Model RM-20

Radiation Monitor Technical Manual

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LIST OF EFFECTIVE PAGES

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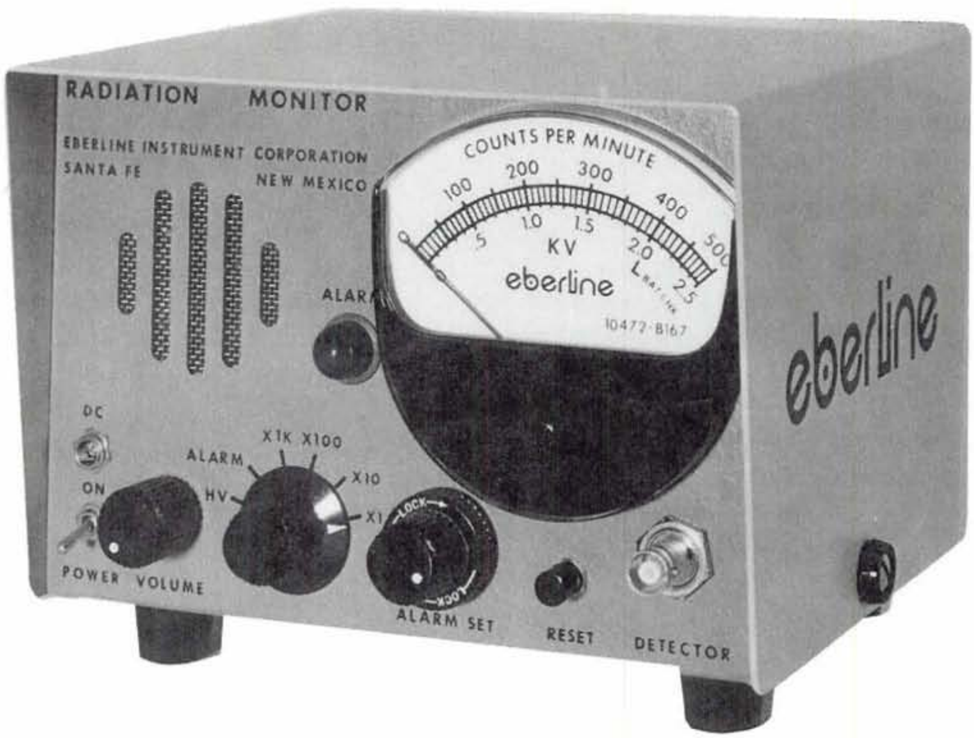

Figure 1-1. Model RM-20 Radiation Monitor

SECTION I
GENERAL

A. PURPOSE AND DESCRIPTION

The RM-20 series Radiation Monitor is a compact, versatile, alarming count rate meter with a charge-sensitive input and variable high voltage, suiting the unit for use with most Geiger-Mueller (GM), scintillation, and proportional detectors.

Power is supplied by the ac line or external dc supply. An internal 12 V gelled electrolyte lead-acid battery is optional, and is float-charged when the unit is operating from the ac line.

Four linear count rate ranges are indicated by the meter. The ranges are selected by the *X1, X10, X100* and *X1K* positions of the range switch. The alarm set point and the high voltage output are also read out on the meter when selected by the range switch. The high voltage is adjusted by an internal control, and the alarm set point is adjustable over the scale of the meter by a front panel control. The alarm, when actuated, does not interrupt or affect meter reading and is a locking type which will continue to provide a loud tone on the speaker until the reset switch is depressed.

Under non-alarm counting conditions, the speaker produces one click for each event detected, with volume variable from zero to maximum by means of a front panel control.

All individual units in the RM-20 series of instruments are identical except for the meter faces and name tags. Specific model numbers presently assigned are as follows:

1. RM-20-1

a. Meter Scale: 0 to 500 counts per minute (cpm).

b. Ranges: 0-500, 0-5k, 0-50k and 0-500k cpm.

2. RM-20-5

a. Meter Scale: 0 to 10 counts per second (cps).

b. Ranges: 0-10, 0-100, 0-1k, and 0-10k cps.

B. SPECIFICATIONS

1. Meter

a. Scale Length: 3.3 inches (8.4 cm).

b. High Voltage Scale Marking: 0 to 2.5 kV in 50 V increments.

c. Battery Check: All meter faces have a battery check mark which is used only when the optional internal battery is installed.

2. Response Time

Adjustable by internal control from approximately 2 seconds to 20 seconds, measured from 0 to 90 percent of final reading.

3. Linearity

Within ±5 percent of full scale, typically ±2 percent of full scale.

4. Alarm Point

Adjustable from zero to greater than full scale by a front panel control, displayed when the range switch is in the *ALARM* position.

5. Alarm Indication

Front panel alarm light (red) and approximately 1 kHz tone on speaker, independent of volume control.

6. Speaker

Two-inch-diameter. One click for each event counted. Volume adjustable from zero to maximum.

7. High Voltage

Adjustable by internal control from less than +300 V to +1800 V with a 100 MΩ load and to +2500 V on a proportional chamber (no load).

8. Input Sensitivity

Selectable by an internal switch from approximately 2×10^{-13} C to 3×10^{-12} C. (Approximately equivalent to 1 mV to 15 mV.)

9. Threshold

Adjustable from 0 to approximately 3 V.

10. Power

a. Alternating Current: 105-125 V, 50/60 Hz at less than 0.1 A. (A 230 V, 50/60 Hz option is available.)

b. Direct Current: 10 to 20 V (12 Vdc nominal) at approximately 25 mA dc (no alarm). Up to 400 mA dc under alarm conditions with high count rates.

c. Optional internal battery life approximately 40 hours on one full charge (no alarm).

d. Mating connector to front panel dc connector is Switchcraft No. 760. The center conductor is positive.

11. Temperature

The instrument is operational from -20 °F to +140 °F (-29 °C to +60 °C) with less than ±10 percent of full scale change in calibration or alarm point, and less than 5 percent change in high voltage.

12. Detector Connector: MHV coaxial.

13. Detector Requirements

a. Operating Voltage: Any positive voltage from 300 to 1800 V with a 100 MΩ load and up to 2500 V for a proportional chamber.

b. Impedance: 100 MΩ minimum dc resistance.

c. Pulse Height: At least 1.0 mV (negative going) with a rise time of 1 microsecond (μs) or less.

14. Mechanical

a. Size: 5½ inches high x 6½ inches deep x 7½ inches wide (14 cm x 16.5 cm x 19 cm).

b. Weight: 2¾ pounds (1.25 kg). [4¼ pounds (1.9 kg) with optional battery installed.]

SECTION II
OPERATION

A. DESCRIPTION OF CONTROLS AND CONNECTORS

1. External (See Figures 1-1, 2-1, and 2-2)

a. Switch: A six-position rotary switch selects readout of the high voltage, alarm set point, and one of the four scale multipliers: *X1, X10, X100* and *X1K*. This number must be multiplied by the meter reading to obtain the proper count rate.

b. *POWER*: A toggle switch turns the instrument *ON*.

c. *DC*: Connector jack which accepts external dc power. Mates with Switchcraft No. 760. Center pin positive.

d. *VOLUME*: Varies loudness of speaker clicks from zero to maximum.

e. *ALARM SET*: Sets the point on the meter scale at which the alarm will actuate.

f. *RESET*: Unlatches the alarm, if actuated, and returns the meter reading to zero.

g. *DETECTOR*: Connection to detector. MHV coaxial. Center pin positive.

h. Line Filter and ac Connector: Mates with the power cord for ac input.

2. Internal (See Figure 2-1)

a. *1, 10, 100,* and *1K* Controls: One control for each range, which individually calibrates that range.

b. Response: Adjusts the meter response time for compromise between speed and fluctuation of reading.

c. *HV CAL*: Calibrates the *HV* readout to indicate the actual high voltage.

d. *GM/P* Switch: Selects low gain (*GM*) amplifier configuration for the Geiger tube and high gain scintillation detectors, or the high gain (*P*) configuration for gas proportional and low gain scintillation detectors.

e. *DISCR*: Discriminator control which sets the threshold level between 0 and 3 V, approximately.

f. *HV ADJ*: A control which adjusts the high voltage applied to the detector.

B. PREPARATION FOR USE

1. Inspection

The instrument should be checked for physical damage.

2. Connections

Plug the ac cord into a 115 V, 60 Hz line or connect 10 to 20 Vdc to the dc connector and turn the *POWER* switch *ON*. (If the optional internal battery is installed, the unit will operate without an external power connection.)

C. USING THE INSTRUMENT

1. Starting

Turn the switch to *HV* and verify that the high voltage is suitable for the detector to be used. If in doubt about this, refer to the calibration procedure in the maintenance section.

2. Operation Check

With the detector connected and the range switch in the appropriate range, place a check source in a repeatable position adjacent to the detector, and note that a suitable reading is obtained.

Push the *RESET* button. The reading should drop to zero rapidly, then climb back to the source reading when the *RESET* is released.

The *RESPONSE* control (internal) may be adjusted for the best compromise between fast response and steady reading.

Rotate the *ALARM SET* counterclockwise until an alarm occurs as indicated by the *ALARM* light and a 1000 Hz squeal on the speaker. Push the *RESET* button; the alarm should desist until the reading again reaches the alarm set point.

3. Interpretation of Indications

The meter reading must be multiplied by the scale switch setting to obtain the proper number. The fluctuation of the meter is normal and is caused by the random nature of radioactive decay.

Figure 2-1. Model RM-20 Rear View

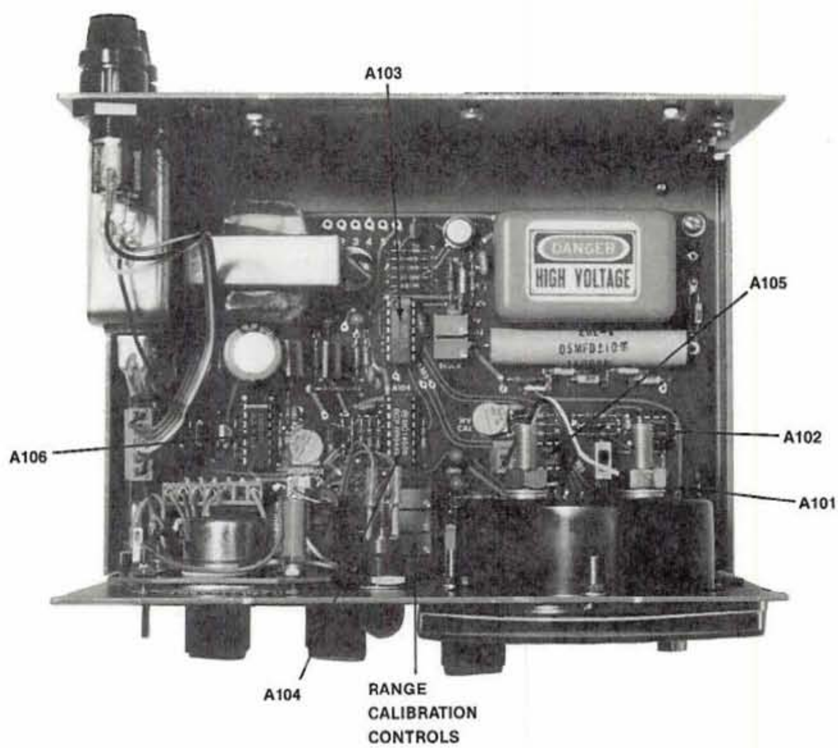

Figure 2-2. Model RM-20 Top View

SECTION III
THEORY OF OPERATION

A. GENERAL

The high voltage supply develops high voltage for the detector. When radiation reacts in the detector, negative pulses are generated. These pulses are coupled into an amplifier.

The amplified pulses are applied to a discriminator circuit which passes pulses of a given size or greater, converting them to a standard amplitude for further processing.

The discriminator output pulses drive the meter and speaker trigger circuits, which generate standard width pulses for input to their respective drivers. The meter driver converts the trigger pulses to current pulses, integrates the current, and drives the meter. Thus the meter reading is proportional to the average rate of radiation at the detector.

The meter drive voltage is applied to a comparator which has a reference voltage controlled by the *ALARM SET* control. When the meter drive voltage exceeds the reference voltage, the circuit recognizes an alarm condition, which turns on the alarm oscillator and couples its frequency to the speaker.

B. FUNCTIONAL THEORY (See Figure 6-1)

1. High Voltage Supply

This unit consists of controlled oscillator Q101, voltage step-up and rectification T102, high voltage division for feedback R138-R142, feedback buffer amplifier A105, and the oscillator control comparator A103.

The *HV ADJ* control R149 sets a reference voltage at one input of A103, and the buffered feedback from the high voltage output drives the other input. The regulation circuit is in balance when these voltages are approximately equal. If the reference voltage is increased, by adjusting *HV ADJ* clockwise, comparator A103's output, pin 14, goes low, gating oscillator Q101 on, increasing the high voltage output and the feedback voltage until the comparator output gates the oscillator off again.

A heavier load tends to lower the high voltage, unbalancing the comparator. This tends to increase the duty cycle of the oscillator to maintain the desired output.

2. Amplifier

The amplifier consists of A101, A102, and associated circuitry. A101 is configured as an inverting charge-sensitive stage, the sensitivity of which is inversely proportional to the capacitance of C102. R109 and R110 bias the amplifiers to a +4 V quiescent operating point. R102 provides dc feedback around the stage and C103 ensures stability. R101, CR101, and CR102 protect the input of the amplifier from transient spikes. A102 is a non-inverting stage with a gain of 20, approximately. CR105 limits the undershoot amplitude to improve overload recovery time. The *GM/P* switch S103 connects the output of A101 or A102 to the discriminator. The *P* (proportional) position utilizes the gain of A102 in series with A101 to provide the greater sensitivity required with gas proportional detectors. The Geiger-Mueller *(GM)* position uses A101 only, providing lower gain and better overload recovery for better performance with Geiger tube detectors. Most scintillation detectors will work satisfactorily with either gain configuration; the only operating difference being the different high voltages required.

3. Discriminator

The discriminator consists of one-fourth of a quad comparator, A103, and associated circuitry. The *DISCR* control R107 sets a reference voltage at the positive input to the comparator. When the positive-going amplifier output pulse at the negative input to the comparator exceeds the reference voltage, the comparator output switches to ground. C106 provides positive feedback for jitter-free switching. When the amplifier pulse returns to baseline, the comparator output returns to +8 V through pull-up resistor R108.

4. Trigger Circuits

The triggers consist of A104 and associated circuitry. A104 is a dual monostable multivibrator, one section of which is the meter circuit trigger and the other half is the speaker circuit trigger. The width of the pulse out of the meter trigger is controlled by the R-C time constant at pins 14 and 15, which is selected by the range switch S102. Each of the range positions *(X1, X10, X100, X1K)* incorporates its own R-C network so that the pulse width for each range is individually adjustable for calibration.

The speaker trigger pulse width is fixed at approximately 250 μs. The circuit between pins 6 and 4 sets a maximum speaker rate of about 1000 pps.

5. Meter Integrator-Driver

The negative meter trigger pulse out of A104 pin 9 causes Q108 to conduct a given current for the duration of the trigger pulse. C108 integrates this charge and discharges through R115, the *RESPONSE* control, and R116.

The voltage developed across R116 drives the input of A105, the meter drive amplifier, which provides meter current proportional to this voltage. The *RESPONSE* control varies the R-C time constant of the discharge circuit, which essentially filters the voltage to the operational amplifier, smoothing or speeding up the meter response.

When the range switch is in the *HV* position, the high voltage feedback signal, through the high voltage calibration control R147, is connected to the meter drive amplifier so that the meter indicates the high voltage.

When the range switch is in the *ALARM* position, the alarm reference voltage, which is selected by the alarm set control R135, is connected to A105, indicating the alarm set point on the meter.

6. Speaker Driver

The 250 μs speaker trigger pulse from A104, pin 6, is amplified by Q107 and Q106 to drive the *VOLUME* control R125 and the speaker coil through isolating diode CR107. One click is heard for each event counted.

The 1 kHz alarm tone is amplified by Q104 and Q105 to drive the speaker voice coil, with CR107 providing isolation from the volume control so that the alarm tone is not affected by the volume setting.

7. Alarm Circuit

The alarm circuit consists mainly of A103, A106, and associated circuitry.

The meter drive signal on R116 is connected to A103, pin 6. The *ALARM SET* R135 reference voltage is applied to the other input of the same comparator, pin 7. When the meter signal becomes greater than the reference, the output, pin 1, goes to ground, causing the other comparator output, pin 2, to switch to ground also, latching the alarm condition. This low signal turns on Q102 and Q103, causing the *ALARM* light to come on. If the *RESET* switch S104 is pushed after the alarm-causing high reading has gone away, the comparators will unlatch, allowing pins 1 and 2 to rise to +8 V again.

During the alarm condition, the low output from the comparator gates the 1 kHz tone oscillator A106 into operation. A high output disables the oscillator. The frequency is determined by R129 and C115.

8. Power Circuitry

The ac line voltage is stepped down by T101, full wave rectified by CR109-CR112, and filtered by C120. A107 provides a regulated +14.5 V line for the speaker

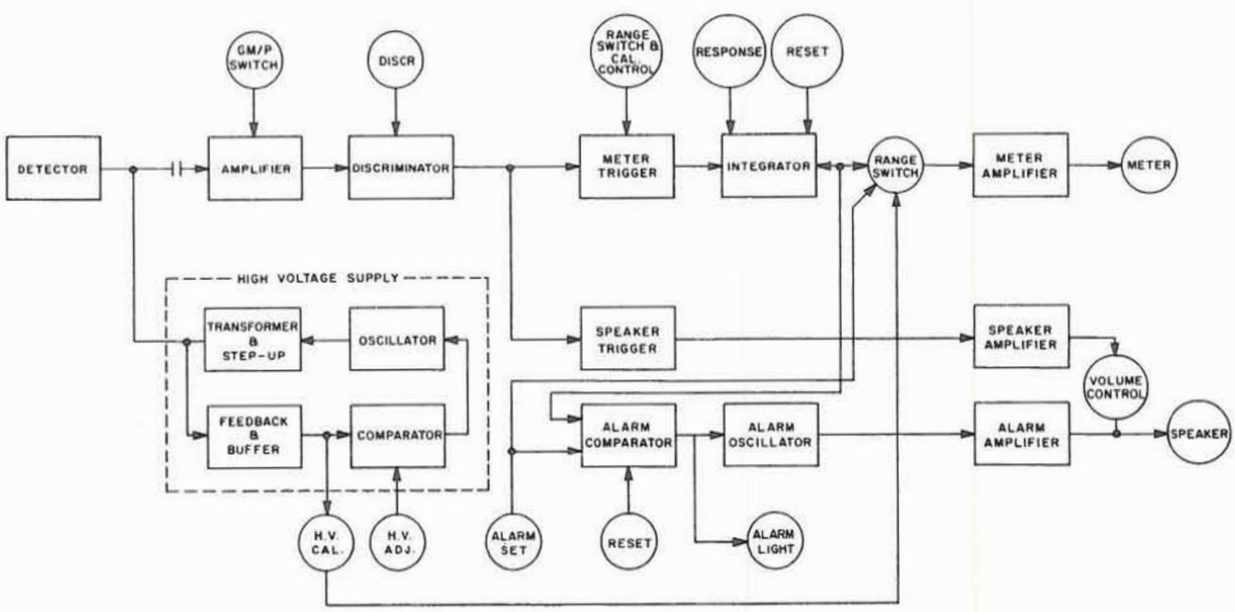

Figure 3-1. RM-20 Block Diagram (11068-C21A-1)

amplifiers and for battery charging if the optional internal battery is installed or an external 12 V battery is in use. A108 provides a regulated +8 V line for all the remaining circuitry. The design is such that T101 limits the current available for heavy alarm and charging loads, allowing A107 to pull out of regulation without affecting the +8 V line.

The dc connector J3 on the front panel permits the instrument to be powered by an external dc source, such as an automobile battery. In this case (or if the internal battery is installed) the +14.5 V line will be approximately +10 V, resulting in somewhat less audio from the speaker.

C. OPTIONS AND MODIFICATIONS

1. Internal Battery Option

This option includes a 12 V gelled-electrolyte, sealed, lead-acid type battery. This will provide more than 40 hours of normal operation (no alarm) on one recharge. The battery is continuously float-charged while the instrument is turned on and operating from the ac line. A dishcarged battery will recharge in 8 hours or less. Actuating the *BATTERY CHECK* pushbutton S105 on the rear panel causes the meter to read above the *BAT CHK* mark if the battery is charged.

2. 230 Vac Option

This option permits the instrument to be operated from a 230 V, 50 or 60 Hz line. The only component change is that a 230 V transformer is substituted for the 115 V version of T101.

3. Non-Locking Alarm

When this modification is made, the alarm will end any time the input signal rate falls below the alarm set point.

To make this modification, locate the upper outside lead on the back of the *RESET* switch (the lead nearest A101) and cut it in two.

4. Modifications

The circuit board terminals, numbered 1 through 6, shown at the lower left corner of Figure 6-1, provide for possible modifications. Terminal 6 is forced low during an alarm condition. Terminal 1 provides a positive pulse (for counting by an external scaler) each time a count is registered by the RM-20. Terminals 2, 3, and 4 may be used to adjust the high voltage externally.

SECTION IV
MAINTENANCE

A. DISASSEMBLY AND REASSEMBLY

1. To remove the cover, remove the 10-32 screw from each side of the unit and lift the cover off.

2. To remove the circuit board, unplug the three nylon connectors and the two tab connectors near the *DETECTOR* connector. Remove the knobs and nuts from the board-mounted components which protrude through the front panel; that is *POWER, VOLUME,* range switch, *ALARM SET,* and *RESET*. Unscrew the ac input connector and line filter assembly from the rear panel. Remove the two 4-40 screws at the rear corners of the board and slide the board back and out to the side. (If the battery is installed, it will have to be removed first.)

B. PREVENTIVE MAINTENANCE

Keep the instrument clean and dry. There is no scheduled preventive maintenance.

C. CALIBRATION

1. High Voltage Indication

Calibration of the high voltage readout requires the use of a very high impedance voltmeter (1000 MΩ or more) capable of measuring up to 2500 V.

a. Connect the positive side of the high voltage voltmeter to the outboard end of C117, the high voltage filter capacitor. Connect the reference side to chassis ground at the lug on the *DETECTOR* connector. Set the range switch to the *HV* position.

b. Adjust the *HV ADJ* potentiometer R149 until the high voltage meter reads 2000 V. Adjust the *HV CAL* potentiometer R147 until the front panel meter also indicates 2.0 kV.

c. Set the *HV ADJ* potentiometer for 2500, 1500, 1000, and 500 V. The front panel meter should agree with each setting within 50 V.

2. Calibration to True Frequency

If calibration to true incoming pulse rate is appropriate, a pulse generator such as the Eberline Model MP-2 or equivalent is necessary. The pulser must produce negative-going pulses with a rise time of 1 μs or less. The pulser should be connected to the instrument through a 0.001 μF, 3 k V capacitor to block the dc high voltage at the *DETECTOR* connector. (The MP-2 pulser has this capacitor built in.)

a. Set the RM-20 *DISCR* control for 1 V between pins 10 and 11 of A103. Set the *ALARM SET* control fully clockwise. Set the *GM/P* switch to *P*.

b. Connect the pulser to the *DETECTOR* connector on the front panel. Set the pulse amplitude at 10 mV.

c. Set the range switch to *X1K* and the pulser for approximately 80 percent of full range. Adjust the 1k range potentiometer until the meter reads the input pulse rate.

d. Calibrate the remaining (X100, X10, X1) ranges in a similar manner.

e. Set the range switch to *X100* and set the pulser for approximately 80 percent of full scale.

f. Turn the range switch to the *ALARM* position, and adjust the *ALARM SET* control for a reading of one minor division below the meter indication of step e. above.

g. Set the range switch back to *X100,* and verify that the alarm actuates within one minor division of the alarm set position.

h. Press the *RESET* switch. The alarm should stop and the meter reading should go toward zero.

i. Set the *ALARM SET* control fully clockwise and disconnect the pulser.

j. Set the function switch to the *HV* position, and adjust the high voltage to suit the intended detector. (If this voltage is not known, follow steps 3.a. and 3.b. following.)

k. Connect the detector to the RM-20 with the cable to be used in actual operation (if possible). Expose the detector to a source of radiation to assure that the system is operational.

3. Calibration to Detector Response

If it is appropriate to calibrate the instrument to the response of a detector (instead of counts per minute) such as mR/h, for example, proceed as follows.

a. For GM detectors, set the *GM/P* switch to the *GM* position. For scintillation detectors use the *GM* position unless more than 1500 V is required, in which case the *P* position should be used. For gas proportional detectors, *P* position gain and higher detector voltages are required. The *DISCR* control may be set lower, which simulates increased gain, but care must be exercised to avoid setting the sensitivity below the level of internal noise generated by the alarm and speaker circuits.

b. Before connecting the detector, make sure the high voltage is not set excessively high. If the proper voltage is known, set the controls for that output. If the proper high voltage is not known, set the voltage low, connect the detector, and plot a voltage plateau curve (count rate versus detector voltage) for both background radiation and for the radiation of interest. Use the curves to select the best operating voltage and set the high voltage to that value.

c. If facilities are available, expose the detector to four different known radiation intensities to allow calibration of all four ranges (*X1k, X100, X10, X1*) in the upper half of the meter scale. If facilities are limited, calibrate as many ranges to radiation as is possible. The other ranges may be roughly calibrated by using a pulser to ratio a pulse rate up or down by a factor of 10 for adjacent ranges.

d. Check the operation of the alarm controls in a manner similar to steps 2.e., f., g., and h. above.

D. TROUBLESHOOTING

Typical voltages and waveforms are given on the schematic Figure 6-1, and component locations are shown in Figure 6-2.

Voltages are measured with a digital voltmeter with 10 MΩ or higher input impedance. High voltage is best measured with an electrostatic voltmeter or DVM with high voltage probe having 1000 MΩ impedance or higher.

SECTION V
PARTS LIST

The following table lists the electronic items incorporated in the RM-20 and should contain any part necessary for normal repair. Unless otherwise specified, callouts of manufacturers and manufacturers' part numbers are to be considered typical examples only and not restrictions against using equivalent parts with the same operating characteristics. When ordering parts from Eberline, specify model number, serial number, reference designation, value, Eberline part number, or a word description if the part has no reference designation. Eberline will automatically substitute equivalent parts when the one called out by the manufacturers' part number is not available.

REF DESIG	PART	DESCRIPTION	MANUFACTURER AND PART NUMBER	EBERLINE PART NUMBER
1. Chassis and Miscellaneous				
	Power Cord	3-wire, #18	Belden 17250	WRAC4 (4)
DS1	Speaker		Lafayette S-433	ADSP3 (6)
DS2	Lamp	14 V, 0.08 A	No. 330	LPBU6 (5)
F1	Fuse	3 AG, 1/8 A, Slo Blo		FUSB2 (1)
F2	Fuse	3 AG, 1 A, Slo Blo		FUSB12 (1)
	Fuseholder		Littelfuse 342022	FUHO3 (5)
J1	Connector	MHV	Amphenol 27025	CXMH2 (7)
J2	Line Filter/ Connector		Corcom 1ED1	MEVE102 (3)
J3	Connector	dc	Switchcraft 712A	COAF16 (5)
M1**	Meter	0-50 μA dc	Jewell MM3T	MTPA29 (8)
** When ordering a replacement meter, specify complete instrument model number, scale labeling (cpm, cps, mR/h, etc.), full scale value and meter face identification number (10472-______).				
P101	Connector	5-pin	Molex 09-50-7051	COMR205 (6)
P102 (Partial)	Connector	4-pin	Molex 09-50-7041	COMR104 (1)
P103	Connector	2-pin	Molex 09-50-7021	COMR902 (8)
	Crimp Terminals (for P101, P102, P103)		Molex 08-50-0106	COHD11 (7)
R1	Resistor	15, ±5 percent, 2 W, Carbon Film		RECC150B25 (0)
2. Circuit Board YP11068004 (8)				
A101	Op-Amp		RCA CA3130AE	ICAOC3130S (2)
A102	Op-Amp		RCA CA3160E	ICAOA03160 (9)
A103	Quad Comparator		National LM339N	ICACA0339N (8)
A104	Dual Monostable		Motorola MC14538BCP	ICCMA4538B (9)
A105	Dual Op-Amp		National LM358N	ICAOA00358 (7)

REF DESIG	PART	DESCRIPTION	MANUFACTURER AND PART NUMBER	EBERLINE PART NUMBER
A106	Quad NOR Gate	CMOS, 14-pin DIP	RCA CD4001BE	ICCMA4001B (8)
A107, A108	Voltage Regulator	Programmable	National LM317T	ICAVA0317T (1)
C101	Capacitor	220 pF, 3 kV, 20%, X5F	Sprague 30GAT22 or equivalent	CPXX4 (4)
C102, C106	Capacitor	4.7 pF, 1 kV	Sprague 10TCC-V47 or equivalent	CPCE472F2U (2)
C103	Capacitor	20 pF, 1 kV, 10%, S2L	CRL DD200 or equivalent	CPCE200P3U (3)
C105	Capacitor	0.01 μF, 50 V, 20%, X7R	AVX SR155C103KAA or equivalent	CPCE103P3N (9)
C107, C122, C123	Capacitor	39 μF, 10 V, Tantalum	Sprague 199D396X9010DA1	CPTA390M3F (5)
C108	Capacitor	68 μF, 10 V, Tantalum	Sprague 150D686X9010R2	CPTA680M3F (9)
C109	Capacitor	100 pF, 500V, 10%, COG (NPO)	AVX SR155A101KAA	CPSP101P3N (8)
C110	Capacitor	0.001 μF, 50 V, 10%, COG (NPO)	CRL CY15C102M	CPSP102P3N (6)
C111	Capacitor	0.01 μF, 50 V, 10%, COG (NPO)	AVX SR305A103KAA	CPSP103P3N (4)
C112, C113, C115, C116, C125, C126, C128	Capacitor	0.1 μF, 50V, 10%, X7R	CRL CW20C104K or equivalent	CPCE104P3N (7)
C118	Capacitor	0.22 μF, 50 V, 20%	Centralab CW30C224M	CPCE224P4N (1)
C114	Capacitor	220 pF, 1 kV, 10%, Z5F	CRL DD221 or equivalent	CPCE221P3U (9)
C117	Capacitor	0.047 μF, 4.0kV, 10%	American Shizuki X675HV.047104000V020	CPPF503PXY (9)
C119	Capacitor	1.0 μF, 50 V, 10%, Tantalum	CS13	CPTA105P3N (4)
C120	Capacitor	470 μF, 50 V	Sprague 513D-477M063EK4	CPAL471M3N (8)
C121	Capacitor	15μF, 20 V Tantalum	Sprague type 196D	CPXX10 (0)
C124	Capacitor	120 μF, 10 V, 10%, Tantalum	CS13	CPTA121M3F (4)
C127	Capacitor	0.001 μF, 1 kV, 10%, Z5R	CRL DD-102	CPCE102P3U (1)
CR101, CR102, CR104, CR114	Diode	Silicon	1N4148	CRSI1N4148 (7)
CR105	Diode	Germanium	1N34A	CRGE1N0034 (9)
CR106	Diode	Silicon, HV		CRSIVA0025 (3)
CR107, CR108, CR109, CR110, CR111, CR112, CR113	Diode	Silicon	1N4002	CRSI1N4002 (2)
J101	Connector	5-pin, male	Molex 09-60-1051	COMR305 (4)
J102 (Partial)	Connector	4-pin, male	Molex 09-60-1041	COMR304 (7)

REF DESIG	PART	DESCRIPTION	MANUFACTURER AND PART NUMBER	EBERLINE PART NUMBER
J102 (Partial)	Connector	3-pin, male	Molex 09-60-1031	COMR803 (8)
J103	Connector	2-pin, male	Molex 09-60-1021	COMR802 (0)
P102 (Partial)	Connector	3-pin, female	Molex 09-50-7031	COMR703 (0)
Q101	Transistor	PNP, silicon	2N4234	TRSP2N4234 (7)
Q102, Q108	Transistor	PNP, silicon	2N4126	TRSP2N4126 (8)
Q103	Transistor	NPN, silicon	2N4401	TRSN2N4401 (6)
Q104, Q107	Transistor	NPN, silicon	2N4124	TRSN2N4124 (2)
Q105	Transistor	PNP, silicon	2N4403	TRSP2N4403 (2)
Q106	Transistor	PNP, silicon	2N6124	TRSP2N6124 (5)
R101, R105, R113	Resistor	1k, 5%, 1/4 W, Carbon Composition		RECC102B22 (4)
R102	Resistor	510k, 5%, 1/4 W, Carbon Composition		RECC514B22 (0)
R103, R106, R112, R109, R110, R123, R130, R145, R146, R150	Resistor	10k, 5%, 1/4 W, Carbon Composition		RECC103B22 (2)
R104, R133, R131, R144	Resistor	20k, 5%, 1/4 W, Carbon Composition		RECC203B22 (0)
R107, R118, R119, R120, R121	Potentiometer	100k, multiturn, PC mount	Bourns 3299W-1-104	PTCE104B03 (5)
R108	Resistor	39k, 5%, 1/4 W, Carbon Composition		RECC393B22 (9)
R111, R122, R136, R158	Resistor	1M, 5%, 1/4 W, Carbon Composition		RECC105B22 (7)
R114	Resistor	820, 5%, 1/4 W, Carbon Composition		RECC821B22 (9)
R115	Potentiometer	100k, PC mount	CTS 375Y-104B	PTCE104B04 (4)
R116	Resistor	12k, 5%, 1/4 W, Carbon Composition		RECC123B22 (0)
R117, R156	Resistor	10k, 1%, 1/4 W	RN55D	RECE103B12 (2)
R124	Resistor	120, 5%, 1/4 W, Carbon Composition		RECC121B22 (4)
R125	Potentiometer	100, PC mount	Bourns 81J1AB20A05	PTXX101B0X (7)
R126	Resistor	430, 5%, 1/4 W, Carbon Composition		RECC431B22 (7)
R127, R129	Resistor	5.1k, 5%, 1/4 W, Carbon Composition		RECC512B22 (4)
R128	Resistor	22k, 5%, 1/4 W, Carbon Composition		RECC223B22 (8)
R132	Resistor	2k, 5%, 1/4 W, Carbon Composition		RECC202B22 (2)
R134	Resistor	33k, 5%, 1/4 W, Carbon Composition		RECC333B22 (5)

REF DESIG	PART	DESCRIPTION	MANUFACTURER AND PART NUMBER	EBERLINE PART NUMBER
R135	Potentiometer	2.5k, PC mount	Bourns 81A1AB20A12	PTXX252B0X (8)
R137, R138, R139, R140 R141	Resistor	20M, 1%, 1/4 W	RN55D	RECE206B12 (3)
R142	Resistor	20k, 1%, 1/4 W	RN55D	RECE203B12 (0)
R147	Potentiometer	10k, PC Mount	CTS 375Y-103B	PTCE103B04 (6)
R148	Resistor	100k, 5%, 1/4 W, Carbon Composition		RECC104B22 (0)
R149	Potentiometer	10k, multiturn, PC mount	Bourns 3299W	PTCE103B33 (1)
R151	Resistor	470, 5%, 1/4 W, Carbon Composition		RECC471B22 (3)
R152, R154	Resistor	243, 1%, 1/4 W	RN55D	RECE241B12 (0)
R153	Resistor	2.55k, 1%, 1/4 W	RN55D	RECE252B12 (7)
R155	Resistor	1.3k, 1%, 1/4 W	RN55D	RECE132B12 (1)
R157	Resistor	340, 1%, 1/4W	RN55D	RECE341B12 (8)
S101	Switch	Toggle, DPDT, PC mount	C&K 7201 SDAV2BE	SWTO22 (5)
S102	Switch	2 pole, 6 pos./pole, PC mount, non-shorting	Grayhill 71BF30-01-2-6N	SWR013 (5)
S103	Switch	Slide, SPDT, PC mount	Alco TSS11DG-PC	SWSL6 (3)
S104	Switch	Momentary PB, PC mount, DPDT	C&K 8225DAV2	SWPB13 (4)
T101	Transformer	117/12 Vac, 350 mA (Note: 230 Vac option requires Stancor P8721, Eberline Part Number TFPO34)	Stancor P8391	TFPO10 (2)
T102	HV Assembly		Eberline	YP10931000 (2)
3. Battery Option YP11138000				
	Battery	12 V	Powersonic PS-1212	BTGC6 (4)
Part of P102	Connector	3-pin	Molex 09-50-7031	COMR703 (0)
	Crimp terminals for P102		Molex 08-50-0106	COHD11 (7)
S105	Switch	Momentary PB, SPDT	C&K 8121-S-Y4-Z-GE	SWPB14 (3)

SECTION VI
DIAGRAMS

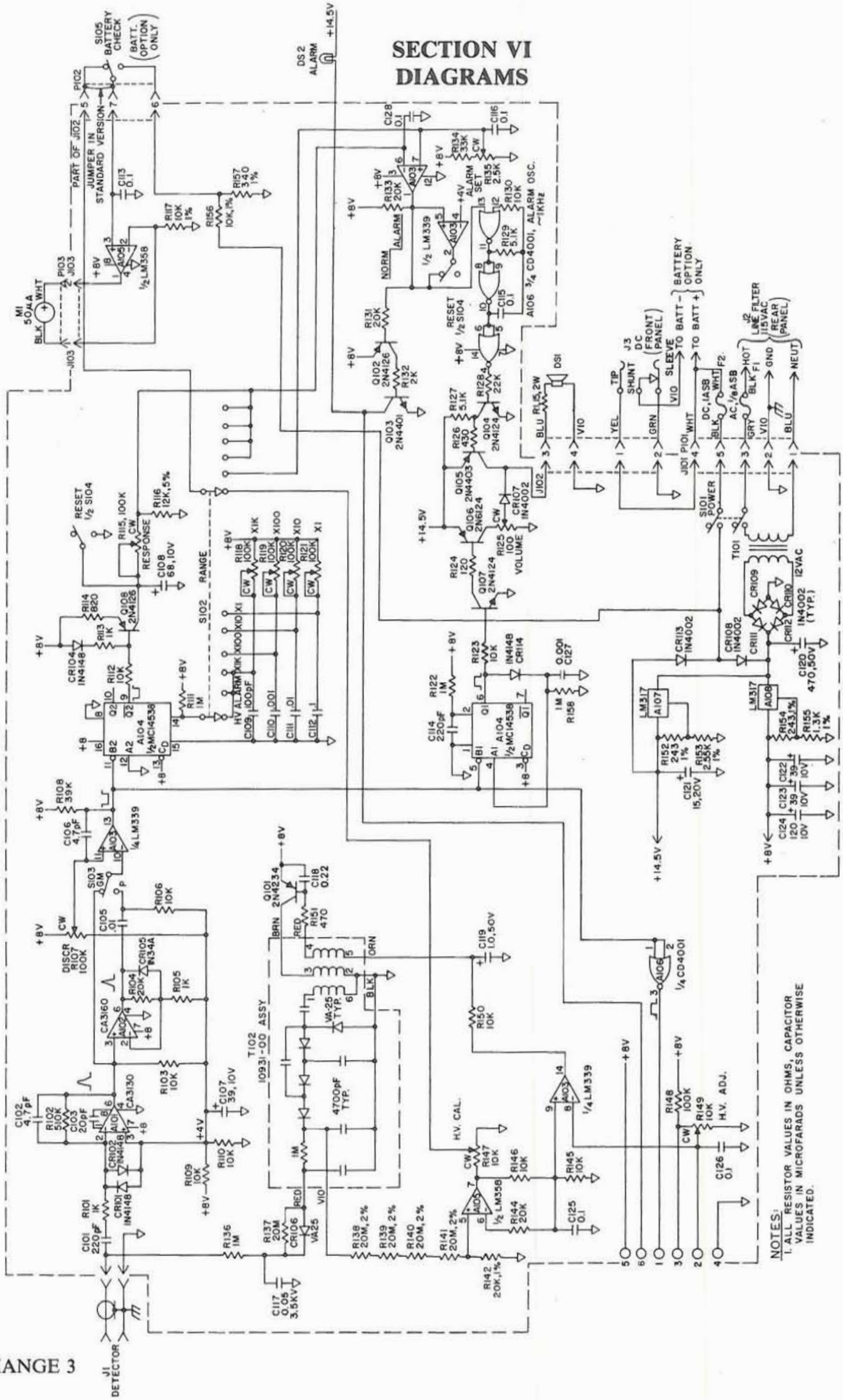

Figure 6-1. RM-20 Schematic (11068-D20G)

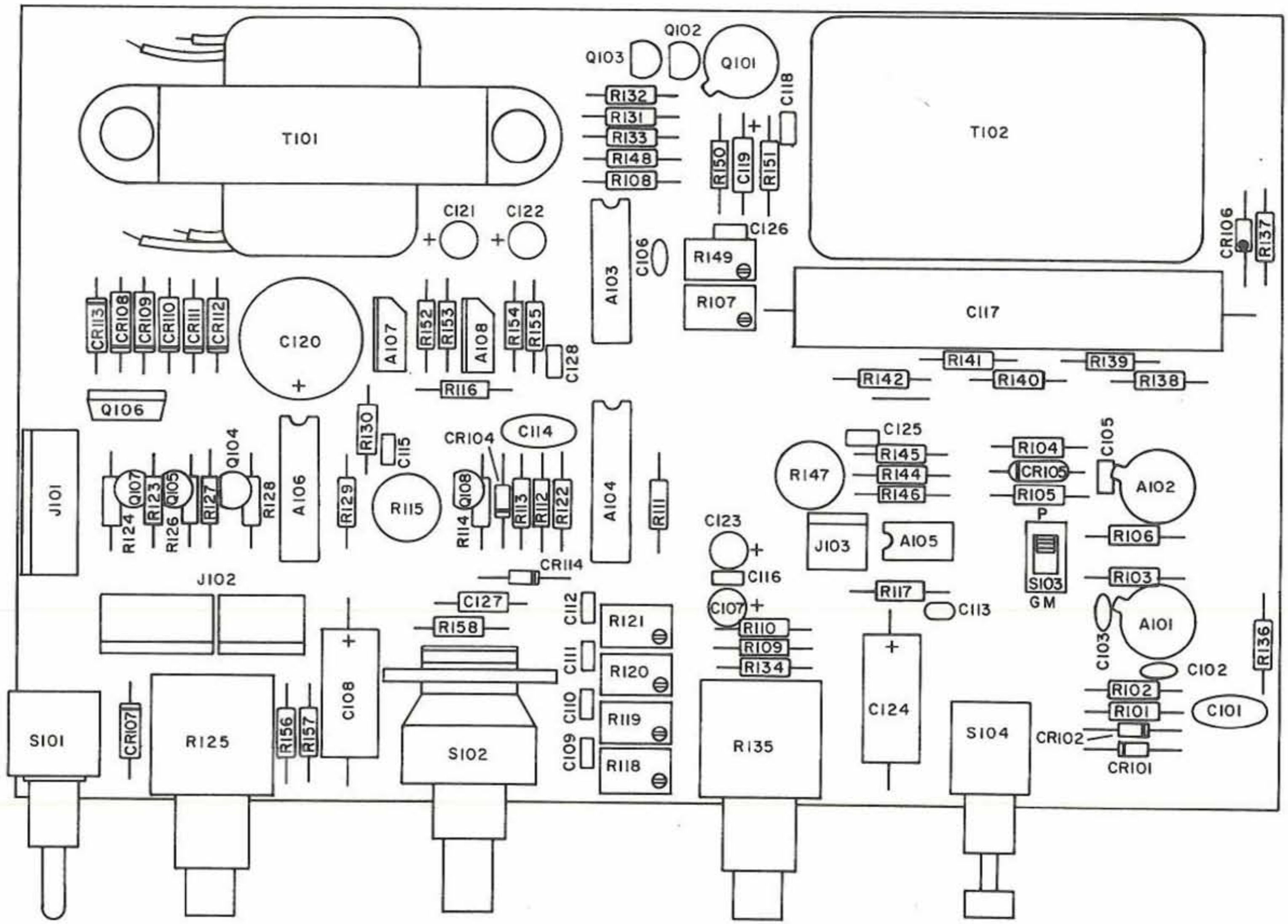

Figure 6-2. RM-20 Component Layout of Circuit Board (11068-C19C)