THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
SILVER SPRING, MARYLAND

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TO: Distribution

FROM: R. E. Cashion

SUBJECT: Design Report for the CPME Analog Commutator and Noise Monitor.

Introduction

This report documents the design of the CPME Analog Commutator and Noise Monitor circuit. The purpose of this circuit is to sequentially sample eight (8) analog voltages from the experiment and to subcommutate these measurements into one analog output. The signal is labeled AP-1 in the telemetry format, and is read out at the rate of one reading each page. The eight parameters are listed below.

	Parameter	Label
AP1-1	Detector A noise	D1
AP1-2	Detector B noise	D2
AP1-3	Detector C noise	D3
AP1-4	PET temperature	TP
AP1-5	High voltage monitor	HV
AP1-6	Gain switch identify	GA
AP1-7	PMT power supply identify	PM
AP1-8	Calibrator disable identify	CD

The AP output specification is given as follows:

Load impedance	= 100 K ohms to ground
Range	= 0 to 5 volts
Quantization error	= 1 part in 200
Accuracy	= $\pm$ 1% from 0^oC to 40^oC
Repetition Rate	= Readout once every page (20.48 seconds at the high bit rate), repeat each parameter each 163 seconds.

Spacecraft timing inputs = a_5, a_6, a_7

This system is the same as that flown in the SPME on IMP-I and the following discussion is taken from a writeup for IMP-I. The circuit schematic is given in Figure 1, SRA-6593. Basically the operation is as follows. The noise monitor is essentially an average reading voltmeter with a passband extending from approximately 50 kHz to 10 MHz. Detector amplifier outputs are sampled by diode gates D1 through D3, switched into the noise monitor and are read as AP1-1, AP1-2, and AP1-3.

AP1-6, AP1-7, and AP1-8 monitor the state of the command relays, but in addition, they give a measure of experiment voltage levels by switching a different voltage point into the output for each command state. In this way, the level is telemetered for voltage lines, +6V, +6V regulated, +9V, -6V, +20 regulated, and +23V.

All measurements are converted to a voltage source 0 to 250 mv full scale. These are sequentially switched by FET gates into an operational amplifier with a gain of 20 to give an output of 0 to 5 volts full scale.

A detailed discussion of the circuit design follows.

Noise Monitor

The noise monitor consists of a transconductance amplifier and a diode rectifier. A transconductance of $\frac{1}{R_E + r_e}$ is obtained from Q1 while Q2 is bootstrapped to raise the amplifier output impedance. This high output impedance lowers the high frequency response. For this reason, 2N3307 transistors and HP2302 diodes are used because their low capacitance will have less effect on the high frequency cutoff than high capacitance units.

The transconductance is

$$gm = \frac{1}{R_E + r_e} = \frac{1}{42.2 + \frac{26}{1.5}} = \frac{1}{60} \text{ mho}$$

The amplifier gain is

$$Av = \frac{511 \; \Omega}{60 \; \text{mho}} = 8.5$$

$$V_{DC} = V_{RMS} \; \frac{1.4}{3.14}$$

$$Av = 8.5 \left(\frac{1.4}{3.14}\right) = 3.79 \; \frac{mV_{DC}}{mV_{RMS}}$$

The measured voltage gain at 40 mV_{RMS} is $3.8 \; \frac{mV_{DC}}{mV_{RMS}}$.

The deviation with power supply is approximately 1/2%/%, and the temperature coefficient is 330 PPM/^{o}C. The transfer function exhibits a $\pm$ 5% non-linearity over the operating range of 10 mV_{RMS} to 80 mV_{RMS}. The response with frequency is given in Figure 2, while the output vs. input at mid-band is given in Figure 3.

Analog Parameter Commutator

The spacecraft timing signals a_5, a_6, and a_7 clock the commutator through light states. Override lines are provided on each line to allow the GSE to control the commutator position in preference to the spacecraft. Zener diodes and capacitive filters are at the junction of the timing control lines to protect both the spacecraft and the experiment. CMOS gates buffer the control lines, and in turn drive LP DTL gates which decode the address lines.

The FET gates F1 through F6 are simple analog switches. The 2N5116 is a low V_p p-channel FET which can be driven from the DTL gates without a level shifter. The resistor divider ensures that the FET gate to source is not forward biased when turned on.

The diode gates, D1 through D3, are low capacitance analog switches. In operation, the base of Q 100 is biased at +3 volts. The gate will be "ON" when the gate input is less than 2.5 volts and "OFF" otherwise. When the gate is "on" the diode is forward biased and will pass the noise signal. When the gate is "off", the +20V input reverse biases the diode so that the gate does not pass the signal. The circuit presents a load to the detector amplifier that looks like 2.5K when the gate is on and 5.6K at all other times. This does not affect the amplifier output which is much lower in impedance.

Output Amplifier

The output amplifier is a LM 108H operational amplifier with a feedback ratio to give a gain of 20. The input resistor is 5K and inputs are tailored to give this impedance.

Input Calculations

The following section is calculations for the individual AP readings using nominal values for each channel.

Channel AP1-1

Measurement of the PET A Detector noise.

Amplifier gain = 2 volts/Mev

Noise without detectors = 35 kev

Detector noise = 25 kev

Measured Channel Noise = 54 kev

$$\frac{54 \text{ kev}}{2.35} \text{ FWHM} = 23 \text{ kev rms}$$

Amplifier output = $\frac{2\ mv}{kev}$ x 23 kev rms = 46 mV rms

Lookup from Figure 3, 46 mV = 0.145 mv DCout

Output = 0.145 x 20 = 2.9V

Actual Reading = 2.50 volts

Channel AP1-2

Measurement of the PET B Detector Noise.

Amplifier gain = 1 volt/Mev

Noise without detectors = 16 kev

Detector noise = 25 kev

Measured Channel Noise = 26 kev

$\frac{26\ kev}{2.35}$ FWHM = 11 kev rms

Amplifier output = $\frac{1\ mv}{kev}$ x 11 kev rms = 22 mV rms

Lookup from Figure 3, 11 mV rms = 0.03 mV DC

Output = 0.03 x 20 = 0.60V

Actual Reading = 0.59V

Channel AP1-3

Measurement of the PET C Detector Noise.

Amplifier gain = 0.15 volts/Mev

Noise without detectors = 12 kev

Detector noise = 17 kev

Measured Channel Noise = 21 kev FWHM

$\frac{21\ kev}{2.35}$ FWHM = 9 kev rms

Amplifier output = $\frac{0.15\ mv}{kev}$ x 9 kev = 1.3 mV rms

From Figure 3, 1.3 mV = 0.003 V_{DC}

Output = 0.003 x 20 = 0.06 V_{DC}

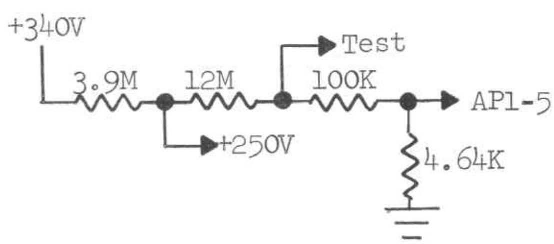
Actual Reading = 0.06V

Channel AP1-4

The temperature of Proton-Electron Telescope. Uses the standard IMP thermistor furnished by the project office, and the standard IMP measuring circuit except that the supply voltage is 6.0 volts instead of 7.75. Figure 4 gives the temperature vs AP voltage.

Channel AP1-5

Measurement of the voltage divider resistor current for the +250 volt bias line:



$$I_{BIAS} = \frac{V_{IN}}{R_{TOTAL}} = \frac{340V}{16M} = 21\mu amp$$

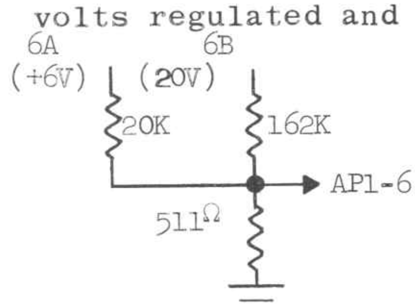
$$V_{AP} = IR = 21 \times 10^{-6} \times 4.64K$$

$$= 1.97 \text{ volts}$$

Actual reading = 1.87 volts

Channel AP1-6

Gives an indication of the gain switch positions for amplifiers A and B. Also gives a measurement of +6 volts regulated and +23 volts.



for 6A - $V_{out} = \frac{6V}{20.5K} \times 511\Omega = 0.149V$

$0.149 \times 20 = 2.99$ volts

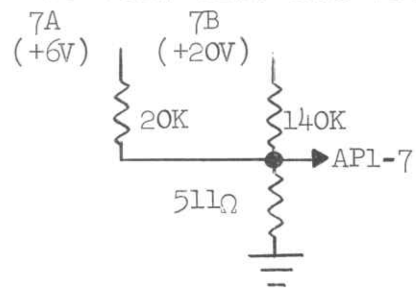
for 6B - $V_{out} = \frac{23V}{162.5K} \times 511\Omega = 72.5$ mV

$0.0725 \times 20 = 1.45$ volts

Measured values are 2.95, 1.48, and 4.43 volts.

Channel AP1-7

Gives an indication of the switch positions for the PMT power supplies. Also gives a measurement of the +6 volt line and +20 volt line.



for 7A - $V_{out} = \frac{6V}{20.5K} \times 511\Omega = 0.149V$

$0.149 \times 20 = 2.99$ volts

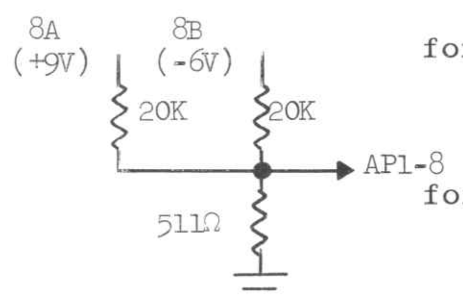
for 7B - $V_{out} = \frac{20V}{140.5K} \times 511\Omega = 72.8mV$

$0.0728 \times 20 = 1.46$ volts

Measured values are 3.00, 1.49, and 4.43 volts.

Channel AP1-8

Gives an indication of the power disable switch for the in-flight calibrator. Also gives a measurement of the +9V volt and the -6 volt line. The normal position is with the calibrator enabled when both the +9 volt and -6 volt line are summed. When the calibrator disable command is sent, the -6 volt line is opened and the AP contribution is from the +9 volt line only.



for +9V - $V_{out} = \frac{9V}{20.5K} \times 511\Omega = 0.224V$

$0.224V \times 20 = 4.48$ volts

for -6V - $V_{out} = 0.149V$

$.149V \times 20 = 2.98$ volts

$4.48 - 2.98 - 1.50$ volts

Measured values are 1.45 and 4.43 volts.

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REC:ks
Distribution page 8

Distribution:
COBostrom
SMKrimigis
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JCArmstrong
JWKohl
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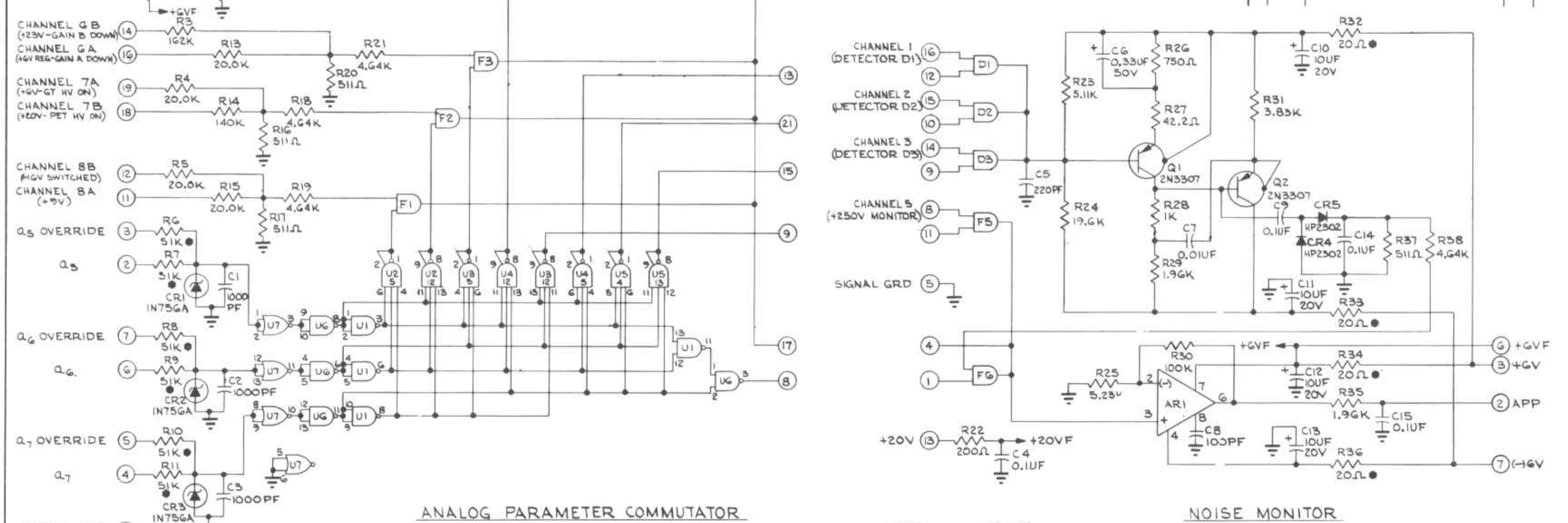
S1P-2 Project
Archives (2)
File

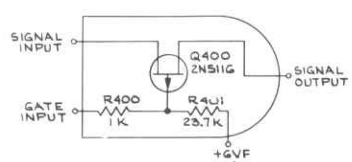
REVISIONS			
B	J.T.M. 18JUN71	CHANGED RESISTOR VALUES R3, R4, R13, R14, R15, R25	J.G.M. 18JUN71



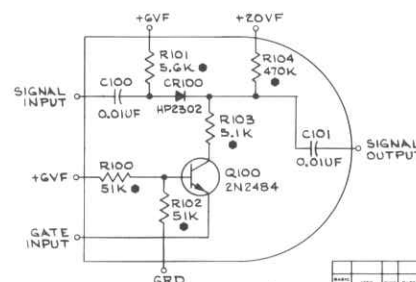
HIGHEST REF DESIGNATION	
R38	R901
C15	C301
Q2	Q300
CR5	CR300
U7	
AR1	

NOTES - UNLESS OTHERWISE SPECIFIED:

1. ALL RESISTORS ARE 1/8W, 1%
2. ALL RESISTORS MARKED ● ARE 1/8W, 5%
3. INTEGRATED CIRCUITS ARE:
   U1, U6 - 9046 U7 - CD4001 (RCA)
   U2, U3, U4, U5 - 9042 AR1 - LM108H
4. PIN 7 OF U1 THRU U7 CONNECTED TO GRD; PIN 14 CONNECTED TO +6VF
5. DIODE GATES ARE SERIES NUMBERED D1 = 100 SERIES, ETC
   FET GATES ARE SERIES NUMBERED F1 = 400 SERIES, F2 = 500 SERIES, ETC



FET GATE ⚠5



DIODE GATE ⚠5

LIST OF MATERIAL

	A	SRA-6596	REF
	C	SRA-6599	REF
SRA-6593	C	SRA-6598	REF
	A	SRA-6596	REF
	C	SRA-6595	REF
SRA-6593	C	SRA-6594	REF

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SCHEMATIC DIAGRAM
ANALOG COMMUTATOR + NOISE MONITOR
C P M E
IMP H+J SATELLITE

88898 D SRA-6593 B

SHEET 1 OF 1

FORM # 500-401

NOISE MONITOR RESPONSE vs INPUT

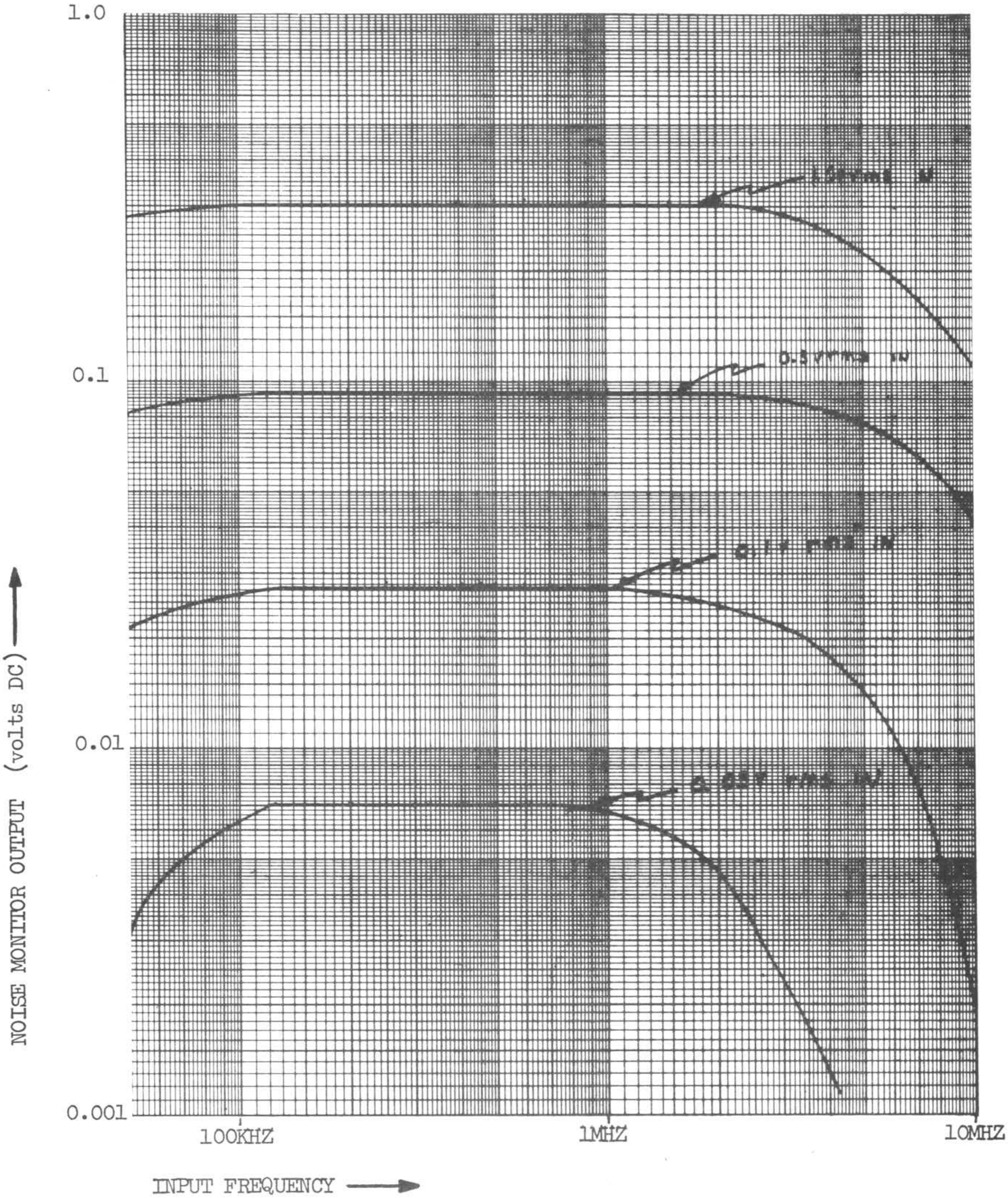


FIGURE 2

AP RESPONSE FOR NOISE MONITOR CHANNELS (AP1-1, AP1-2, AP1-3)

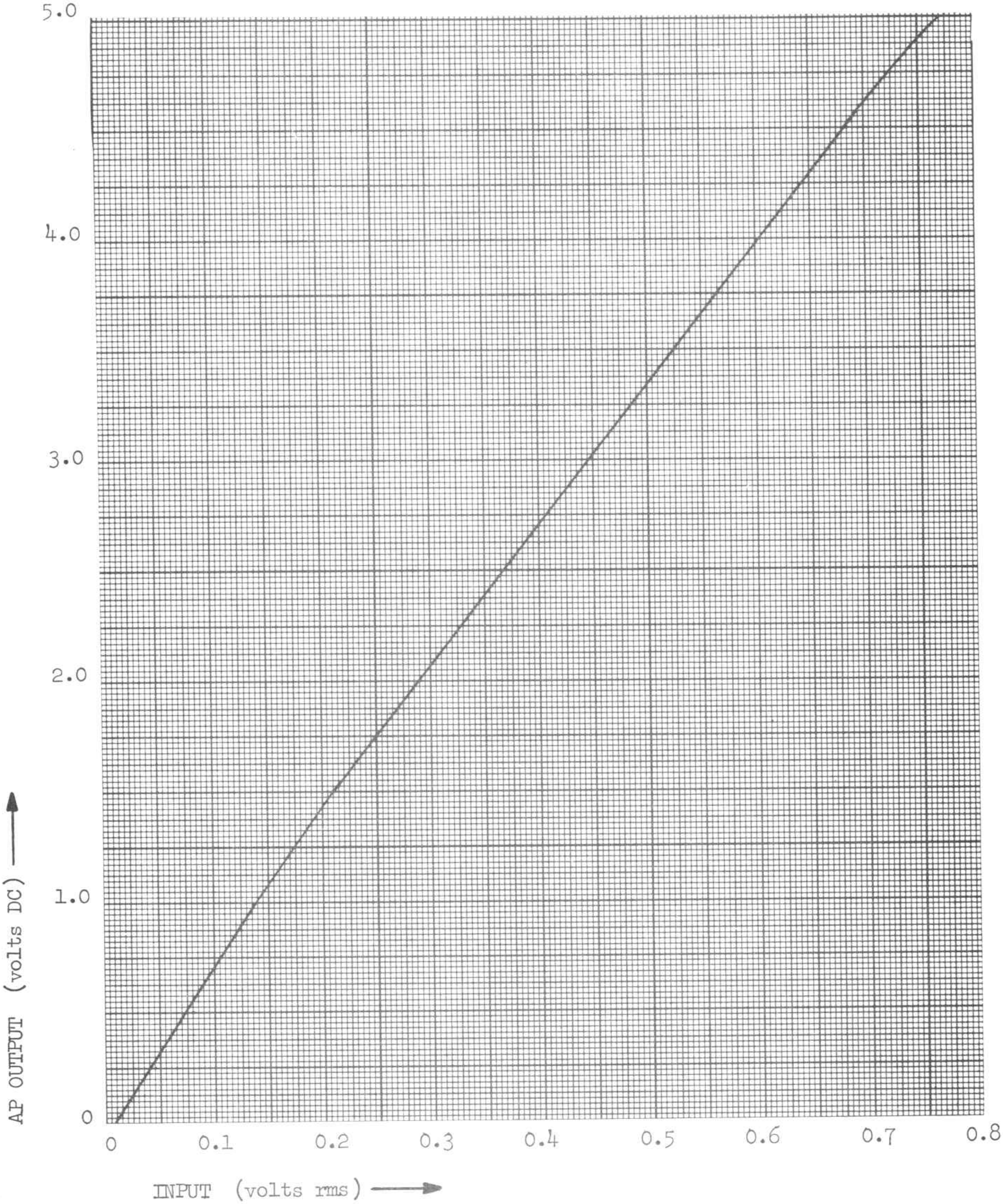
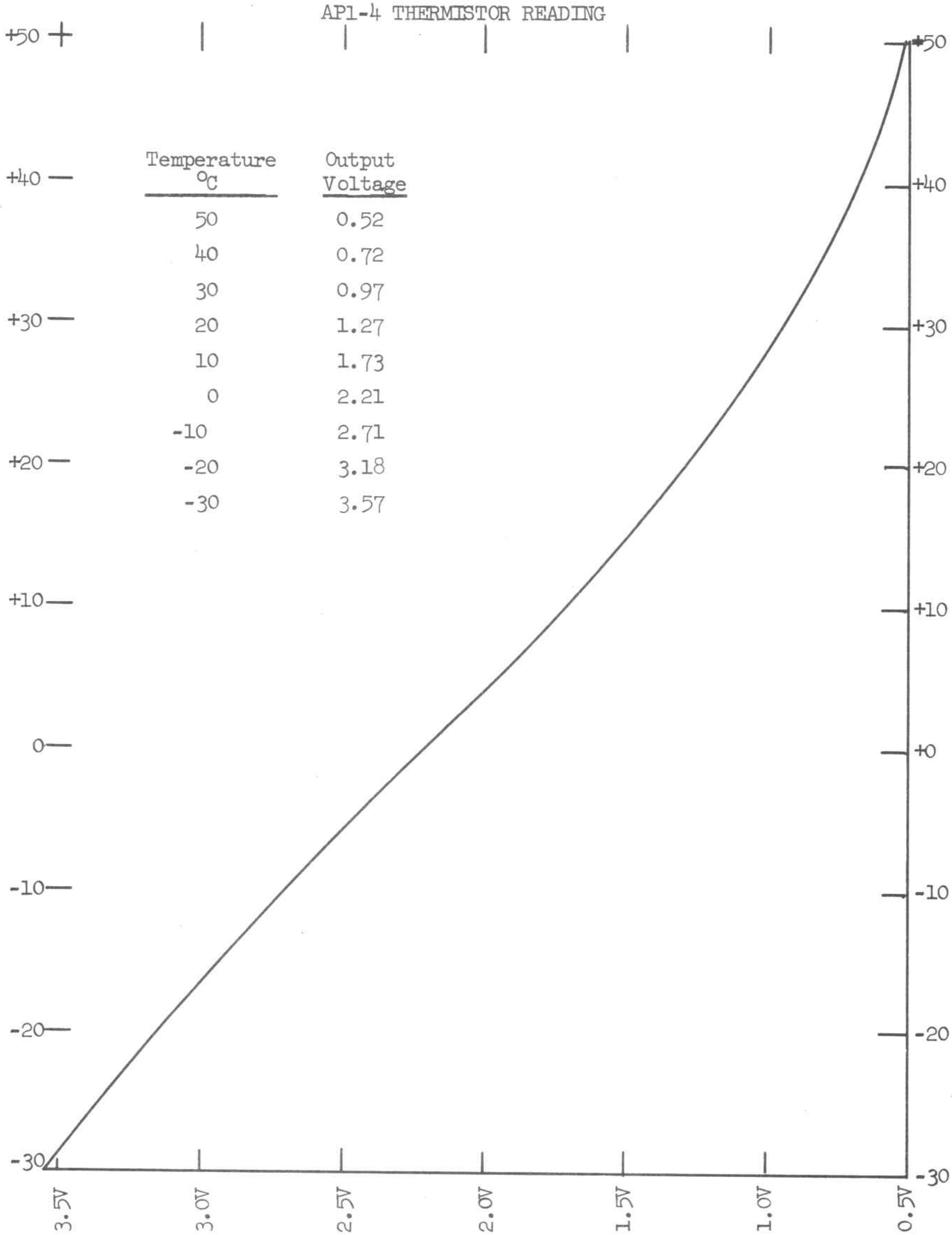


FIGURE 3

AP1-4 THERMISTOR READING



Temperature °C	Output Voltage
50	0.52
40	0.72
30	0.97
20	1.27
10	1.73
0	2.21
-10	2.71
-20	3.18
-30	3.57

FIGURE 4