete clears and inhibits the CDU read counter. When the CDU Zero discrete is removed the read counter will repeat the input angle.

b) D/A Enable.- The D/A Enable discrete will enable the Error Angle Counter and the feedback path between the read counter and the error counter. This discrete is used to implement the acquisition mode.

c) Display Inertial Data.- The Display Inertial Data discrete, not to be used when the OTS is operating, is used to produce the Display Inertial Data mode. In this mode, the computer will display information to the astronaut by connecting the D/A converter DC output to a meter. The D/A Enable and the Display Inertial Data discrete must be present to accomplish this. In this mode, the feedback loop between the read counter and the error counter is not closed.

3.4.5.2.3 Inputs and Outputs.- The inputs and outputs for a single axis of the CDU shall be as shown in Figure 3.4.5.2.3.

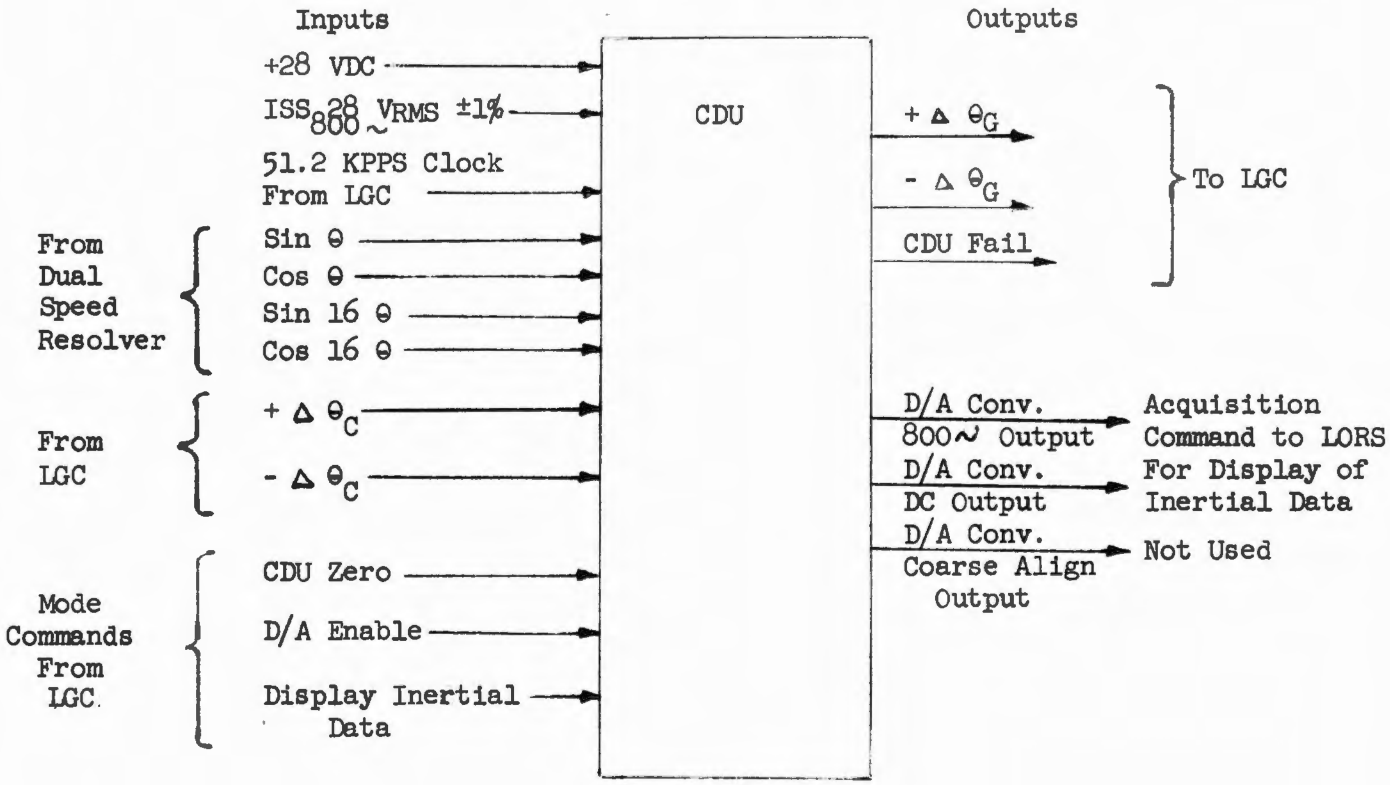


Figure 3.4.5.2.3

3.4.5.3 Amplifier and Demodulator.- The amplifier and demodulator circuitry shall demodulate the 800 cps ac signal of the CDU output and provide a dc output with the following gain characteristics.

a) Azimuth axis - 3.75 Volts dc/Volt ac rms

b) Elevation axis - 5.00 Volts dc/Volt ac rms

3.4.5.4 Compensation Electronics for Elevation Axis.- The compensation electronics for the elevation axis in the acquisition mode shall be as defined for the servomechanism mode 3.4.4.2.

3.4.5.5 Elevation and Azimuth Electromechanical Integrators.- The Elevation and Azimuth electromechanical integrators for the acquisition mode shall be as defined for the standard and beacon mode 3.3.4.2.1.

3.4.6 Acquisition/Scan.- In order to meet the requirements specified in section 3.3.6, the following components shall be utilized:

a) Acquisition mode components--Section 3.4.5

b) Scan electronics

c) Elevation axis mixing ratio adjustment.

3.4.6.1. Scan Electronics.- The scan electronics shall be comprised of three functions, the staircase scan, triangle scan and scan logic. The purpose is to generate servo drive signals which will sweep the tracker through a 2° square field of view according to the pattern shown in figure 3.4.6.1A Scan programs are generated whenever the tracker power is turned on and are not synchronized to any reference.

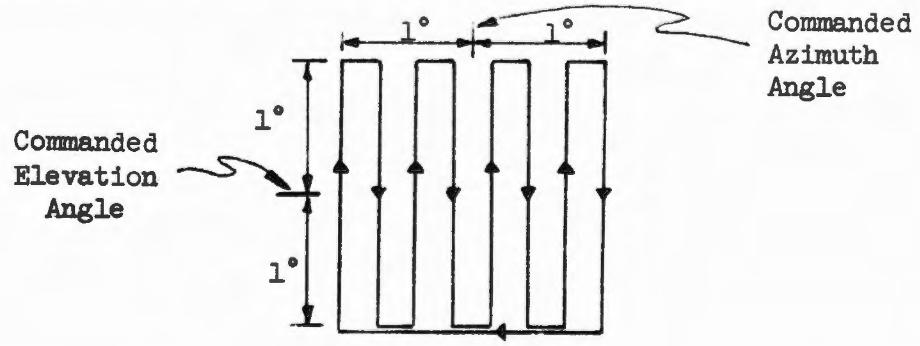


Figure 3.4.6.1A

The scan logic function synchronizes the staircase scan and the triangle scan to produce the pattern shown above. It accomplishes this function by using the output of the first stage of the binary counter in the staircase scan function to drive the sweep generator in the triangle scan function.

The function of the staircase scan is to drive the azimuth servo gimbal during scan mode by providing the output waveform shown in figure 3.4.6.1B.

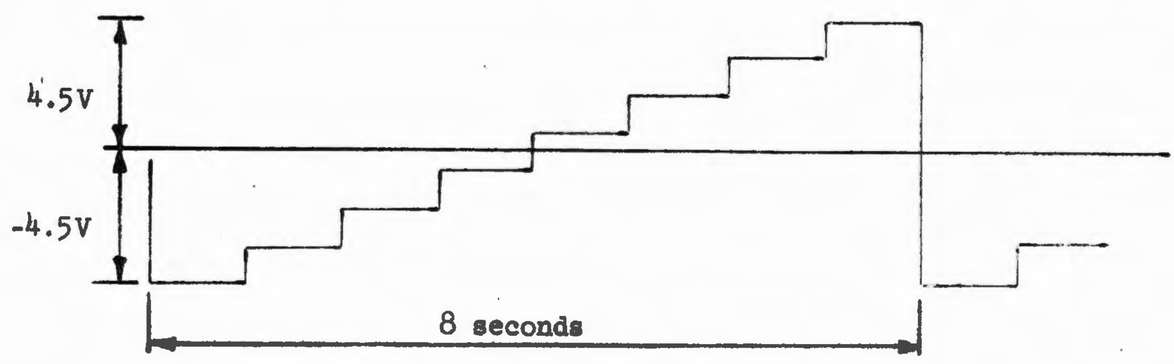


Figure 3.4.6.1.B

The desired waveform is produced by using a three stage binary counter to drive a resistive summing network which acts as a digital to analog convertor. The first stage of the counter is a free running multivibrator with a period of two (2) seconds.

The function of the triangle scan module is to drive the elevation gimbal during the scan mode by generating the waveform shown in figure 3.4.6.1.C.

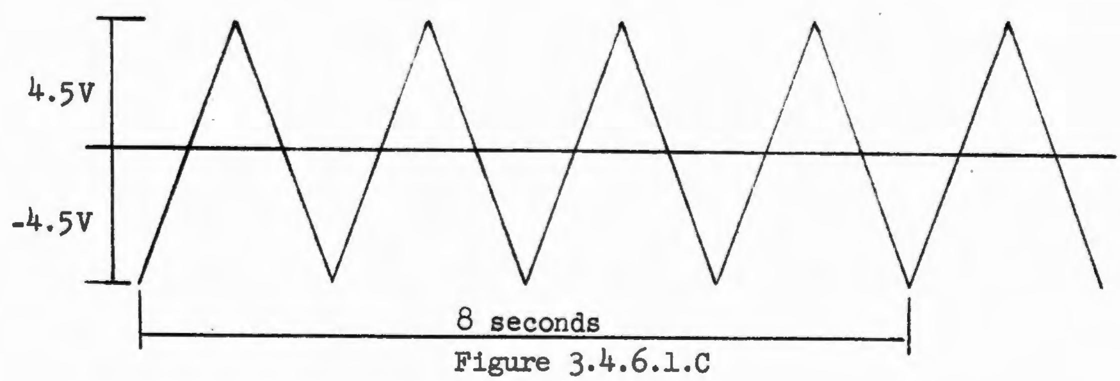


Figure 3.4.6.1.C

The waveform shown above is synchronized to the staircase scan by the scan logic. The scan logic accomplishes this by generating a signal which drives a sweep generator in the triangle scan in either the positive or negative direction depending upon the output of the staircase scan.

3.4.6.2 Elevation Axis Mixing Ratio Adjustment.- The mixing ratio adjustment in 3.3.6 is a block diagram accommodation to the definition of the compensation amplifier function. The gain of the compensation amplifier is as defined by the acquisition mode, i.e. 5 volts/volt (3.3.8.2). Since mixing of CDU signals at a gain of 5 v/v is combined with scan signals at a gain of 1.7 v/v, a compensation factor of 1.7/5.0 must be used in the block diagram.

4. Preinstallation G&N Testing.- The following recommendations on preinstallation testing are made without regard to test facility accommodations or availability of GSE. Sections 4.1 through 4.5 are references from which detailed documentation on G&N testing may be derived. The test point and logic events which are pertinent to each of the following sections are shown in Table 4.

4.1 G&N Self Testing of the Optical Tracker.-

4.1.1 Turn-On.- The 28 VDC and 28 V rms, 800 cps power shall be turned on and the tracker checked to see that it is in the star mode.

4.1.2 Angle Readout.- The azimuth and elevation angles in the latched position shall be +90° and -26°, respectively.

4.1.3 Lock-On.- With the tracker still latched, the self-test light source shall be turned on and the track enable command issued. After 30 sec. the lock-on signal shall be present. Azimuth and elevation torque motor currents shall be monitored for phasing and magnitude.

4.1.4 Tracker Loop.- With the self-test light still on, the stow latch shall be released by commanding track enable and then commanding an elevation angle greater than 2°. After 30 seconds the azimuth and elevation angles shall indicate the self-test light coordinates and the data good and lock-on signals shall be present.

4.1.5 Stow.- The tracker enable discrete shall be removed and the tracker commanded to an azimuth angle of +90° and an elevation angle of -30° sequentially. After an interval of 15 seconds the CDU error command output will be removed by removing the D/A error counter enable command discrete to the CDU. This shall latch the tracker in the stow position.

4.1.6 Beacon Mode.- Perform 4.1.2 - 4.1.5, except that the beacon track mode indication shall be present and the self-test lamp shall be pulsed at 32 pps.

4.2 G&N Acquisition and Track Testing.- Acquisition mode testing shall consist of the following tests. Appropriate test points shall be as shown in Table 4.

SIGNALS AVAILABLE FOR G&N TEST
TABLE 4.0

	4.1.1	4.1.2	4.1.3	4.1.4	4.1.5	4.1.6*	4.2.1	4.2.2	4.2.3	4.2.4	4.2.5	4.2.6	4.2.7	4.2.8	4.3.1	4.3.2	4.3.3	4.4.1	4.4.2
MODING																			
Composite Analog:																			
a) -30V Reg. Good	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
b) +30V Reg. Good	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
c) Scan Motor On	X	X	X	X	X		X	X	X	X	X	X		X	X		X	X	X
d) Beacon Mode Operation						X							X			X			
e) Data Good Present				X								X	X	X	X	X	X		
f) Lock-On Present			X	X								X	X	X	X	X	X		
Track Enable			X	X			X	X	X	X	X	X	X	X	X	X	X		
SIGNALS NORMALLY AVAILABLE																			
Main Automatic Gain Control	X		X				X	X	X	X	X	X	X	X	X	X	X	X	X
Sun Shutter Operate																		X	X
PMT Star Mode			X	X	X							X		X	X	X	X	X	X
LOTS Operate +	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
LOTS Operate -	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Servo Secant Pot			X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Elevation Drive (sample & hold)			X	X	X							X	X	X	X	X	X	X	X
Azimuth Drive (sample & hold)			X	X	X							X	X	X	X	X	X	X	X
Elevation Torque Motor Current			X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Azimuth Torque Motor Current			X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
R&D INSTRUMENTATION																			
Automatic Gain Control	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
PMT Tube Temp.	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Azimuth Tachometer Amp.			X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Elevation Tachometer Amp.			X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Azimuth Error Amp.			X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Elevation Error Amp.			X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X

* Repeat 4.1.1 through 4.1.5 measurements, except PMT Star Mode and Scan Motor On.

4.2.1 The computer shall position the tracker from the stow position to an attitude of -20° Elevation, 0° Azimuth. The computer shall reposition the tracker to the stow position after the track enable discrete has been issued.

4.2.2 The computer shall position the tracker from the stow position to an attitude of $+88^{\circ}$ Elevation, 90° Azimuth. The computer shall reposition the tracker to the stow position after the track enable discrete has been issued.

4.2.3 The computer shall position the tracker from the stow position to an attitude of $+84^{\circ}$ Elevation, $+450^{\circ}$ Azimuth. The computer shall reposition the tracker to the stow position after the track enable discrete has been issued.

4.2.4 The computer shall position the tracker from the stow position to an attitude of $+84^{\circ}$ Elevation, -270° Azimuth. The computer shall reposition the tracker to the stow position after the track enable discrete has been issued.

4.2.5 The acquisition/scan/acquisition test shall be performed with the target simulator off and the star track mode selected. With the tracker on the 84° fixture, the computer shall position the tracker from the stow position to an attitude of $+84^{\circ}$ Elevation and an appropriate azimuth angle such that alignment is achieved with the target simulator. The track enable discrete shall be issued from the computer and the scan program started. Thirty seconds after issuance of the track enable discrete the computer shall remove the track enable discrete and stop the scan program. The computer shall then be commanded to return the tracker to the stow position.

4.2.6 The Acquisition/scan/star track test shall be performed with the target simulator set to a +3.0 visual magnitude star (sunlit CSM) against a star background and the star track mode selected. With the tracker on the 84° fixture, the computer shall position the tracker from the stow position to an attitude of $+84^{\circ}$ Elevation and an appropriate azimuth angle such that alignment is achieved with the target simulator. After alignment is completed the track enable discrete shall be issued from the computer and the scan program started. Within 30 seconds after issuance of the track enable discrete the tracker shall issue a lock-on discrete and the scan program shall be terminated. Automatic tracking shall occur and the tracker shall issue a data good discrete. After tracking characteristics have been determined, the target simulator shall be turned off. Data good and lock-on shall be lost and the computer shall reacquire control and hold the tracker at the tracking attitude. The computer shall then be commanded to return the tracker to the stow position.

4.2.7 The acquisition/scan/beacon track test shall be performed with the target simulator set to a flashing beacon with a star background and the beacon track mode selected. With the tracker on the 84° fixture, the computer shall position the tracker from the stow position to an attitude of +84° Elevation and an appropriate azimuth angle such that alignment with the target simulator is achieved. After alignment is achieved, the track enable discrete shall be issued from the computer and the scan program started. Within 30 seconds after issuance of the track enable discrete the tracker shall issue a lock-on discrete and the scan program shall be terminated. Automatic tracking shall occur and the tracker shall issue a data good discrete. After tracking characteristics have been determined the sunlit lunar background shall be introduced into the field of view. After the resulting transients and tracking characteristics have been determined, the target simulator shall be turned off. The computer shall reacquire and hold the tracker at the tracking attitude. The computer shall then be commanded to return the tracker to the stow position.

4.2.8 The acquisition/scan/reflecting marker test shall be performed with the target simulator set to a sunlit reflecting marker against the sunlit lunar surface. The procedure for the test shall be the same as that specified in 4.2.6.

4.3 G&N Testing of Pole Passage.-

4.3.1 The 84° pole passage test shall be performed with the target simulator set to the +3.0 visual magnitude star (sunlit CSM) against a star background. With the tracker on the 84° fixture and the system in the star track mode, the computer shall position the tracker from the stow position to an attitude of +84° Elevation and an appropriate Azimuth angle such that alignment is achieved with the target simulator. After alignment is completed and automatic track achieved the rate table shall be repositioned until the tracker elevation readouts indicate 70°.

With the above as an initial condition, the tracking characteristics for pole passage within 6° of azimuth may be tested by rotating the rate table at 0.58°/sec in a direction which causes the elevation angle to increase to 84° and then decrease to 70°. Data good may be lost during this event but lock-on shall not be lost.

4.3.2 The 84° pole passage test shall be performed with the target simulator set to a flashing beacon against a star background and the system in the beacon track mode. The procedure shall be the same as that defined in 4.3.1.

4.3.3 The 90° pole passage test shall be performed with the target simulator set to the +3.0 visual magnitude star against a star background. With the tracker on the 90° fixture and the systems in the star track mode, the computer shall position the tracker from the stow position to an attitude of +80° Elevation and 0° Azimuth. The rate table shall then be positioned until automatic tracking is achieved. With the above as an initial condition, the tracking and computer control characteristics shall be tested by rotating the rate table at 0.63°/sec. Lock-on should be lost during this event and the computer should position the tracker such that lock-on and data good is reachieved as the elevation angle decreases from 90°.

4.4 Sun Shutter Operation

4.4.1 Shutter Functional Limits.- The tracker shall be positioned from stow to be aligned with the luminous target simulator. Thirty seconds after the scan mode is entered, the tracker will down-mode to steady state pointing. The simulated sun shall then be turned on and the rate table slewed until the sun shutter operates. The shutter shall function when the limb of the simulated sun is a minimum of 5° from the tracker LOS.

4.4.2 Shutter Operation During Acquisition.- The tracker shall be commanded to an angle in such a fashion that the tracker LOS will pass within 5° of the simulated sun. The shutter shall close and open without interrupting the acquire mode tracker operation.

4.5 Luminous Beacon

4.5.1 One Point Intensity Check.- The far-field irradiance of each lamp shall be measured using the auxiliary tester.