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DP-1202

AEC RESEARCH AND DEVELOPMENT REPORT

A DUAL-CHANNEL LOG COUNT RATE METER

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Instruments
(TID-4500, UC-37)

A DUAL-CHANNEL LOG COUNT RATE METER

by

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ABSTRACT

An instrument was developed to monitor two locations for radioactivity. Each monitoring channel contains four plug-in circuit boards connected to form a count rate meter with a four-decade logarithmic readout.

INTRODUCTION

At the Savannah River Laboratory, the presence of radioactive isotopes is detected at various locations by scintillation probes. Electrical pulses from the scintillation probes are electronically processed to yield a count rate proportional to the amount of the isotope present.

In certain cases, the count rate may vary from zero to many thousands of counts per minute. For those cases, a logarithmic readout is advantageous because it affords meaningful readings at high as well as at low count rates. Therefore an instrument was designed and built to accept pulses from two scintillation probes and convert them to logarithmic readouts, each in four decades from 10 to 10^5 counts per minute.

GENERAL DESIGN

Design of the instrument is similar to that of other monitors in use at the Savannah River Laboratory (SRL) in that standard plug-in circuit cards and integral power supplies are used.[1] This provides circuitry and hardware familiar to maintenance personnel, and at the same time minimizes spare parts requirements.[2]

The instrument fits standard mounting holes in conventional 19-inch racks or cabinets (Figure 1). Signal and power connections for two probes are on the chassis rear apron along with two pairs of recorder output terminals (Figure 2).

Front panel controls are clearly marked, and the two readout meters are large enough to display four logarithmic decades with adequate readability. The meters also serve as alarm devices because they are contact-making types with adjustable high-level set points.

Calibration controls are behind a small, removable cover on the front panel. Each channel may be calibrated from the front of the instrument without removing it from its mount or disturbing its normal connections (Figure 3). Chassis layout and internal wiring are shown in Figures 4 and 5.

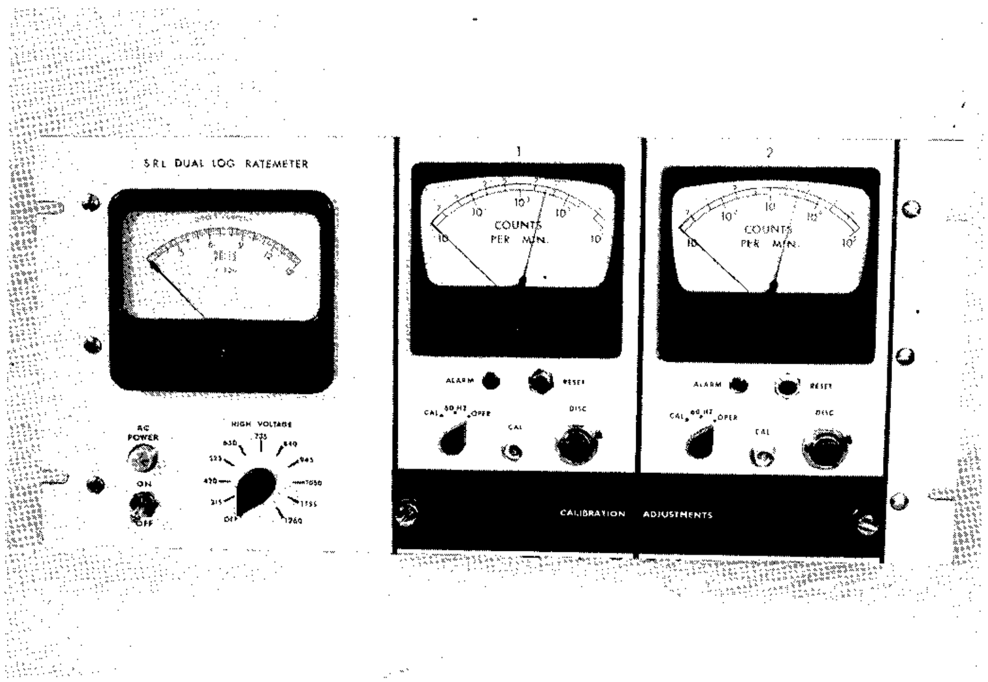


FIG. 1 DUAL LOG RATE METER

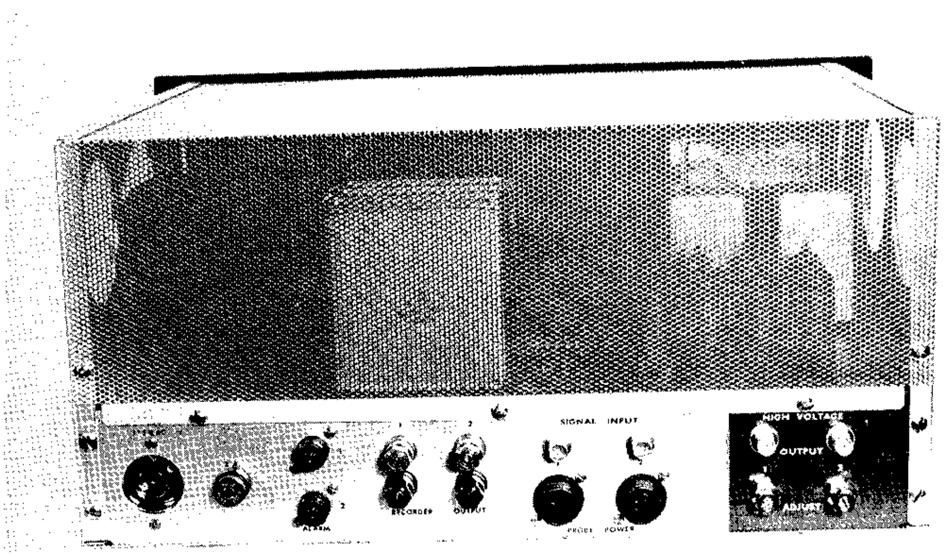


FIG. 2 REAR VIEW SHOWING EXTERNAL CONNECTIONS

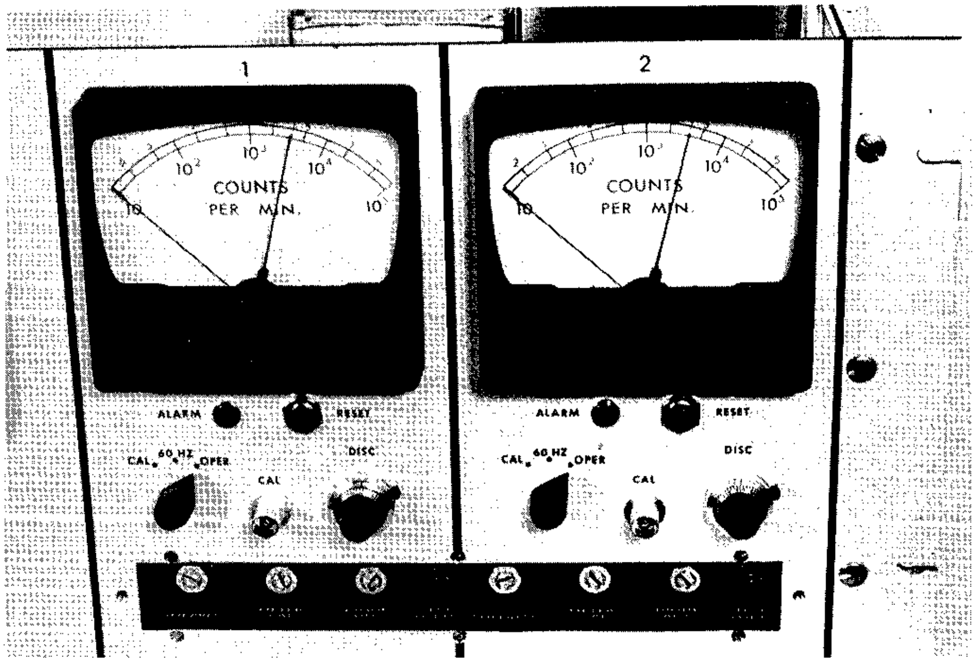


FIG. 3 FRONT PANEL WITH COVER REMOVED SHOWING CALIBRATION ADJUSTMENTS

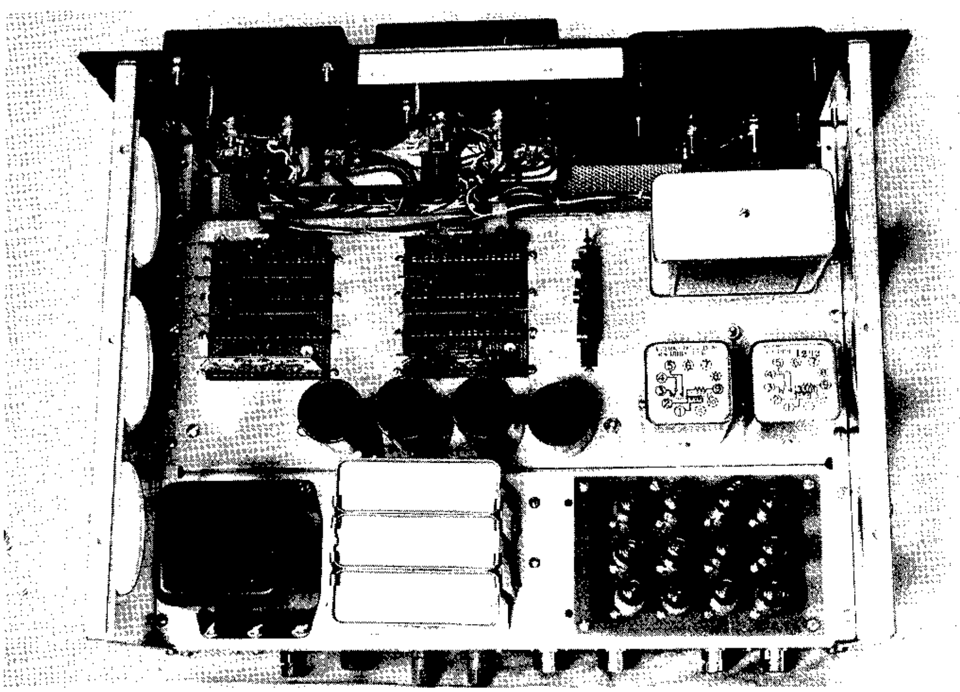


FIG. 4 CHASSIS LAYOUT

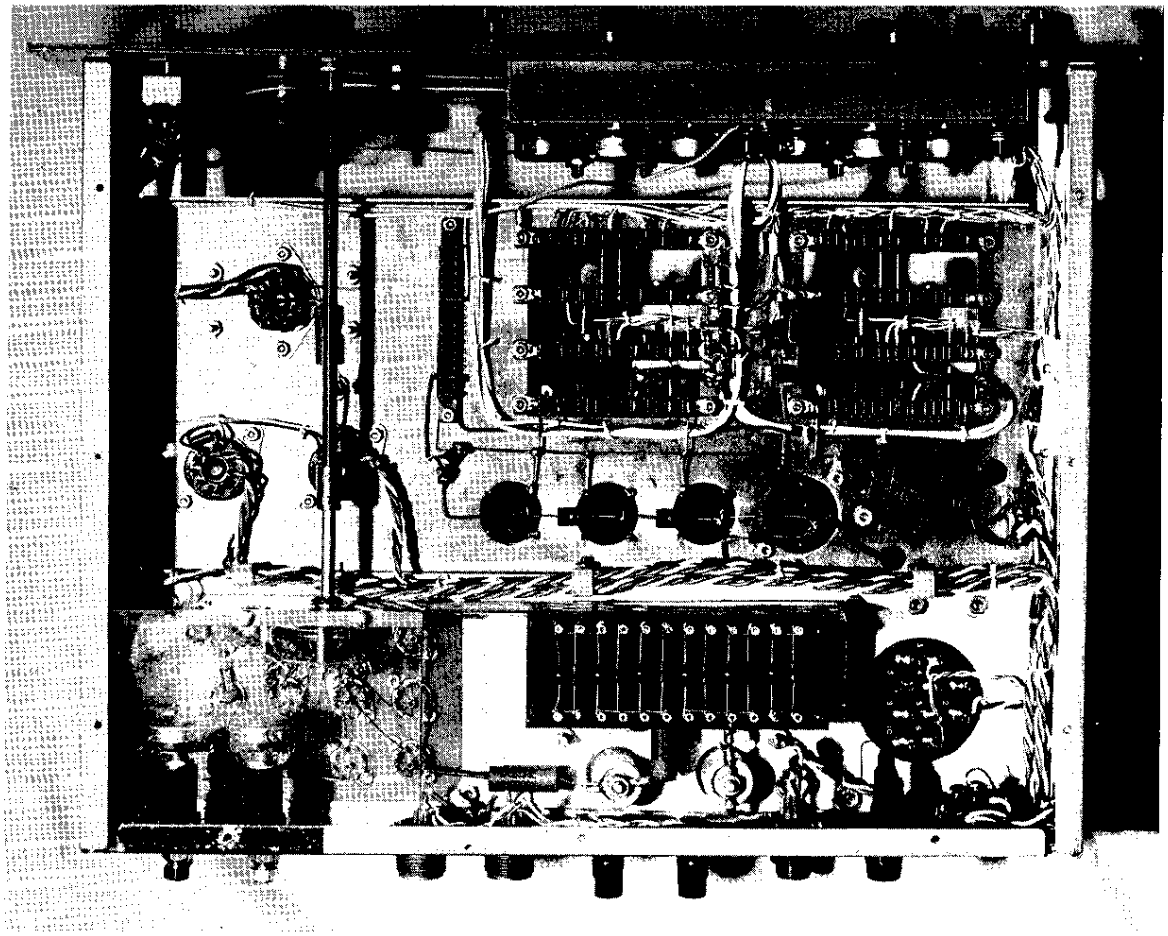


FIG. 5 CHASSIS WIRING

SIGNAL CIRCUITS

Negative pulses ranging from 0 to 130 millivolts are accepted from the scintillation probes via coaxial cables and BNC connectors at the rear of the chassis (Figure 6). Each channel has a selector switch that applies the rear connector signal to an amplifier input when the switch is in the *OPERATE* position. In the *CALIBRATE* position, a front panel connector is substituted for the rear amplifier input; in the *60 Hz* position, the amplifier input is grounded and line frequency pulses are sent directly to the discriminator. The amplifier has a voltage gain of 100 and bandwidth sufficient to handle fast-rising pulses.

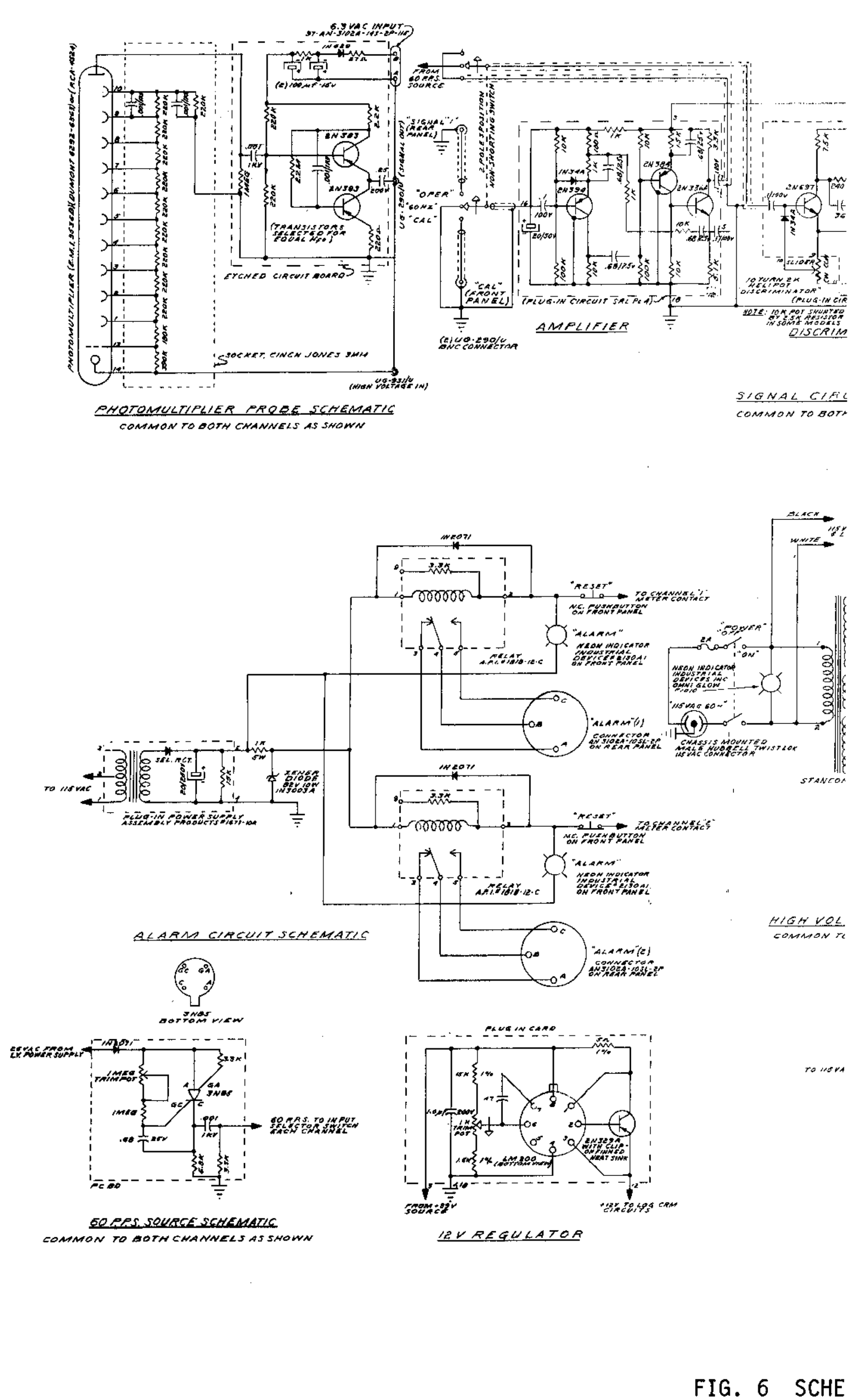
Amplifier output is fed to an integral discriminator, where pulse amplitudes greater than the base-line potentiometer setting cause a modified Schmitt trigger to operate. The trigger circuit output is then differentiated and rectified, producing unipolar output pulses having high amplitude, low width, and short rise time.

These pulses from the discriminator are then used to trigger a count rate meter (CRM) circuit consisting of a univibrator coupled to a constant current source. The univibrator, or *ONE-SHOT*, produces square pulses of constant amplitude and width, and the constant current source transistor is used to feed an integrating network in the log converter circuit.

The integrating network consists of two silicon diodes in series, shunted by a large capacitor. Current pulses from the CRM card are averaged by the integrator, and the average voltage developed across the diodes is proportional to the logarithm of the average current through them. The voltage equation is

$$V_0 = A \log I + BI + C$$

where A is a linear function of the absolute temperature (approximately 0.3%/°C at room temperature), B is the diode series resistance (negligible over the operating range in this case), and C is the barrier voltage (also temperature dependent). Alloyed diodes exhibit a linear voltage slope approximately 60 millivolts per decade over 6 to 8 decades, while diffused diodes exhibit a linear slope of approximately 120 millivolts per decade over 4 to 6 decades of current at temperatures around 25°C. Because of this characteristic of the diodes, the integration time constant varies inversely as the count rate, becoming very long at low diode currents and quite short at high diode currents.



PHOTOMULTIPLIER PROBE SCHEMATIC
COMMON TO BOTH CHANNELS AS SHOWN

AMPLIFIER

DISCRIM

SIGNAL CIR

COMMON TO BOTH

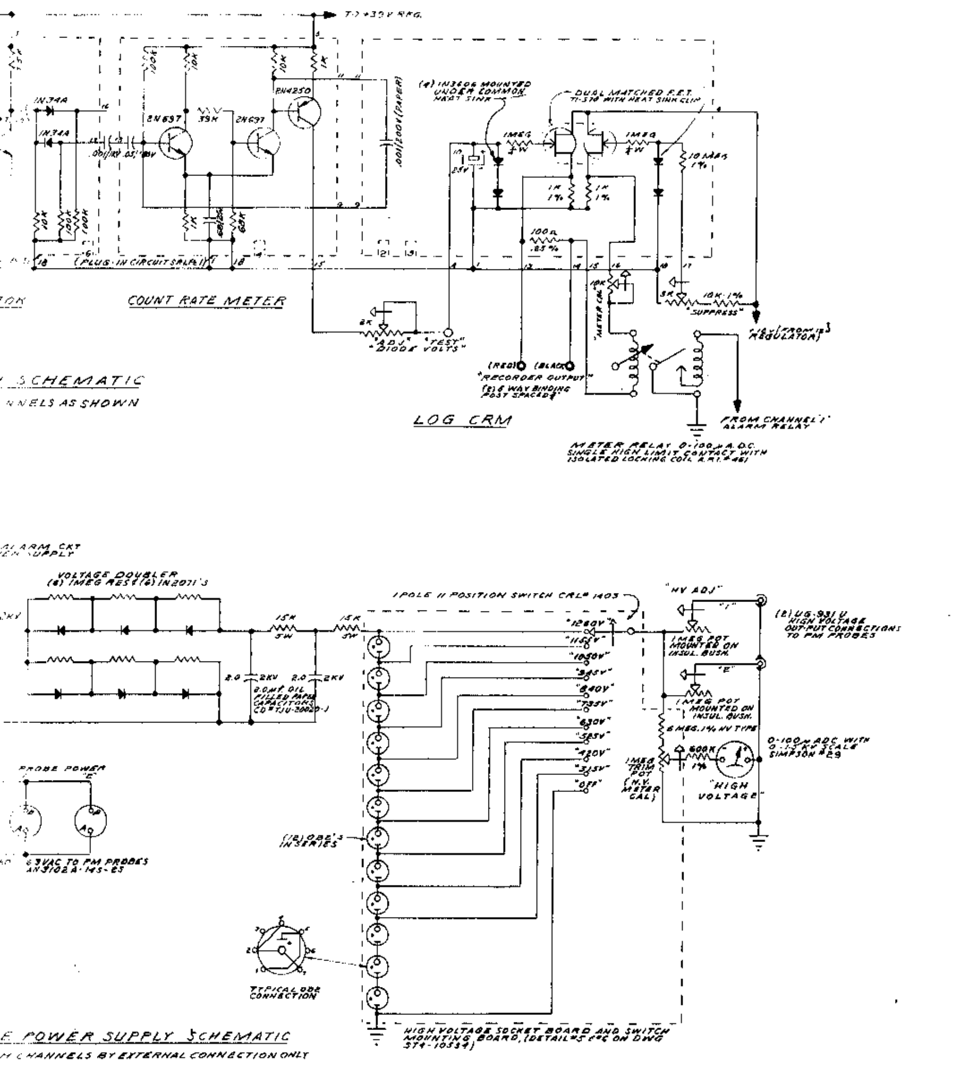
ALARM CIRCUIT SCHEMATIC

HIGH VOL

60 PPS SOURCE SCHEMATIC
COMMON TO BOTH CHANNELS AS SHOWN

12 V REGULATOR

FIG. 6 SCHE



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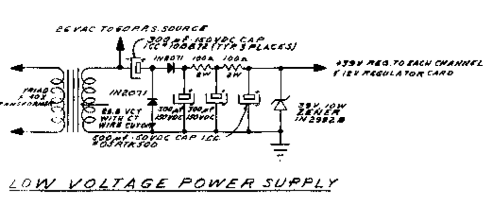

NOTES:

1- All Resistors ½ watt unless noted
2- All Electrolytic Capacitors shown polarized, value in MFD.
3- All Paper & Ceramic Capacitors voltage rated, value in MFD.
4- All other Capacitors Mica, whole number values in MMF.
5- All Plug-in units shown with socket pin numbers
6- Clockwise rotation of all controls shown by arrow
7- All Panel markings associated with component shown by " "
8- Unused connections shown by simple termination of line.

TIC DIAGRAM

Diode voltage is detected at the variable input side of a differential FET (field effect transistor) voltmeter, and the difference between that and the fixed input side voltage is displayed on a front panel meter. The differential circuit was used for two reasons: (1) it allows a controlled suppression voltage to be applied at the fixed input side so that the meter scale can begin at some power of ten rather than at zero; and (2) by using a matched pair of FET's and the same type diodes at the fixed input as at the variable input, temperature effects will be the same on one side as on the other, cancelling themselves in the meter reading. To enhance the temperature compensation thus achieved, the transistors are mounted in intimate thermal contact with each other, and the diodes are all thermally connected to a common heat sink (Figure 7).

The readout meter is calibrated from 10 to 10^5 counts per minute. A series resistor in the meter circuit provides a 0-10 millivolt output for a null-balance recorder.

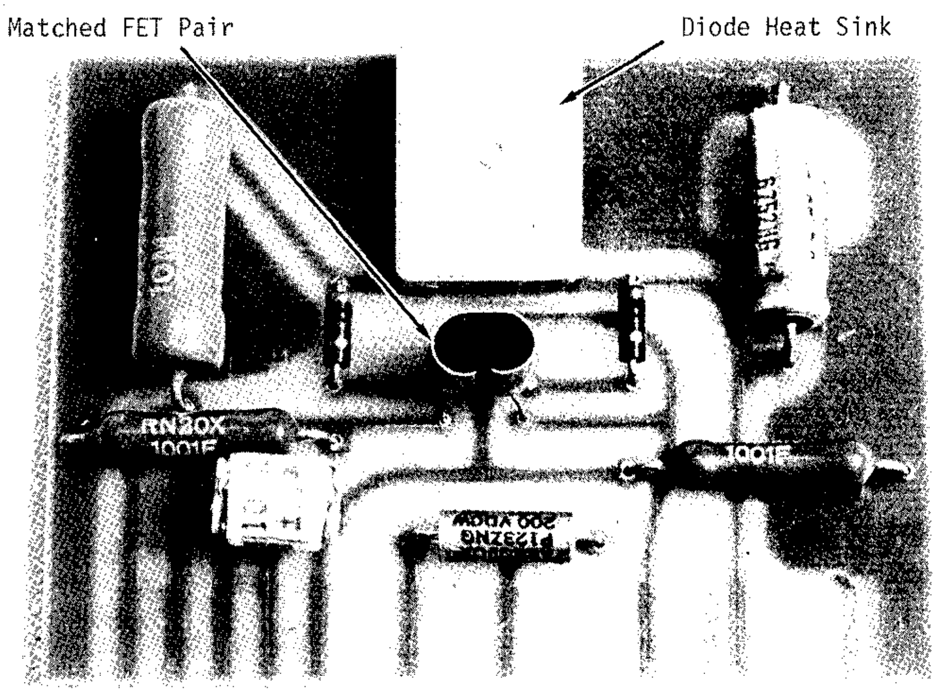

FIG. 7 LOG CONVERTER CARD

ALARM CIRCUITS

The meters have adjustable high-level contacts with series locking coils isolated from the measuring circuits. Whenever the pointer of either meter moves up to the alarm set point, the contacts make and a relay is energized. Relay coil current is conducted through the meter locking coil in the direction to cause the contacts to make tightly until the current is interrupted. A separate alarm relay for each meter is paralleled by a small neon indicator on the front panel. A normally closed pushbutton is in series with each of the meter-relay circuits to restore it to normal operation after an alarm condition has been cleared. Both relays have single form *C* contact configuration, and both sets of contacts are terminated by connectors on the rear of the chassis so that external alarm circuits may be connected.

POWER SUPPLIES

Power for the standardized circuit cards used in the instrument is derived from a Zener-regulated half-wave doubler identical to that in other instruments developed at SRL. Because the circuit is familiar to maintenance personnel, spare parts are available locally.

An additional regulator is used for power to the log converter circuit, because the FET's cannot withstand the higher potential of the main supply, and the improved regulation is necessary for proper biasing of the suppression circuit.

Relay power is obtained from a plug-in module supplied by the relay manufacturer. A Zener diode regulator was added to lower the locking coil current to the proper value and extend meter contact life.

High voltage for the scintillation probes is produced by a half-wave doubler and a gas tube regulator chain. The regulator chain is tapped at tube interconnection points, and a rotary switch is provided to select voltages from 315 to 1260 in steps of 105 volts each. The selected voltage is read out on a front panel meter, and at the same time is applied to two 1-megohm potentiometers, each in series with a high voltage output jack at the rear of the chassis. The scintillation probes normally used at SRL have a dynode voltage divider totaling almost 3 megohms; therefore voltage may be adjusted by the series potentiometer[3] from that shown on the meter to about 25% below that value to compensate for variations between photomultiplier tubes. The high voltage power supply is identical to that used in other multichannel instruments at SRL for the same reasons given for the power supply duplication.

AC power for the probes is available from a pair of connectors at the rear of the chassis.

All power supplies are transformer-isolated from the line input, and all are referenced to chassis ground. A single fuse in the high side of the line and a three-wire AC power input with direct grounding of the third wire protect operating personnel.

CALIBRATION

Adjustment potentiometers and test points used in calibrating both channels of the instrument are concealed by a small removable cover on the front panel (Figure 3). The simple calibration procedure for either channel is accomplished with instrument in place:

1. Connect instrument to 115 volts AC and allow 30 minutes for warmup.
2. Connect a source of negative pulses 1 to 10 microseconds wide and approximately 100 millivolts in amplitude to the *CAL* input on the front panel.
3. Set the selector switch to the *CAL* position.
4. Adjust the pulse source repetition rate to 10^5 per minute (1.667×10^3 per second).
5. Connect an accurate high-impedance voltmeter between the *DIODE VOLTS - TEST* point and chassis ground.
6. Adjust the *DIODE VOLTS - ADJ* potentiometer to read exactly +1.20 volts on the voltmeter.
7. Disconnect the voltmeter.
8. Readjust the pulse rate to 10 per minute (0.1667 per second).
9. After allowing the *COUNTS PER MINUTE* meter to stabilize, adjust the *SUPPRESS* potentiometer for equal excursions of the meter on either side of 10. (This is accomplished more easily with the *METER CAL* potentiometer fully counterclockwise.)
10. Reset the selector switch to *60 Hz*.
11. Adjust the *METER CAL* potentiometer to align the meter pointer with the *60 Hz* mark on the scale.

Calibration of one channel is complete. The same simple procedure is followed to calibrate the other channel. Either channel may be calibrated without removing the other from service.

OPERATION

Two instruments have been placed in service at SRL, and a third is under construction. Service has been satisfactory.

REFERENCES

1. W. J. Woodward. *A Four-Channel Monitor for Airborne Radioactive Contaminants*. USAEC Report DP-1176, E. I. du Pont de Nemours and Co., Savannah River Laboratory, Aiken, S. C. (1968).

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3. W. J. Woodward. *A Transistorized Photomultiplier Probe with a Stacked Emitter Follower*. USAEC Report DP-786, E. I. du Pont de Nemours and Co., Savannah River Laboratory, Aiken, S. C. (1962).