SPACE SYSTEMS

DOCUMENT NO. 70SD4232

20 MAY 1970

NAS 9-8887

FINAL REPORT

LABORATORY MODEL HIGH RESOLUTION TELEVISION CAMERA

FACILITY FORM 602

N70-39077 (ACCESSION NUMBER) (THRU) 1

88 (PAGES) (CODE)

CR-108576 (NASA CR OR TMX OR AD NUMBER) 07 (CATEGORY)

GENERAL ELECTRIC

N70-39077

LABORATORY MODEL HIGH RESOLUTION TELEVISION CAMERA

A. B. Schechner

General Electric
Valley Forge Space Center
Philadelphia, Pennsylvania

20 May 1970

NOTICE

108576
~~CR 108628~~

DOCUMENT NO. 70SD4232
20 MAY 1970

FINAL REPORT

LABORATORY MODEL HIGH RESOLUTION TELEVISION CAMERA

PREPARED FOR

MANNED SPACECRAFT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HOUSTON, TEXAS

PREPARED UNDER

CONTRACT NO. NAS-98887

PREPARED BY

A.B. SCHECHNER

GENERAL ELECTRIC

SPACE SYSTEMS ORGANIZATION
Valley Forge Space Center
P. O. Box 8555 • Philadelphia, Penna. 19101

TABLE OF CONTENTS

PRECEDING PAGE BLANK NOT FILMED.

TABLE OF CONTENTS (Cont'd)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Cont'd)

INTRODUCTION

The UHR Laboratory Model Vidicon Camera System was built for the NASA/Manned Spacecraft Center under Contract No. NAS 9-8887. The objective was twofold: 1) to construct a television camera system utilizing the newly developed FPS-5 vidicon pick-up tube from General Electric's IDO facility in Syracuse, N. Y., and 2) to conduct a measurement program aimed at learning the features of this tube and its performance capabilities.

The camera design had to take into account some ten bias voltages and four deflection signals, whose nominal values were not known to a sufficient degree when the program began. Consequently, a control network resulted that was, perhaps, even more flexible than needed in light of what has been learned since. Specifications were drawn up at the start of the program and the most significant of these, with final results, are shown in Table I. In all, the camera performed as well as or better than anticipated, pointing the way to various applications.

Contained in this report are the following:

1. A discussion of UHR Sensor Development
2. A description of the system with photographs, drawings and schematics
3. Camera operating parameters
4. Test Procedures and Photographs
5. Results and Analysis
6. Recommendations
7. Appendix, supporting material

This opportunity is taken to acknowledge the contributions and advice of Dr. K. Schlesinger, regarding the sensor; A. Baran, J. Smith and C. Mazzocco for Electronic Design; F. M. Leccese and G. J. Rayl for their consultation and support.

Table I. High Resolution TV Camera System

Parameter	Specification	Measured Performance
Resolution	4000 TVL/picture height	4200 X and Y
Signal Level	1 V P-P into 50 ohms	1.45 V P-P
Signal-to-Noise	26 dB min	39.4 dB
Gray Steps	6	9
Shading	15% edge-to-edge	± 10%
Lag	50%	45%
Light Intensity	2 ft-candles	0.9 ft-candles for all measurements
Gamma	1.2 → 0.7	1.29 → 0.7
Bandwidth	± 2 dB over operating range	± 1 dB 8 Hz to 12 mHz
Frame Time	< 10 seconds	1 second
Scan Line No.	--	5499
Jitter in Scan	± 0.01%	< 0.0035%
Power Consumption	50 watts nom.	≈ 80 watts

SECTION 1

SENSOR DEVELOPMENT

1.1 ULTRA HIGH RESOLUTION (UHR) VIDICON

A UHR vidicon with 2.5-inch slow scan photoconductor was developed for application to this high resolution camera. This tube is referred to as Type FPS-5. It was designed to scan a square format (aspect ratio 1:1) on a minimum usable target diagonal of 2.5 inches. Resolution was specified as 4000 TV lines per picture height. This implies a spot size of approximately 0.4 mil or 10 microns. Present developmental tubes yield consistent readings of 0.28 mil = 7 microns, spot size in the paraxial region.

The basic design of the FPS-5 is shown in Figure 1-1 and a photograph of the tube is shown in Figure 1-2. This shows a high-intensity source with a small-spot defining aperture (0.005-inch) at (4).* This object is followed by an imaging system comprising two magnetic lenses (2) and (3). Lens (3) is a shielded lens with short focus. It is powered by less than 1 watt and projects a real image of the aperature (4) with a demagnification of 1:1/3. The result is an extremely sharp (3.5 microns) "primary focus" F_1 whose position at the entrance to the FPS cavity can be controlled to some extent by varying the focal length of lens (3). Lens (2) is adjusted to focus on target a 1:1 real image of this primary focus. This "secondary focus" (F_2) sweeps the target under the influence of crossed electric (1) and magnetic (2) fields generated within the FPS cavity. Given a sufficiently narrow beam divergence at F_1 (half-angle $\beta \leq 2$ degrees) spherical-aberration in the relaying lens (2) can be kept under control. This is borne out by experimental evidence.

To prove this concept of tube design, two tubes of the type shown in Figure 1-1 were built and tested. The first of these tube samples proved the superiority of magnetic prefocusing over an electrostatic lens system which had also been incorporated within the same envelope.

* Numbers in parentheses refer to numbers called out in Figure 1-1.

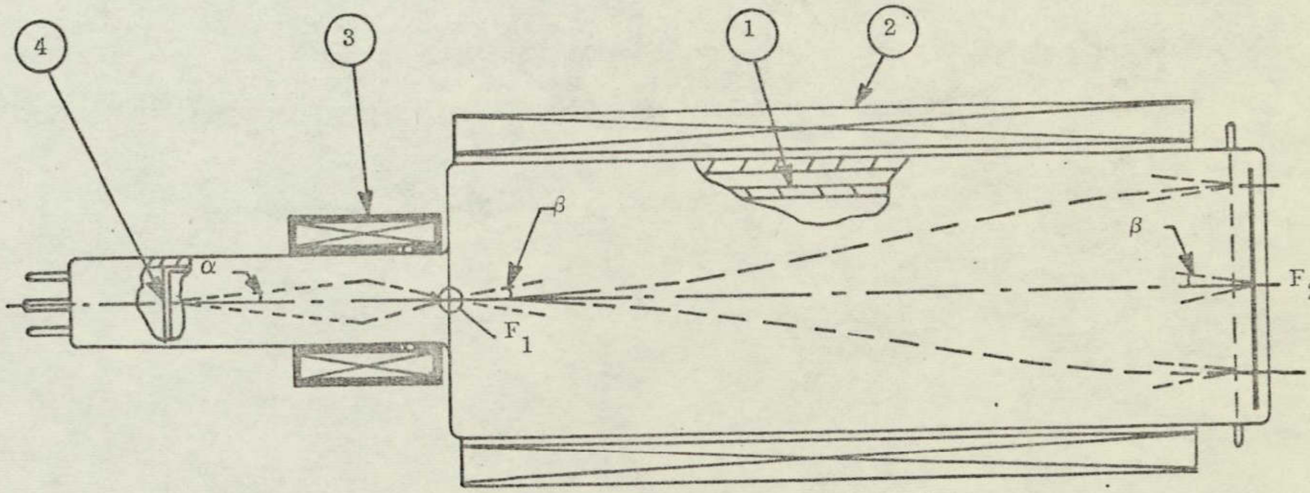


Figure 1-1. Basic Structure of UHR Vidicon, Type FPS-5

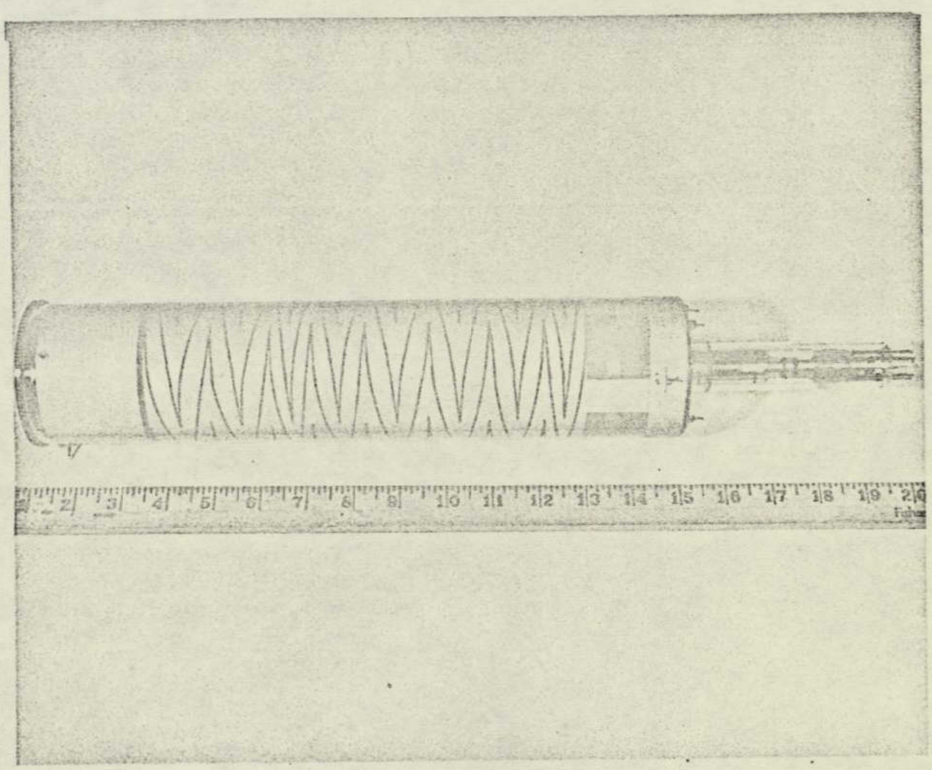


Figure 1-2. UHR Vidicon, Type FPS-5

The all-magnetic approach was then continued for the rest of the project. The tubes used the same type of emission system. This was a small Pierce triode with impregnated cathode, built for an anode voltage of 1 kv.

1.2 SLOW SCAN PHOTOCONDUCTOR (SELENIUM DOPED)

General Electric slow scan vidicons possess exceptional light integration and storage characteristics that make them well adapted to widely different modes of slow scan operation. They may be used with continuous exposure and readout at low scan rates for narrow band-pass facilities, or the exposure may be accomplished between scans with readout performed at any convenient scan rate after the exposure. Excellent storage characteristics and extremely low dark current permit storage and readout times of several minutes. Signal output is dependent upon the product of target illumination and exposure time. Thus, the exposure may be of high intensity and short duration to stop motion, or it may be at low light levels and long duration to integrate the signal from a low illumination scene.

This photoconductor is one that operates by the principle of true charge storage, not as "sticky" or "laggy" vidicons.

The data supplied here refers to data taken with a standard 1-inch magnetic focus and deflection tube, but may be reasonably extrapolated to the FPS vidicon tube type.

1.2.1 SENSITIVITY

Signal output current is dependent upon illumination, target voltage, scanned area, and scanning rate. The following graphs help illustrate these relationships.

Figure 1-3. Signal Output versus Illumination

Figure 1-4. Signal and Dark Current versus Target Voltage

Figure 1-5. Signal Output versus Frame Time

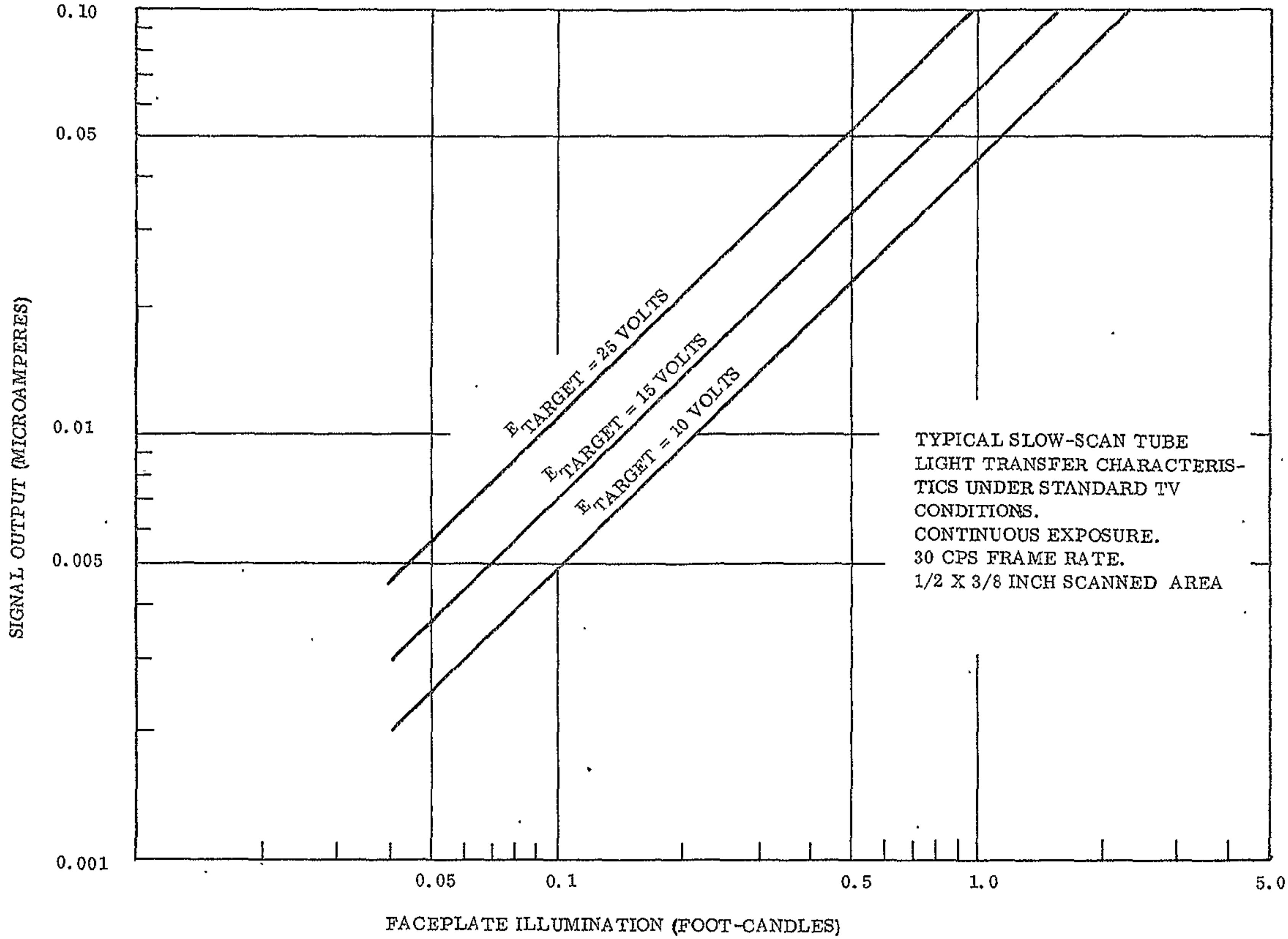


Figure 1-3. Signal Output versus Illumination

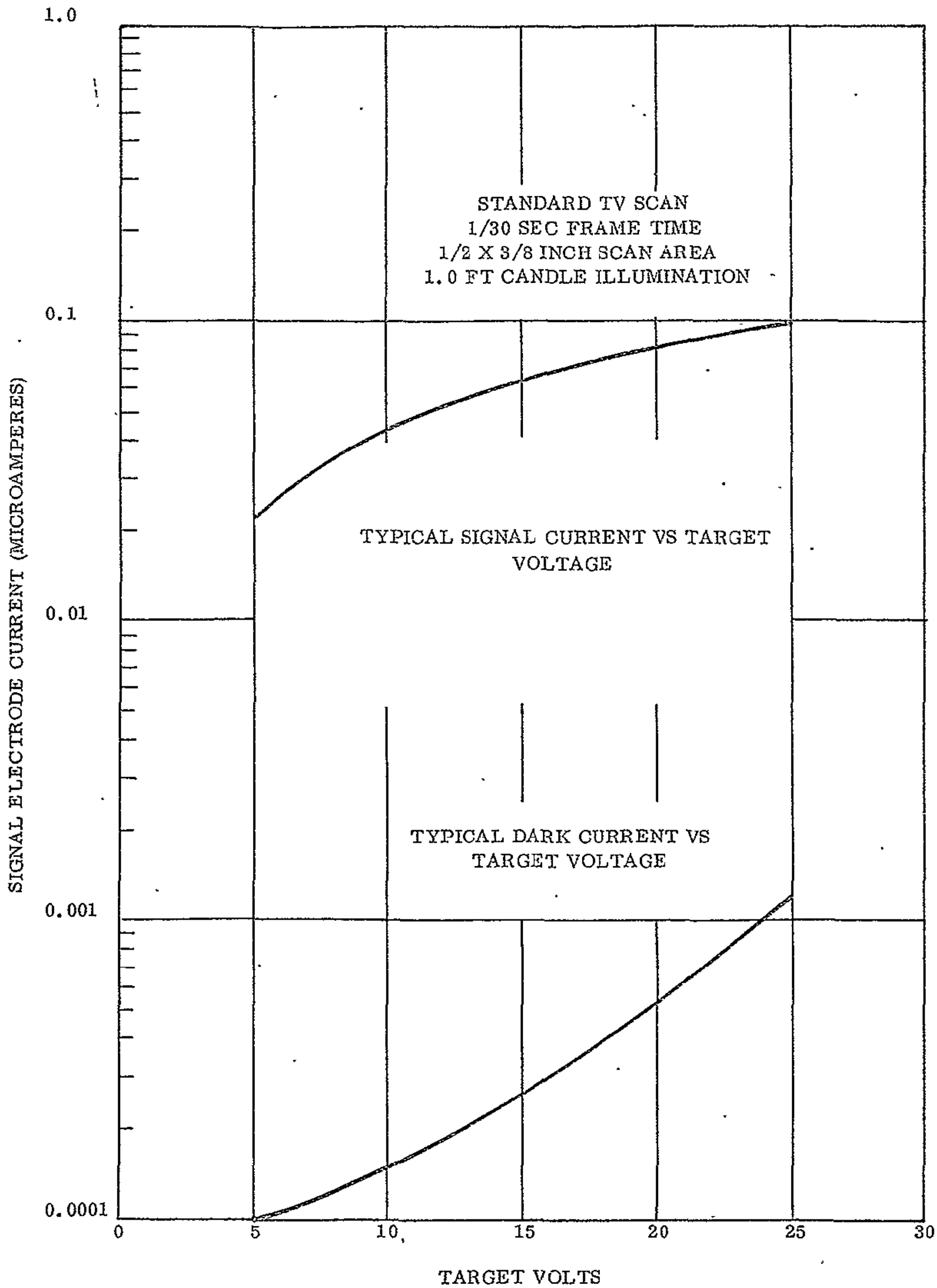


Figure 1-4. Signal and Dark Current versus Target Voltage

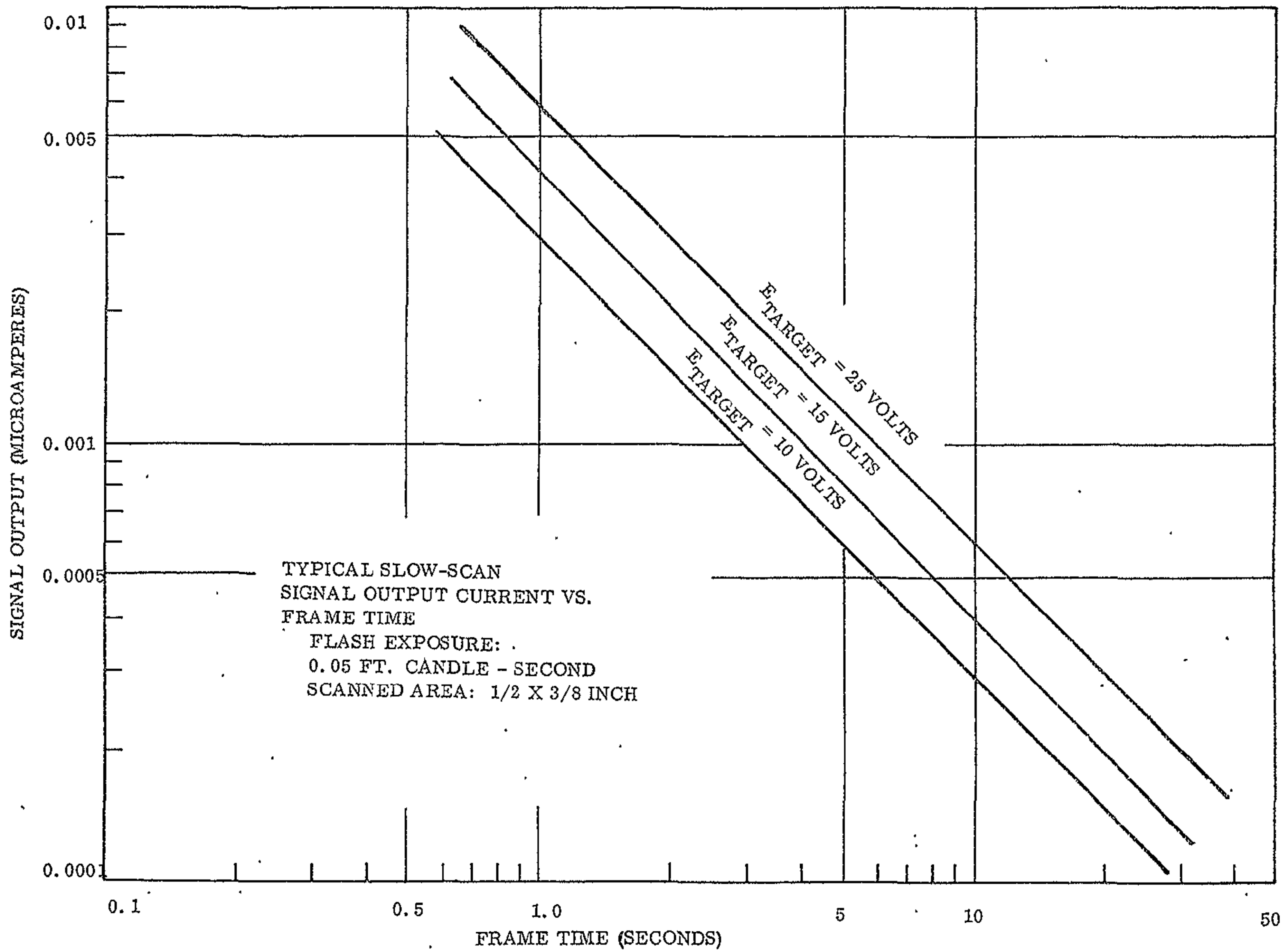


Figure 1-5. Signal Output versus Frame Time

1.2.2 SPECTRAL RESPONSE

Relative spectral response is shown in Figure 1-6, with curve I indicating the performance of the standard slow-scan types, while curve II illustrates the UV sensitivity that can be provided through the use of special UV transmitting faceplates.

1.2.3 RESOLUTION

Resolution is dependent upon tube type, camera chain bandwidth, tube electrode voltages and focusing field as well as scanning mode. Figure 1-7 shows typical resolution versus storage time for a 1-inch magnetic tube. Resolution for a 1-inch FPS tube is greater than 1000 TV lines, with a corresponding decrease in resolution at long storage times. This loss of resolution as storage time increases is due to lateral charge leakage along the photoconductor surface.

1.2.4 TARGET VOLTAGE

The preferred target voltage is 15 volts, but operation up to 25 volts is permitted. At maximum target potential, white spots may become visible that will disappear again when the target voltage is reduced (Figure 1-4).

1.2.5 DARK CURRENT

With target voltage in the specified range, dark current is negligible and can be disregarded. Typical dark current is 0.0001 to 0.0003 microamperes. The target voltage should not be increased to produce 0.02 microamperes dark current as is customary with a standard photoconductor. This would require excessive target voltage and cause white spots to appear (Figure 1-4).

1.2.6 TEMPERATURE

Typical target temperature is 25 to 35°C, the range found in most cameras without temperature controls. Maximum permitted temperature is 45°C.

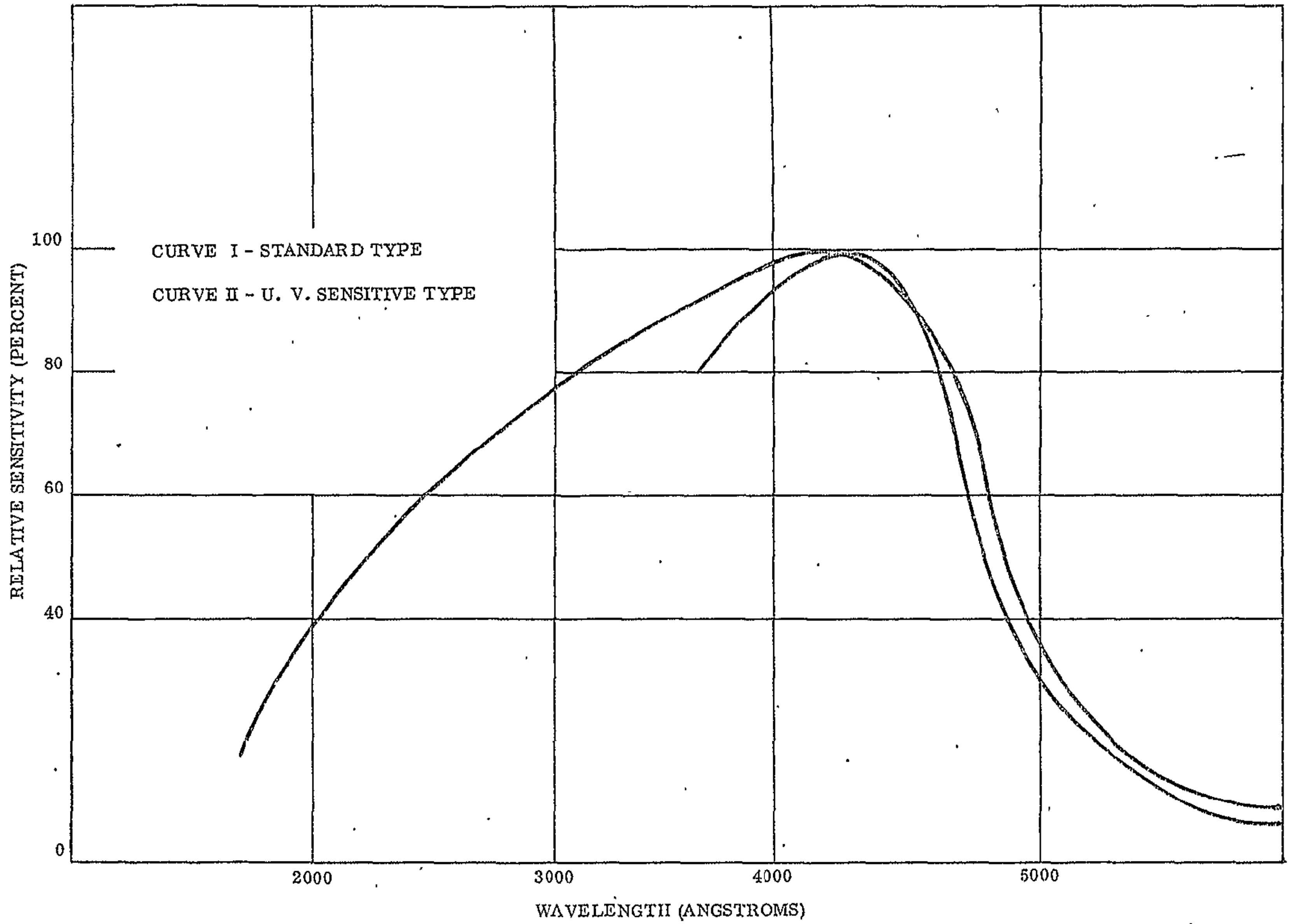


Figure 1-6. Relative Spectral Response of Slow Scan Vidicons

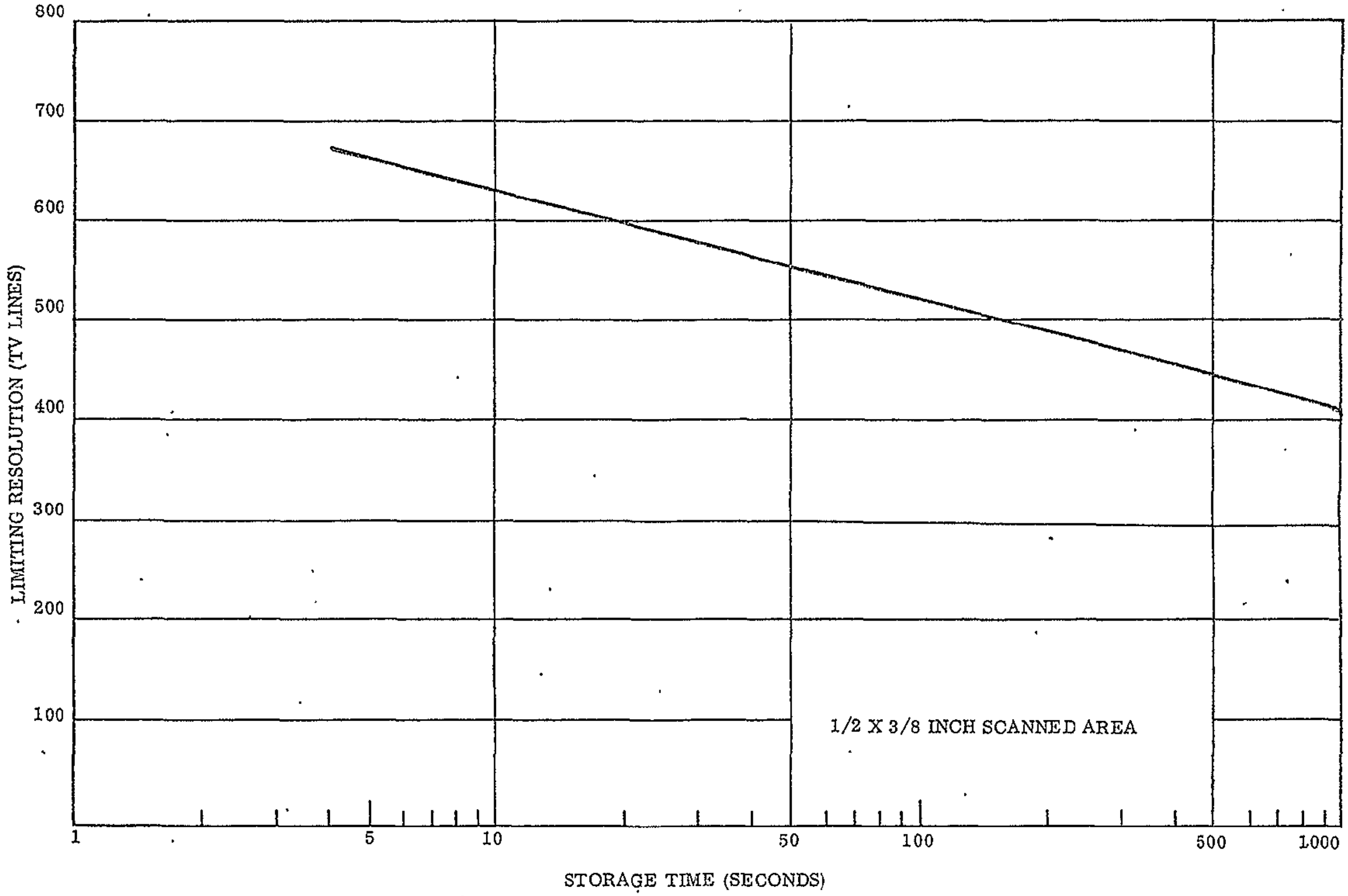


Figure 1-7. · Typical Resolution versus Storage Time

1.2.7 RESIDUAL SIGNAL

The slow scan vidicons operate by the principle of charge storage, rather than photoconductive lag, thus it is possible to have short lag, yet storage times of several minutes. Typical third field lag with standard 30 frame TV operation is approximately 30 percent. Using long frame times, photoconductive lag may be neglected and residual signal after scanning depends only on the beam current used. By proper adjustment of beam current, residual signal is negligible, making the tube well suited for imaging a new scene with each frame.

SECTION 2

FPS-5 HIGH RESOLUTION TELEVISION

The entire FPS-5 High Resolution Television System includes the camera tube, synchronizing circuit, video preamplifier, video processor, sync buffers (line drivers), electrostatic deflection circuit and power supplies (Figure 2-1). In this configuration it is similar to other cameras. The differences appear in the unusual deflection and bias requirements, long vertical frame rate and other features such as the inclusion of target cooling and power supply sequencing. Figure 2-2 shows the layout of the camera.

The video preamplifier is built on a ring-shaped printed board that surrounds the vidicon target, within an aluminum cylinder that also supports the lens. Target, mesh and test point connections exist within this structure and are accessed from outside the cylinder.

Bias circuitry, size and position, video gain, blanking and focus and all associated controls are located on the front panel. Both coarse and fine controls are available where needed. Fourteen meters on this panel allow constant monitoring of operating parameters. It was deemed important that this amount of flexibility exist in a laboratory camera using a new type sensor.

All other electronics are located in five printed circuit boards in a plug-in matrix. There is a panel for all power supplies but the two high voltage types, which are isolated for safety. A low pressure air pipe provides cooling air for the vidicon target and controls two vacuum timing switches that sequence the power supplies, again a safety measure.

The structure is completed by the focus coil, wound on and shielded by an aluminum bobbin, which encloses the entire length of the larger diameter portion of the tube. Prefocus and alignment coils rest on the neck of the tube.

An overall cabling diagram is shown in Figure 2-3 (Schematic No. 4000-24C).

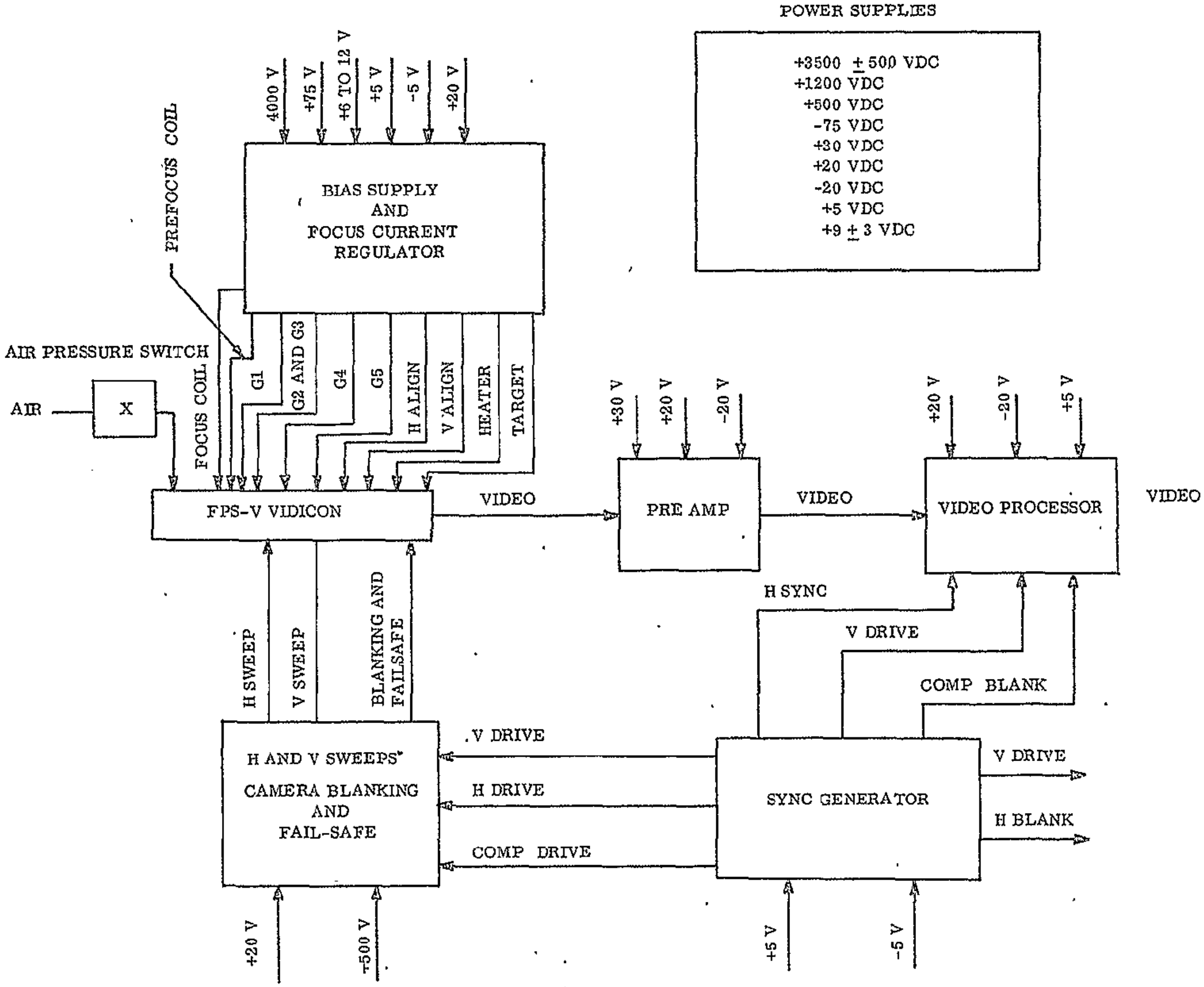


Figure 2-1. Camera System, Block Diagram

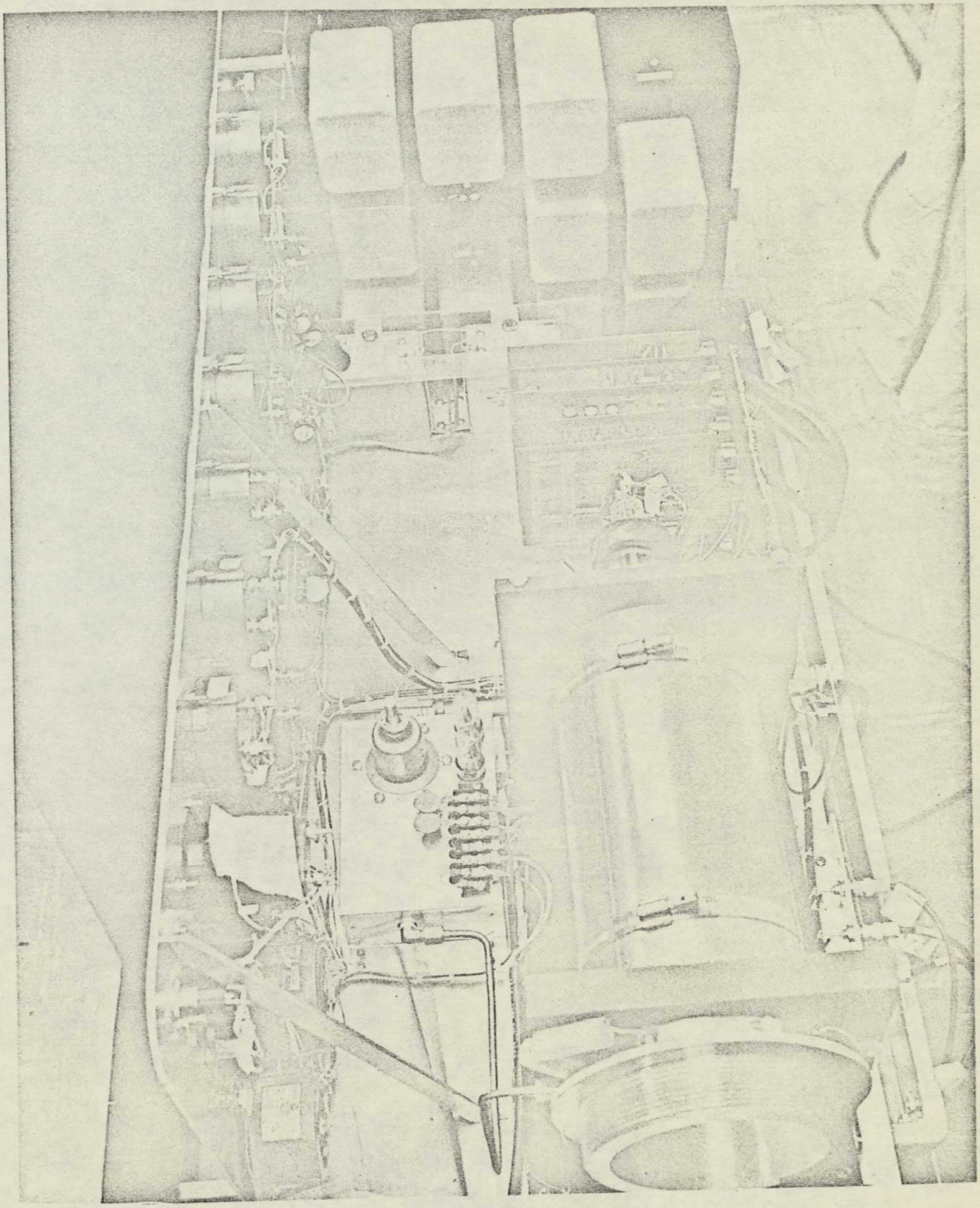
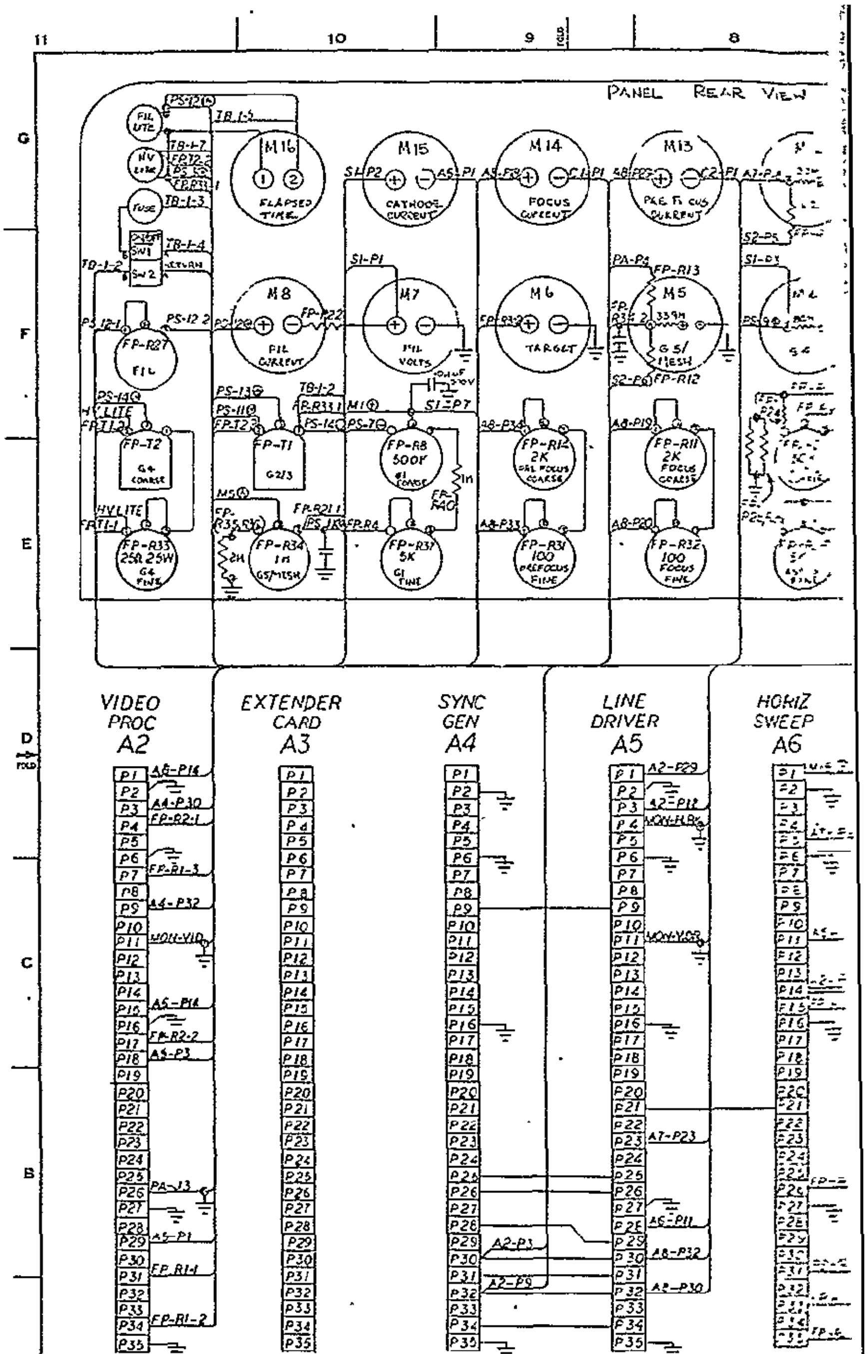


Figure 2-2. Camera System Layout



NOTES:
1 ALL CAPACITORS 0.01μF UNLESS OTHERWISE NOTED
2 SOCKETS A1, A9, A10 UNUSED

FOLDOUT FRAME 2

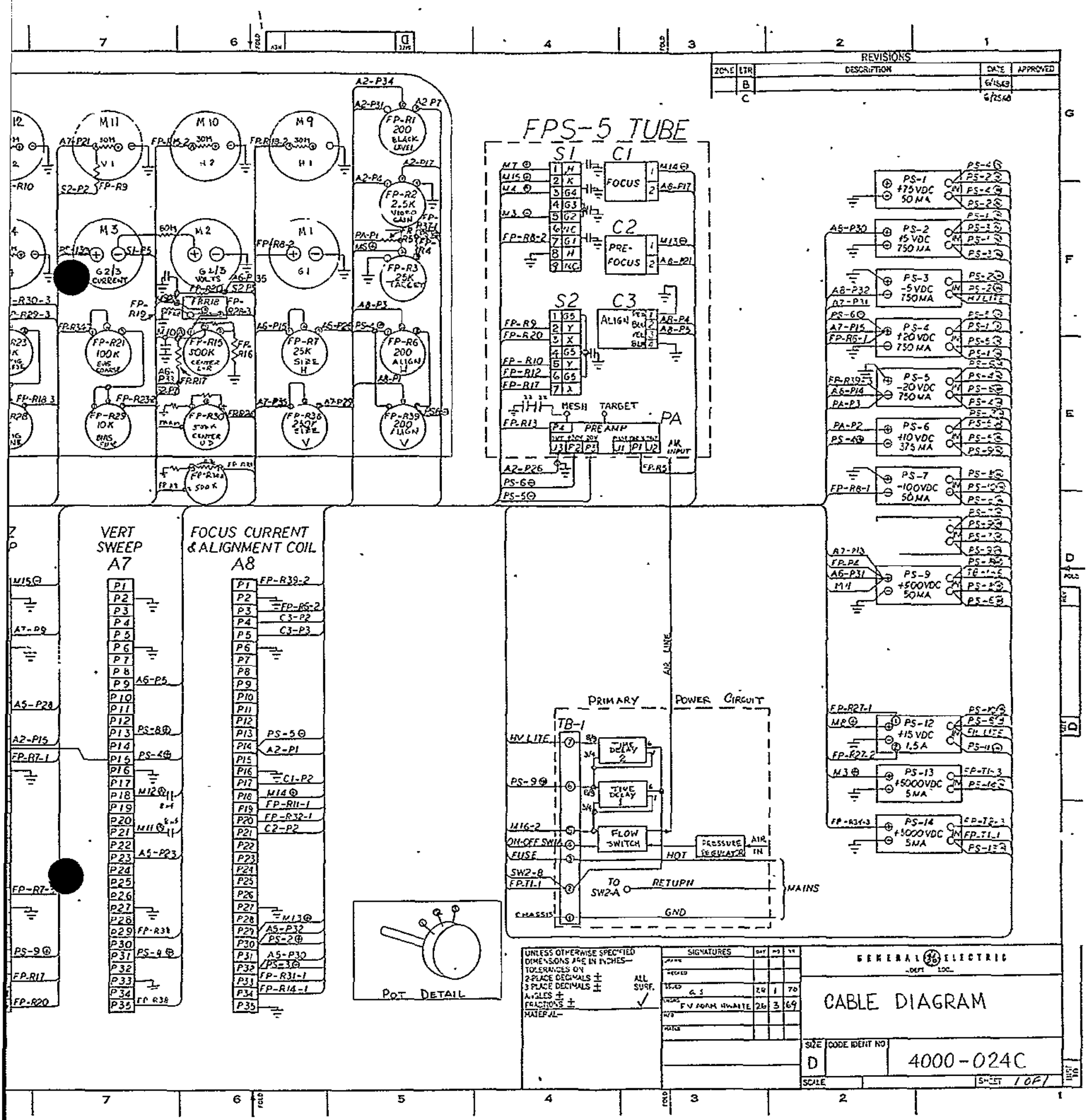


Figure 2-3. Cable Diagram

FOLDOUT FRAME 2

2.1 SYNC GENERATOR

The sync generator design consists of a master oscillator, integrated circuit (TTL), countdown circuit, burst oscillator, logic and line driver circuits as shown in Figure 2-4 (Schematic No. 4000-031, 3 parts).

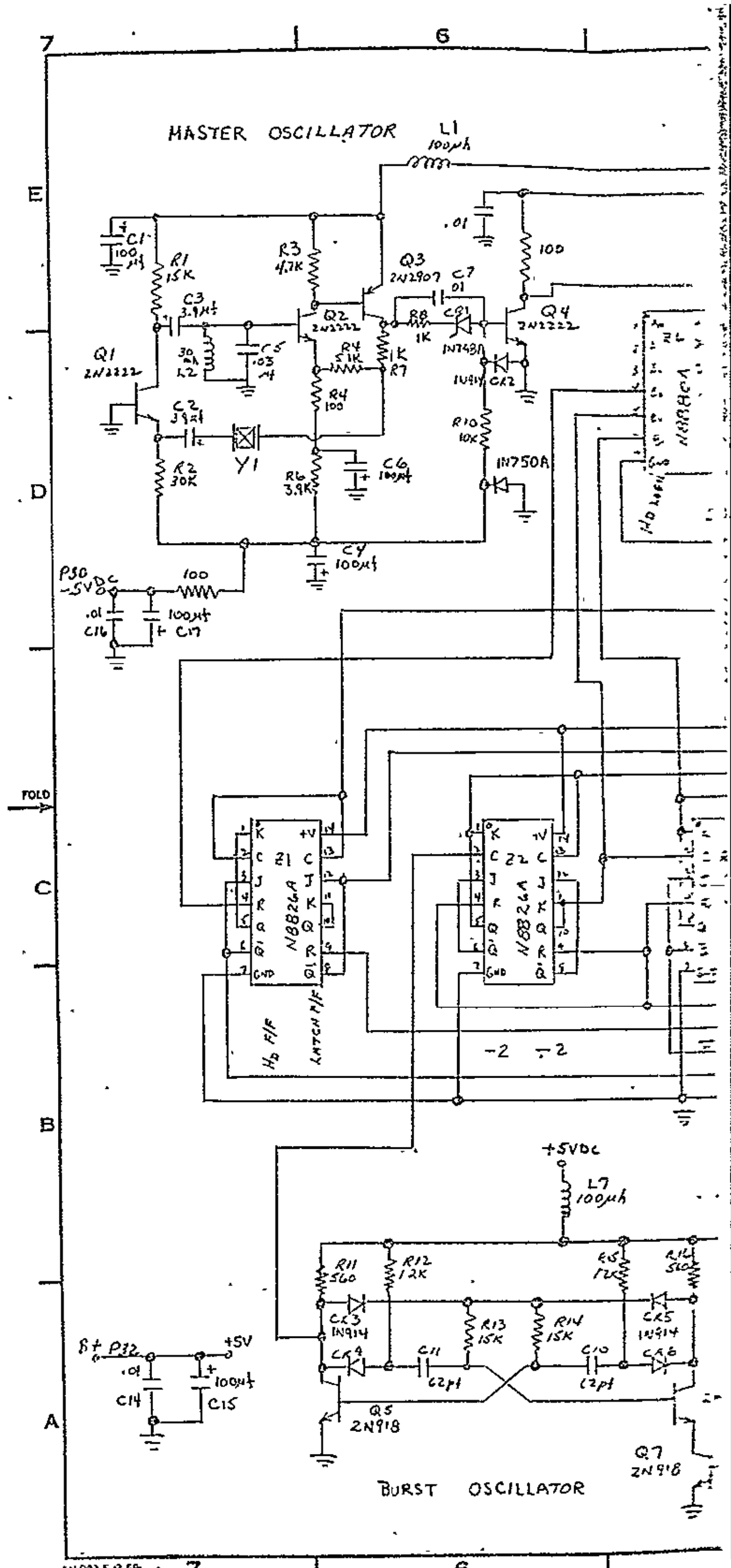
The master oscillator is a modified, crystal-controlled Butler oscillator. It will be operated at any one of the following three frequencies: 5499 Hz, 5525 Hz, or 6223 Hz. These frequencies were selected to generate the horizontal line rate of the camera system. The frame rate is fixed at 1 Hz. The horizontal frequencies were selected to accommodate scan formats of 4:3, 1:1 or 3:4, with the accompanying variation in number of scan lines. A frequency of 5499 Hz was chosen to provide a 1 x 1 format.

The countdown circuits utilize the Signetics 8281 integrated circuits. These units contain four flip-flops per package. By connecting the preset input to B+ or ground, any count from 1 to 8192 can be obtained. The countdown circuit is laid out on a printed wiring board and proper selection of jumper wires will generate any of the above frequencies selected.

A burst oscillator (750 kHz) is turned on with each line (horizontal) timing pulse. The burst oscillator output is fed into a countdown circuit from which the proper timing pulses are selected, via logic circuits, to generate the horizontal sync, drive, and blanking pulses. At the end of the horizontal blanking period, the burst oscillator is turned off. This technique was chosen to minimize jitter in the horizontal timing pulses.

The line drivers are designed to drive 50-ohm coaxial lines to the sweep circuits, video processor and monitor.

The vertical blanking pulse is one line period long and is generated by triggering a flip-flop with the countdown output and resetting the flip-flop with the next line pulse.



FOLDOUT FRAME 1

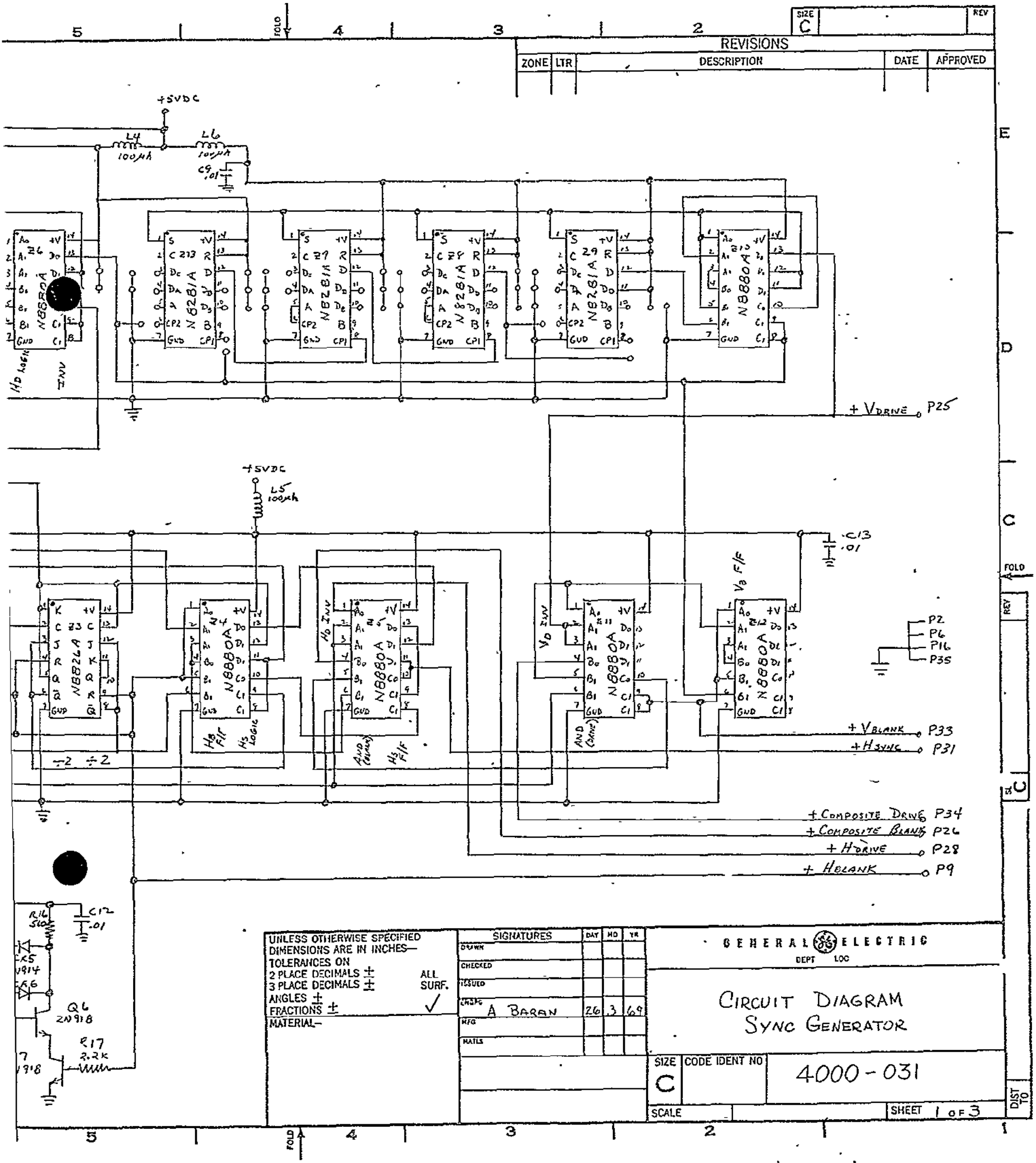
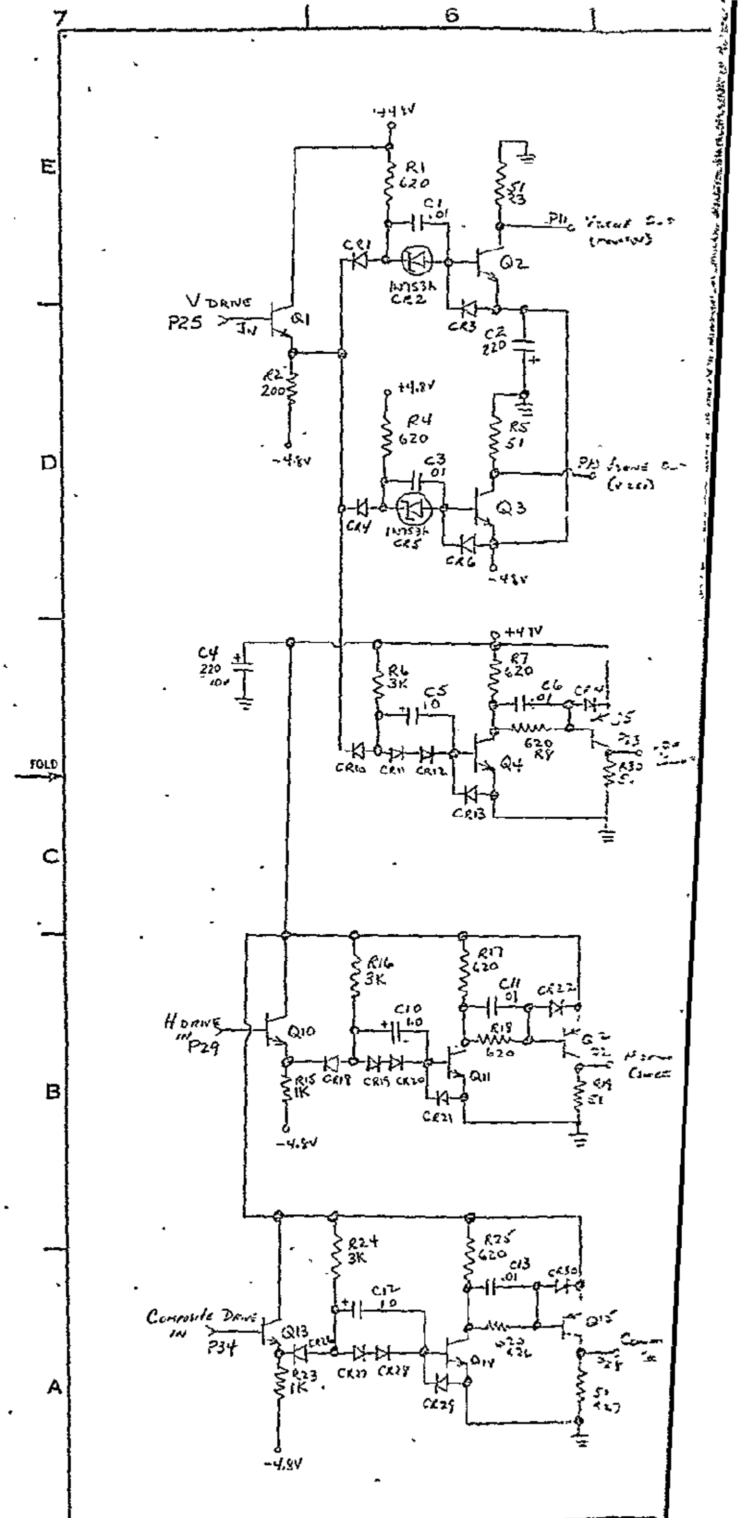


Figure 2-4. Sync Generator Circuit Diagram (Sheet 1 of 3)

FOLDOUT FRAME 2



FN 903 F (3-68)
PRINTED IN U.S.A.

FOLDOUT FRAME 2

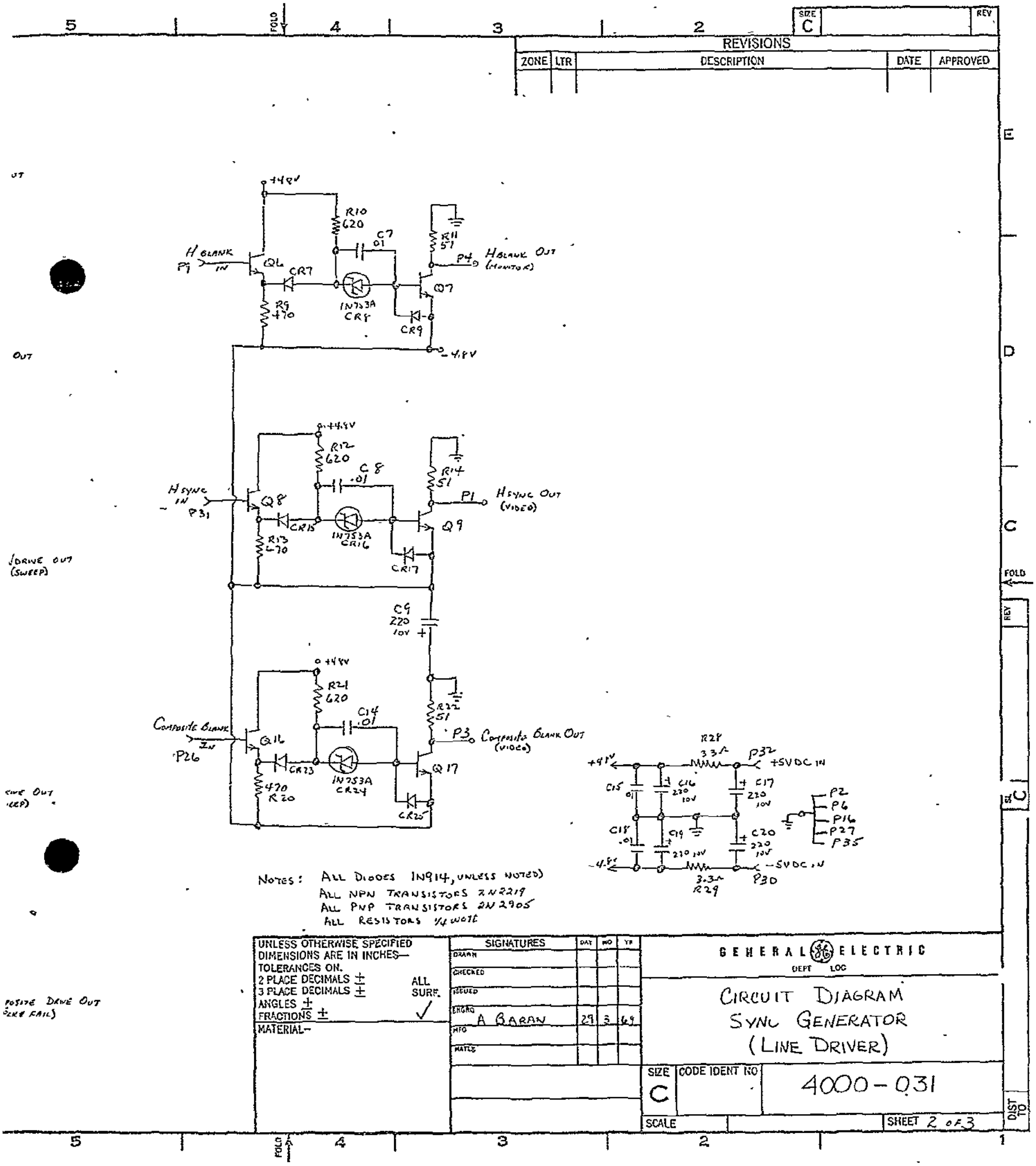


Figure 2-4. Sync Generator Circuit Diagram
(Sheet 2 of 3)

COUNTDOWN	5499	5525	62[illegible]
TIE ↓ TO →			
Z6 - 13	Z13-6	Z13-6	Z13-
Z 13 - 5	NC	NC	NC
Z 13 - 4	—	—	—
Z 13 - 10	+5V	+5V	+5V
Z 13 - 3	0	+5V	0
Z 13 - 11	+5V	0	0
Z 7 - 4	0	+5V	0
Z 7 - 10	0	0	+5V
Z 7 - 3	0	+5V	+5V
Z 7 - 11	0	+5V	0
Z 8 - 4	+5V	0	+5V
Z 8 - 10	0	0	+5V
Z 8 - 3	+5V	+5V	+5V
Z 8 - 11	0	0	+5V
Z 8 - 12	Z9-6	Z9-6	Z9-
Z 9 - 4	—	—	—
Z 9 - 10	+5V	+5V	0
Z 9 - 3	0	0	0
Z 9 - 5	NC	NC	NC

NOTES:

NC = NO CONNECTION
0 = GROUND
+5V = B+, +5V DC
— = EITHER GROUND OR B+

FN-903-F (3-68)
PRINTED IN U.S.A.

FOLDOUT FRAME 2

223	7000	9000	
13-6	3-6	Z13-8	
NC	NC	Z13-6	
—	—	0	
+5V	0	0	
0	0	0	
0	0	+5V	
0	+5V	+5V	
+5V	0	0	
+5V	+5V	+5V	
0	0	+5V	
+5V	+5V	0	
+5V	0	0	
+5V	0	+5V	
+5V	+5V	+5V	
9-6	Z9-6	Z9-6	
—	—	—	
0	0	+5V	
0	0	0	
NC	NC	NC	

SIZE C | REV

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES—
TOLERANCES ON
2 PLACE DECIMALS ±
3 PLACE DECIMALS ±
ANGLES ±
FRACTIONS ±
ALL SURF. ✓
MATERIAL—

SIGNATURES	DAY	MO	YR
DRAWN			
CHECKED			
ISSUED			
ENGRG A BARAN	8	4	69
MFG			
MATLS			

GENERAL ELECTRIC
DEPT LOC

CIRCUIT DIAGRAM
SYNC GENERATOR

SIZE C | CODE IDENT NO | 4000-031

SCALE | SHEET 3 OF 3

DIST TO

Figure 2-4. Sync Generator Circuit Diagram
(Sheet 3 of 3)

FOLDOUT FRAME 2

The vertical drive pulse is one-half the line period in width. The vertical drive flip-flop is triggered with the countdown output and reset by the opposite polarity pulse of the master oscillator output. This pulse occurs for one-half the line period if the master oscillator output is a symmetrical square wave.

The following table lists the parameters involved in the 1 x 1 format chosen:

H and V Rates	
H. Freq.	5499 Hz
Aspect Ratio	1 x 1
V. Freq.	1 Hz
V. Drive	<91 μs (.091%)
V. Blank	182 μs (.18%)
V. Flyback	91 μs (.091%)
H. Drive	6.5 μs (3.6%)
H. Blank	20 μs (5.5%)
H. Flyback	20 μs (11%)
H. Period	181.8 μs
Active Scan	161.8 μs

The vertical pulses are quite short (0.18 percent) compared with the more standard 7.5 percent. This is to allow the maximum number of useful raster lines. It was planned to use short horizontal pulses (5.5 percent) to permit the maximum number of horizontal resolution elements. Practical considerations such as difficulty in obtaining short retrace in the deflection circuit have limited the useful retrace time to no less than 20 microseconds (11 percent). The useful sweep time is therefore $\approx$160 microseconds.

2.2 DEFLECTION CIRCUITRY

Drive requirements for the FPS-5 deflections exceed those of most other cameras. In order to scan a square inscribing the target, a sweep voltage of 350 volts, peak-to-peak/plate is needed. At the same time, the capacitance between the deflectrons is 300 picofarads, a considerably high value. At the horizontal rate of 5499 Hz, the retrace waveforms (10 microseconds) can be distorted due to the low capacitive reactance. The result would be a loss of net sweep amplitude, a widening of the retrace time and unwanted pickup in the video channel. This is overcome by driving the deflectrons with a low impedance amplifier.

The circuits (both H and V) consist of a constant-current integrator, reset by the appropriate drive pulses. The integrator is followed by an amplifier with feedback which increases the deflection voltage to the proper value, while maintaining linearity. On-board controls are shown on Figure 2-5 (Schematic No. 4000-025). Emitter followers supply the push-pull deflection voltages via coupling capacitors to the deflectrons. Dc bias voltages are added to the deflectrons to provide an "Electron lens". By adjusting these voltages, astigmatism may be minimized and centering of the raster achieved.

2.2.1 COMMERCIAL RATES

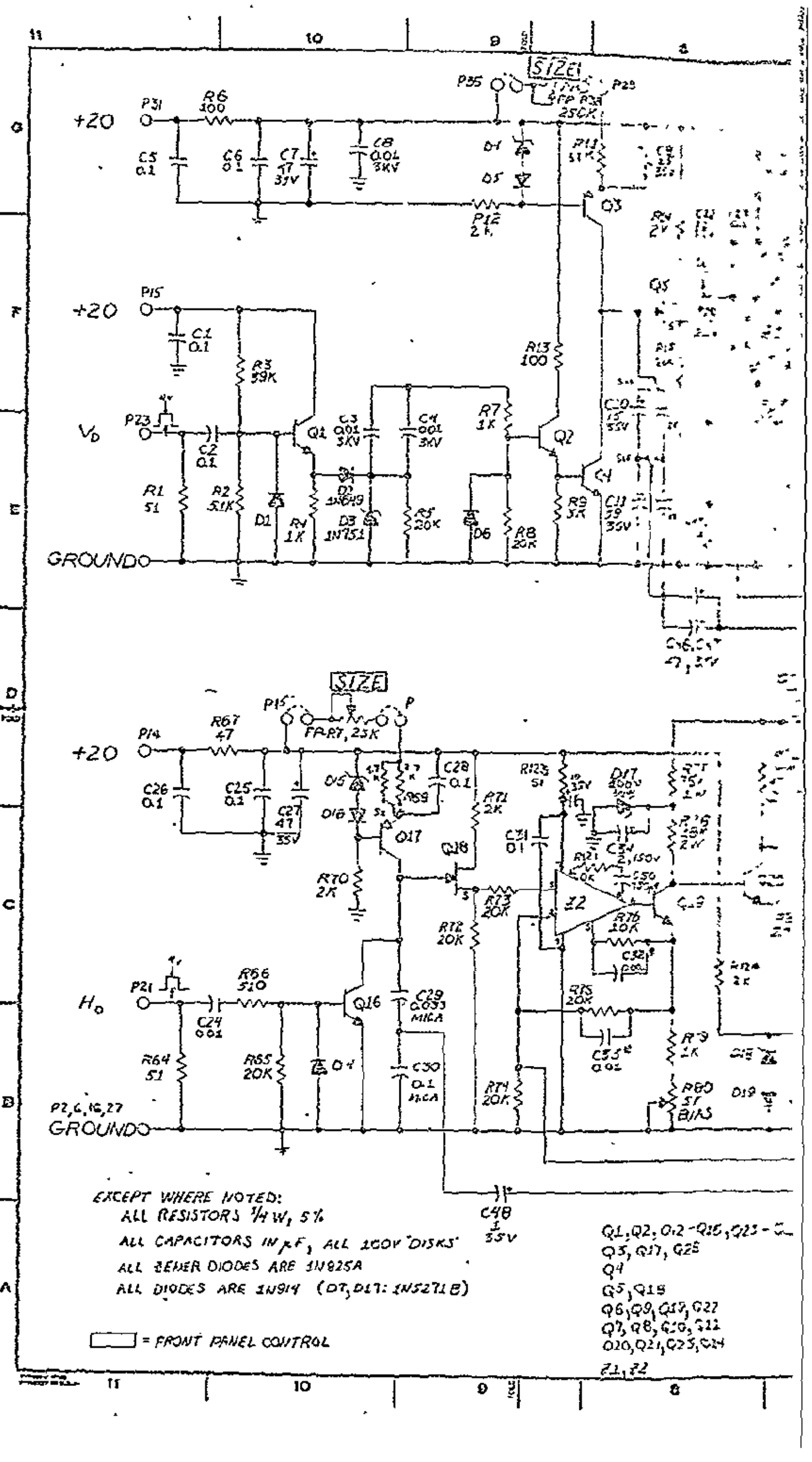
During the testing phase, switchable integrating time constants were added to the sweep boards to allow the generation of commercial scanning rates (15750 Hz horizontal, 60 Hz vertical). With an external sync generator connected properly (replacing the internal sync drive and blank signals) the camera output may be displayed on a commercial monitor. The resolution would then obviously be only 300-400 lines, but if the test chart is underscanned, resolution information can be obtained. This technique was not pursued during the initial testing phase.

2.2.2 SHADING CORRECTION

A shading control was originally included on the X and Y deflection boards but not put into use. Instead the alignment controls were used to correct for non-uniformity.

2.3 VIDEO PREAMPLIFIER

The preamplifier schematic is shown in Figure 2-6 (Schematic No. 4000-037). Two MOSFET's are operated in parallel to provide a high effective gfs and a low noise resistance. These are followed by a compensation amplifier whose rising response compensates for the input RC roll-off. The last two transistors form a low impedance driver with a direct coupled output. Due to the large amount of gain in the preamp, considerable decoupling of the power lines is required.



FOLDOUT FRAME 1

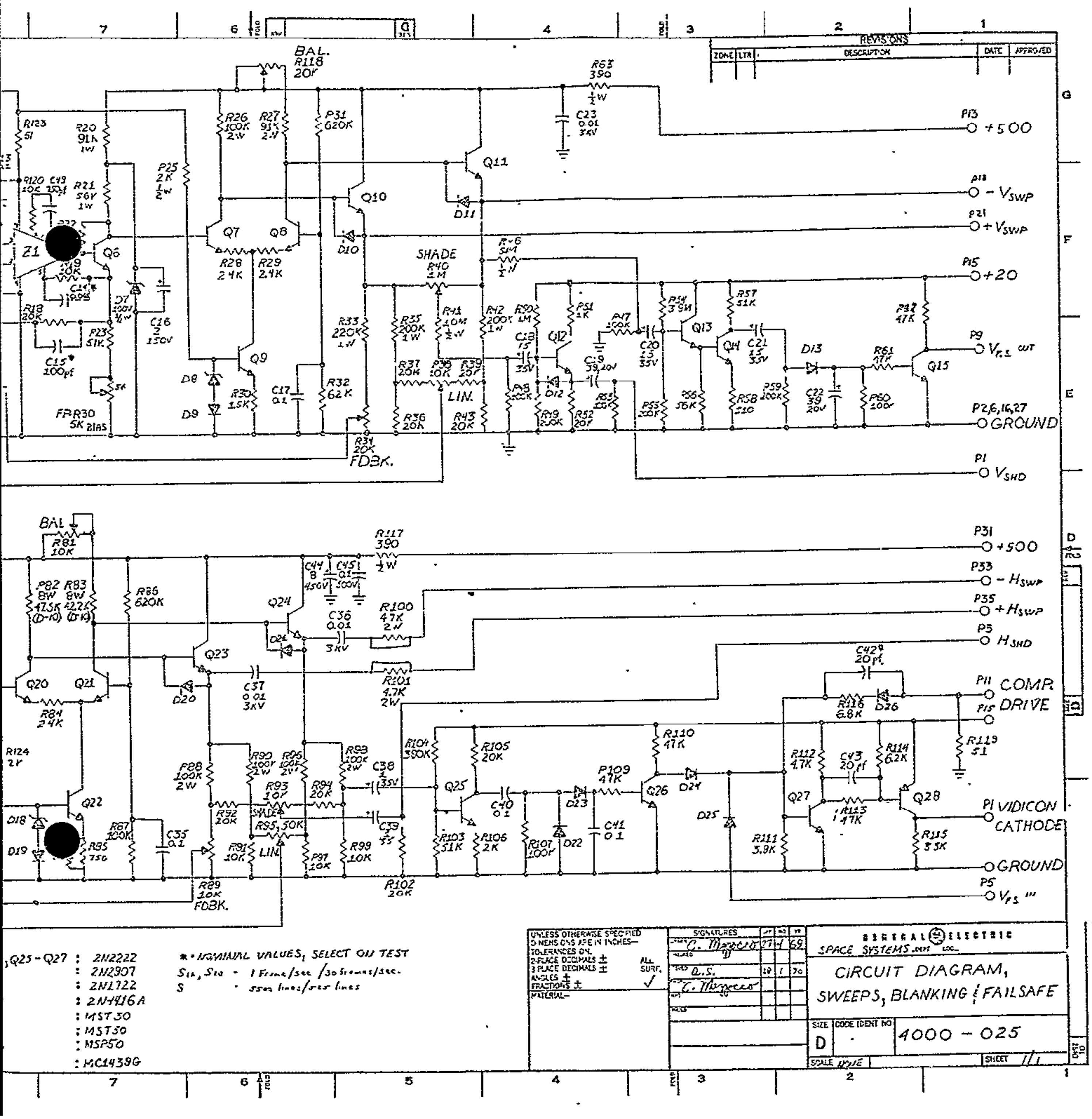


Figure 2-5. Sweeps, Blanking and Failsafe Circuit Diagram

FOLDOUT FRAME 2

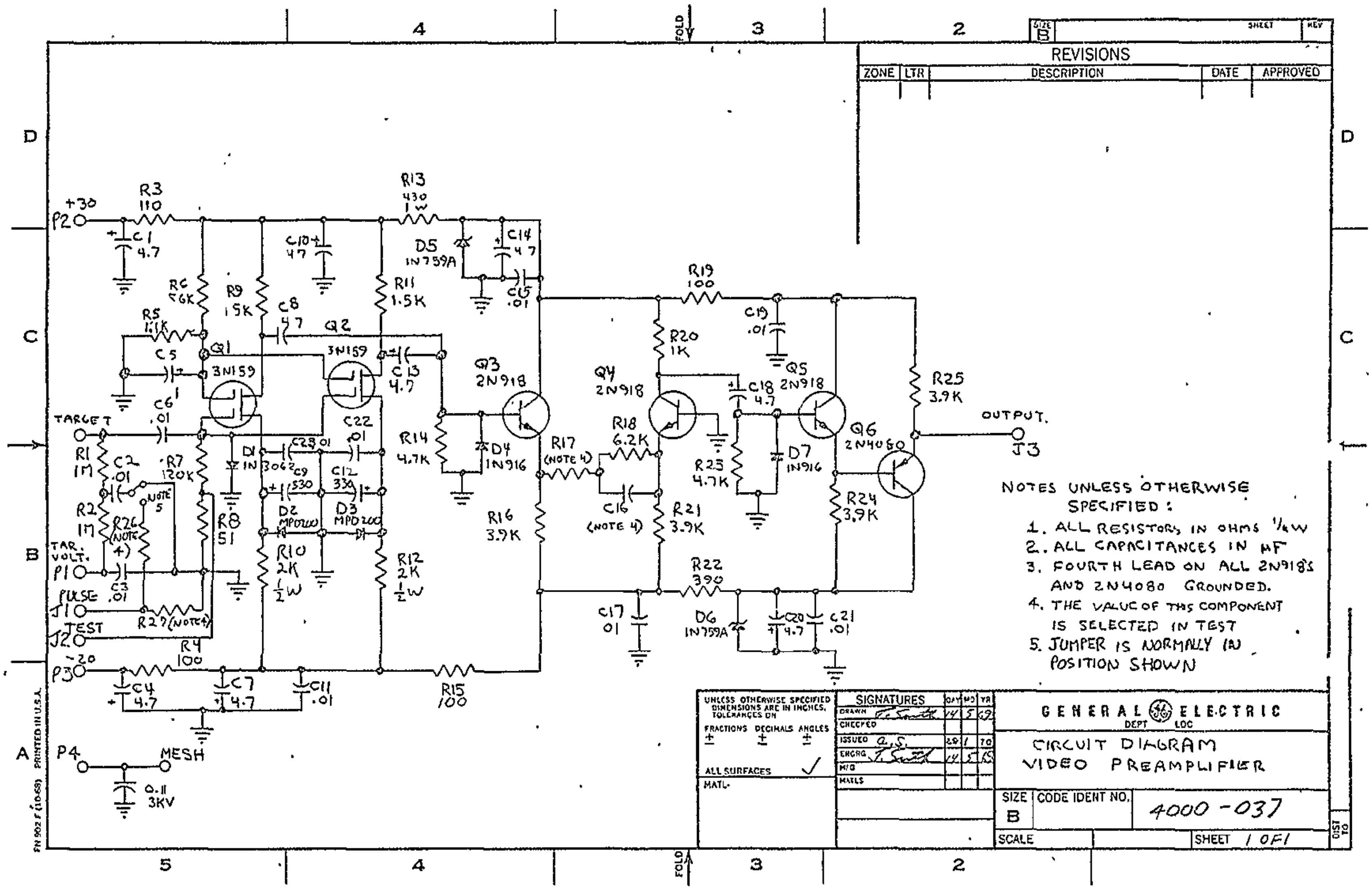


Figure 2-6. Video Preamplifier Circuit Diagram

Assuming a signal shunt capacitance of 25 picofarads or less, the preamp meets the original specification, that is, an equivalent noise current of less than 4.4 na over a 13 MHz bandwidth.

2.4 VIDEO PROCESSOR

A block diagram of the video processor is shown in Figure 2-7. A detailed circuit diagram is shown in Figure 2-8 (Schematic No. 4000-036).

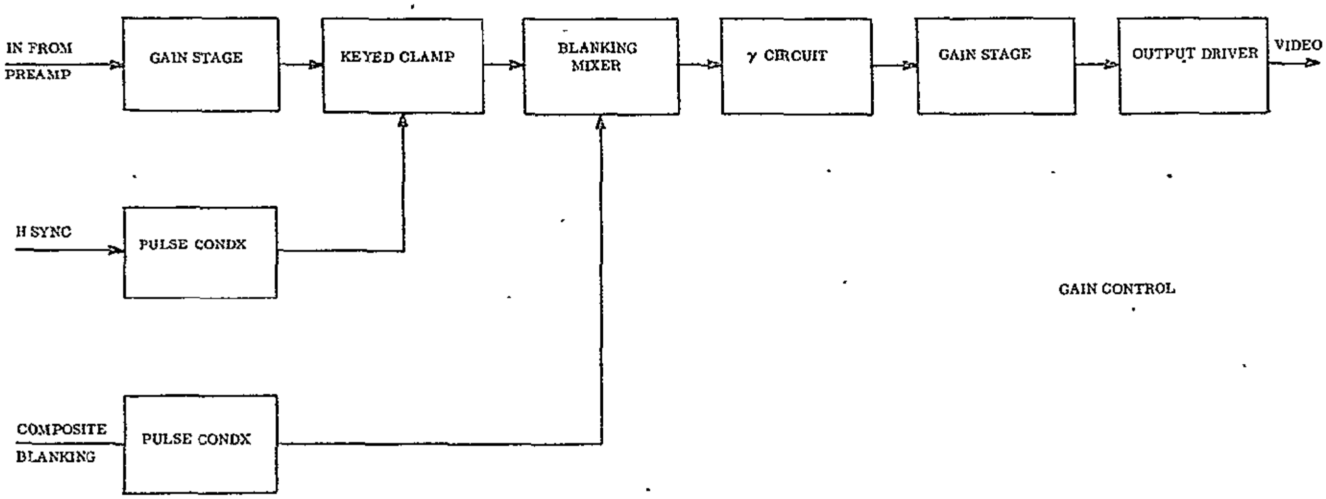
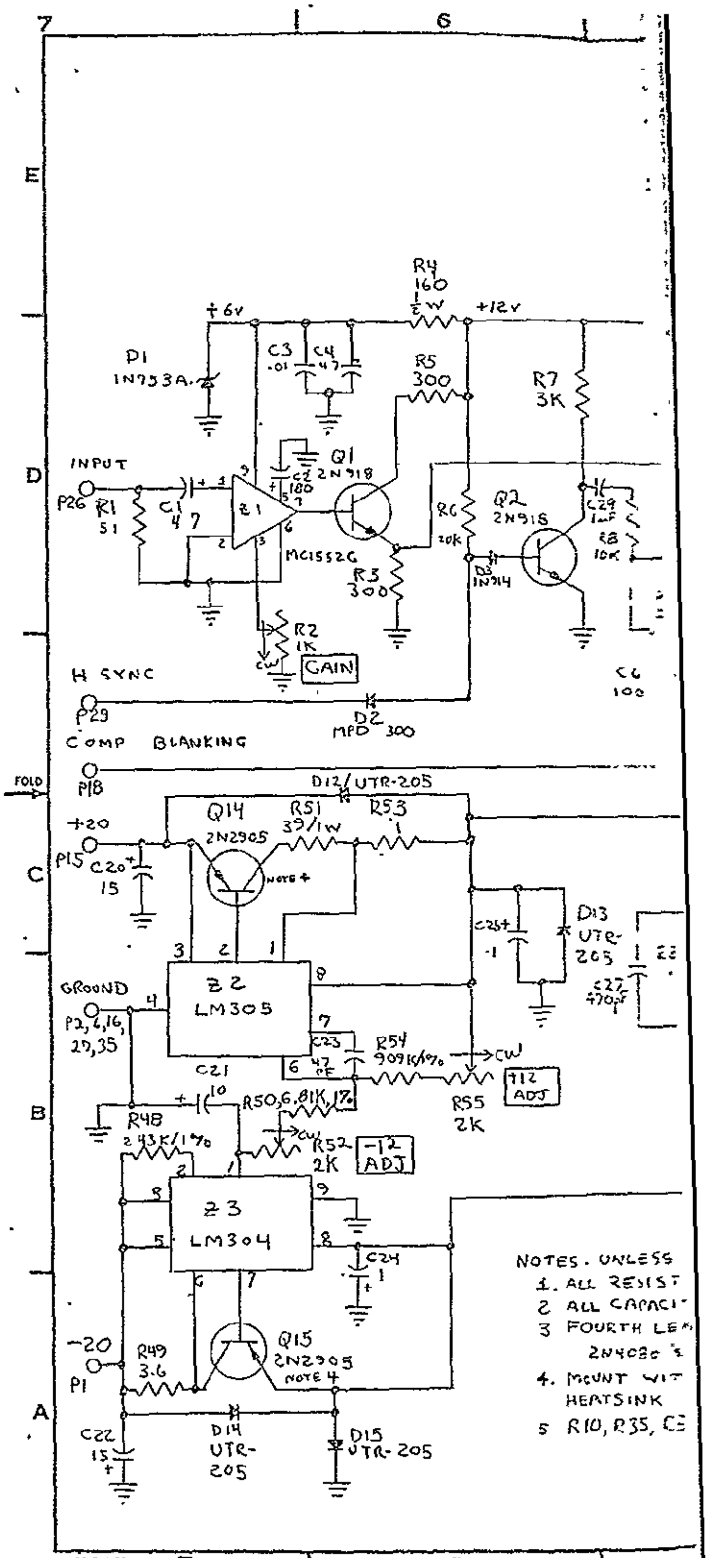


Figure 2-7. Video Processor Block Diagram



FN703 F (5-68)
PRINTED IN U.S.A.

FOLDOUT FRAME

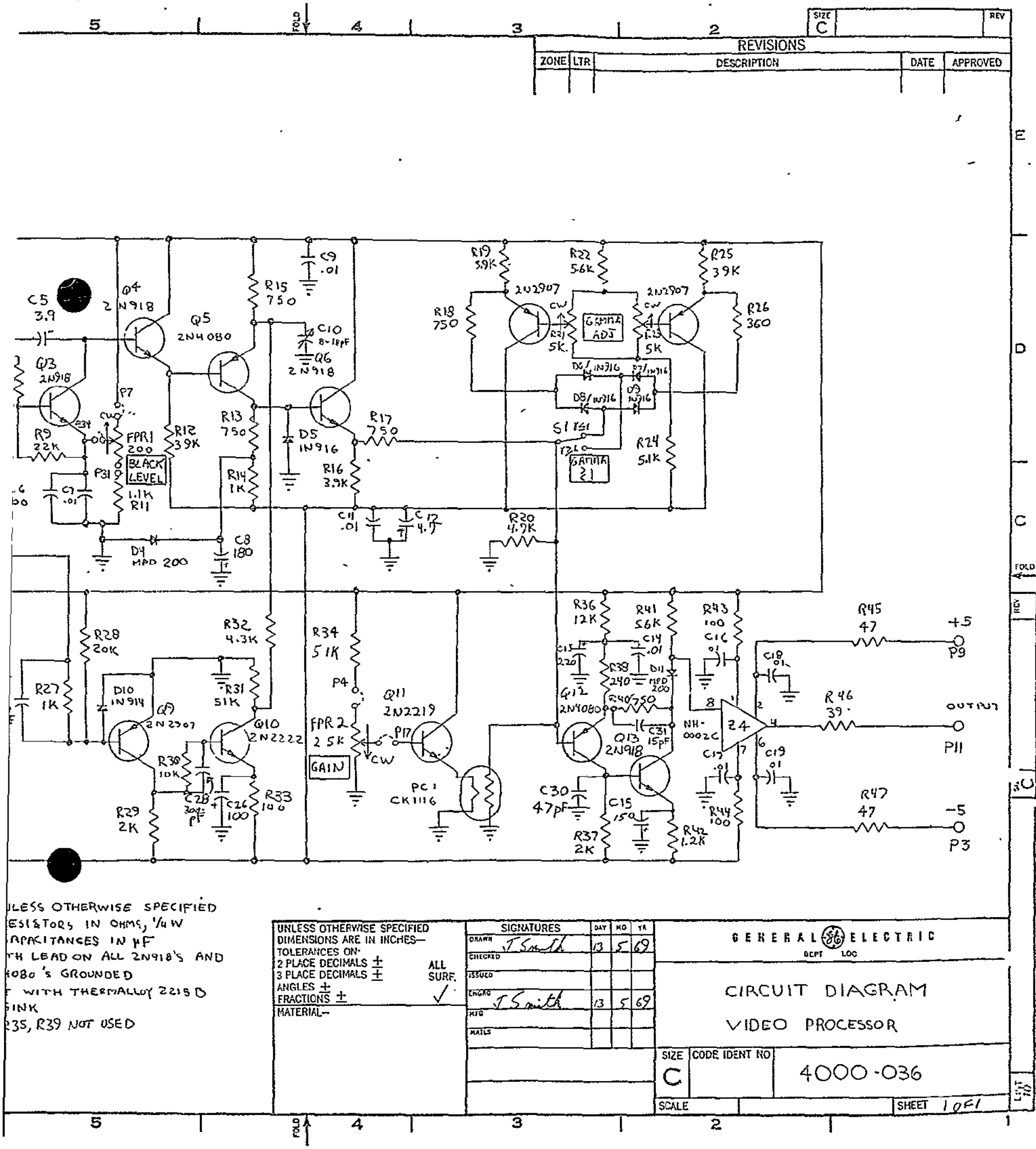


Figure 2-8. Video Processor Circuit Diagram

FOLDOUT FRAME 2

The initial gain stage consists of Z1, a wideband adjustable gain inverting amplifier. This feeds Q1, an emitter follower to provide the proper impedance level for the keyed clamp. Q2 is the pulse conditioner of the keyed clamp, Q3. The function of Q3 is to clamp the video to a fixed dc voltage for a portion of the retrace interval. This voltage is held for a line period by the 0.47 microfarad capacitor. This dc level (black level), is updated every line. Q4 is an emitter follower to provide isolation. Q5 is the blanking mixer. A small amount of emitter peaking is used here to make up for any loss of bandwidth. The blanking pulses are conditioned by Q9 and Q10. Q6 is an emitter follower used to provide a low impedance for the gamma circuit. The gamma circuit itself consists of a non-linear adjustable threshold voltage divider. Q7 and Q8 provide adjustable low dc impedance voltage sources for the load resistors. Q12 and Q13 form a gain stage. Q11 drives a silicon raysistor to provide a remote adjustable video gain control. Z2 is a low output impedance thick film driver.

The video processor will provide 1 volt peak-to-peak video signal into a 50-ohm load with a bandwidth of 15 MHz. Since this circuit is direct-coupled from the keyed clamp to the output, it should provide excellent low frequency response.

2.5 BIAS SYSTEM POWER SUPPLIES

Figure 2-9 shows the basic bias network. They are shown in more detail in Figure 2-10 (Schematic No. 4000-038, 2 parts). Six power supplies, shared with other camera circuits, are used to provide sensor tube voltages and currents. Nominal operating values are indicated. Most of the controls consist of both coarse and fine adjustments. Of these, focus, prefocus and target are the most critical, see Figure 2-11 (Schematic No. 4000-032). Grid 4 is least critical and is operated from a fixed supply at its nominal value. Grid 1 may be biased with either positive or negative values, so a bipolar power source is used. Grid 2 (anode) operates nominally at 2 kv, but may be varied along with Grid 1 to control beam current. The last power supply provides a dc bias for the deflectrons, Grid 5 and mesh, all of which are practically at the same potential.

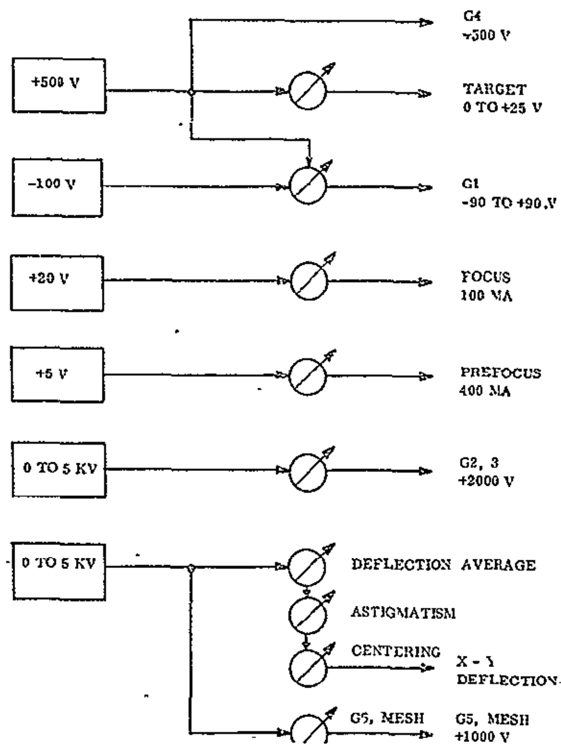


Figure 2-9. Bias Network

2.6 LINE DRIVERS

This collection of circuits on a printed circuit board interfaces between the sync generator and video processor and display/readout. It provides correct polarity pulses at the proper source impedance and voltage levels.

2.7 FAILSAFE AND BLANKING

A 30-volt dc level is produced on the vertical deflection board in the event that vertical sweep fails. This voltage is produced by rectifying the output deflection voltage. The 20 volts is summed with a similar voltage on the horizontal board through diode gates so that if either sweep fails, the composite blanking circuit will be disabled, putting the cathode at 20 volts. These circuits are shown with the deflection circuitry on Schematic No. 4000-025.

POWER SUPPLY ASSIGNMENT

NUMBER[1]	TYPE	VOLTAGE[2]	I
P.S. 1	DELETED		
P.S. 2	P-5.1-0.750A	(+)5	
P.S. 3	P-5.1-0 750A	(-)5	
P.S. 4	HFC-30.0-0 750A	(+)20	
P.S. 5	HFC-30 0-0.750A	(-)20	
P.S. 6	P-9.8-0.375A	(+)10	
P.S. 7	P-100.0-0.050A	(+)100	
P.S. 8	DELETED		
P.S. 9	HFC-500.0-0 050U	500	38 mA.
P.S. 10	DELETED		
P.S. 11	DELETED		
P.S. 12	HFC-15.0-1.5EY	(EXT. ADJ.)	
P.S. 13	HV50-502M	(EXT. ADJ.)	
P.S. 14	HV50-502M	(EXT. ADJ.)	

NOTES:

1. REF DWG # 4000-024
2. ADJ. TO THIS VOLTAGE BEFORE INSTALLATION

TURN ON SEQUENCE:

A. SWITCHED LINE, P.S.'s 2, 3, 4, 5, 6, 12
B. 1ST DELAY, P.S.'s 7, 9
C. 2ND DELAY, P.S.'s 13, 14

ALL RESISTORS 2W, 5%, COMPOSITION
ALL CAPACITORS 0.01 μF, 3KV

FN903 F (5-68) PRINTED IN U.S.A.

FOLDOUT FRAME 1

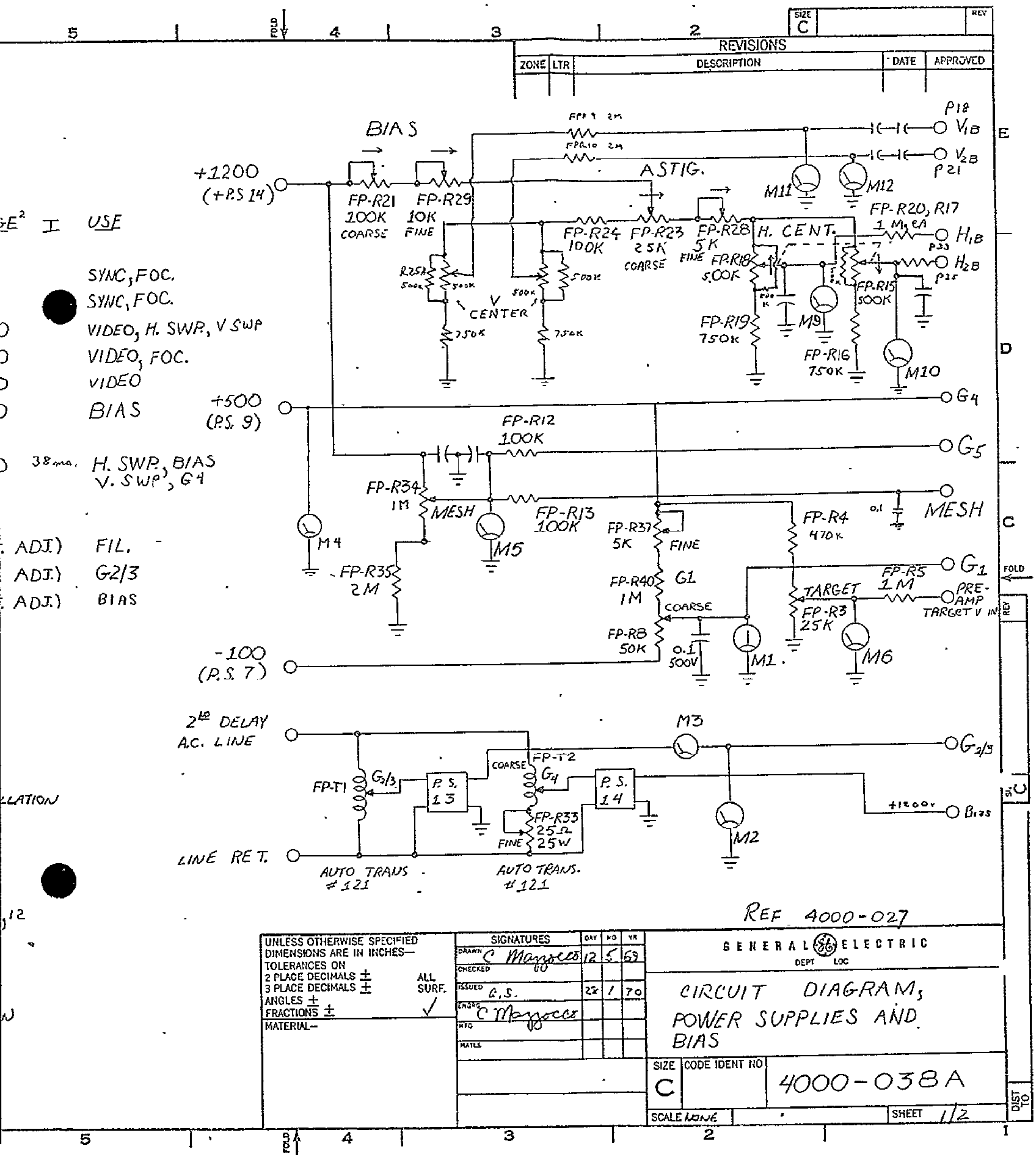
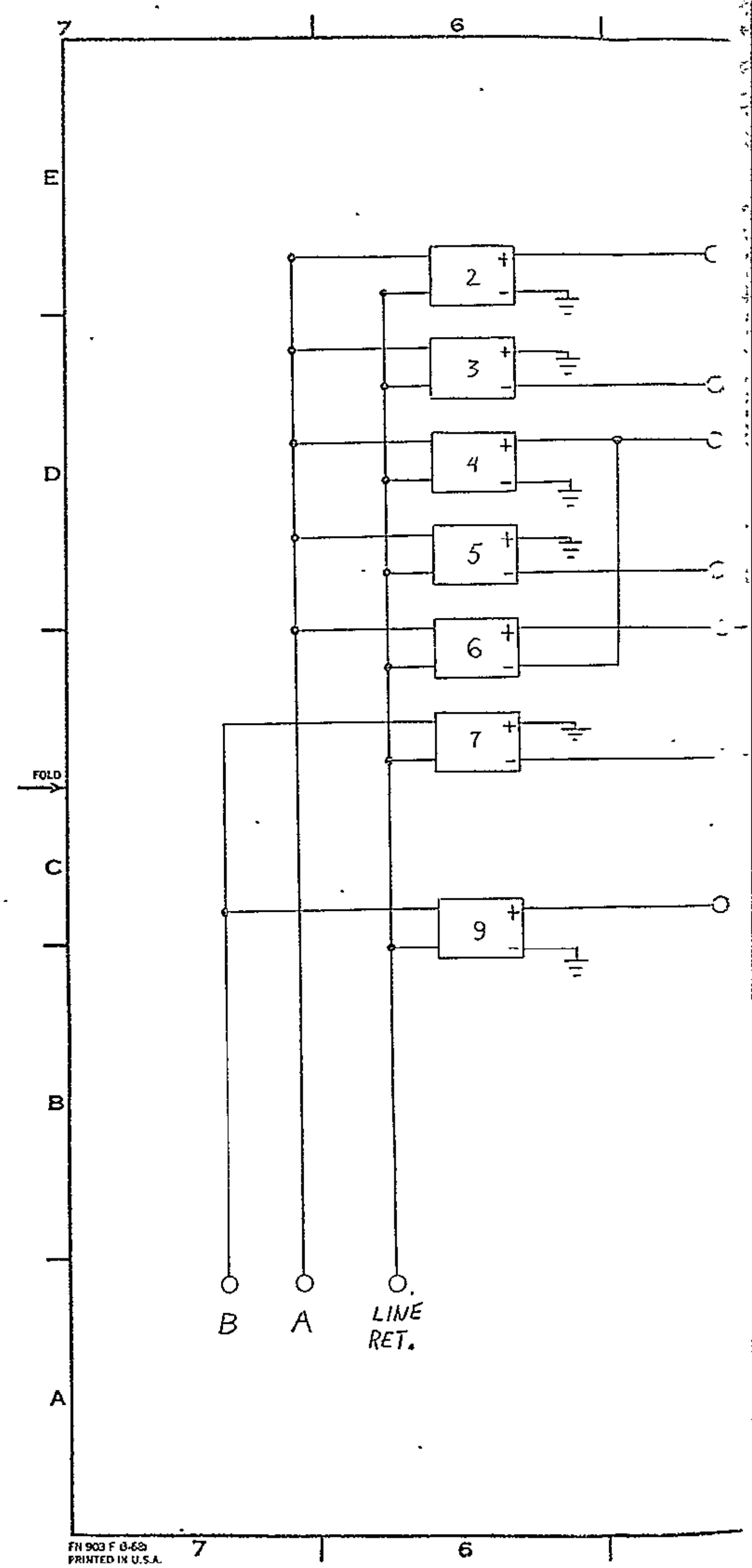


Figure 2-10. Power Supplies and Bias, Circuit Diagram (Sheet 1 of 2)



FOLDOUT FRAME (

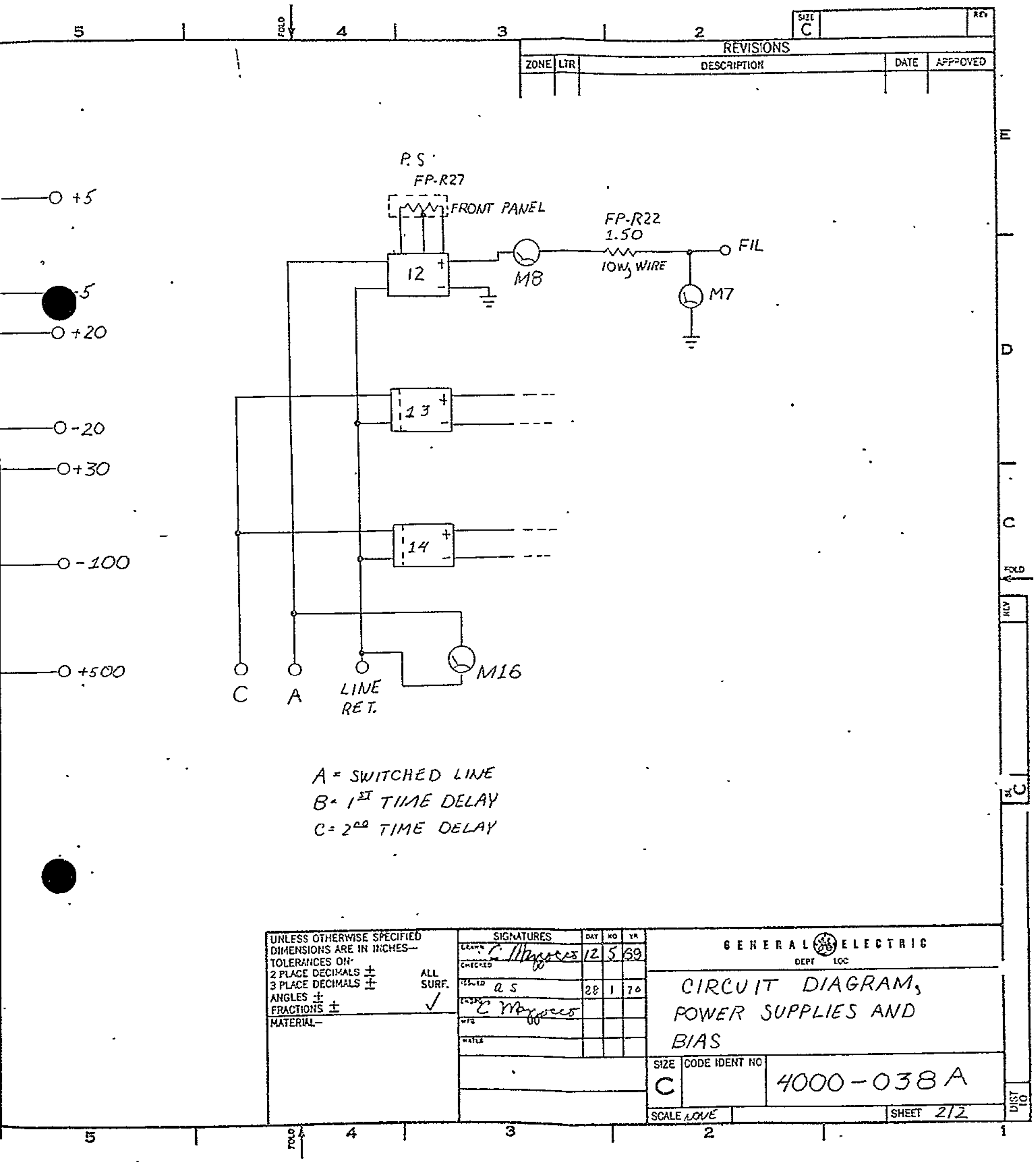
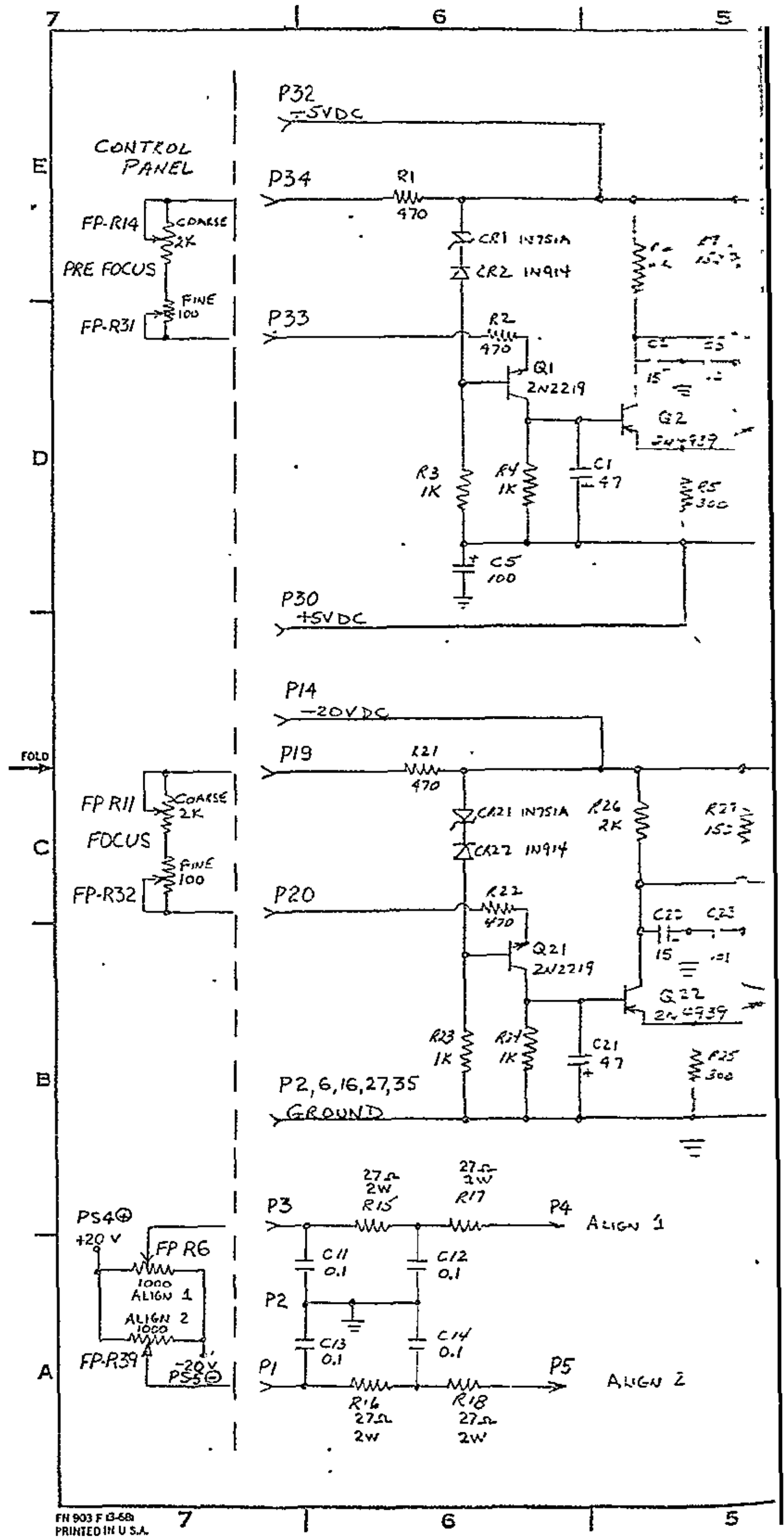


Figure 2-10. Power Supplies and Bias, Circuit Diagram (Sheet 2 of 2)



FN 903 F (3-68)
PRINTED IN U.S.A.

FOLDOUT FRAME

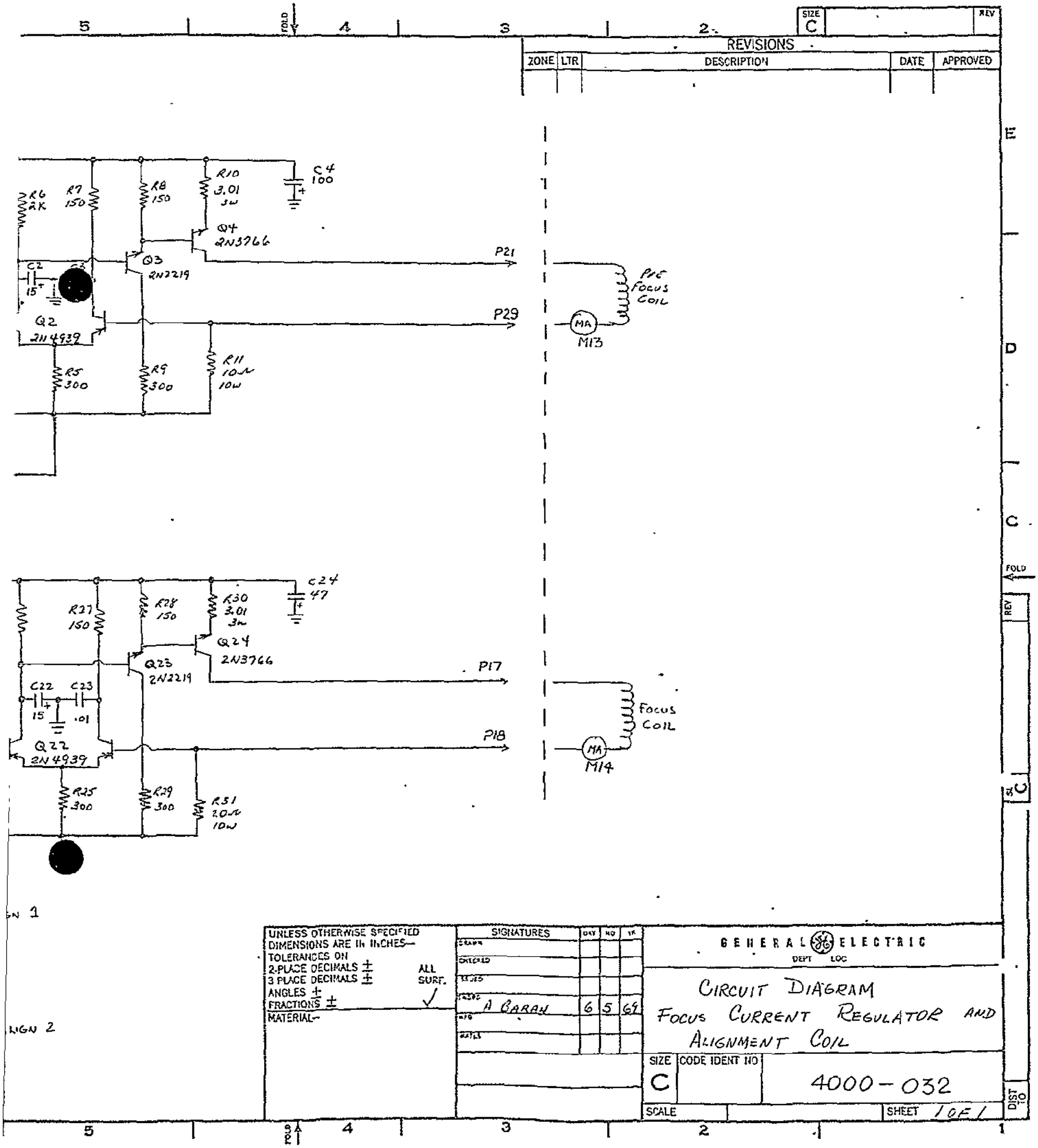


Figure 2-11. Focus Current Regulator and Alignment Coil

SECTION 3

CAMERA OPERATION

3.1 CAMERA STARTUP

This sequence consists of: 1) providing air pressure ($\approx$ 10 psig), and 2) activating the ON switch at the top right of the panel. Note the filament voltage and current at the appropriate meters. Readings should be 8 volts and 900 ma, respectively (ignore initial surge). Filament voltage is preset with a labeled, locked control. This should be readjusted only upon obtaining a new sensor tube, if the new tube's specifications are different. The peak filament voltage available is 15 volts, which would damage the sensor.

The following nominal values should be present immediately:

Focus Current	100 ma
Prefocus Current	400 ma
G1	0
G2/3	0
G4	0
G5, Mesh	0
Target	0
I_k	0

Also, at this time, sync pulses will be available from the camera.

After a delay of 25 seconds, the readings will be:

Focus Current	100 ma
Prefocus Current	400 ma
G1	+30 volts
G2/3	0
G4	+500 volts
G5, Mesh	0
Target	0 to +25 volts
I_k	0

The next time delay of 25 seconds will bring G2, 3 to +2000 volts and bias (on V and H meters) to +1000 volts. These are nominal values. The 1 second vertical sweep voltage will be noted oscillating on the V meters after the first delay. After the second delay, the dc reading on these meters will gradually rise over a period of perhaps 60 seconds to the bias voltage. This is due to ac coupling in the vertical deflectron circuit.

Full cathode (or G2) current is not immediately available, as the cathode must "warm-up", a process that requires at least 10 minutes. A cathode current of 600 μa to 900 μa appears to be best.

3.2 OPERATING PARAMETERS

Most of the voltages and currents to the sensor tube may be varied over a range of values and a video output will still be available. There are, however, optimum values that have been arrived at through on-the-air testing. It is recommended that all experiments begin with these values. Observed effects and interactions per parameter are discussed here.

3.2.1 GRID 1

This is the main control of cathode current, along with G2. At least 600 μa should be available. G1 may operate positive <u>or</u> negative, so long as the cathode current does not exceed 1000 μa. If G1 goes more positive, the current may be lowered by decreasing G2. Camera sensitivity is somewhat affected by these changes. Nominal G1 is 30 volts.

3.2.2 GRID 2

As mentioned, Grid 2 controls cathode current and may vary, going as high as 3600 volts. Approximately 99.9 percent of the cathode current is removed at G2 (first anode). The remaining current is focused on the target. No significant effects result from adjustment of G2 as long as such changes are counteracted by changes in G1. Nominal G2 is 2000 volts.

3.2.3 GRID 4

Grid 4 has no significant effects; fixed bias is 500 volts.

3.2.4 GRID 5

Grid 5 is biased at deflectron average value, $\approx$ 1000 volts. No control.

3.2.5 MESH

Mesh is biased at deflectron average value. Some control is provided, but it is not significant.

3.2.6 TARGET

The signal element, or target, operates between zero and 25 volts. There is an optimum value for maximum video output, which is a function of G1, beam current and alignment current. Nominal target voltage is 17 volts.

3.2.7 FOCUS AND PREFOCUS COILS

These coils provide the magnetic fields required to bring the beam to a focus at the target surface. One complements the other, so that a change in one current requires a change in the other, up to the point of achieving maximum resolution. It must not be overlooked that the lens be brought into focus. This may be accomplished by a first gross adjustment of electrical focus followed by a lens adjustment, etc., until best resolution is achieved. A high resolution test chart must be used, as explained later.

Lowering the focus current increases the deflection sensitivity. With the sweep voltages available, this must be done in order to see the entire target at once. Best focus cannot be maintained, however, at this setting. Nominal values are 400 ma prefocus, 100 ma focus.

3.2.8 DEFLECTRONS

The deflectron sensitivity is approximately 200 volts/inch per plate, or 400 vp between plates. The plate-to-plate capacitance is 300 pf. Horizontal sweep retrace is affected by this large capacitance and is effectively lengthened to 20 μsecond. The two voltages for a pair of deflectrons will not be affected equally, so the waveforms must be adjusted by small potentiometers on the circuit boards, <u>while in the camera</u>. Periodic adjustments should be made for best performance by using a dual trace oscilloscope (1500-volt input breakdown) with a probe on each of the two Y or H deflectrons. Location of these controls is shown in

Figure 3-1. The procedure consists of turning both sweep amplitudes to 75 percent (front panel) and adjusting controls in this order: feedback, balance, repeat. Adjust linearity if necessary. Feedback controls the maximum amplitude available. The oscilloscope may be used in either "sampled" mode or subtractive (tune for minimum differential error). Figure 3-2 shows vertical board control placements.

3.2.9 BIAS

The deflectrons form a part of the electron optics and as such require a dc bias voltage, nominally 1000 volts. Changing this value will cause loss of focus (correctable) and misalignment such as "portholing". Unbalancing the dc potential between X and Y deflectrons may also cause or correct this condition (astigmatism). Unbalancing the dc potential between X or between Y deflectrons causes de-centering. In the case of vertical centering, a time period of about 15 seconds should be allowed for the position to stabilize.

3.2.10 ALIGNMENT COILS

Alignment coils are critical for minimum shading, maximum signal and best focus. Attaining these goals is the criterion for adjusting alignment coil current.

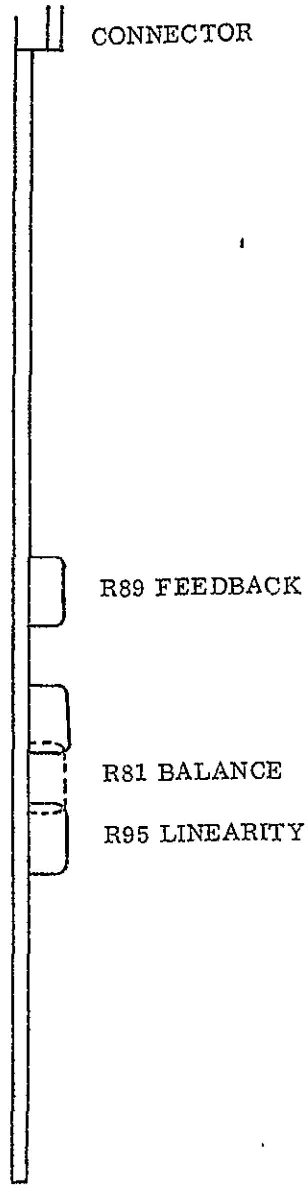


Figure 3-1. Horizontal Sweep Adjustments

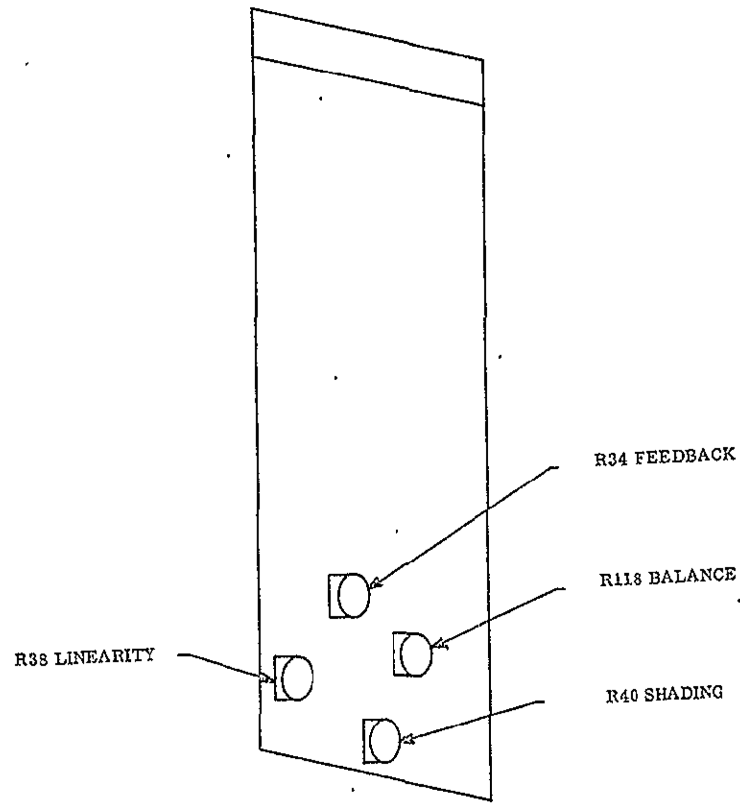


Figure 3-2. Vertical Sweep Adjustments

SECTION 4
CAMERA EVALUATION

Tests were conducted to study the following basic parameters:

1. Resolution
2. Gray Scale
3. Signal-to-Noise Ratio
4. Shading
5. Lag
6. Video Channel Characteristics

The procedure for each test will be discussed since the techniques vary. Two main problems were encountered. First, the lack of a high resolution display, and second the annoyance of making adjustments with a one-second delay. In most cases, the standard oscilloscope with 12mHz+ bandwidth and delaying sweep will suffice for an A-trace display. In some cases, however, it is good to have an X-Y display, to check centering, size, shading and other gross effects. By overscanning the display, smaller portions of the image at a higher display resolution may be observed. Most oscilloscopes will be limited by spot size, phosphor spreading and insufficient beam current. Adjustments must be made in small increments as some parameters are quite sensitive. This is indicated in the test procedures.

4.1 DETERMINATION OF ILLUMINATION

Using a Spectra Physics Spot Brightness meter, a brightness of 80 foot-lamberts was measured. The light-box source was operating on 76 vdc to eliminate 60-cycle modulation on the lamps that would be picked up by the sensor tube. At the commercial vertical scan rate of 60 frames/second, such modulation might only have a minor shading effect on the sensor video output, but at one frame/second, with an ac-operated light box, a false raster of 60 lines could appear in the display.

The light source was placed so that the horizontal dimension of 9 inches imaged on the target as 1.75 inches, giving an $M = \frac{1.75}{9} = 0.195$. The lens aperture was f/4 (see Figure 4-1).

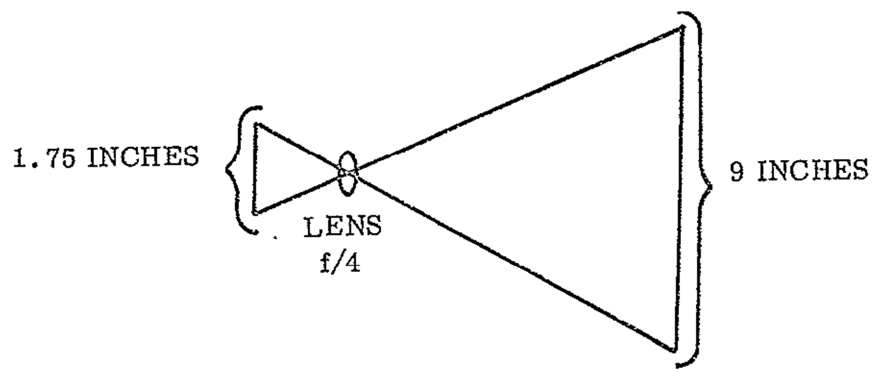


Figure 4-1. Optical Path

To find illumination, the formula for finite conjugates is used:

$$\Sigma = \frac{BT}{4f^2 (m + 1)^2}$$

where Σ = illumination

B = brightness = 80

T = transmission = 1

f = aperture = 4

m = demag. - 0.195

Σ = 0.87 foot-candles

4.2 SETTING UP THE TEST CHART

Standard test charts have usable dimensions of 7 x 9.3 inches. A gross estimate of position may be made by simple geometry, knowing the focal length of the lens. An accurate setting may be found by displaying the video output on an X-Y display. The available deflection voltage is insufficient to fully scan the 2.5-inch target, so a compromise was found. By adjusting the horizontal centering, both sides of the target may be seen (Figures 4-2 and 4-3) and the image size determined. The image should be in reasonably sharp focus. Knowing

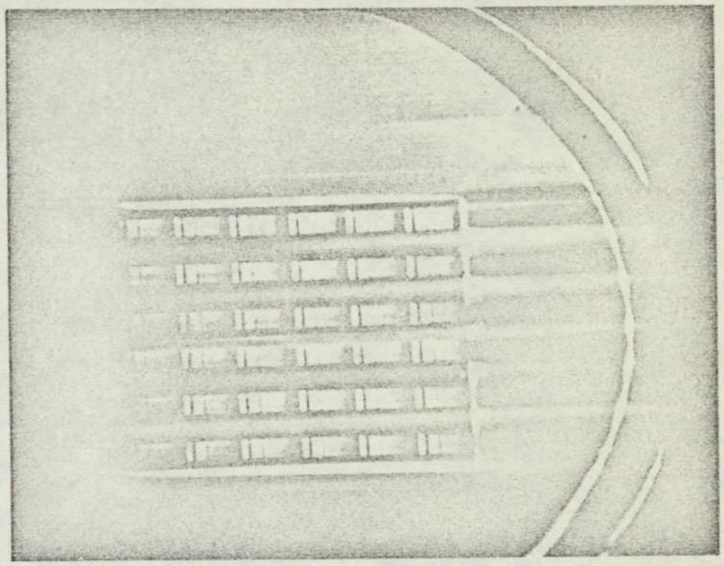


Figure 4-2. Image of Double Doyle Chart on Target. H Centering Shifted to Include Right Side of Target (Inner Circle)

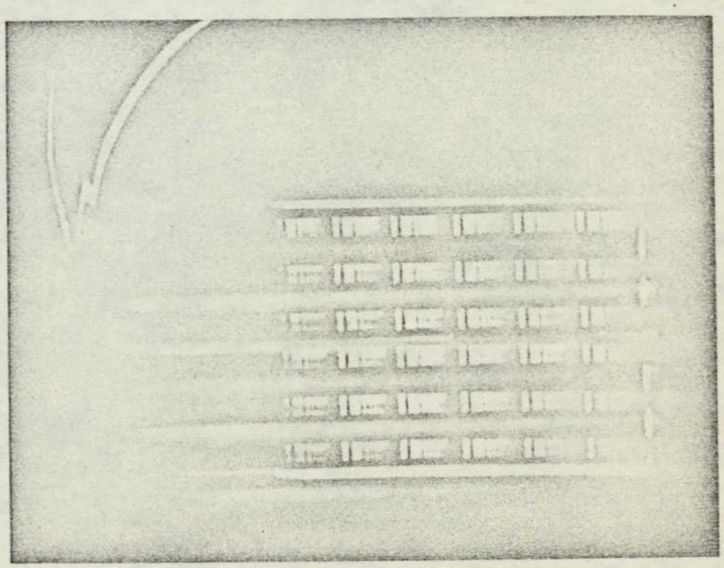


Figure 4-3. Image of Left Side

this, the desired scan voltage may be determined by the A trace, allowing 160 microseconds for scan. For example, if the chart is imaged less than 1.75 x 1.75 inches on the target, and the scanned area = 1.75 x 1.75 inches, the ratio of image size/1.75 inches determines the percentage scan time of the sweep on the image and may be set up on the oscilloscope. If the image equals 1.1 inches, the scan time equals:

$$\frac{1.1}{1.75} \times 160\ \mu s = \mu s$$

based on this, the sweep voltages may be set to produce desired scan coverage.

4.3 LIMITING RESOLUTION

A test chart with markings spaced to represent 4000 TV lines with a 1.75-inch image was not available, so the following expedient was adopted: A Doyle chart (maximum resolution - 1000 TV lines/picture height) was photographically reduced by 1/2, and four such slides combined to produce a 2000 TV lines/picture height chart. By imaging the chart at 1.1 inches on the target, the equivalent resolution of the chart across 1.75 inches on the target equals

$$4/3 \times \frac{1.75}{1.1} \times 2000$$

$$= 4200 \text{ TV lines total.}$$

In making the resolution measurement, of course, the entire 1.75 inch is scanned (in 160 microseconds).

Procedure

The camera should be set up at all nominal values, and the proper light source placed as indicated previously to bring the lens to focus. This can best be done by observing fine detail in the test chart on the A-trace (one line displayed). Now, Electrical Focus should be brought up as fine as possible. It may be necessary to repeat this process a number of times.

Alignment current and target voltage changes might be necessary to obtain maximum signal level. Laboratory results are shown in Figure 4-4.

4.4 GRAY SCALE

A RETMA chart was used, although any gray scale chart with the right step ratio may be substituted (see Appendix C). An auxilliary X-Y display might be useful to observe shading and correct deficiencies with alignment controls. Figure 4-5 consists of a single line through the horizontal gray scale.

4.5 SIGNAL/NOISE

With a white field (no test chart in lightbox) tune for maximum signal without saturating either Target or Video Amplifier. This involves Target, G1, and alignment coils. Figure 4-6 shows maximum signal obtained and Figures 4-7 and 4-8 show noise with a minimum signal and with the lens capped. The result was 39.4 dB. It was found convenient to mask off part of the left and right sides of the light-box to obtain a clearly defined signal well apart from the blanking pulses, which would have confused the reading.

4.6 SHADING

In this case, the image was 1.75 x 1.75 inches and fully scanned to measure edge-to-edge shading. Using Target, X and Y alignment coils, and Focus coil, the field was brought to considerable flatness. The double (2X) Doyle chart was used. (Figure 4-9).

4.7 LAG

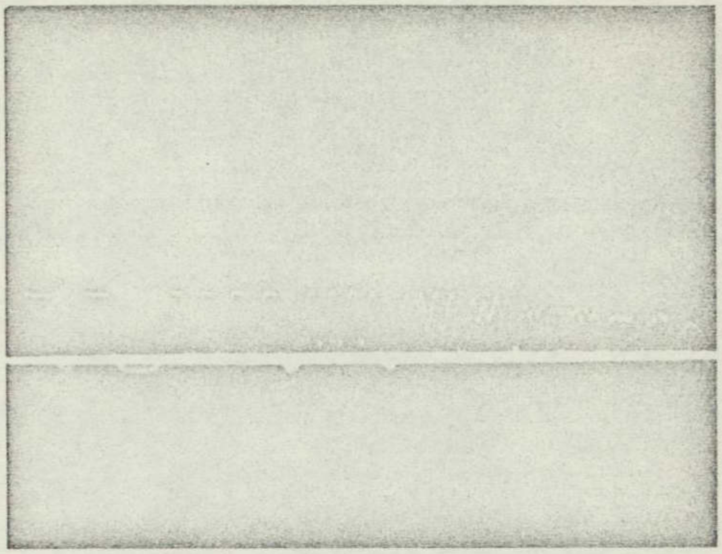
With the light box used as in Section 4.5, and grossly imaged at 1.1 inch, the scan was reduced to 1.1 x 1.1 inch. Using a Polaroid camera with electric remote shutter and an observer at the oscilloscope, the following procedure took place: Operator No. 1 observing the scope gave a synchronizing command at the appearance of a line trace. Operator No. 2 then shuttered the high resolution camera and film camera simultaneously. A time exposure for four frames yielded the decay pattern shown in Figure 4-10. This procedure was repeated six times to obtain an average, but all photos agreed within 5 percent. A manual technique such as this is, of course, possible only at slow-scan rates.

4.8 SYSTEM VIDEO RESPONSE

Using a Kay Marka-Sweep Generator applied to the preamplifier input (schematic 4000-037, J2) the preamplifier and processor in series were swept with frequencies from dc to 20 mHz. The bandwidth of Figure 4-11 is nominally 1 volt peak-to-peak, $\pm$ 1.6 dB from 8 Hz to 12 mHz with some continuing response beyond. The input signal was equivalent to 230 na-- full video gain.

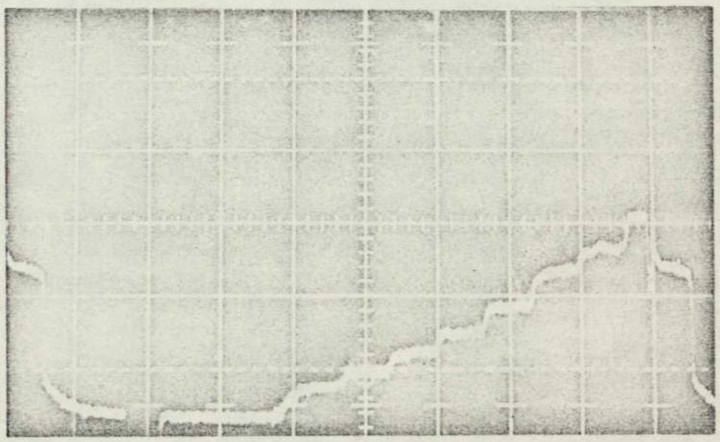
4.9 GAMMA CORRECTION

A low frequency triangular wave was inserted into the video processor (solid line, Figures 4-12, 4-13) and the gamma control set to its two extremes. The range of 1.29 to 0.7 was produced in the output (chopped by blanking pulses).



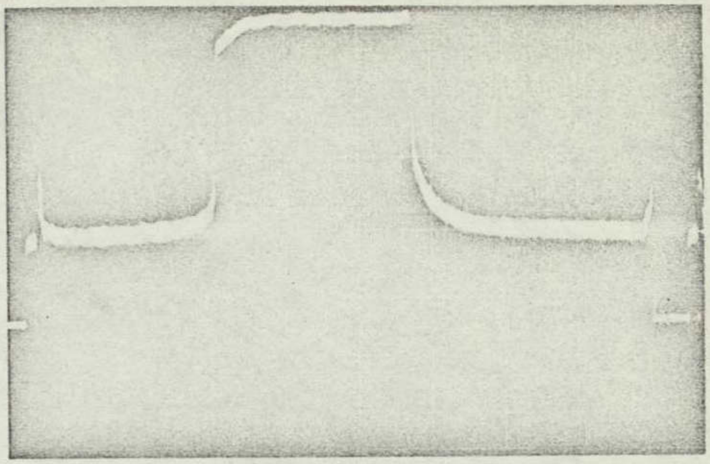
2 X Doyle Chart
One Horizontal Line Displayed
Last Burst = 4200 T.V. L.
1.0 v/cm
Full Chart Scan
Target scanned 1-3/4 x 1-3/4 inches
12 mHz B.W.

Figure 4-4. Resolution



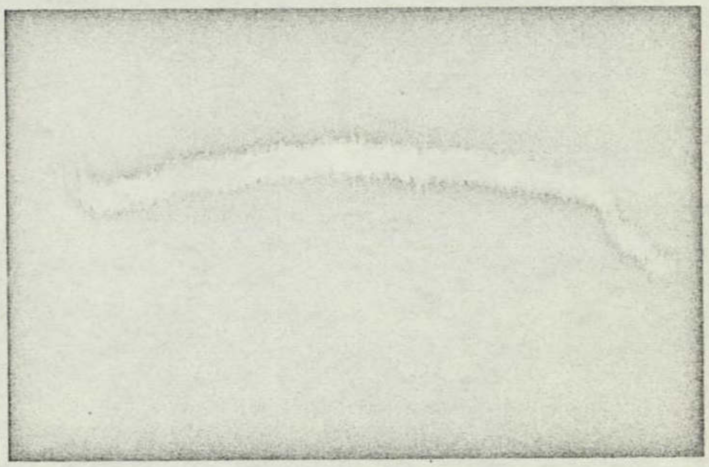
Video Signal
0.2 v/cm
20 μs/cm
9 Shades Visible

Figure 4-5. Gray Scale



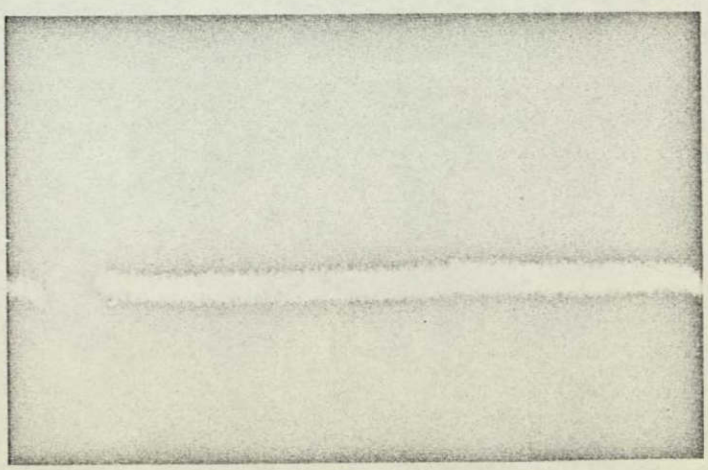
1.45 v peak into 51 Ω
Noise ~ 0.1 v p-p
S/N = 20 Log 6 S/N
= 39.4 dB
Scale 0.5 v/cm
20 ns/cm
Noise on Peak Video = 0.1 v p-p
One line/frame readout
5 consecutive frames
12 mHz B.W.

Figure 4-6. Signal Output



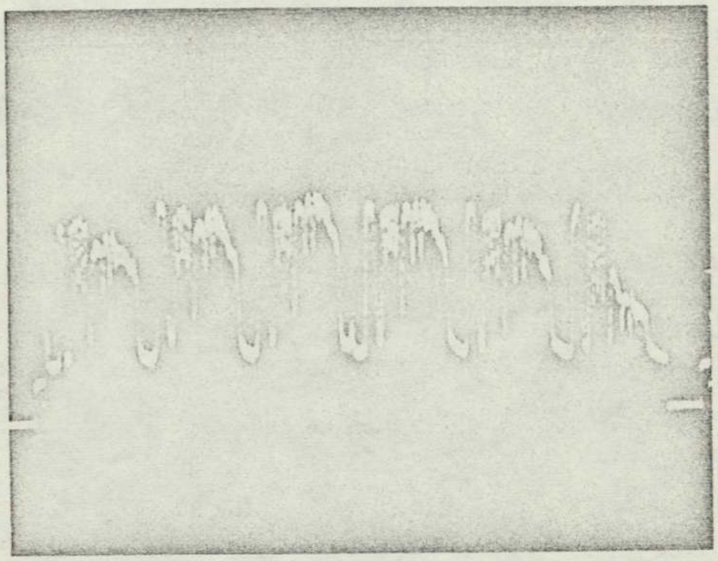
Signal output 0.2 v
Noise ~ 0.1 v p-p
Scale = 0.2 v/cm
= 20 μs/cm
12 mHz B.W.
Same Readout Technique.

Figure 4-7. Noise



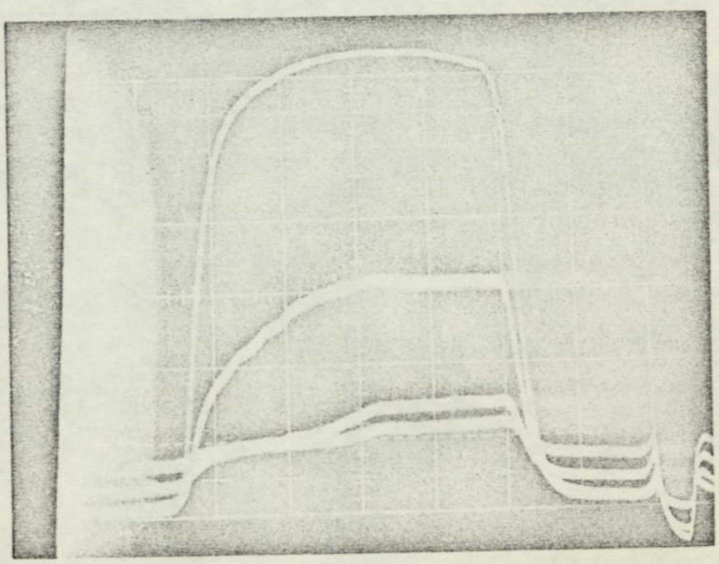
Lens Capped
Noise ~ 0.1 v p-p
Scale = 0.2 v/cm
= 20 μs/cm
Same Readout Technique
12 mHz B.W.

Figure 4-8. Noise



2 X Doyle Chart
Image on Target
1.75 x 1.75 inches
0.9 ft-candles
0.5 v/cm
~ ± 10% shading

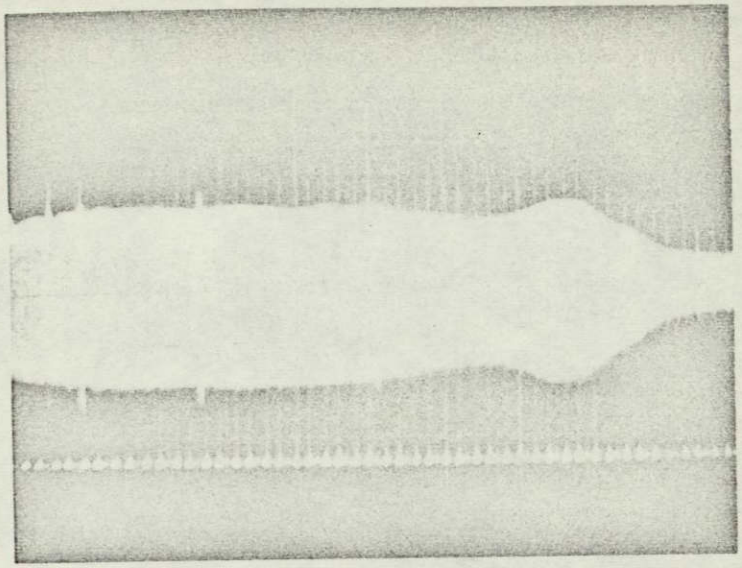
Figure 4-9. Shading



Light Source - white field
Display - one line/frame (4 frames)
Lens shuttered at first trace.
2nd trace 45%
0.2 v/cm
20 μs/cm

Figure 4-10. Lag

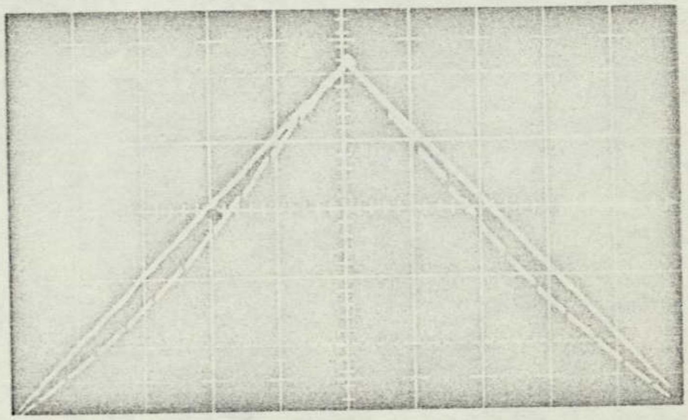
2



Input to preamp 230 NA
Output shown is composite video across 51 Ω termination, 0.5 v/cm.

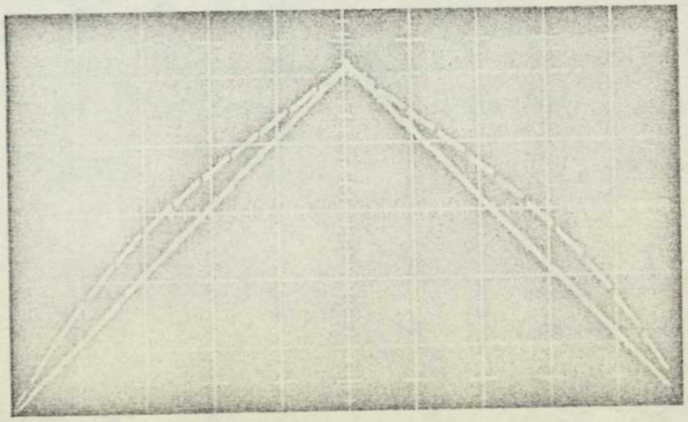
Response 0 ± 1.6 dB
12 mHz B. W.

Figure 4-11. System Video Response



Triangular Wave input
Output Gamma (γ) =1.29
0.2 v/cm

Figure 4-12. Gamma Correction



Same Input
Output Gamma 0.7

Figure 4-13. Gamma Correction

SECTION 5

DATA EVALUATION

5.1 RESOLUTION

As described in Section 4 the camera system resolution was measured with the use of the Doyle Chart, as modified for the higher spatial frequency capability. A line of video taken through one burst of frequencies on the chart was used and the peak-to-peak video signal was measured for each frequency. The signal-to-noise (S/N) measured at essentially zero spatial frequency was 37.0 dB. As previously indicated the S/N measured against a white field was 39.4 dB. Thus, it was assumed that the reduction was due to a chart contrast of 85 percent. The data was corrected for this chart attenuation and is presented for 100 percent contrast.

Figure 5-1 shows the relative square wave response as measured with the equivalent rms noise level indicated. The last data point taken was at approximately 3800 TV lines/picture height with the extrapolation to the noise level showing a limiting resolution of 4400 TV lines/ picture height. The square wave response in terms of S/N is shown in Figure 5-2. The contract specification of 26 dB S/N is seen to occur at 2500 TV lines/picture height.

The lens used for these measurements is a Nikkor, 63 mm focal length, f/3.5. The optical transfer function for this lens was measured as shown in Figure 5-3. The system square wave response data was converted to sine wave response by means of a Fourier transformation and then corrected for the lens optical transfer function. The results are shown in Figures 5-4, 5-5, and 5-6. From this data the sensor limiting resolution is projected as 4850 TV lines/picture height or 48 line pairs/mm.

An estimate of the limiting resolution for less than 100 percent contrast was made by using the data of Figures 5-1 and 5-4. These curves were proportionately scaled down for a given contrast value and the intersection of the resultant curve with the equivalent rms noise was designated as the limiting resolution. The results are shown in Figure 5-7. For example, a

10 percent contrast scene would have a limiting system resolution of 3100 TV lines/picture height. Based upon the square wave response data, a limiting sensor resolution of 3350 TV lines/picture height is arrived at based upon the data corrected for the lens response.

5.2 TRANSFER CHARACTERISTIC

The transfer characteristic of the vidicon was measured with the gray scale on the RETMA Chart. Signal amplitudes were measured for each of the blocks in the gray scale and presented as a function of faceplate illumination. The result is shown in Figure 5-8. The data was taken with the gamma correction circuit in the video processor disconnected; the measured gamma of 0.86 is the vidicon response. The intersection of the transfer characteristic with the rms noise level shows a limiting sensitivity of approximately 0.01 foot-candles.

5.3 IMAGE LAG

The results of the image lag measurement as previously described is shown in Figure 5-9. The second readout shows the signal amplitude at 45 percent of the initial scan without the amplitude down to 8 percent on the fourth readout.

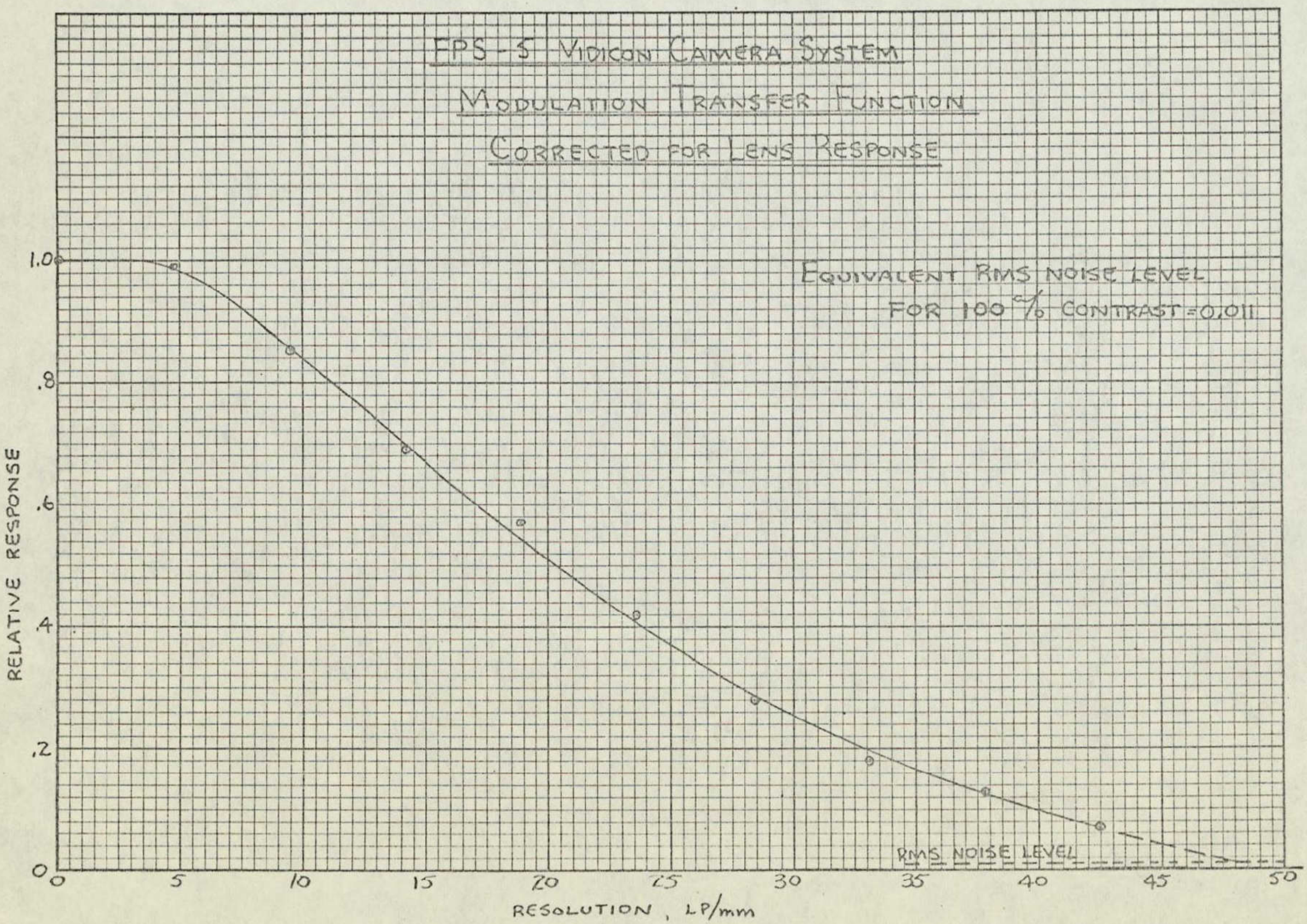


Figure 5-1. Modulation Transfer Function Corrected for Lens Response

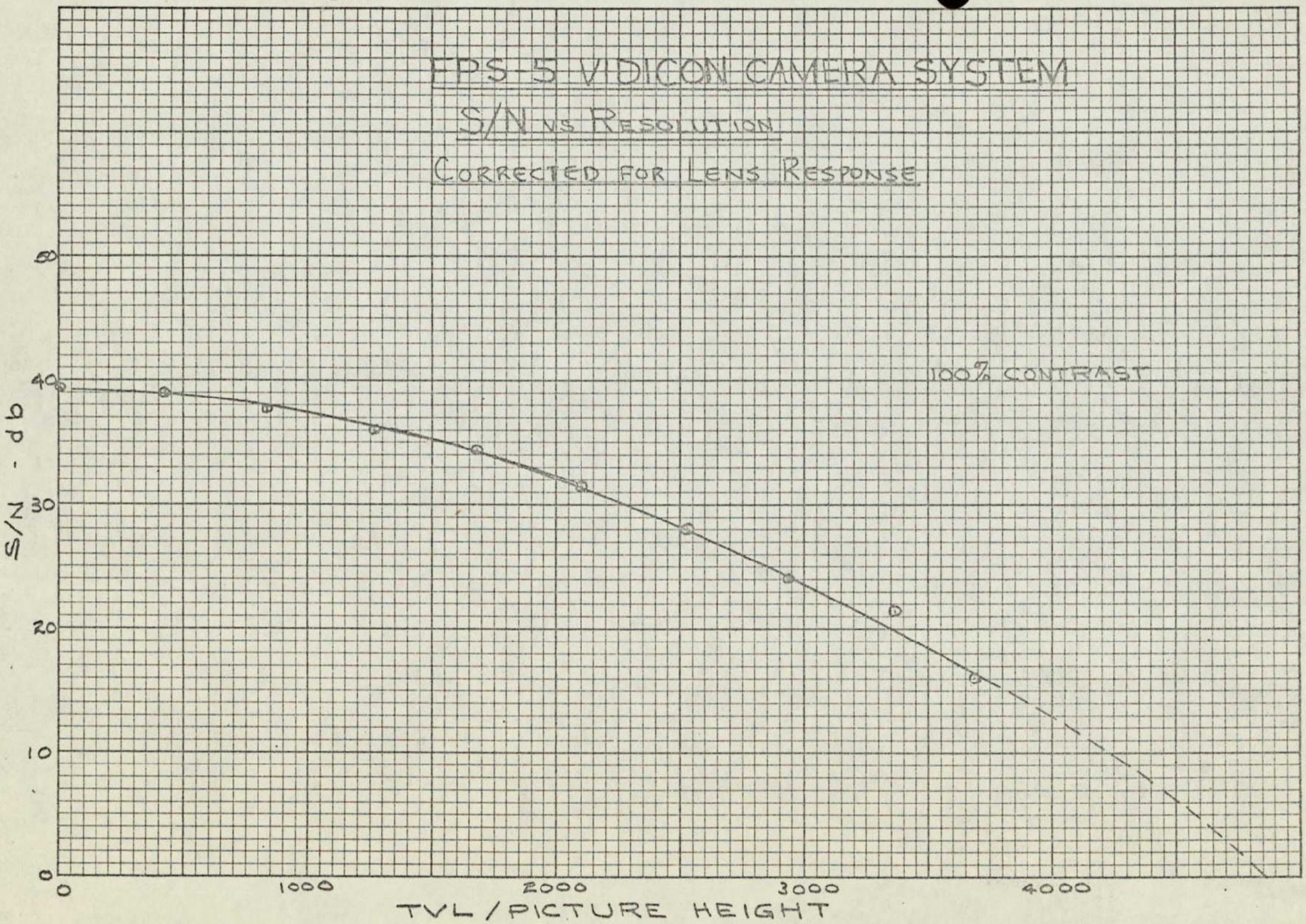


Figure 5-2. S/N Versus Resolution

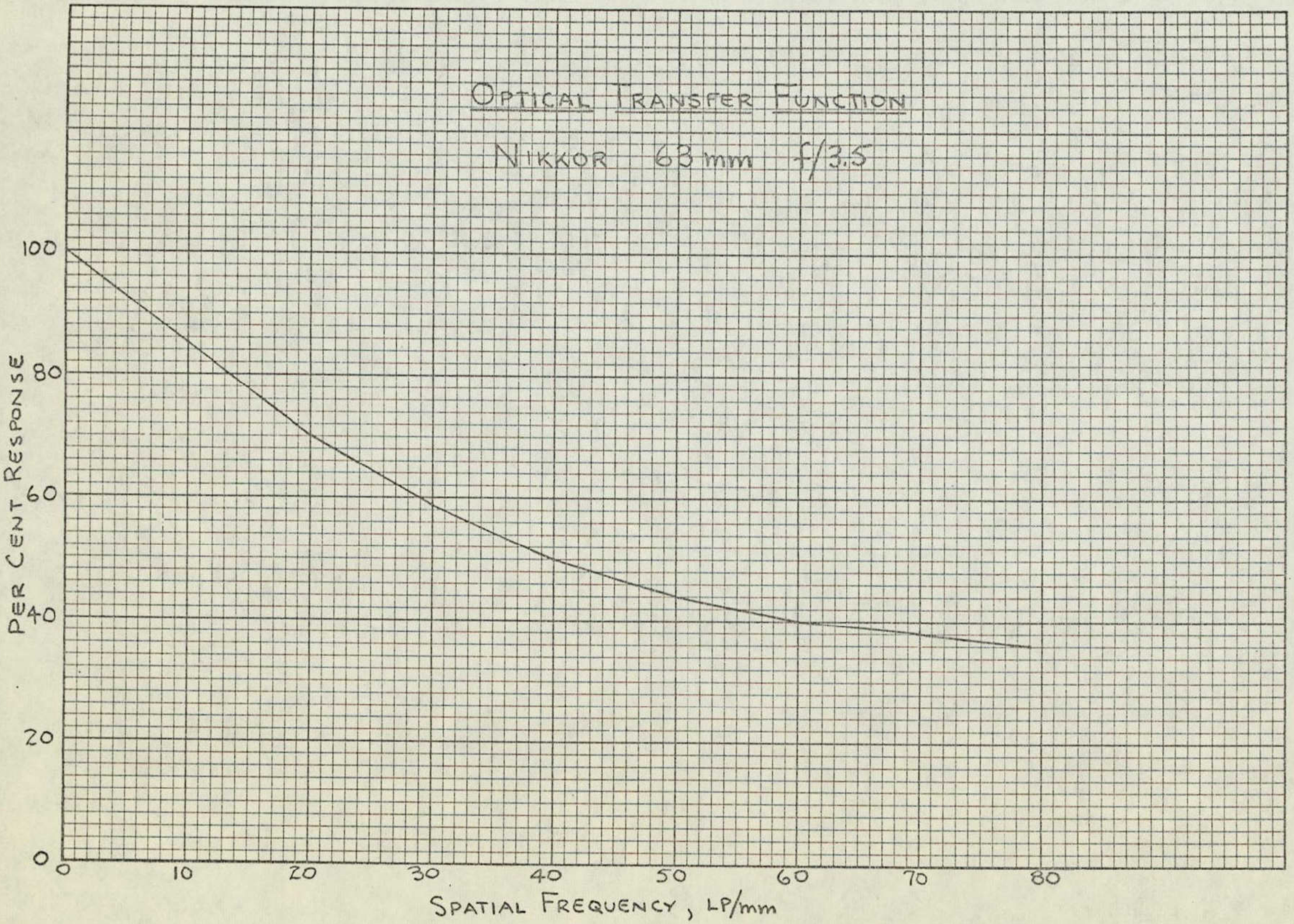


Figure 5-3. Optical Transfer Function

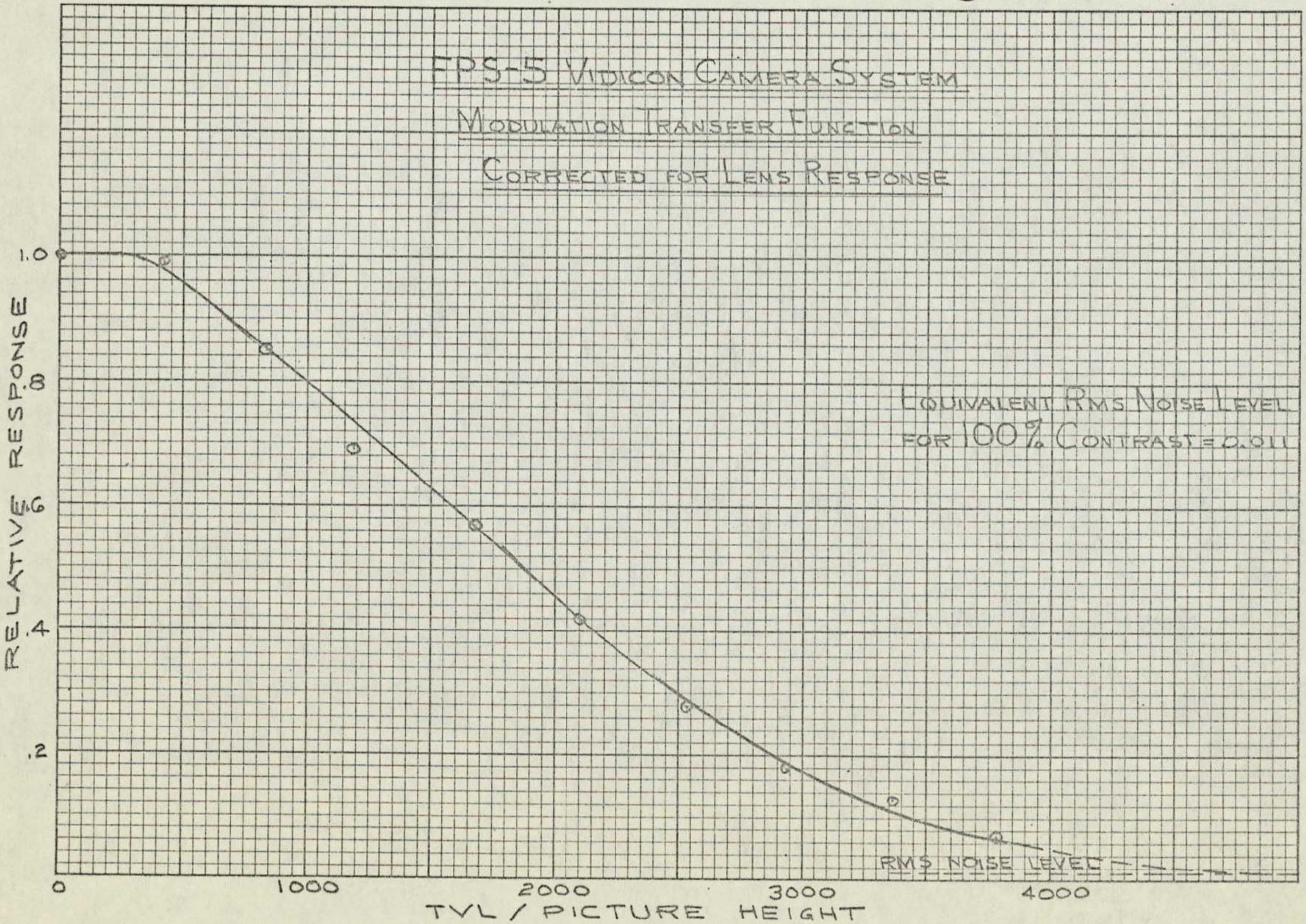


Figure 5-4. Modulation Transfer Function Corrected For Lens Response

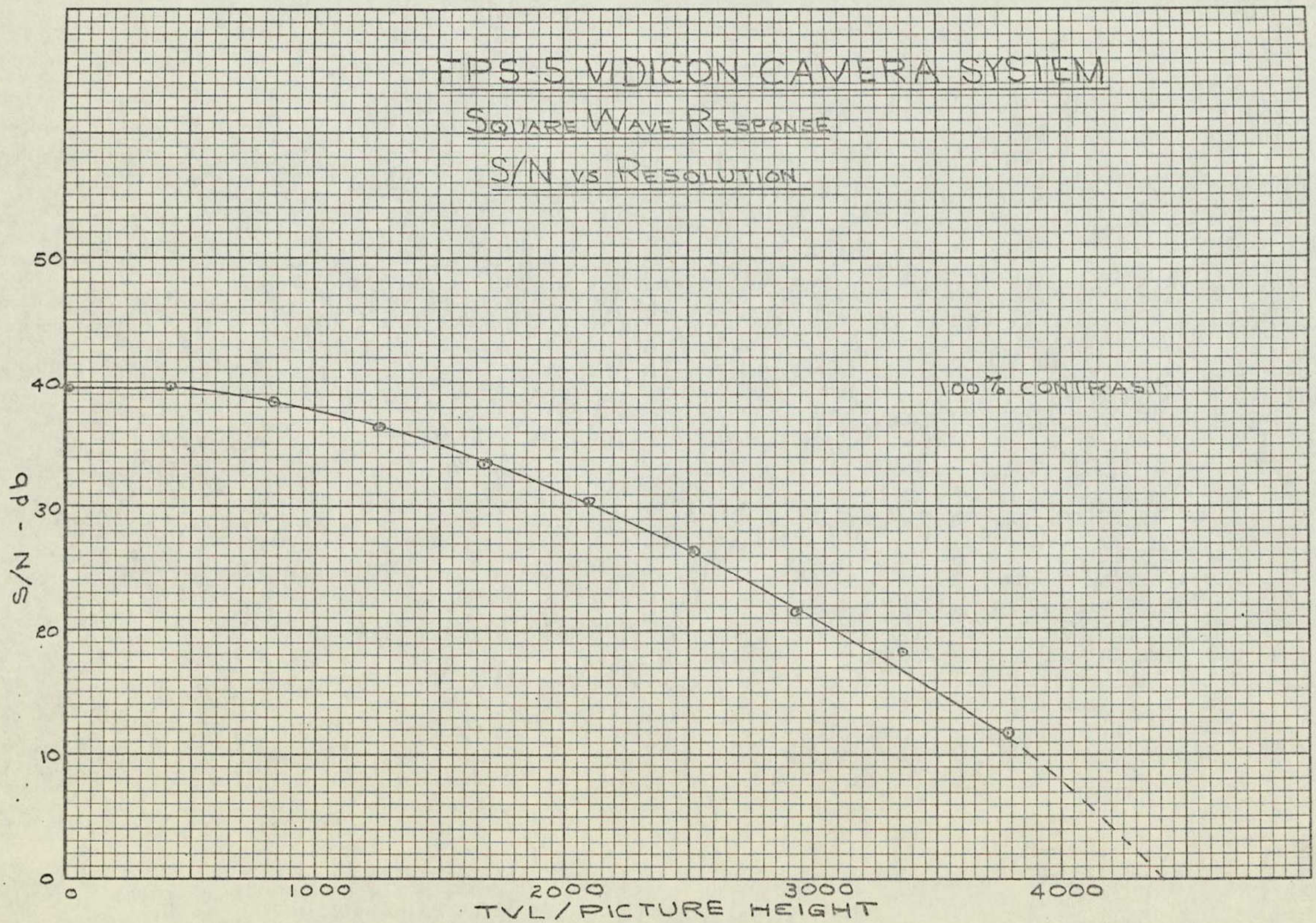


Figure 5-5. Square Wave Response - S/N Versus Resolution

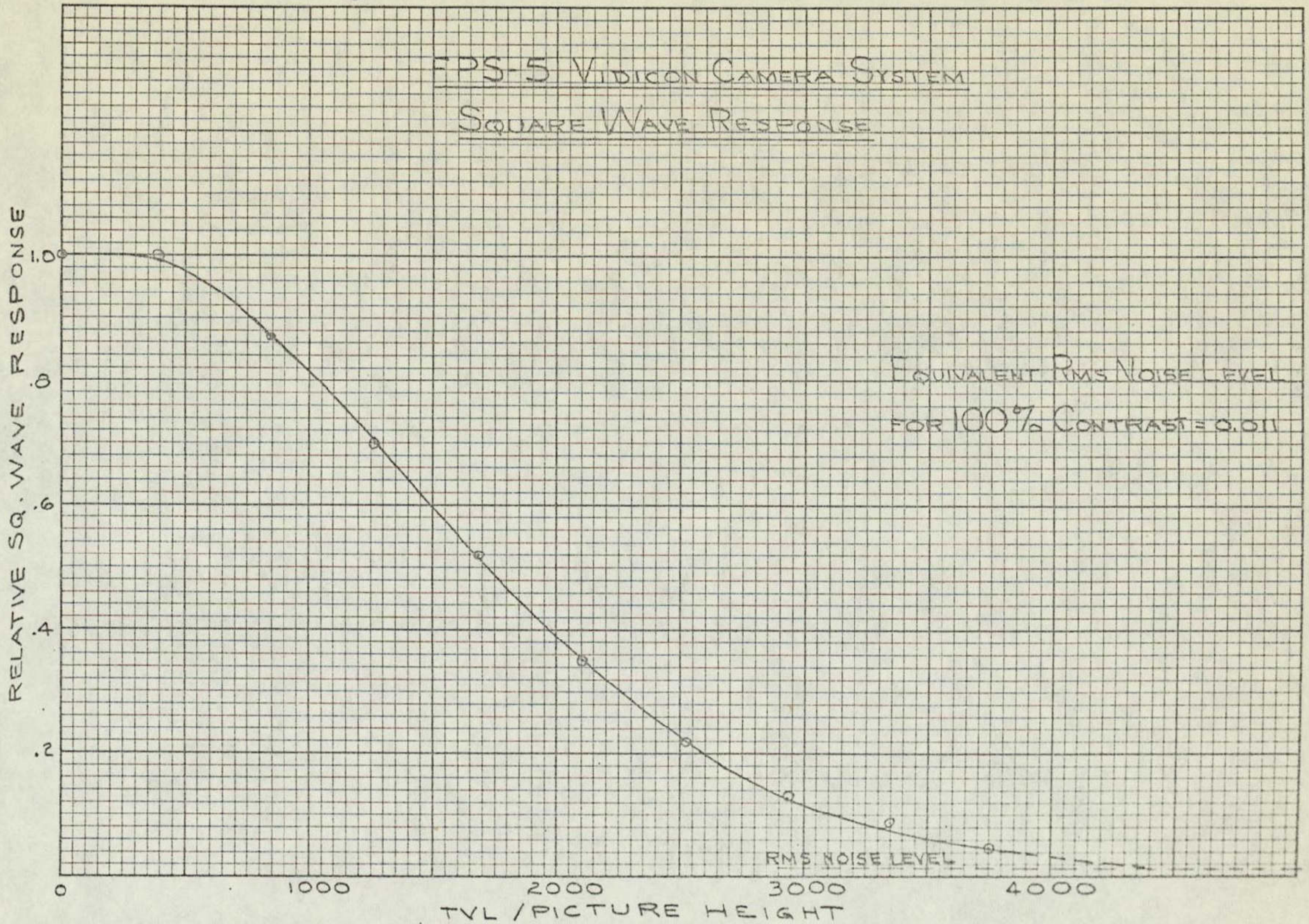


Figure 5-6. Square Wave Response

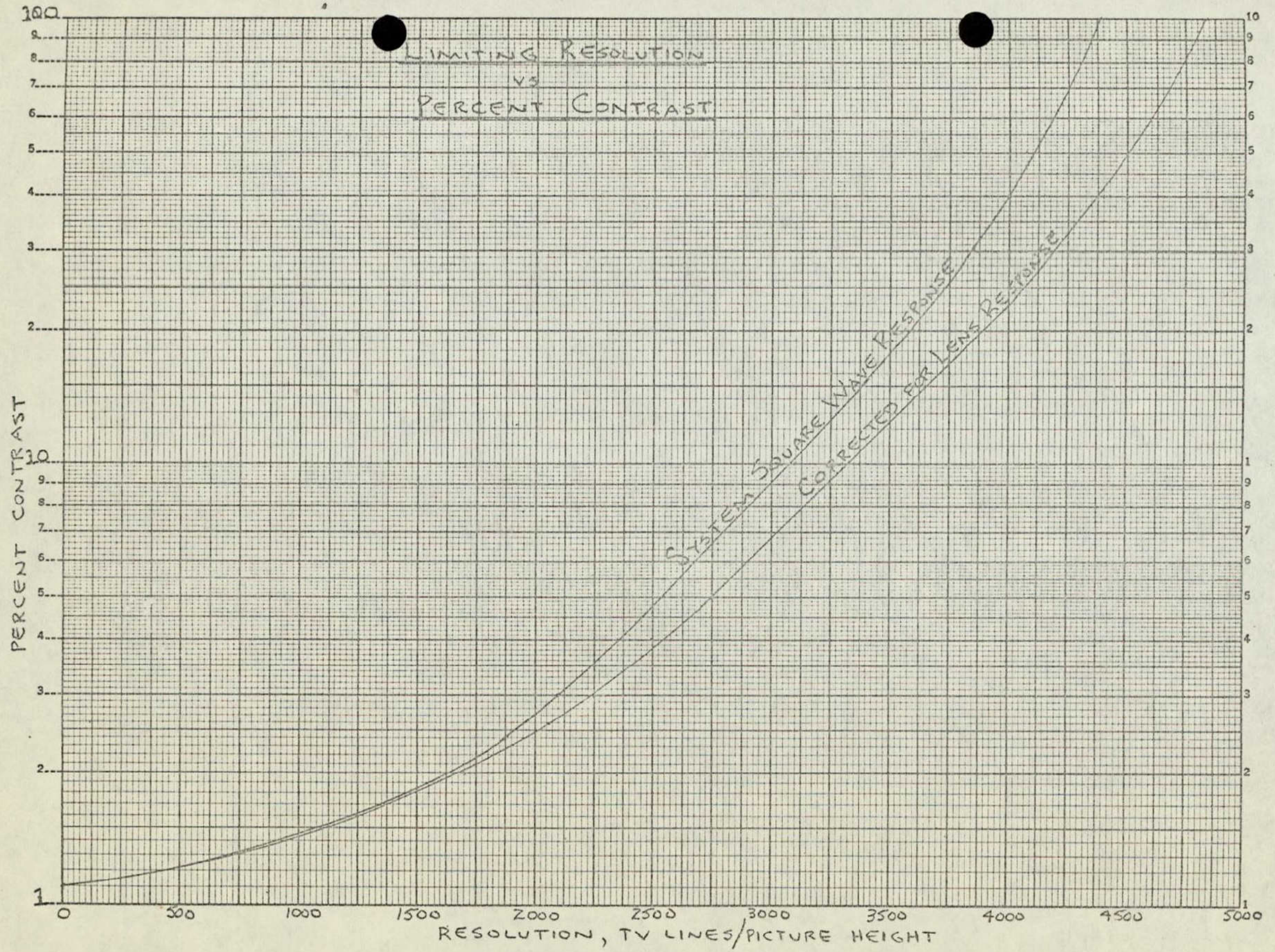


Figure 5-7. Limiting Resolution Versus Percent Contrast

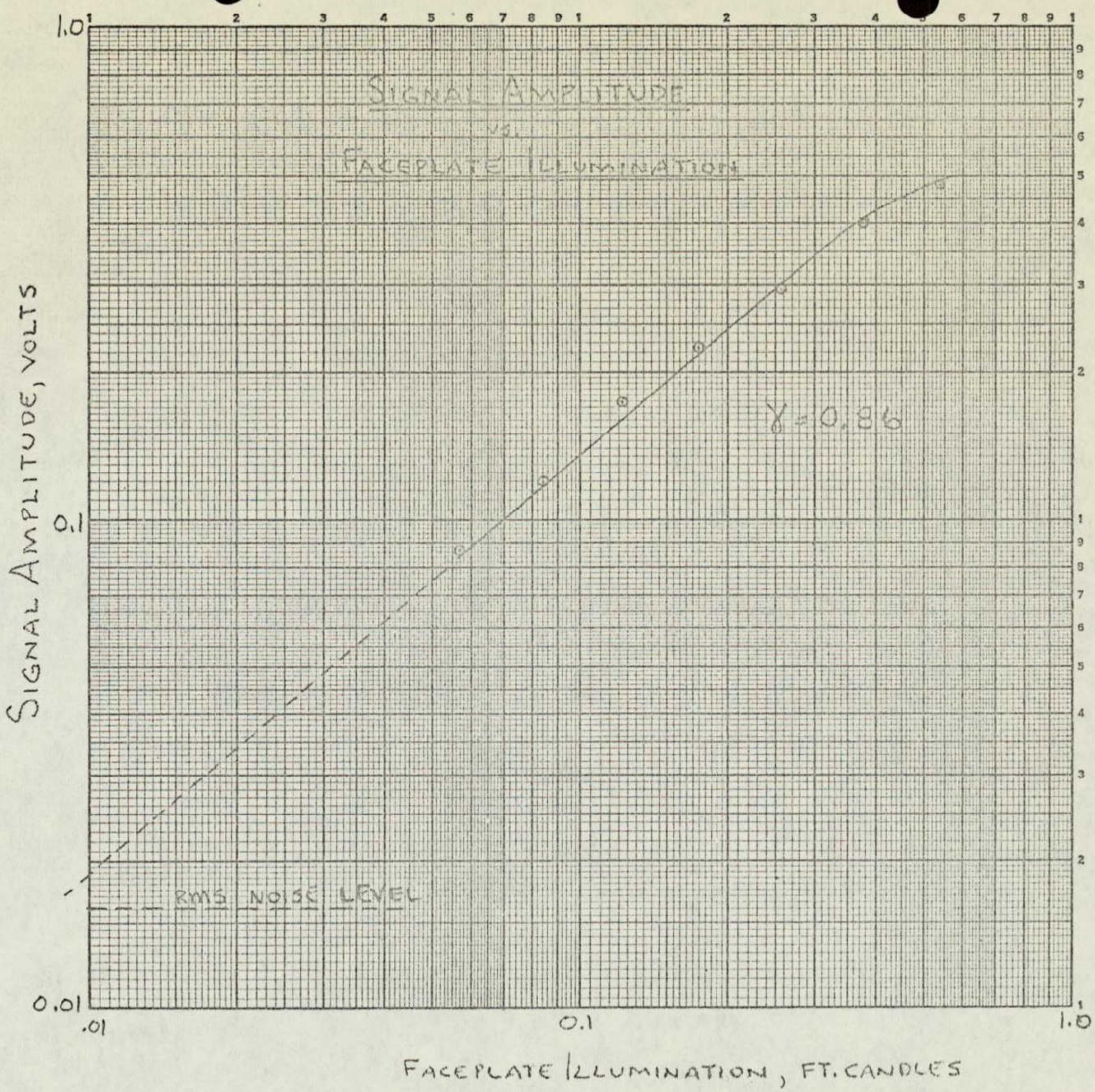


Figure 5-8. Signal Amplitude Versus Faceplate Illumination

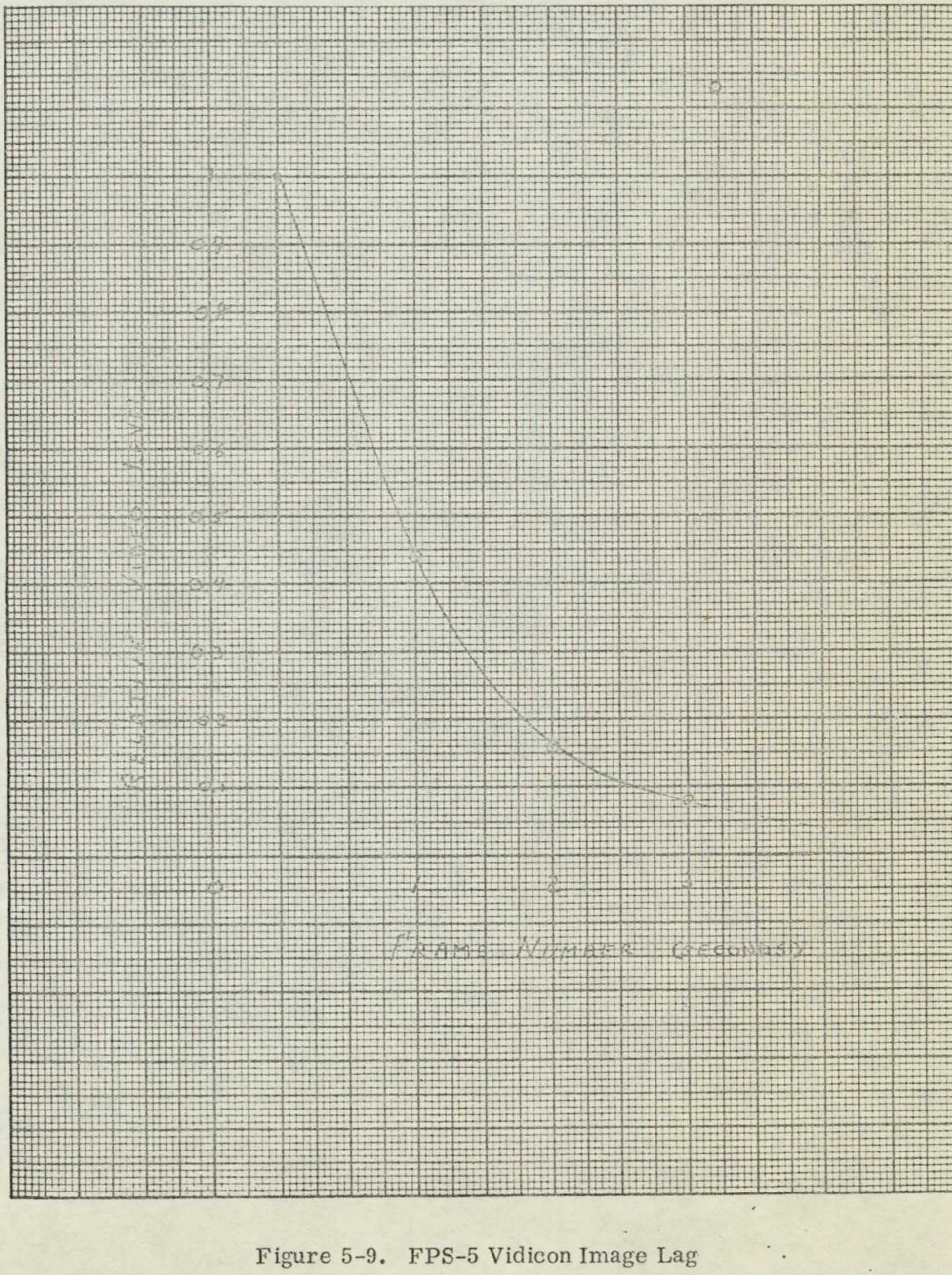


Figure 5-9. FPS-5 Vidicon Image Lag

SECTION 6

CONCLUSIONS

The initial evaluation of the High Resolution Television Camera System with the selenium-doped antimony trisulfide photoconductor FPS-5 vidicon has shown encouraging resolution and signal-to-noise performance. This data has been taken on-axis with a high contrast scene and fixed illumination condition. The camera operating parameters were a 1 second frame time, 5500 line scan, and 12 MHz bandwidth. Proposed applications for this system indicate the requirement for operating at a slower frame rate reducing the electronics bandwidth, and viewing low contrast scenes at a varying illumination level. This indicates the desirability of a measurement program to obtain further useful performance data. The following are recommended.

6.1 SCENE CONTRAST

Predictions from data obtained at 100 percent scene contrast have indicated the expected resolution performance at reduced contrast. However, in order to verify this estimate, measurements of resolution should be made at variable scene contrast. The results would be presented in terms of the modulation transfer function (MTF) for various scene contrasts. From this data the limiting resolution can be determined for reduced contrast scenes.

An Ealing Variable Modulation Test Target could be used for these tests. This instrument is a test target display where the viewed contrast between the light and dark portions of the test pattern can be varied from zero to 97 percent in a continuous and predictable manner, while automatically maintaining a constant average intensity over the whole field of view. A test target is used that has fifteen bars at each spatial frequency (1 line pair/mm to 1000 line pairs/mm) providing a better approximation to an unbounded domain and avoiding the boundary errors produced with three-or four-bar targets.

6.2 SCENE ILLUMINATION

These measurements involve obtaining transfer characteristic data (signal-to-noise versus photocathode illumination) for different tube operating parameters (target voltage and beam current) to establish the sensitivity, dynamic range and gamma of the tube. Also the MTF would be measured at various illumination levels to determine the limiting resolution as a function of photocathode illumination.

The Ealing Test Target should be used for these measurements with a series of neutral density filters for varying the illumination level. A fixed optical f-number must be maintained to minimize the effect of optics resolution on the results. A high resolution display would be used for correlation of the observable resolution with limiting MTF resolution measurement.

6.3 OFF-AXIS RESOLUTION

The vidicon MTF can be measured off-axis with the camera system focused for best resolution in the center of the photoconductor and then re-focused for best edge resolution. The results of this test will show the amount of off-axis resolution degradation and provide information as to the necessity and/or requirements for dynamic focus correction.

6.4 STORAGE TIME

This measurement would consist of illuminating the tube for a fixed time interval with the electron beam turned off and then reading out the signal after a varying period of time (nominally 1 through 60 seconds). In this manner the effect of the charge storage time on signal-to-noise and resolution can be determined.

6.5 CAMERA DESIGN IMPROVEMENT

6.5.1 REDUCE FRAME RATE

The camera electronics could be modified to obtain the 5500 line scan in a 2 or 3 second frame time rather than the present frame time of 1 second. This will result in a bandwidth reduction from the present 12 MHz to 6 MHz or 4 MHz, respectively, which would reduce the noise by a factor of 3 or 4. The signal current will also be reduced at the slower rate, however, the net effect will be an increase of about 1.5 to 2 in signal-to-noise. Operation at the slower rate provides a bandwidth that is more compatible with spaceborne video recorders and transmission links, thus it appears the evaluation of the camera at this rate is desirable.

6.5.2 APERTURE RESPONSE CORRECTION

An aperture response correction circuit can be designed and integrated with the present camera system. Its function will be to enhance the response at the higher spatial frequencies to provide a flatter MTF response out to 2500-3000 TV lines/picture height. The addition of this feature will add some noise, thereby sacrificing the low spatial frequency signal-to-noise ratio for the improved higher frequency response. The reduction of the frame rate will enable the correction to be accomplished at a lower electrical frequency, which will simplify the implementation and improve the overall signal-to-noise.

6.5.3 CAMERA EVALUATION AT REDUCED FRAME RATE

The standard resolution, signal-to-noise, image lag, shading and transfer characteristic measurements may be performed on the camera system at the reduced rate and compared to the 1 frame per second rate data. Also, the measurements outlined in Section 6.1 should be performed at the reduced rate. The aperture response correction would be evaluated for its effect on the MTF and signal-to-noise.

APPENDIX A

DOYLE CHART

Westinghouse

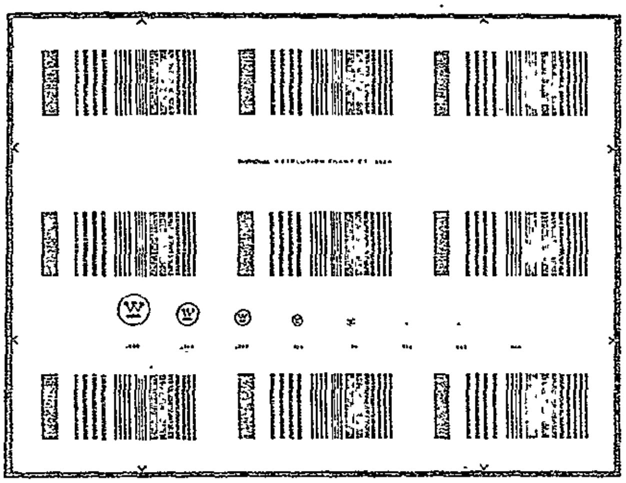
RESOLUTION CHART ET-1332A

To simplify the taking of accurate and objective resolution data this new type of resolurion chart ET-1332A was designed by Westinghouse. The chart in combination with a line selector oscilloscope makes it possible to obtain from a single oscilloscope presentation all the data necessary to plot a complete square-wave aperture response curve.

The basic format of the chart is 8 × 10" while the inside reference height is 7 inches and the width is 9⅓ inches. There are nine resolution patterns within the chart, each of which contains a wide black and white reference bar followed by ten sets of 4 black and 3 white bars. The wide bars represent 100% response factor and the ten bar-sets of decreasing width represent from 100 to 1000 TV lines per raster height in 100 line increments.

The bar width and TV lines per raster height equivalent are given below:

TV Line Equivalent	Bar Width (Inches)
Wide Bar	0.250
100	0.070
200	0.035
300	0.0233
400	0.0175
500	0.0140
600	0.0117
700	0.0100
800	0.0088
900	0.0078
1000	0.0070



The dimensional width of the bars which represent from 600 to 1000 TV lines is within ± 0.0003 inch while the tolerance for the remaining bars is better than ± 0.0005 inch. In addition to the bar groups the chart contains eight (W) patterns whose diameters decrease from 0.500 inch to 0.044 inch as a function of the square root of two.

The chart is normally set-up in a light box so that the area of the chart determined by the small triangular marks just fits the imaging region to be evaluated. The tube and/or system to be evaluated is than adjusted for the desired operating conditions while the video signal is fed into an oscilloscope with delayed sweep such as the Tektronix 545A. The oscilloscope is set to select the desired horizontal raster line and from its signal presentation all the data required to plot a square wave aperture response curve are available without recourse to oscilloscope settings, amplifier gains, etc.

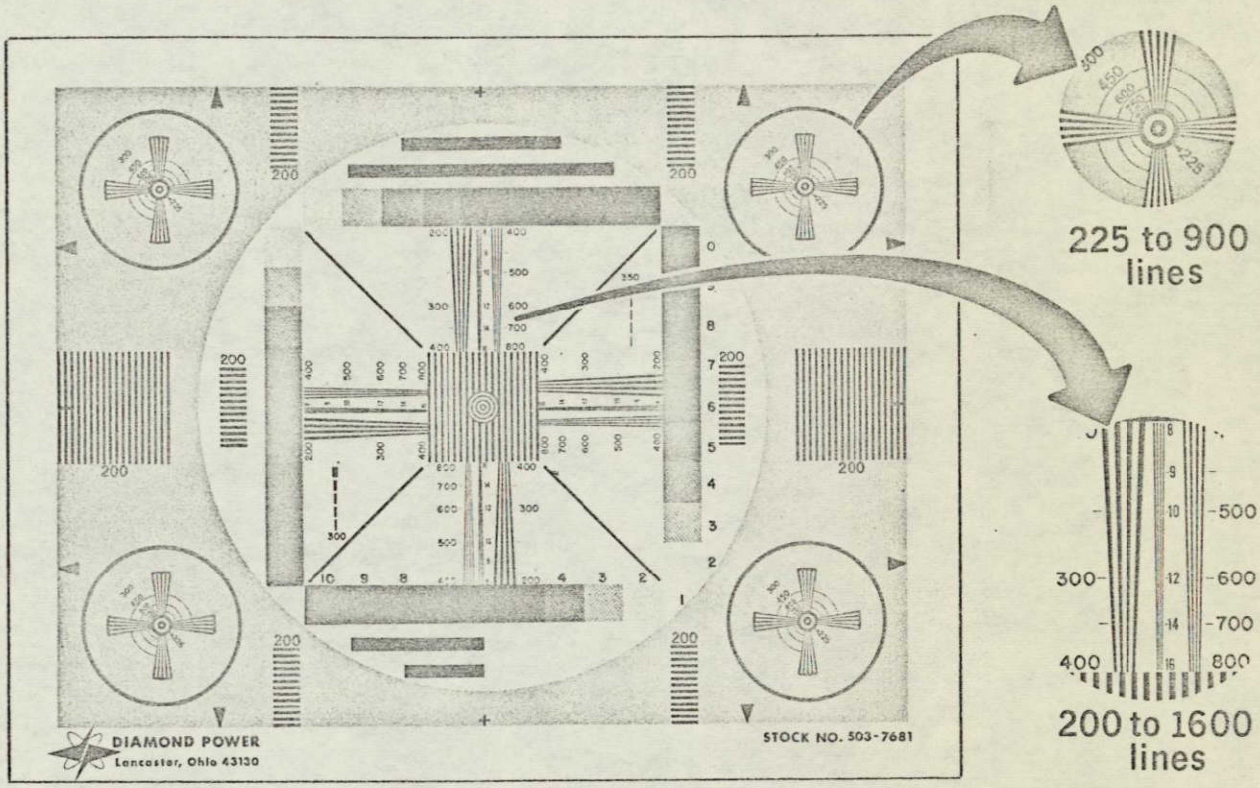
Thus, this chart in coordination with an oscilloscope makes it possible to obtain, from even the simplest of imaging systems, complete and objective resolution measurements.

APPENDIX B

RETMA CHART

Designed for Tomorrow - Available NOW!

The NEW 503-7681



Diamond's advanced technology in the manufacture of High Resolution Closed Circuit Television Systems required an advanced quality test pattern to measure the increased picture quality.

Our Photo-Test Materials Lab developed this pattern because of the numerous requests we have had from our customers.

Now you can obtain this high resolution test pattern in an 8" x 10" transparency from stock.

Order it by stock number 503-7681 at $15., F.O.B. Lancaster, Ohio.

DIAMOND POWER

Diamond Power Specialty Corporation   Post Office Box 415   Lancaster, Ohio 43130 · Telephone: 653-6540

APPENDIX C

EXPLANATION OF RETMA CHART

INSTRUCTIONS FOR RETMA RESOLUTION CHART 1956

1. PURPOSE

The RETMA Resolution Chart 1956 was designed to provide a standard reference for measuring resolution of television cameras and as an aid in testing for streaking, ringing, interlace, shading, scanning linearity, aspect ratio, and gray scale reproduction.

The horizontal resolution which may be obtained from many camera chains is limited by the resolving capabilities of the camera tube, and not by the bandwidth of the video amplifiers employed. Therefore, much useful information concerning the limiting resolution, percent response at various line numbers, and degradation of resolution with aging of camera tubes can be obtained from a test chart containing a high number of lines. For these reasons the horizontal and vertical wedges of the RETMA Resolution chart 1956 have been arranged to permit resolution measurements from 200 to 800 lines, whereas the wedges in the original RMA Resolution Chart 1946 extend from 200 to 600 lines. The reflection density of the various steps of the "paste-on" gray scales used with the 1956 chart are very accurately maintained in the manufacturing process, while the reflection density of the gray scale steps on the 1946 chart were not as accurately controlled.

2. DESCRIPTION

With the exception of the changes in the resolution wedges and gray scales the new chart is identical to the RMA Resolution Chart 1946.

The center horizontal and vertical wedges are composed of four black lines separated by three equal width white lines. The numbers printed alongside the wedges correspond to the total number of lines (black and white) of the indicated thickness that may be placed adjacent to one another in the height of the chart. For example, if black and white lines having the same thickness as those indicated at the 320 position were placed adjacent to one another a total of 320 (black and white) lines could fit into the height of the chart. Since the aspect ratio of the chart is 4 to 3, a total of ($320 \times \frac{4}{3}$) or 426.7 of these same thickness lines could be placed in the width of the chart. The fundamental frequency developed in scanning through the 320 position of one vertical wedge may be calculated as follows: *

Horizontal Scanning Frequency	=	15,750 Hz
H = time for Active Scan + Hor. Blanking	=	63.5 μ sec
Assume Horizontal Blanking	=	0.17 H
Hence active scan	=	0.83 H
And, active scanning time	=	52.7 μ sec

Total number of vertical black and white lines, having thickness indicated at 320 position, that could be placed adjacent to one another in width of chart is 426.7 lines.

Since a complete cycle includes one black and one white line there would be $\frac{426.7}{2}$ or 213.3 cycles in 52.7 μ sec. cyclic variations in scanning this pattern.

Time to horizontally scan one black and one white line would be $\frac{52.7}{213.3} = 0.25\ \mu$ sec.

Fundamental Vidèo Frequency = 4 mHz

$$f = \frac{1}{t}$$

From this example it can be seen that the fundamental video frequencies generated by scanning through different parts of the vertical wedges may be determined from the following formula.

$$\frac{N}{f} = K$$

N = indicated line number on chart
f = fundamental video frequency in mHz per second.

$$\frac{320 \text{ lines}}{4 \text{ mHz}} = K = 80$$

$$f = \frac{N}{80}$$

* Based upon FCC Television Standards

The fundamental video frequencies generated in scanning through various parts of the vertical wedges are tabulated in Table 1.

Table 1. Fundamental Video Frequencies Generated By Scanning Through Various Parts of Vertical Wedges (FCC Television Standards)

Line Number of Vertical Wedge	Fundamental Video Frequency (mHz per sec)
200	2.5
240	3.0
280	3.5
320	4.0
400	5.0
480	6.0
560	7.0
640	8.0
720	9.0
800	10.0

The four ten-step gray scales cover a contrast range of approximately 30 to 1. The reflectance of step No. 1 is determined by the reflection density of the chart material comprising the center circle. The nine step "paste-on" gray scales cover a nominal contrast range of 20 to 1, step No. 2 having a reflectance of 60 percent and step No. 10 a reflectance of 3 percent. The steps are arranged in logarithmic decreasing values of reflectance such that the difference in reflection density between adjacent steps is equal to 0.16. Table 2 gives the reflectance and reflection density of the steps on the gray scales. The background reflectance of the outer useful area of the chart is 40 ± 5 percent.

Table 2. Specifications for Gray Scales

Gray Scale Number		Nominal Reflectance Relative to MgO (1%)	Nominal Reflection Density
(Center Circle)	1	>60.0	> 0.22
	2	60.0	0.22
	3	41.7	0.38
	4	28.2	0.55
	5	19.5	0.71
	6	13.5	0.87
	7	9.3	1.03
	8	6.3	1.20
	9	4.4	1.36
	10	3.0	1.52

3. SHADING

Shading may be checked by visual inspection of the picture monitor to determine if the background is an even gray, and if the same number of gray steps are discernible on all four gray scales. A wave form monitor may also be used to determine if the average picture signal axis is parallel to the black level line at both line and field frequencies.

4. STREAKING

Streaking of the horizontal black bars at the top or bottom of the large circle is an indication of low frequency phase shift or of poor dc restoration. The black bars are also very useful for adjusting the high peaking circuits which are used in camera chains to compensate for the high frequency roll off of the coupling network between the camera tube and first video amplifier.

5. INTERLACE

The four diagonal black lines inside the square formed by the gray scales may be used to check interlace. A jagged line indicates pairing of the interlaced lines.

6. GRAY SCALE REPRODUCTION

The transfer characteristic of the camera, for given operating conditions, may be determined by using an oscilloscope with a line selector.

The gray scale reproduction achieved will depend on the amount of gamma correction employed, the manner in which the camera tube is operated, and the adjustment of the picture monitor. The user will have to standardize these operating conditions if comparative subjective measurements are to be made.

7. RINGING

The two sections of single line widths located in the upper right hand portion, and lower left hand portion of the square formed by the gray scale may be used to check ringing. These lines are included because the multiple lines in the wedges are confusing for checks of this type. The lines in the upper right hand section have widths from 350-550 (350, 400, 450, 500, 550) and the lines in the lower left hand section have widths from 100-300 (100, 150, 200, 250, 300).

APPENDIX D

TUBE PIN LAYOUT

F.P.S. V - 7

TWO LAYER SELENIUM TARGET