THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
SILVER SPRING, MARYLAND

S1P-589-70
August 27, 1970

TO: R. E. Cashion

FROM: C. Cunningham

SUBJECT: Modification of Anti-Coincidence Electronics for Charged Particle Measurement Experiment.

Tests of the assembled prototype of the CPME, both in the Laboratory and at SREL, have revealed several problem areas in the PET and GT anti-coincidence electronics. These are:

1. Noise pickup on test inputs to photomultiplier electronics (including DC-DC converter spikes).
2. Noise on analog test points.
3. Cross-talk between the PET anti-coincidence pulse shaper and the PM tube amplifier (PET channel).
4. Only partial anti-coincidence was obtained during calibration tests at SREL using high-energy protons.

Several modifications have been incorporated in the CPME to correct these problems. These are as follows:

<u>Noise on Test Inputs</u>

The test input to the photomultiplier preamps had previously consisted of a 1 pf capacitor connected from the input of the preamplifier to a shielded cable from the test connector. This tended to act as an antenna, coupling DC-DC converter spikes and anti-coincidence pulse spikes into the PM tube preamps. The difficulty has been resolved by connecting 51 Ω resistors from the signal end of the 1 pf capacitors to ground as shown in Figure 1.

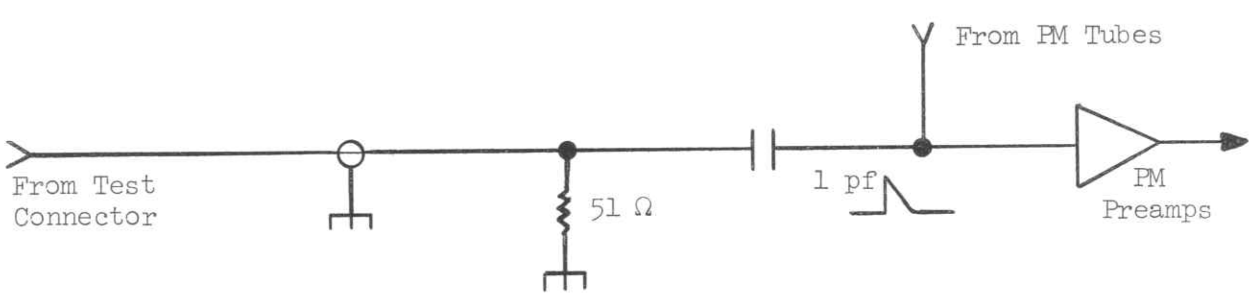

Figure 1

Revised Test Inputs - Photomultiplier Electronics

The 51 Ω impedance level at the test input makes it relatively insensitive to stray coupling from interference sources. As shown in Figure 1, the test input is driven by the non-differentiated output of a pulser and the 1 pf capacitor and 250 Ω input impedance of the preamplifier provide the differentiation. The loading effects of the 51 Ω resistor on the pulser output are not important, since a separate calibration of the pulsers for use with the PM tube electronics would have to be made in any case. The 51 Ω resistors will be mounted on the motherboard.

Noise on Analog Test Points

Some noise and cross talk was also observed on the amplifier test points. The test point is coupled from the amplifier through a 10:1 voltage divider. The resistance levels in the divider have been reduced in order to provide a quieter signal at the test point and to reduce the possibility of stray coupling into the amplifier from the test point. The original and revised test point connections are shown in Figure 2.

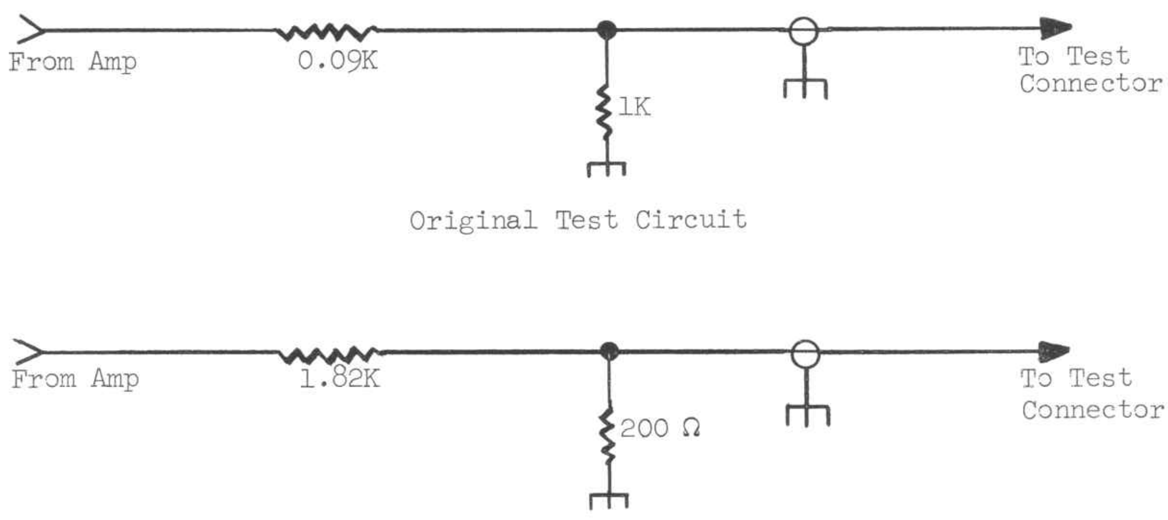

Figure 2

Original and Revised Analog Test Circuits
for PM Tube Amplifiers

Cross Talk (or Feedback) between Anti-Coincidence Pulse Shaper and PET PM Tube Amplifier

Some feedback from the anti-coincidence pulse shaper output to the input of the photomultiplier amplifier board, as evidenced by a positive "kick" on the trailing edge of the output pulse to the discriminator and anti-coincidence pulse generator module. This signal had been previously reduced somewhat by shielding the lead from the preamplifier to the amplifier, since a large part of the coupling was between printed-circuit lands on the "mother-board". However, because of the close proximity of the pulse shaper and amplifier boards, there remained some coupling directly between the two boards. This became a problem when the amplifier gains were increased to lower the anti-coincidence threshold energy, in that it tended to cause after-pulsing in the anti-coincidence circuitry. To eliminate this, it would be necessary to either place a shield between the two boards or relocate the pulse shaper board some distance from the amplifier board. At present a shield has been installed between the boards. This reduces the amplitude of the cross-talk pulse from approximately 65 millivolts to approximately 8 millivolts which is well below the discriminator threshold ($\approx$ 40 millivolts). This in turn will allow the amplifier gain to be increased further if necessary (provided of course that interference from other sources, such as power supplies, is not a problem). The CPME will have to be reassembled with an operational power supply before this can be completely tested.

Inadequate Anti-Coincidence For High Energy Protons

During the calibration tests at SREL, it appeared that anti-coincidence was being obtained only a small percentage of the time when the experiment was placed in a high energy proton beam. From tests performed in the Laboratory, it appears that the problem is due, at least in part, to poor light output from the PET scintillator, causing the effective energy threshold to be somewhat higher than was anticipated. Laboratory tests indicate that the scintillator threshold was set at an energy level slightly greater than 1 Mev. There is some question concerning the validity of this number. This was obtained by stimulating the scintillator with a Thorium^{228} α-particle source and attempting to identify the 6 Mev and 9 Mev α-particle peaks to obtain an energy calibration for the multi-channel analyzer. Then a conversion factor published by the scintillator manufacturer was used to obtain an equivalent electron energy. If these calculations are correct, then a 5.6 Mev α-particle will produce approximately the same light output as a 1 Mev electron. A mercury pulser was then set to produce a line corresponding to the 5.6 Mev α peak (1 Mev e^-) and the amplifier gain increased by a factor of 4X, which should cause the threshold energy to be 250-300 Kev. It was at this point that the after-pulsing in the scintillator electronics became evident. As was mentioned previously, this problem has since been corrected and the amplifier gain can probably be increased again by a factor of 2 or 3; however, it should be borne in mind that external noise sources will become a much more serious problem as the amplifier gain is increased further, and the background counting rate due to photomultiplier noise will increase also.

In the Laboratory, an attempt was made to perform some anti-coincidence measurements in two different ways: in the first test a second PET unit was disassembled so that a detector (40 micron) could be mounted in one half of the scintillator as shown in Figure 3.

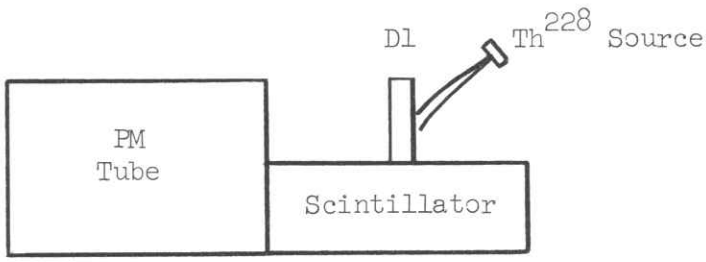

Figure 3

Anti-Coincidence Test Using $Thorium^{228}$

With this arrangement, approximately 30% anti-coincidence was obtained. The problem here in interpreting the results is that not all of the α-particles entering the detector can be expected to penetrate the detector and leave enough energy in the scintillator to produce an anti-coincidence pulse.

Some additional tests were performed using the entire scintillator (with the metal shell removed) and a $Strontium^{90}$ electron source as shown in Figure 4.

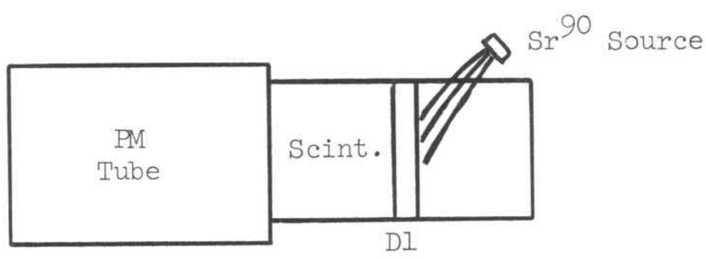

Figure 4

Anti-Coincidence Test Using $Strontium^{90}$

Again, the results are rather difficult to interpret. Initially, with an amplifier gain of approximately 250, approximately 12% anti-coincidence was obtained. With the amplifier gain increased to 1000, approximately 60% anti-coincidence was obtained. The uncertainty in this number is due to the extremely high counting rate on the anti-coincidence ($\approx 3 \times 10^5$ c/s) due to the low-energy, non-penetrating electrons which introduce approximately 15% "dead-time" into the pulse height electrons, so that one would expect some reduction in the observed counting rate on D1 due to dead-time alone. On the other hand, there is an opposing effect due to the dead time (15-20%) in the scintillator channel which should cause some loss in true anti-coincidence pulses. The relative weights of these two effects is difficult to estimate. Nevertheless, the improvement in anti-coincidence achieved by increasing the amplifier gain would indicate that the discrimination threshold was initially set too high. It is suggested that in future calibration tests some additional tests be performed with the PET oblique to the accelerator beam, particularly at low and intermediate energies. In addition to increasing the amplifier gain, the anti-coincidence timing was adjusted to allow the anti-coincidence pulse to appear approximately 100 ns earlier (relative to the timing strobes) than was the case during the tests at SREL. This was done by taking the anti-coincidence trigger pulse from point A (instead of point B) in the anti-coincidence pulse shaper (Figure 5).

The original and revised amplifier configurations are shown in Figures 6 and 7 respectively. The changes incorporated serve three functions:

1. Increase overall gain to lower effective threshold.
2. Provide a greater range of gain adjustment with the trimpot ($\approx$ 20%).
3. Increase integration time constant slightly to provide a quieter signal at the amplifier output.

With the amplifier gain set at approximately 1000, the background counting rate due to noise was approximately 50 c/s as opposed to 8 c/s at a gain of 250.

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CC:ks

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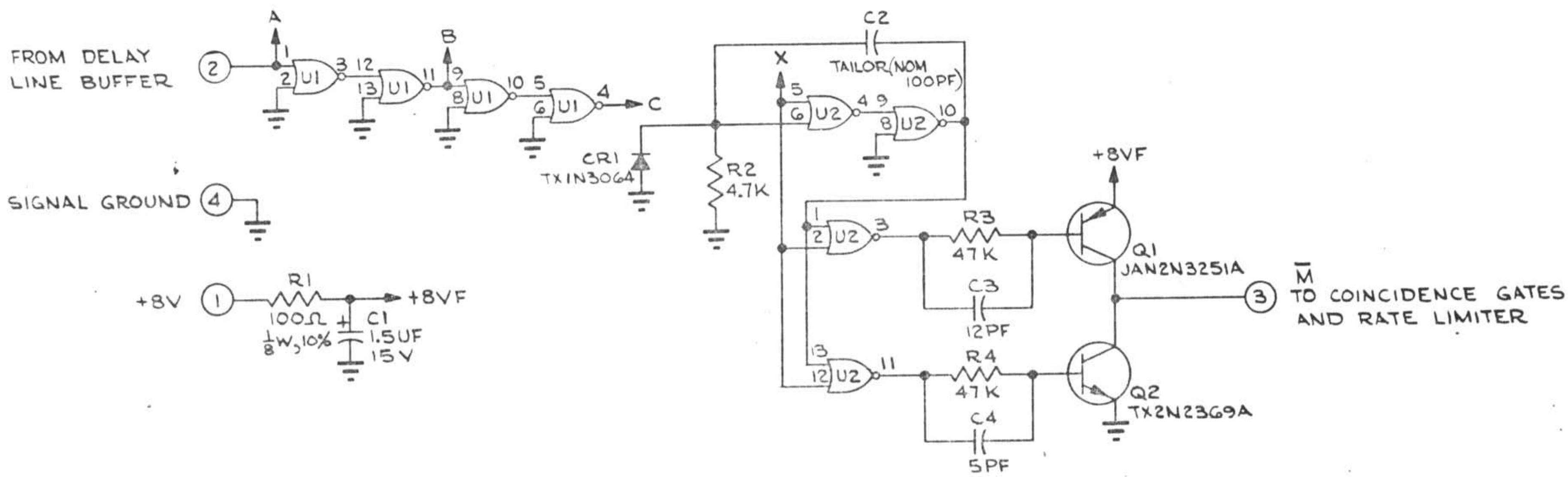

NOTES-UNLESS OTHERWISE SPECIFIED

1. ALL RESISTORS ARE $\frac{1}{8}$W, 5%
2. INTEGRATED CIRCUITS ARE CD4001 (RCA)
3. PIN 7 OF I.C.'S IS SIG GRD;
   PIN 14 IS +8FV
4. POINT X IS CONNECTED TO A, B OR C
   DEPENDING ON REQUIRED DELAY

Figure 5

HIGHEST REF DESIGNATION	
R4	Q2
C4	CR1
U2	

PART NUMBER	SIZE	NEXT ASSEMBLY	QTY	USED ON
	A	SRA-G540	REF	
	C	SRA-G539	REF	
SRA-G537	C	SRA-G538	REF	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON DECIMALS
XX = ± .03
XXX = ± .010
ANGULAR ± 1/2°
DIM & TOL PER MIL STD 8B
BREAK SHARP EDGES, REMOVE ALL BURRS

DRAWN BY J.T. MUELLER 4 MAR 70

LIST OF MATERIAL

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
8621 GEORGIA AVENUE SILVER SPRING MARYLAND

SCHEMATIC DIAGRAM
PET ANTICOINCIDENCE PULSE SHAPER
CPME
IMP H + J SATELLITE

CODE IDENT NO	SIZE		ISSUE
88898	C	SRA-G537	a

DO NOT SCALE PRINT — SHEET 1 OF 1

FORM # SDO-301

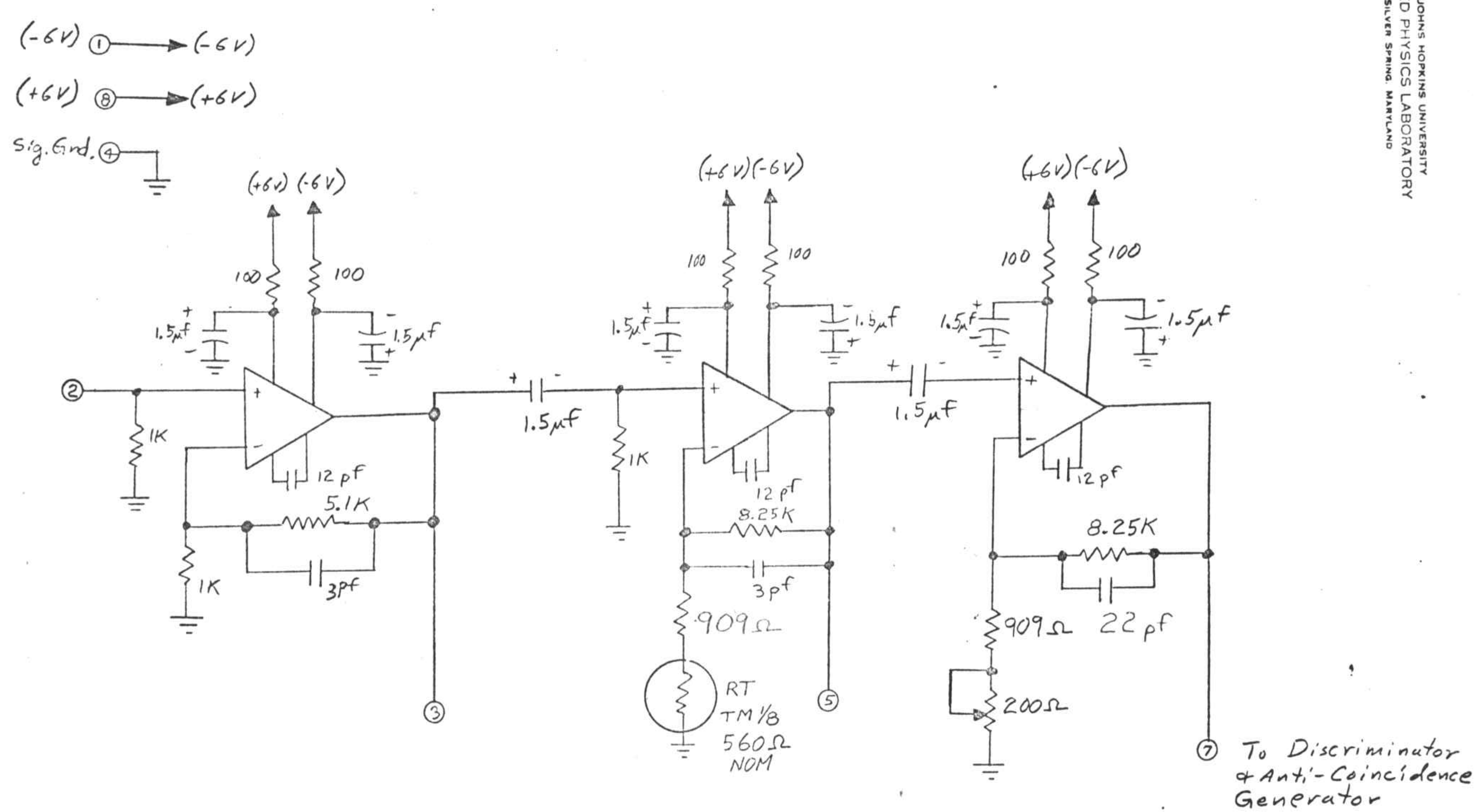

Figure 6

Photomultiplier Amplifier Chains
PET and GT Anti-Coincidence Electronics

(Original)

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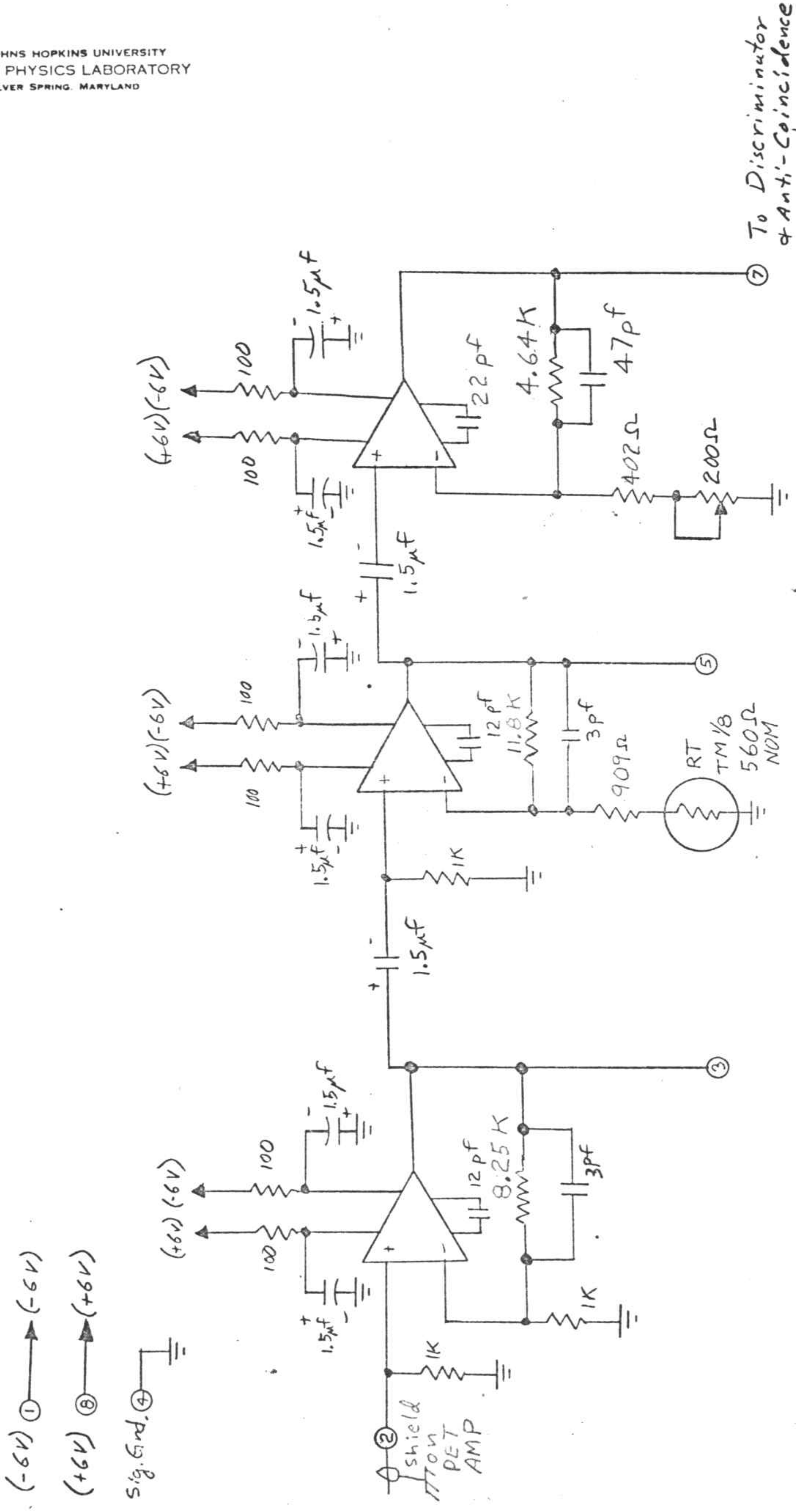

Figure 7
Photomultiplier Amplifier Chains
PET and GT Anti-Coincidence Electronics
(Revised)