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SUBJECT: CPME In-Flight Calibrator Design

INTRODUCTION

The purpose of the In-Flight Calibrator is to test the Charged Particles Measurement Experiment (CPME) preamplifiers, amplifiers, discriminators and logic during ground checkout and in orbit and to quantitatively measure the effective discriminator drift. The following ground rules were established at the inception of the design:

1. A calibration failure will have essentially zero probability of effecting normal CPME operation.

2. A command will provide the capability of turning the calibrator power off.

3. Calibration data will be read out as part of the normal particle data in the CPME rate registers.

4. Weight and size will be considered premium quantities.

Calibration Technique

Figure 1 shows a block diagram of the CPME. The part of the experiment to be calibrated consists of a telescope made up of three solid state detectors (D_1, D_2, and D_3) which drive three linear amplifiers (Channels A, B, and C). Each channel drives several discriminators (A_i, B_i, C_i, $i = 1, 2, 3 \ldots$) and the "logic unit" analyzes the height of the pulse by noting which discriminators have been triggered in each channel. The logic unit sorts and directs pulse height data into rate registers

(R_1 thru R_{25}) and sector registers (S_1 thru S_4), all of which are located in the spacecraft encoder.

The in-flight calibrator tests the linear amplifiers, discriminators, and logic for channels A, B, and C by generating voltage pulses* which drive the CPME preamplifiers thru precision 5.1 pf capacitors, simulating an energy of about 112 kev per mV. Since the calibration pulses must simulate energy depositions up to 32 Mev with 20% over-ranging to allow for discriminator level drift, the voltage pulses at the preamplifier inputs must be as large as 350 mV.

Information about discriminators A_1 and A_5 appears in sector data registers and the α_1 and P_1 data lines are subcommutated into registers R_7 and R_4 during a calibration so that A_1 and A_5 calibration data appear in rate registers. In this manner, all discriminators in channels A, B, and C are checked by information contained in rate registers and the calibrator can be operated in synchronism with the encoder clock.

Four linear voltage pulse envelopes are used during the calibration sequence and Figure 2 illustrates how these envelopes are used to determine discriminator levels. One uses the smallest ramp that triggers the discriminator of interest to maximize resolution. Then the calibration pulses are directed to those amplifier channels which satisfy the logic requirements of the logic unit. For example, the first discriminator level of channel B is obtained by using a pulse ramp with a 400 kev maximum pulse into preamplifiers B and C and observing register R14 data which records all counts from the point of firing of discriminator B1 to 400 kev. At 2000 counts/ramp the pulse resolution $= \frac{400}{2000} = 0.2$ kev/pulse and the calibration counts in R_{14} = $= \frac{400\text{ kev} - 250\text{ kev}}{0.2\text{ kev/ct}} = 750$ counts. The spacecraft encoder log compression

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* The detectors produce negative pulses and the calibrator must therefore simulate negative pulses.

error for R_{14} is 3%, and 3% of 750 cts = 22 cts. Therefore, at 0.2 kev/ct the resolution = 4.4 kev or $\frac{4.4}{250}$ x 100% = 1.76%. In some cases it is convenient to read the window between two levels and infer the position of the upper discriminator from a knowledge of the lower discriminator position (see Figure 2). The A_2 discriminator is found by this method.

By selecting the proper ramp slope and driving the proper preamplifiers at the proper times, all discriminators in the telescope are tested. Figure 3 is a chart showing where the calibration data appears in the TM readout and what resolution error is introduced by the encoder log compression. Rate Registers R_1 through R_{11} are 24-12 bit log-compressed (3/4% resolution) and R_{12} through R_{25} are 24-10 bit log-compressed (3% resolution). The exact discriminator settings are found with the aid of the equations of Figure 4.

CIRCUIT DESCRIPTION

General

Figure 5 shows a block diagram of the CPME in-flight calibrator. A linear envelope of calibration pulses is obtained by chopping a voltage ramp derived from a Miller integrator. The pulses are attenuated with 600Ω pads and directed to the preamplifier of the desired channel via diode switches. Power to the calibrator is duty-cycled using the encoder timing signals C_{35} and a_6. Figure 6 shows a schematic diagram of the calibrator and specific circuits are described below.

Power Switching

The MOS elements G_9, G_{10}, G_{11} and FF2 (Figure 6) are controlled by encoder timing signals C_{35} and a_6 and perform the logic necessary to turn on the series power switches (Q_5 and Q_7) for one full cycle of a_6

(82 seconds in high bit rate) every 46 hours (C_{35} period), constituting a 1:2160 duty cycle.

Ramp Generator

As long as the calibrator is powered, an 800 ms ramp is generated when a_3 goes to ground (period = 10.24 seconds in high bit rate). The negative transition of a_3 is inverted by G_4, differentiated and sets a control RS flip-flop (G_6, G_7) which turns off a reset FET (Q_1) and allows the Miller integrator (AR1) to be driven by a 5 μa current source at node "A". The integrated current produces a ramp with a slope of about $\frac{\Delta V}{\Delta T} = \frac{I}{C} = \frac{5 \times 10^{-6}}{2 \times 10^{-6}} = -2.5$ volts/sec. When the ramp reaches minus 2.0 volts, a level detector (AR2) resets the control R-S flip-flop and the Miller capacitor discharges until the next a_3 negative transition.

When power turns on, the R-S control flip-flop may assume the wrong state, so G_7 is set by an RC delay (100K, .1 μf) to ensure that the initial control state is "reset".

As an aid in troubleshooting on the ground, the Miller integrator may be changed into a D.C. inverting amplifier by grounding the "pulser mode" terminal. The AR1 output voltage is then set by a voltage applied at the "pulser input" terminal.

Chopper

The chopper is a capacitor charge/discharge type in which a capacitor is charged thru Q_9 during the first half of a 2.5 kHz square wave and discharged thru Q_{10} into the load during the second half of the square wave. The discharge switch (Q_{10}) is an over-driven PNP transistor in which the base current drive is removed from the emitter without passing thru the load. Q_{12} and Q_{14} are current mode switches which supply the drive currents for the PNP chopper.

Attenuators

Four attenuator values; 0 db, 20 db, 30 db, and 40 db are obtained using four 600Ω π-attenuators having values; 10 db, 10 db, 20 db, and 0 db. When 40 db attenuation is desired, Q_{19} is switched on and Q_{20}, Q_{21}, and Q_{22} are off. When 30 db attenuation is required, Q_{20} is on and Q_{19}, Q_{21}, and Q_{22} are off, etc. A tailor attenuator in each preamplifier provides a fine adjustment to the voltage/energy conversion.

The FET gates Q_{19} thru Q_{22} are by-passed to form an a.c. common gate switch which greatly minimizes feedthru. a_5 and a_6 drive MOS gates (G_{12} thru G_{15}) which select the attenuation to conform with the table in Figure 3.

Buffers

The calibrator output circuits utilize a hot-carrier diode (HP2302) to provide a means of switching calibration pulses into the desired channels while providing minimum feedthru to the "off" channels G_{16} thru G_{22} to give results described in the table in Figure 3.

RAMP AND PULSE SLOPE CONSTRAINTS

The characteristics of the ramp of calibration pulses are restricted within limits imposed by the imperfect nature of the components in the calibrator. For example, the capacitance of the Miller capacitor is limited to some C_{MAX} by available volume and the minimum Miller charging current I_{MIN} is required to be much larger than circuit leakage currents and operational amplifier offset currents. Consequently, the slope of the

Miller ramp can be no smaller than

$$\left.\frac{\Delta V}{\Delta T}\right|_{MIN} = \frac{-I_{MIN}}{C_{MAX}}$$

For the components of CPME calibrator

$$\left.\frac{\Delta V}{\Delta T}\right|_{MIN} = \frac{-5\ \mu a}{2\ \mu f} = -2.5\ \frac{\text{volts}}{\text{second}}$$

The practical limit of the ramp voltage is set by the power supply voltages available to power the Miller operational amplifier and the chopper. In the CPME the maximum practical ramp voltage is -2.0 volts. Since the slope and one non-trivial point on the ramp are defined, the entire ramp is defined.

The shape of the pulses is established by the time constants of the amplifier being calibrated. Ideally each pulse would be a step function, rising in zero time and falling with zero slope. However, the amplifier being calibrated has an integrator and at least one differentiator which permits a non-ideal step function to suffice as a calibration pulse. Since the amplifier may have two differentiators, the third differentiation introduced by the calibrator must be long enough to prevent a large double overshoot at the amplifier output which would look like a small secondary pulse. With the above points in mind the CPME calibration pulse is constrained as shown in Figure 7.

With the ramp and the pulse defined one needs only to define how many pulses per ramp are required to make the calibration counts large compared to normal data background counts. Assuming a 1 count/second background rate,* choosing a 10:1 calibration/background count rate and remembering

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* refer to S. M. Krimigis

that the longest data accumulation time is 20 seconds, one arrives at a minimum calibration count of 200. As verified by Figure 3, about 200 calibration counts per data channel or greater will be obtained if the ramp contains 2000 pulses. In other words, a 2.5 kHz chopping rate is required. One half of the chopping period (200 ms) is available for the decay of the calibration pulse and since its differentiation time is 30 ms it will have 6 2/3 time constants to decay. Figure 8 illustrates the above discussion graphically.

Sources of Error

Sources of error which effect the pulse and ramp constraints are quantitatively listed below.

	-15°C	+25°C	+40°C
1. FET leakage current:	31 pa	.5 na	1.42 na

(No data is available on FET leakage vs. time)

2. Miller Capacitor leakage current:

-15°C	+25°C	+40°C
$\frac{2V}{200 \times 10^9 \Omega} = 10$ pa	$\frac{2V}{50 \times 10^9 \Omega} = 40$ pa	$\frac{2V}{20 \times 10^9 \Omega} = 100$ pa

After the 250 hour life test (140% rated voltage and 125°C) the insulation resistance is specified to be at least 60% of its initial value.

3. Stability of the polycarbonate Miller capacitor:

-15°C	+25°C	+40°C
1.995 µf	2.000 µf	2.002 µf

After the 250 hour life test (140% rated voltage and 125°C) the capacitance is specified not to change more than 5%.

4. Stability of chopper frequency: ± 0.2% from -15°C to $+40^\circ$C.

5. Precision voltage errors:

The zener references will be driven by that current which yields a zero voltage T.C. For the 1N750 the current is about 5 ma which corresponds to an impedance of 40Ω and a voltage of ~ 4.5 volts. For a 1% change in the -6 volt line:

$$\Delta I_z = \frac{1\%(6)\text{V}}{1.5\text{V}} \text{ x } 5 \text{ ma} = \frac{60}{1.5} \text{ x } 5 = 200 \ \mu\text{a};$$

$$\Delta V_z = 40\Omega \text{ x } .2 \text{ ma} = 8 \text{ mV};$$

Therefore

$$V_{REF} \text{ error} = \frac{8}{4700} = \frac{1}{525} \longrightarrow 0.19\%$$

6. Operational amplifier offset errors:

LM 108: From -15°C to $+40^\circ$C:

$$\frac{\Delta V_{os}}{\Delta T} = 15 \ \mu\text{V}/^\circ\text{C} \longrightarrow \Delta V_{in} = 825 \ \mu\text{V} \longrightarrow .0825\%$$

$$\frac{\Delta I_{os}}{\Delta T} = 2.5 \text{ pa}/^\circ\text{C} \longrightarrow \Delta I_{in} = 138 \text{ pa} \longrightarrow 138 \text{ pa x } 196\text{K} = 27.2 \ \mu\text{V} \longrightarrow .0027\%$$

μC 741: From -55°C to $+125^\circ$C

$$\Delta V_{os} = 1 \text{ mV max}$$

$$\Delta I_{os} = 300 \text{ na} \longrightarrow .3 \text{ x } 10^{-6} \text{ x } 5.5\text{K} = 1.65 \text{ mV}$$

Therefore the ΔV_{os} and ΔI_{os} errors = 2.65 mV = 0.133%

7. Attenuator and chopper drive impedance:

The lowest available "on" resistance FET (2N4856A) was chosen ($R_{DS_{on}} = 25\Omega$) and the series chopper PNP $R_{on} = 5\Omega$. Therefore, the drive impedance to the attenuator is 30Ω and since the T.C. is about 0.7%/°C:

	-15°C	+25°C	+40°C
Drive Resistance =	22.6Ω	30Ω	34.8Ω
Attenuation Error	+2.3%	0%	-1.02%

Since this is a difficult place to temperature compensate and because the error is predictable and can be programmed out, this error will be left as is.

8. Buffer attenuation error:

$r_{diode} = 50\Omega$ and will drive about 3K in the preamplifier.

$$\Delta r_e = 50 \ \frac{55}{295} = 5.5\Omega \text{ from } -15^\circ\text{C to } +40^\circ\text{C}$$

$\simeq$ 0.2% attenuation drive error from -15°C to +40°C.

9. Non-linearity due to PNP chopper V_{os} ($\cong$ 25 mV):

Pulse amplitude = V_{in} - 25 mV   0.1% non-linearity (but has no effect on pulse ramp slope).

10. Chopper feed-thru spikes are about 20 mV peak over the temperature range from -15°C to +40°C. Note that 20 mV $\cong$ 1.5% of full scale.

From the above data one concludes that the most significant errors are due to: The change of Miller feedback capacitance with age, which experience has shown to be small if a polycarbonate or a polystyrene dielectric is used; chopper frequency temperature drift (± 0.2%); change of chopper drive impedance with temperature which is large but well defined; and chopper feedthru spikes which are about 1% of full scale.

OVERALL PERFORMANCE

Pictures of the calibration pulses at the input to the attenuators are shown in Figure 9. The pulse leading edge is about 30 ns from 10% to 90% and the trailing edge time constant is about 35 μs. Feedthru spikes which occur midway between the pulses are less than 1 1/2% of full scale and between -60°C and +70°C. Over this 130°C temperature range the pulse rise time remained constant and the pulse amplitude changed by 6%, which is caused by the chopper and attenuator FET impedance variation with temperature. The feedthru spikes depend on power supply voltage tracking in a 1:1 manner. That is, the power supply can vary 10% around nominal without effecting the chopper spiking problem provided the percent change in the +8V and -6V lines is the same. However, if the power supply deviates such that one of the +8V or -6V lines do not change while the other changes by 1%, then a spike of 1% of full scale will appear between calibration pulses.

The linearity of the pulse envelope was checked on a pulse height analyzer which divides the pulse ramp into equal segments and records how many pulses occur in each segment. Over the temperature range from -50°C to +65°C the segments recorded equal pulse counts within 1% which is within the accuracy of the analyzer.

CALIBRATOR SET-UP AND USE

Several steps are required in the set-up of the calibrator. First the two zener diodes used to regulate the +1.00V and -2.00V references must be temperature-cycled to determine the zener bias current which yields a zero drift with temperature. The zener bias resistors must then be tailored to the proper bias currents to each diode as shown in Figure 6.

Next the chopper base and emitter currents are balanced by adjusting the 200Ω potentiometer (Figure 6) until the voltage discontinuity between calibration pulses becomes less than 2.0 mV. The leading edge may be adjusted if necessary by tailoring any or all of the chopper tailor capacitors to obtain the desired result.

One may find it convenient to check the attenuator by grounding the "Pulser Mode" input and "Pulser Input". The a_5 and a_6 encoder signals may then be simulated and the attenuation checked against the timing waveforms in Figure 6. N.B., each channel must be loaded with exactly 6.00 KΩ to provide the required 600Ω load to the attenuators.

Once the calibrator is functioning properly at room temperature, a test is run to obtain a plot of pulse amplitude vs. temperature for the required range of operation ($-15^{\circ}C$ to $+40^{\circ}C$). The "Pulser Mode" is most suitable for this test and the 10:1 attenuation is selected arbitrarily. The amplitude plot is used to obtain f(T) for the equations of Figure 4 which are used to determine the discriminator settings.

Next the calibrator is integrated with the SPME and the preamplifier resistors are selected to yield a 4.00 Mev pulse at the top of the pulse ramp in the 10:1 attenuation mode. A convenient method of doing this is to set the discriminators for channels A, B, and C at 4.00 Mev using a laboratory standard pulser. Then run the calibrator and adjust the preamplifier calibration attenuation resistors to obtain an average of 0.5 cts from the discriminators.

Finally, take a set of calibration data and compare the results to the results listed in Figure 3 under "Nominal Calibration Counts". These may be inconsistant by a few counts and D_i is then selected as a correction factor to make the equations of Figure 4 give the exact results listed in Figure 3. This step is not necessary for proper calibrator operation but it gives one the data necessary to program a computer to calculate the discriminator settings and provides a consistant method for checking the discriminators of any CPME unit.

INTERFACES

A wiring diagram showing connections to the calibrator is shown in Figure 10. Particular care will be taken to keep signal grounds and power grounds separate. The calibration pulse outputs will be grounded at the preamplifiers only.

Power Consumption =	214 nW stby;	240 mW peak;	121 uW average.
+8V →	21 nA stby;	18 mA peak;	72 uW average.
-6V →	0 nA stby;	16 mA peak;	48 uW average.
-23V →	2 nA stby;	90 uA peak;	1 uW average.

Timing Signal Requirements:

a_3, a_3 override

a_4, a_4 override

a_5, a_5 override

a_6, a_6 override

C_{35}, C_{35} override

Extra Test Connector Pins:

(a) "Pulser mode on"

(b) "Pulser input amplitude"

(c) "Pulser return"

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DPP:jgs

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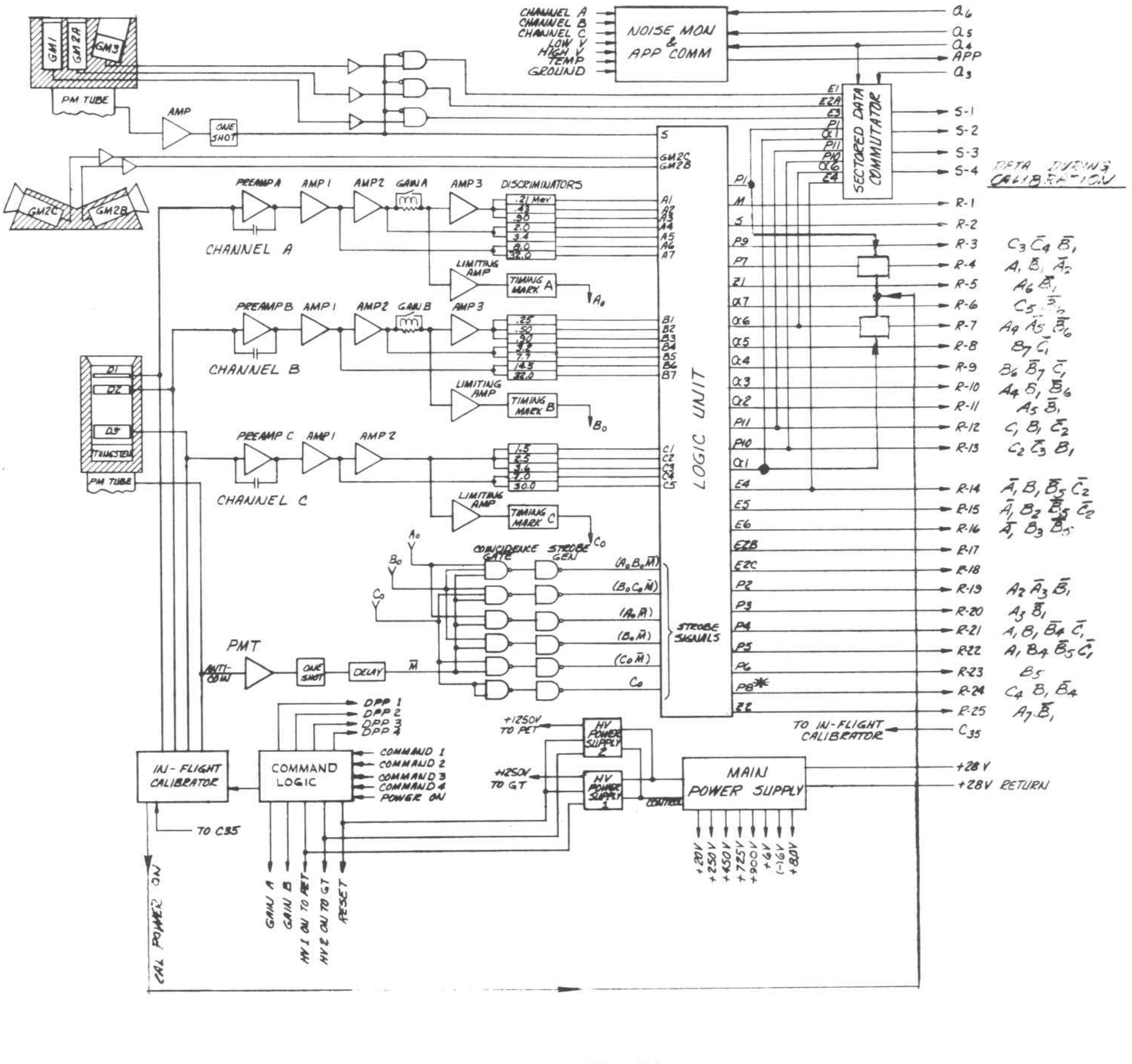
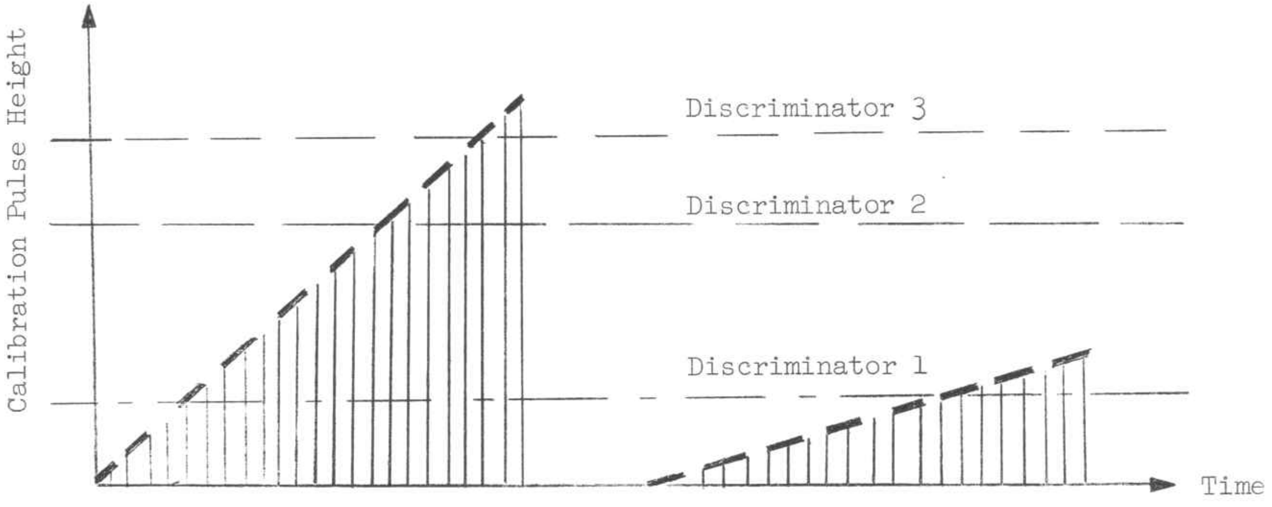
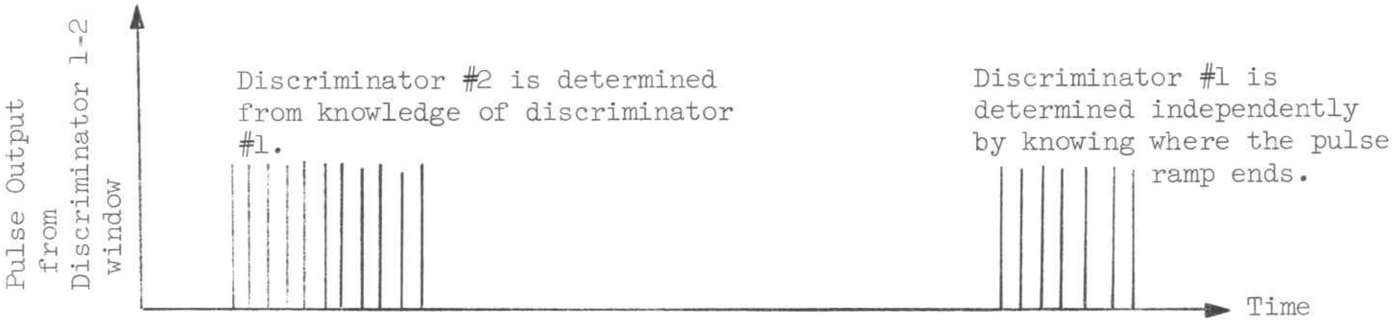


Figure 1. CPME BLOCK DIAGRAM

* DURING NORMAL DATA TAKING PERIODS
R24 CONTAINS $C_4 \bar{B}_1 \bar{B}_4$



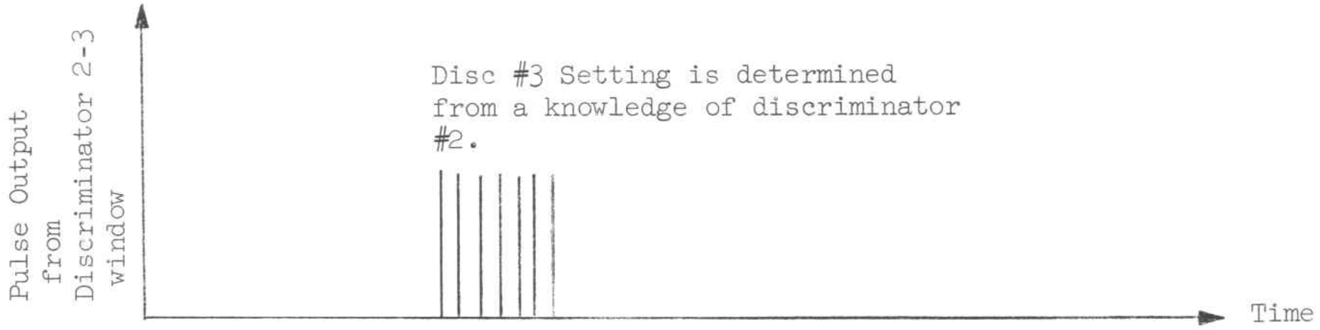
(a) Calibrator Pulse Height Envelopes vs. Time



Discriminator #2 is determined from knowledge of discriminator #1.

Discriminator #1 is determined independently by knowing where the pulse ramp ends.

(b) Pulse Output From Discriminator 1-2 Window vs. Time



Disc #3 Setting is determined from a knowledge of discriminator #2.

(c) Pulse Output From Discriminator 2-3 Window vs. Time

Figure 2.

Obtaining Discriminator Level Calibration from Window Data.

Figure 3.

Listing of Calibration Data Contained in the CPME Rate Registers and Location of the Calibration Count in the TM Readout.

To obtain a calibration of the discriminator listed below	Drive the channel in this column	With a pulse ramp ranging from...	And read the rate register no., resolution	Which is described by the logic in this column	And which contains the following nominal calibration counts	And is read out in page, snap shot	
A_1	A and C	0-400 KeV	R_4 , 3/4%	$A_1\overline{B}_1\overline{A}_2$	Y_{A1} = 950, .68%	3	1
A_2	A and C	0-1.2 MeV	R_4 , 3/4%	$A_1\overline{B}_1\overline{A}_2$	Y_{A2} = 367, .73%	2	1
A_3	A and C	0-1.2 MeV	R_{19} , 3%	$A_2\overline{A}_3\overline{B}_1$	Y_{A3} = 783,1.95%	2	1
A_4	A and B	0-4.0 MeV	R_{10} , 3/4%	$A_4B_1\overline{B}_6$	Y_{A4} = 1000, 3/4%	1	3
A_5	A and B	0-4.0 MeV	R_7 , 3/4%	$A_4\overline{A}_5\overline{B}_6$	Y_{A5} = 700, 3/4%	1	3
A_6	A and C	0-40 MeV	R_5 , 3/4%	$A_6\overline{B}_1$	Y_{A6} = 1600, 3%	0	1
A_7	A and C	0-40 MeV	R_{25} , 3%	$A_7\overline{B}_1$	Y_{A7} = 400, 3/4%	0	1
B_1	B and C	0-400 KeV	R_{14} , 3%	$\overline{A}_1B_1\overline{B}_5\overline{C}_2$	Y_{B1} = 750 1.8%	3	3
B_2	B and C	0-1.2 MeV	R_{15} , 3%	$\overline{A}_1B_2\overline{B}_5\overline{C}_2$	Y_{B2} = 1167, 4.2%	2	3
B_3	B and C	0-1.2 MeV	R_{16} , 3%	$\overline{A}_1B_3\overline{B}_5$	Y_{B3} = 500,1.17%	2	3
B_4	A and B	0-4.0 MeV	R_{22} , 3%	$A_1B_4\overline{B}_5\overline{C}_1$	Y_{B4} = 400, 3/4%	1	3
B_5	A and B	0-40 MeV	R_{22} , 3%	$A_1B_4\overline{B}_5\overline{C}_1$	Y_{B5} = 225,1.65%	0	3
B_6	A and B	0-40 MeV	R_{10} , 3/4%	$A_4B_1\overline{B}_6$	Y_{B6} = 625, 3/4%	0	3
B_7	A and B	0-40 MeV	R_8 , 3/4%	B_7C_1	Y_{B7} = 400,3/16%	0	3
C_1	B and C	0-4.0 MeV	R_{12} , 3%	$C_1B_1\overline{C}_2$	Y_{C1} = 500, 6.7%	1	1
C_2	B and C	0-4.0 MeV	R_{14} , 3%	$\overline{A}_1B_1\overline{B}_5\overline{C}_2$	Y_{C2} = 1125, 2.9%	1	1

Note: Each ramp has 2000 calibration pulses and for this chart the ramp waveform is considered perfect. i.e., Resolution is the encoder's.

Figure 3 (Cont.)

To obtain a calibration of the discriminator listed below	Drive the channel in this column	With a pulse ramp ranging from...	And read the rate register no., resolution	Which is described by the logic in this column	And which contains the following nominal calibration counts	And is read out in page,	snap shot
C_3	B and C	0-4.0 MeV	R_{13}, 3%	$C_2\overline{C}_3B_1$	Y_{C3} = 550, 3%	1	1
C_4	A and C	0-40 MeV	R_3, 3/4%	$C_3\overline{C}_4B_1$	Y_{C4} = 170, 1.9%	0	1
C_5	A and C	0-40 MeV	R_6, 3/4%	$C_5\overline{B}_6$	Y_{C5} = 500, 1/4%	0	1

DISCRIMINATOR SETTINGS

A_1 = 210 KeV
A_2 = 430 KeV
A_3 = 900 KeV
A_4 = 2.0 MeV
A_5 = 3.4 MeV
A_6 = 8.0 MeV
A_7 = 32.0 MeV

B_1 = 250 KeV
B_2 = 500 KeV
B_3 = 900 KeV
B_4 = 3.2 MeV
B_5 = 7.7 MeV
B_6 = 14.5 MeV
B_7 = 32.0 MeV

C_1 = 1.5 MeV
C_2 = 2.5 MeV
C_3 = 3.6 MeV
C_4 = 7.0 MeV
C_5 = 30.0 MeV

Note: Each ramp has 2000 calibration pulses and for this chart the ramp waveform is considered perfect. i.e., Resolution is the encoder's.

Figure 4.

Equations Used To Determine Discriminator Levels.

$$
\begin{aligned}
A_1 \text{ (KeV)} &= 400 - 0.2\, Y_{A1} + D_{A1} \\
A_2 \text{ (KeV)} &= 400 - 0.2\, Y_{A1} + 0.6\, Y_{A2} + D_{A2} \\
A_3 \text{ (KeV)} &= 400 - 0.2\, Y_{A1} + 0.6\, (Y_{A2} + Y_{A3}) + D_{A3} \\
A_4 \text{ (MeV)} &= 4.0 - 2 \times 10^{-3}\, Y_{A4} + D_{A4} \\
A_5 \text{ (MeV)} &= 4.0 - 2 \times 10^{-3}\, (Y_{A4} - Y_{A5}) + D_{A5} \\
A_6 \text{ (MeV)} &= 40.0 - 20 \times 10^{-3}\, Y_{A6} + D_{A6} \\
A_7 \text{ (MeV)} &= 40.0 - 20 \times 10^{-3}\, Y_{A7} + D_{A7} \\
B_1 \text{ (KeV)} &= 400 - 0.2\, Y_{B1} + D_{B1} \\
B_2 \text{ (KeV)} &= 1200 - 0.6\, Y_{B2} + D_{B2} \\
B_3 \text{ (KeV)} &= 1200 - 0.6\, Y_{B3} + D_{B3} \\
B_4 \text{ (MeV)} &= 4.0 - 2 \times 10^{-3}\, Y_{B4} + D_{B4} \\
B_5 \text{ (MeV)} &= 4.0 - 2 \times 10^{-3}\, Y_{B4} + 20 \times 10^{-3}\, Y_{B5} + D_{B5} \\
B_6 \text{ (MeV)} &= 4.0 - 2 \times 10^{-3}\, Y_{A4} + 20 \times 10^{-3}\, Y_{B6} + D_{B6} \\
B_7 \text{ (MeV)} &= 40.0 - 20 \times 10^{-3}\, Y_{B7} + D_{B7} \\
C_1 \text{ (MeV)} &= [400 - 0.2\, Y_{B1} + 2.0\, (Y_{C2} - Y_{C1})] \times 10^{-3} + D_{C1} \\
C_2 \text{ (MeV)} &= (400 - 0.2\, Y_{B1} + 2.0\, Y_{C2}) \times 10^{-3} + D_{C2} \\
C_3 \text{ (MeV)} &= [400 - 0.2\, Y_{B1} + 2.0\, (Y_{C2} + Y_{C3})] \times 10^{-3} + D_{C3} \\
C_4 \text{ (MeV)} &= [400 - 0.2\, Y_{B1} + 2.0\, (Y_{C2} + Y_{C3} + Y_{C4})] \times 10^{-3} + D_{C4} \\
C_5 \text{ (MeV)} &= 40.0 - 20 \times 10^{-3}\, Y_{C5} - D_{C5}
\end{aligned}
$$

Note: 1. D_i is a constant to correct for small variations between amplifiers.

2. Y_i is the calibration count for detector i (see figure 3).

3. Multiply all equations by $f(T) = \dfrac{\text{Attenuation at } 25^\circ\text{C}}{\text{Attenuation at } T}$.

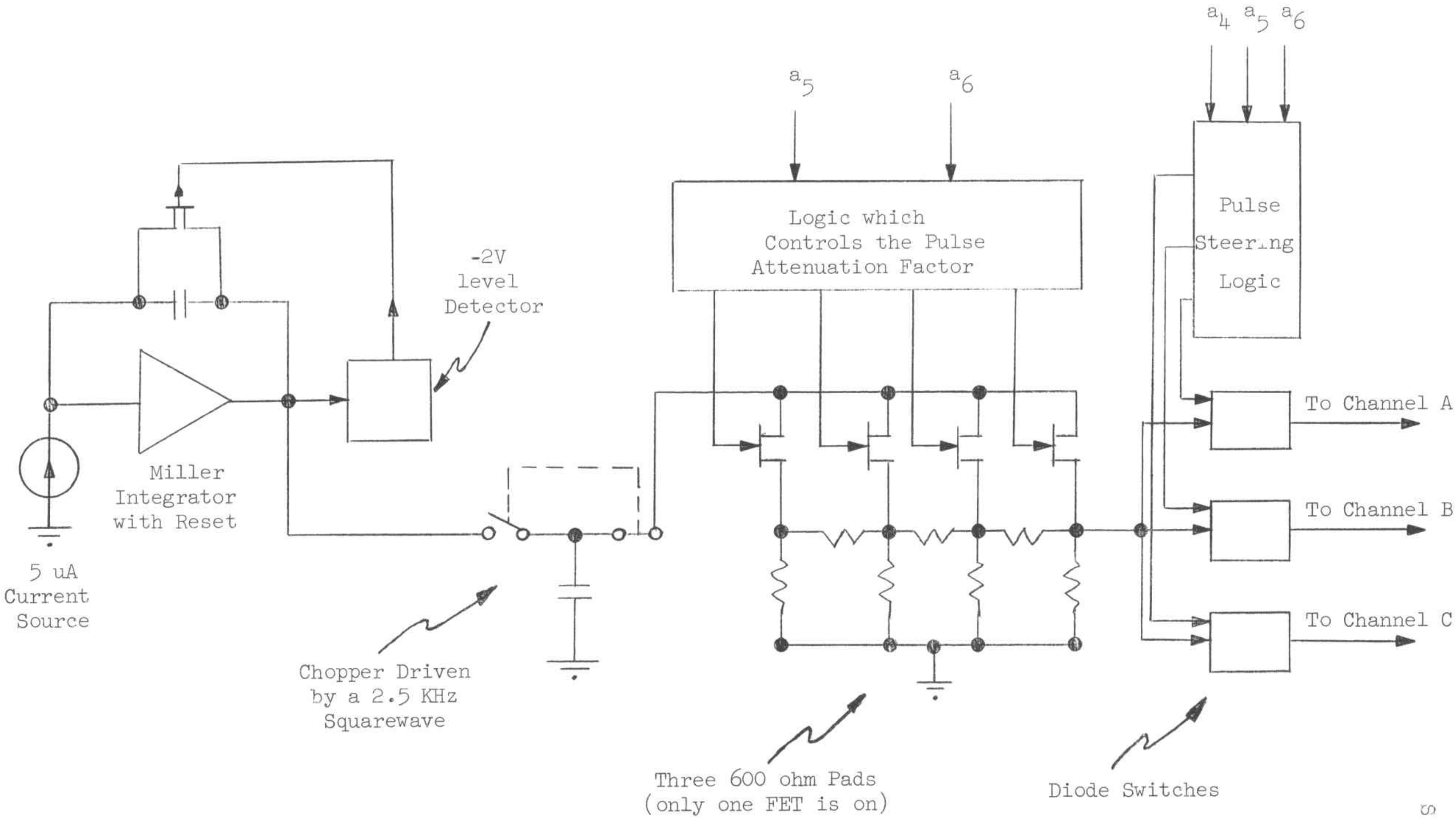
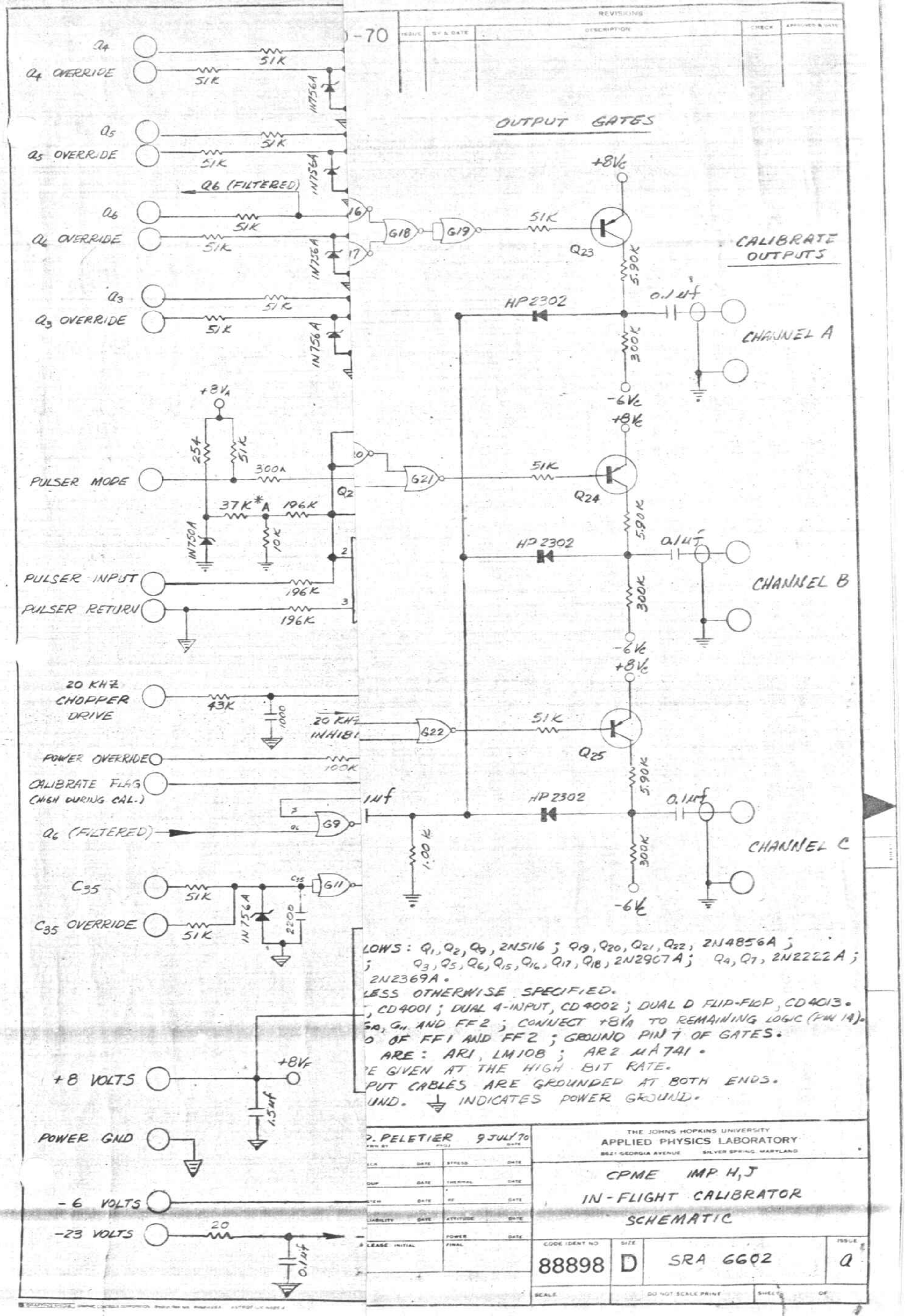


Figure 5

Block Diagram of the CPME In-Flight Calibrator



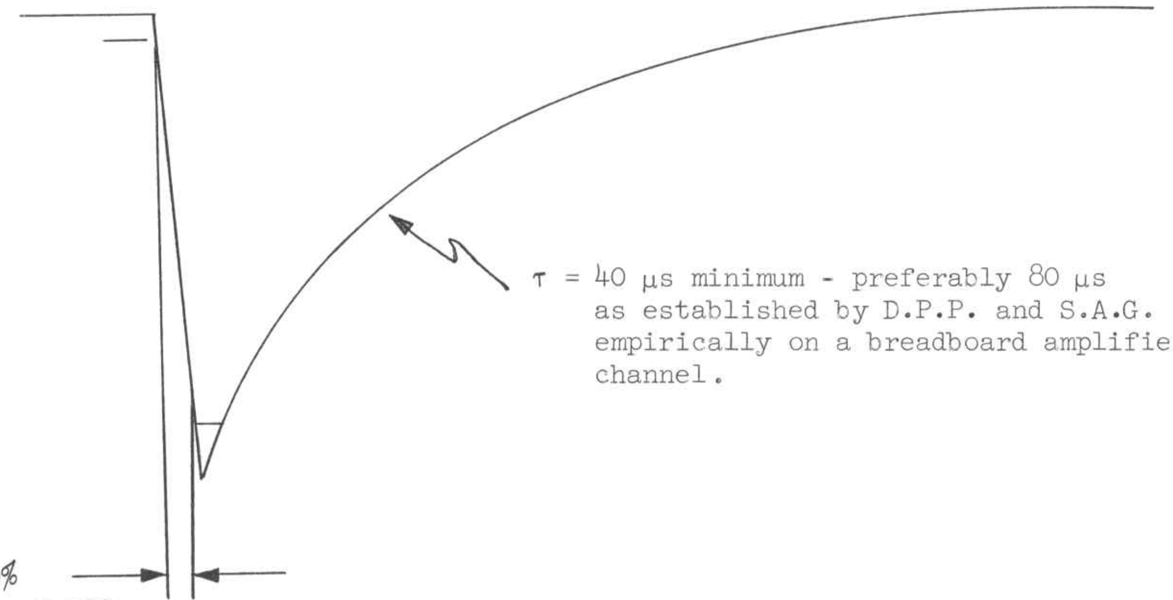
LOWS: Q_1, Q_2, Q_9, 2N5116 ; $Q_{19}, Q_{20}, Q_{21}, Q_{22}$, 2N4856A ;
; $Q_3, Q_5, Q_6, Q_{15}, Q_{16}, Q_{17}, Q_{18}$, 2N2907A ; Q_4, Q_7, 2N2222A ;
2N2369A.
LESS OTHERWISE SPECIFIED.
, CD4001 ; DUAL 4-INPUT, CD4002 ; DUAL D FLIP-FLOP, CD4013.
G_{10}, G_{11} AND FF2 ; CONNECT +8V_A TO REMAINING LOGIC (PIN 14).
O OF FF1 AND FF2 ; GROUND PIN 7 OF GATES.
ARE: AR1, LM108 ; AR2 µA741.
E GIVEN AT THE HIGH BIT RATE.
PUT CABLES ARE GROUNDED AT BOTH ENDS.
UND. ⏚ INDICATES POWER GROUND.

P. PELETIER RAWN BY	PROJ	9 JULY 70 DATE	
ECK	DATE	STRESS	DATE
OUP	DATE	THERMAL	DATE
STEM	DATE	RF	DATE
LIABILITY	DATE	ATTITUDE	DATE
		POWER	DATE
RELEASE	INITIAL	FINAL	

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

CPME IMP H, J
IN-FLIGHT CALIBRATOR
SCHEMATIC

CODE IDENT NO	SIZE		ISSUE
88898	D	SRA 6602	a
SCALE	DO NOT SCALE PRINT	SHEET	OF

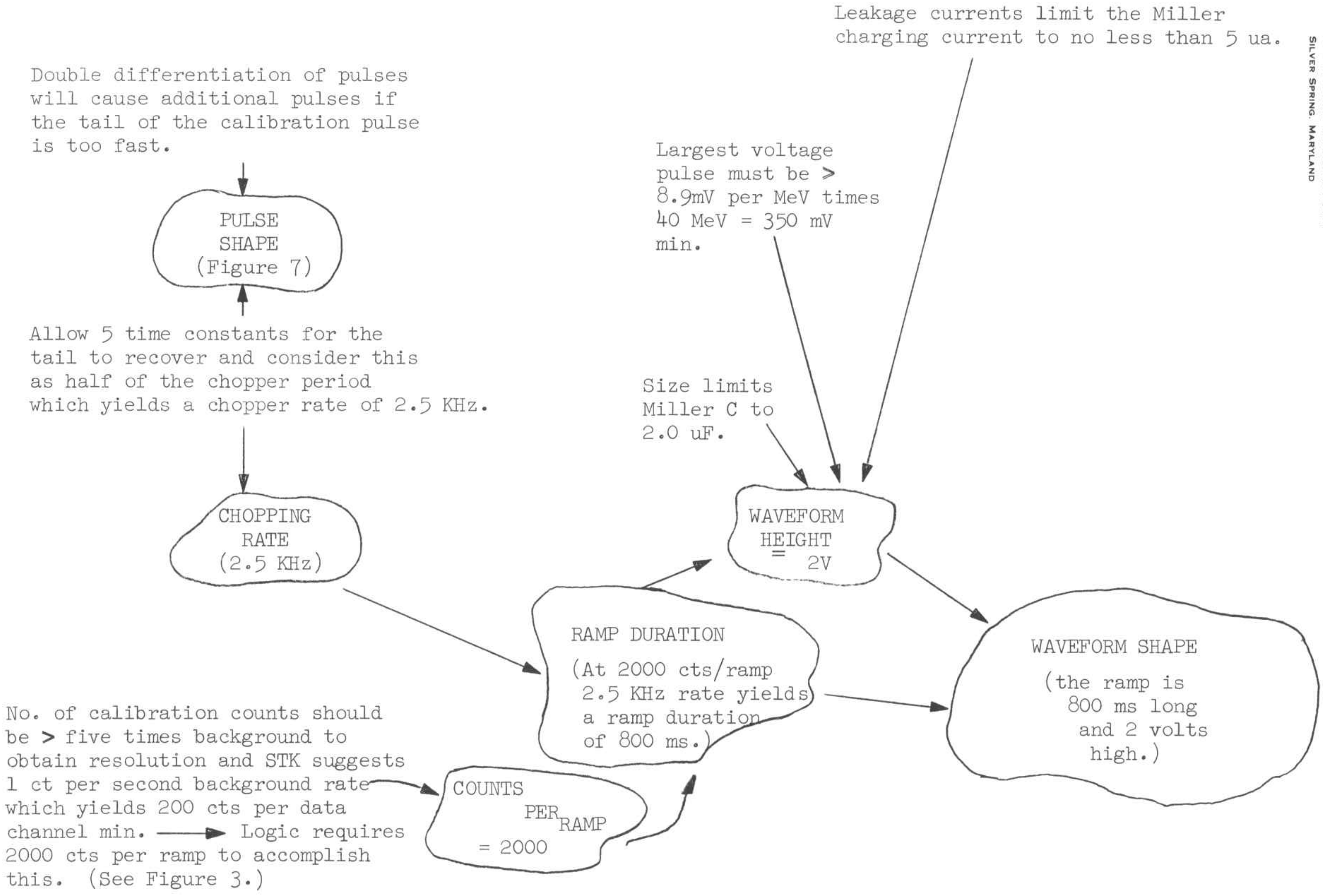


τ = 40 μs minimum - preferably 80 μs
as established by D.P.P. and S.A.G.
empirically on a breadboard amplifier
channel.

10% - 90%
rise time ≤ 100 ns.
Since first integrator is
τ = 300 ns, S.A.G. requests
a τ of 60 ns or less.
Therefore, design spec. = 100 ns
10% - 90%.

Figure 7.

CPME In-Flight Calibrator Pulse Specifications



Double differentiation of pulses will cause additional pulses if the tail of the calibration pulse is too fast.

Allow 5 time constants for the tail to recover and consider this as half of the chopper period which yields a chopper rate of 2.5 KHz.

Leakage currents limit the Miller charging current to no less than 5 ua.

Largest voltage pulse must be > 8.9mV per MeV times 40 MeV = 350 mV min.

Size limits Miller C to 2.0 uF.

(At 2000 cts/ramp 2.5 KHz rate yields a ramp duration of 800 ms.)

(the ramp is 800 ms long and 2 volts high.)

No. of calibration counts should be > five times background to obtain resolution and STK suggests 1 ct per second background rate which yields 200 cts per data channel min. ⟶ Logic requires 2000 cts per ramp to accomplish this. (See Figure 3.)

Figure 8. CPME Inflight Calibrator .... Origin of Constraints

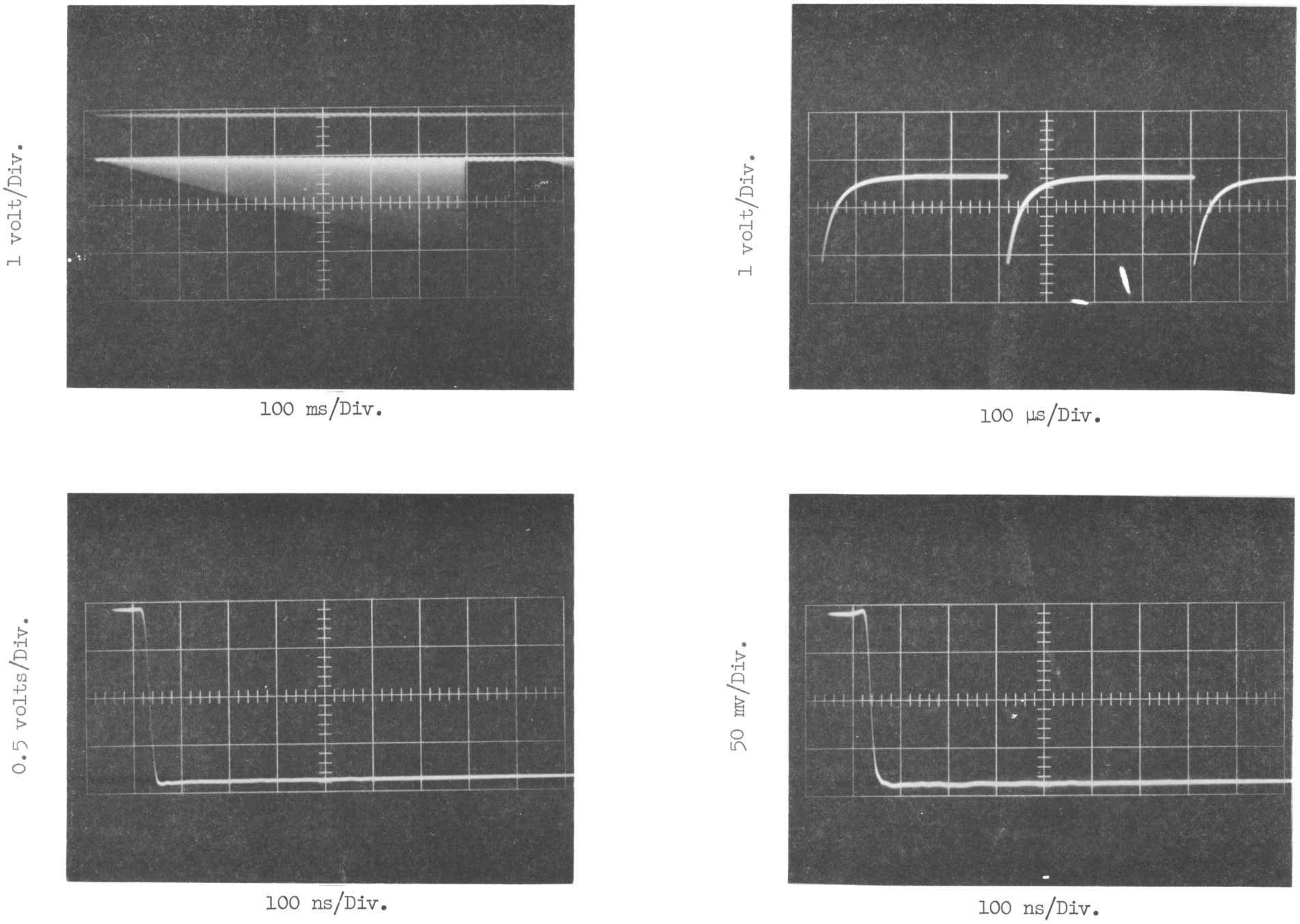
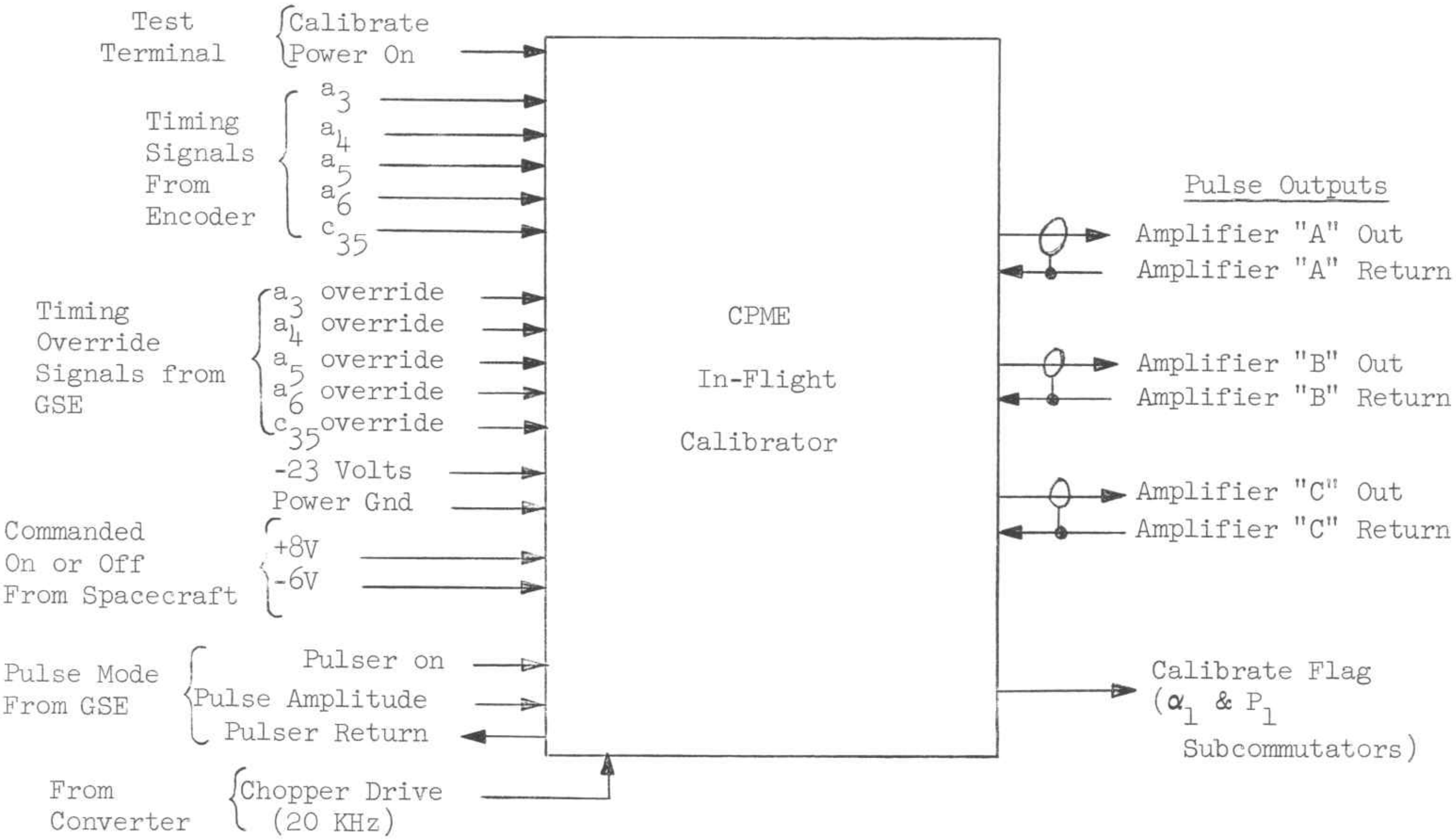


Figure 9. Pulse Waveforms at Chopper Output Before Attenuation

Figure 10.

Interface Diagram For
The CPME In-Flight Calibrator



THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
SILVER SPRING, MARYLAND

S1P-570-70 (a)
8 October 1970

TO: Distribution

FROM: D. P. Peletier

SUBJECT: Revisions to S1P-570-70, "CPME In-Flight Calibrator Design".

Included with this memo are revised figures 3 and 4 for the subject memo. The changes contained therein reflect the impact of logic revisions listed in S1P-588-70, "Channel Logic Revisions for Charged Particle Measurement Experiment".

The CPME calibrator changes include running the second highest ramp to 6.0 MeV instead of 4.0 MeV to obtain the C_3 level which is now 4.8 MeV instead of 3.6 MeV, and obtaining A_5 and C_1 calibration data from a 40 MeV ramp into channels A and C rather than a 4 MeV ramp into channels B and C or A and B. In addition, changes on the logic board were required which in effect change the logic equations of registers R_3 and R_6 during a calibration to obtain C_4 and C_5 discriminator data. The resulting calibration counts and % resolution of discriminators are listed on page 2.

Discriminators of Interest	Are Now		Use to Be	
	(Counts)	(% Res.)	(Counts)	(% Res.)
A_4	1333	1.5%	1000	0.75%
A_5	70	1.47%	700	0.75%
B_2	1233	4.8%	1167	4.2%
B_3	583	1.24%	500	1.17%
B_4	800	2.0%	400	0.75%
B_6	697	0.77%	625	0.75%
C_1	75	9.0%	500	6.7%
C_2	916	3.0%	1125	2.9%
C_3	600	3.0%	550	3.0%
C_4	145	2.15%	170	1.9%

Daniel P. Peletier
D. P. Peletier

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Figure 3.

Listing of Calibration Data Contained in the CPME Rate Registers and Location of the Calibration Count in the TM Readout.

To obtain a calibration of the discriminator listed below	Drive the channel in this column	With a pulse ramp ranging from...	And read the rate register no., resolution	Which is described by the logic in this column	And which contains the following nominal calibration counts	And is read out in page, snap shot
A_1	A and C	0-400 KeV	R_4 , 3/4%	$A_1\overline{B}_1\overline{A}_2$	Y_{A1} = 950, .68%	3 1
A_2	A and C	0-1.2 MeV	R_4 , 3/4%	$A_1\overline{B}_1\overline{A}_2$	Y_{A2} = 367, .73%	2 1
A_3	A and C	0-1.2 MeV	R_{19} , 3%	$A_2\overline{A}_3\overline{B}_1$	Y_{A3} = 783,1.95%	2 1
A_4	A and B	0-6.0 MeV	R_{10} , 3/4%	$A_4B_1\overline{B}_6$	Y_{A4} = 1333, 1.5%	1 3
*A_5	A and C	0-40 MeV	R_7 , 3/4%	$A_4\overline{A}_5\overline{B}_1$	Y_{A5} = 70 ,1.47%	1 3
A_6	A and C	0-40 MeV	R_5 , 3/4%	$A_6\overline{B}_1$	Y_{A6} = 1600, 3%	0 1
A_7	A and C	0-40 MeV	R_{25} , 3%	$A_7\overline{B}_1$	Y_{A7} = 400, 3/4%	0 1
B_1	B and C	0-400 KeV	R_{14} , 3%	$\overline{A}_1B_1\overline{B}_5\overline{C}_2$	Y_{B1} = 750 1.8%	3 3
B_2	B and C	0-1.2 MeV	R_{15} , 3%	$\overline{A}_1B_2\overline{B}_5\overline{C}_2$	Y_{B2} = 1233, 4.8%	2 3
*B_3	B and C	0-1.2 MeV	R_{16} , 3%	$A_1B_3\overline{B}_5\overline{C}_2$	Y_{B3} = 583,1.24%	2 3
B_4	A and B	0-6.0 MeV	R_{22} , 3%	$A_1B_4\overline{B}_5\overline{C}_1$	Y_{B4} = 800, 2.0%	1 3
B_5	A and B	0-40 MeV	R_{22} , 3%	$A_1B_4\overline{B}_5\overline{C}_1$	Y_{B5} = 225,1.65%	0 3
B_6	A and B	0-40 MeV	R_{10} , 3/4%	$A_4B_1\overline{B}_6$	Y_{B6} = 697, .77%	0 3
*B_7	A and B	0-40 MeV	R_8 , 3/4%	$B_7\overline{C}_1A_2$	Y_{B7} = 400,3/16%	0 3
*C_1	A and C	0-40 MeV	R_{12} , 3%	$C_1\overline{B}_3\overline{C}_2$	Y_{C1} = 75, 9.0%	1 1
C_2	B and C	0-6.0 MeV	R_{14} , 3%	$\overline{A}_1B_1\overline{B}_5\overline{C}_2$	Y_{C2} = 916, 3 %	1 1

Note: Each ramp has 2000 calibration pulses and for this chart the ramp waveform is considered perfect. i.e., Resolution is the encoder's.

* Changed according to S1P-588-70.

Figure 3 (Cont.)

To obtain a calibration of the discriminator listed below	Drive the channel in this column	With a pulse ramp ranging from...	And read the rate register no., resolution	Which is described by the logic in this column	And which contains the following nominal calibration counts	And is read out in page, snap shot
* C_3	B and C	0-6.0 MeV	R_{13} , 3%	$C_2\bar{C}_3B_3$	Y_{C3} = 600, 3%	1 1
& * C_4	A and C	0-40 MeV	R_3 , 3/4%	$C_3\bar{C}_4$	Y_{C4} = 145,2.15%	0 1
ß * C_5	A and C	0-40 MeV	R_6 , 3/4%	$C_5\bar{B}_6$	Y_{C5} = 500, 1/4%	0 1

DISCRIMINATOR SETTINGS

A_1 = 210 KeV
A_2 = 430 KeV
A_3 = 900 KeV
A_4 = 2.0 MeV
A_5 = 3.4 MeV
A_6 = 8.0 MeV
A_7 = 32.0 MeV

B_1 = 250 KeV
* B_2 = 460 KeV
* B_3 = 850 KeV
* B_4 = 3.6 MeV
B_5 = 7.7 MeV
* B_6 = 14.2 MeV
B_7 = 32.0 MeV

C_1 = 1.5 MeV
* C_2 = 3.0 MeV
* C_3 = 4.8 MeV
* C_4 = 7.7 MeV
C_5 = 30.0 MeV

Note: Each ramp has 2000 calibration pulses and for this chart the ramp waveform is considered perfect. i.e., Resolution is the encoder's.

* Changed according to S1P-588-70

& The normal logic in R_3 is $C_3\bar{C}_4B_3$ which is changed to $C_3\bar{C}_4$ during a calibration.

ß The normal ligic in R_6 is $C_5\bar{B}_6B_4$ which is changed to $C_5\bar{B}_6$ during calibration.

Figure 4.

Equations Used To Determine Discriminator Levels.

A_1 (KeV) = $400 - 0.2\ Y_{A1} + D_{A1}$

A_2 (KeV) = $400 - 0.2\ Y_{A1} + 0.6\ Y_{A2} + D_{A2}$

A_3 (KeV) = $400 - 0.2\ Y_{A1} + 0.6\ (Y_{A2} + Y_{A3}) + D_{A3}$

A_4 (MeV) = $6.0 - 3 \times 10^{-3}\ Y_{A4} + D_{A4}$

* A_5 (MeV) = $6.0 - 3 \times 10^{-3}\ Y_{A4} + 20 \times 10^{-3}\ Y_{A5} + D_{A5}$

A_6 (MeV) = $40.0 - 20 \times 10^{-3}\ Y_{A6} + D_{A6}$

A_7 (MeV) = $40.0 - 20 \times 10^{-3}\ Y_{A7} + D_{A7}$

B_1 (KeV) = $400 - 0.2\ Y_{B1} + D_{B1}$

B_2 (KeV) = $1200 - 0.6\ Y_{B2} + D_{B2}$

B_3 (KeV) = $1200 - 0.6\ Y_{B3} + D_{B3}$

B_4 (MeV) = $6.0 - 3 \times 10^{-3}\ Y_{B4} + D_{B4}$

B_5 (MeV) = $6.0 - 3 \times 10^{-3}\ Y_{B4} + 20 \times 10^{-3}\ Y_{B5} + D_{B5}$

B_6 (MeV) = $6.0 - 3 \times 10^{-3}\ Y_{A4} + 20 \times 10^{-3}\ Y_{B6} + D_{B6}$

B_7 (MeV) = $40.0 - 20 \times 10^{-3}\ Y_{B7} + D_{B7}$

* C_1 (MeV) = $[400 - 0.2\ Y_{B1} + 6.0\ Y_{C2} - 20\ Y_{C1}] \times 10^{-3} + D_{C1}$

C_2 (MeV) = $(400 - 0.2\ Y_{B1} + 2.0\ Y_{C2}) \times 10^{-3} + D_{C2}$

C_3 (MeV) = $[400 - 0.2\ Y_{B1} + 2.0\ (Y_{C2} + Y_{C3})] \times 10^{-3} + D_{C3}$

C_4 (MeV) = $[400 - 0.2\ Y_{B1} + 2.0\ (Y_{C2} + Y_{C3} + Y_{C4})] \times 10^{-3} + D_{C4}$

C_5 (MeV) = $40.0 - 20 \times 10^{-3}\ Y_{C5} - D_{C5}$

Note:
1. D_i is a constant to correct for small variations between amplifiers.
2. Y_i is the calibration count for detector i (see figure 3).
3. Multiply all equations by $f(T) = \dfrac{\text{Attenuation at } 25^\circ\text{C}}{\text{Attenuation at T}}$.

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* Changed according to S1P-588-70

Dr Armstrong

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
SILVER SPRING, MARYLAND

S1P-570-70 (b)
May 12, 1971

TO: Distribution

FROM: D. P. Peletier

SUBJECT: Revision (b) to S1P-570-70, "CPME In-Flight Calibrator Design".

Included with this memo are revised figures 3 and 4 for the subject memo. The changes contained herein reflect recent discriminator changes as well as corrected equations as well as the impact of logic revisions listed in S1P-588-70, "Channel Logic Revisions for Charged Particle Measurement Experiment". The attenuation temperature coefficient is also specified for your information.

Daniel P. Peletier
D. P. Peletier

DPP:dgb

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Listing of Calibration Data Contained in the CPME Rate Registers and Location of the Calibration Count in the TM Readout.

To obtain a calibration of the discriminator listed below	Drive the channel in this column	With a pulse ramp ranging from...	And read the rate register no., resolution	Which is described by the logic in this column	And which contains the following nominal calibration counts	And is generated page, snap shot	
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A_2	A and C	0-1.2 MeV	R_4 , 3/4%	$A_1\bar{B}_1\bar{A}_2$	Y_{A2} = 367, .73%	2	1
A_3	A and C	0-1.2 MeV	R_{19} , 3%	$A_2\bar{A}_3\bar{B}_1$	Y_{A3} = 783,1.95%	2	1
** A_4	A and B	0-6.0 MeV	R_{10} , 3/4%	$A_4B_1\bar{B}_6$	Y_{A4} = 1163, 1.5%	1	3
** A_5	A and C	0-40 MeV	R_7 , 3/4%	$A_4\bar{A}_5\bar{B}_1$	Y_{A5} = 100,1.47%	1	3
** A_6	A and C	0-40 MeV	R_5 , 3/4%	$A_6\bar{B}_1$	Y_{A6} = 1525, 3%	0	1
B_1	B and C	0-400 KeV	R_{14} , 3%	$\bar{A}_1B_1\bar{B}_5\bar{C}_2$	Y_{B1} = 750 1.8%	3	3
B_2	B and C	0-1.2 MeV	R_{15} , 3%	$\bar{A}_1B_2\bar{B}_5\bar{C}_2$	Y_{B2} = 1233, 4.8%	2	3
*B_3	B and C	0-1.2 MeV	R_{16} , 3%	$\bar{A}_1B_3\bar{B}_5\bar{C}_2$	Y_{B3} = 583,1.24%	2	3 ?
B_4	A and B	0-6.0 MeV	R_{22} , 3%	$A_1B_4\bar{B}_5\bar{C}_1$	Y_{B4} = 800, 2.0%	1	3
B_5	A and B	0-40 MeV	R_{22} , 3%	$A_1B_4\bar{B}_5\bar{C}_1$	Y_{B5} = 225,1.65%	0	3
B_6	A and B	0-40 MeV	R_{10} , 3/4%	$A_4B_1\bar{B}_6$	Y_{B6} = 697, .77%	0	3
*C_1	A and C	0-40 MeV	R_{12} , 3%	$C_1\bar{B}_3\bar{C}_2$	Y_{C1} = 75, 9.0%	1	1
C_2	B and C	0-6.0 MeV	R_{14} , 3%	$\bar{A}_1B_1\bar{B}_5\bar{C}_2$	Y_{C2} = 916, 3%	1	1

why is C needed?

I don't believe there's anyway we can get B_3 readout.

yes. it gets read out in pg 3 SS 1

Note: Each ramp has 2000 calibration pulses and for this chart the ramp waveform is considered perfect. i.e., Resolution is the encoder's.

* Changed according to S1P-588-70.

** New discriminator setting as of revision (b) of this memo.

Figure 3 (Cont.)

To obtain a calibration of the discriminator listed below	Drive the channel in this column	With a pulse ramp ranging from...	And read the rate register no., resolution	Which is described by the logic in this column	And which contains the following nominal calibration counts	And is read out in page, snap shot
* C_3	B and C	0-6.0 MeV	R_{13} , 3%	$C_2\overline{C}_3B_3$	Y_{C3} = 600, 3%	1 1
& * C_4	A and C	0-40 MeV	R_3 , 3/4%	$C_3\overline{C}_4$	Y_{C4} = 145, 2.15%	0 1

NOMINAL APP1-10

A_1 = 210 KeV	B_1 = 250 KeV	C_1 = 1.5 MeV
A_2 = 430 KeV	* B_2 = 460 KeV	* C_2 = 3.0 MeV
A_3 = 900 KeV	* B_3 = 850 KeV	* C_3 = 4.8 MeV
** A_4 = 2.5 MeV	* B_4 = 3.6 MeV	* C_4 = 7.7 MeV
** A_5 = 4.5 MeV	B_5 = 7.7 MeV	
** A_6 = 9.5 MeV	* B_6 = 14.2 MeV	

Note: Each ramp has 2000 calibration pulses and for this chart the ramp waveform is considered perfect. i.e., Resolution is the encoder's.

* Changed according to S1P-588-70

& The normal logic in R_3 is $C_3\overline{C}_4B_3$ which is changed to $C_3\overline{C}_4$ during a calibration.

** New discriminator setting as of revision (b) of this memo.