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NUCLEAR INSTRUMENT MODULE MAINTENANCE MANUAL

Part 22

LINEAR COUNT-RATE METER, ORNL MODEL Q-2622

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ABSTRACT

A linear Count-Rate Meter Module was designed to provide a dc current proportional to the counting rate of input pulses in four switchable ranges. It consists of a flip-flop, limiting amplifier, diode pump driver, and diode pump. The current output of the diode pump feeds directly into the summing junction of an external operational amplifier. The instrument was intended primarily for use in the neutron counting channels of the ORNL High Flux Isotope Reactor. It is packaged in a standard "2-unit" plug-in module of the ORNL Modular Reactor Instrumentation series.

The circuit, application, maintenance procedures, and acceptance tests for the unit are described.

CONTENTS

1. DESCRIPTION

1.1 General

The Linear Count-Rate Meter Module was designed to provide an output dc current which is proportional to the counting rate of input pulses. It consists of a flip-flop, limiting amplifier, diode pump driver, and diode pump. The current output of the diode pump feeds directly into the summing junction of an external operational amplifier. The conventional leak resistor and smoothing capacitor of the pump are the feedback network of this external operational amplifier.

1.2 Construction

The Linear Count-Rate Meter is constructed in a module 2.82 in. wide, 4.72 in. high, and 11.90 in. deep. It is a standard "2-unit" plug-in module of the ORNL Modular Reactor Instrumentation series depicted on drawings Q-2600-1 through Q-2600-5.

With the exception of the range and time-constant switch and the output meter, the entire circuit is mounted on one printed circuit board. This printed board is mounted vertically in the module.

The output meter, the range selection switch, and an input connector (BNC type) are mounted on the front panel. An alternate input is available through the rear plug-in connector of the module on a coaxial contact.

The switch for the smoothing time-constant is mounted internally and is accessible when the drawer containing the module is withdrawn.

1.3 Application

The Linear Count-Rate Meter is intended to provide a more precise reading of count rate in the wide-range neutron counting channel for reactor control. An external operational amplifier is required to obtain an output signal from the unit.

The module can be used in any application where an accurate and stable linear measure of counting rate is needed. A 3- to 4-v positive pulse with a 0.25 μsec or less rise time from a source impedance of 100 ohms or less is required to drive the unit.

1.4 Specifications

1. Range: 100, 1000, 10^4, and 10^5 counts/sec.

2. Accuracy: all points will not deviate by more than 0.25% of full scale reading from a straight line drawn from

zero to full-scale output for regularly spaced input pulses.

3. Input Pulse

a. Polarity and amplitude:	positive, 3 to 4 v.
b. Rise time (10% to 90%):	0.25 μsec or less.
c. Width:	any width.
d. Source impedance:	100 ohms or less.

4. External Operational Amplifier:

a. Open loop gain:	10,000 minimum.
b. Input offset current:	0.5×10^{-9} amp maximum.
c. Input impedance (resistive):	10^4 ohms minimum.
d. Output:	negative 10 v at 1 ma.

5. Smoothing Time Constant:

a. 100 and 1000 count/sec range:	60, 15, and 3 sec ± 20%.
b. 10^4 and 10^5 count/sec range:	6, 1.5, and 0.3 sec ± 20%.

6. Temperature Effects:

a. From 25 to 50°C:	the change in output reading is less than ± 0.02%/°C of full-scale reading at 25°C.
b. From 0 to 25°C:	the change in output reading is less than ± 0.06%/°C of full-scale reading at 25°C.

7. Power Requirements:

a. Voltage:	+ 25 ± 0.05 v; - 25 ± 0.05 v.
b. Current drain:	15 ma from + 25 v v supply; 20 ma from - 25 v supply.

8. Ambient Temperature Range: 0° to 55°C.

1.5 Applicable Drawings and Specifications

The following list gives the drawing numbers (ORNL Instrumentation and Controls Division drawing numbers) and subtitles for the Linear Count-Rate Meter Module:

1.	Q-2622-1	Circuit
2.	Q-2622-2	Details
3.	Q-2622-3	Metalphoto Panel
4.	Q-2622-4	Printed Circuit Board
5.	Q-2522-5	Assembly
6.	Q-2622-6	Parts List.

The following list gives the drawing numbers and subtitles and the number of the fabrication specification for the Plug-In Chassis System:

1.	Q-2600-1	Assembly
2.	Q-2600-2	Details
3.	Q-2600-3	Details
4.	Q-2600-4	Details
5.	Q-2600-5	Details
6.	SF-264	Fabrication Specification.

2. THEORY OF OPERATION

2.1 General

The principle of operation of the Linear Count-Rate Meter Module is described in detail by Cooke-Yarborough.[1] It consists of a flip-flop, limiting amplifier, diode pump driver and diode pump. An external operational amplifier is required to obtain an output signal. The conventional leak resistor and smoothing capacitor of the pump are the feedback network of this external amplifier. This is shown schematically in Fig. 1A.

2.2 Circuit Description

2.2.1 Flip-Flop

Transistors Q1 and Q2 (Fig. 2) form a bistable flip-flop stage which is used to shape the input pulse prior to its application to the diode pump. The output pulse of the flip-flop is rectangular shaped, where the width equals the time elapsed between two successive pulses. This method of shaping automatically provides the pump circuit with wide pulses without any increase in dead-time losses. The consequent division of pulse rate by a factor of two must, of course, be considered in the pump design.

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[1] E. H. Cooke-Yarborough and E. W. Pulsford, "A Counting-Rate Meter of High Accuracy," Proc. IEE, Part II, April 1951, p. 191.

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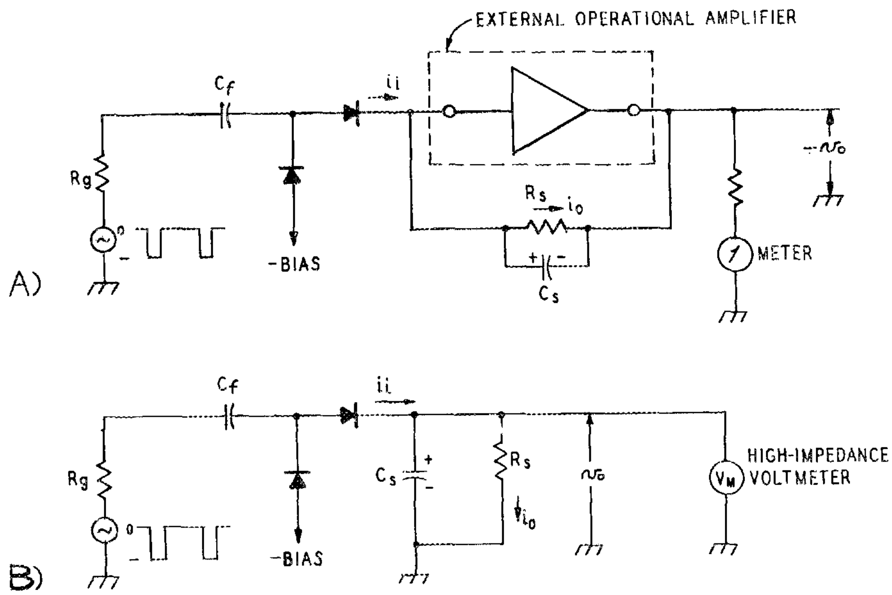

Fig. 1. Schematic Diagram Showing the Principle of Operation of the Linear Count-Rate Meter. A) Circuit for the Linear Count-Rate Meter, ORNL Model Q-2622. B) Circuit for the Conventional Linear Count-Rate Meter.

The flip-flop design as shown is a saturated type (i.e., the "on" transistor is driven into saturation) with 10^7 count/sec resolution capability. Either Q1 or Q2 is hard "on," and the other is off. The positive input pulse acts to turn the "on" transistor off, and the regenerative nature of the circuit then switches the state of the flip-flop. Diodes D2 and D7 serve to steer or apply the pulse to the base of the "on" transistor. To understand how the steering is achieved, assume that Q1 is on and Q2 off. The collector of Q2 will be near ground. Diodes D6 and D7 are in series and are back biased by the difference in potential between the collector and the base of Q2 (about 8 v). The base of Q2 is clamped to + 8.5 v by D5. (The only purpose for D3 and D5 is to limit the back bias applied to Q1 and Q2 when they are turned off. With these diodes, it can never exceed about 0.5 v.) In contrast, diodes D1 and D2, which are also in series, are back biased only by a few tenths of a volt, since Q1 is in a saturated state. Thus, a positive input pulse will take the route through D2 in preference to through D7 because of the greater bias on D7.

Diodes D1 and D6 aid in another manner. These diodes help discharge capacitors C2 and C1, respectively, by providing a low-impedance path to C4 (a 2.2-μf capacitor) through the collector of the "on" transistor between input pulses. These capacitors will acquire some charge as the input signal proceeds to turn off the "on" transistor and, if permitted to accumulate or to not sufficiently recover, can cause a malfunction of the flip-flop.

2.2.2 Limiting Amplifier

The collector swing of Q1 and Q2 is approximately 8 v. This value is marginal to provide reliable operation of a diode pump circuit. Also, the pump-circuit input impedance is quite low and would drastically load the flip-flop and impair its speed. Thus, further amplification and some impedance matching are required. It should be recognized that any amplification process must also achieve high amplitude stability to achieve good pump performance.

Amplification with controlled amplitude is accomplished by transistor Q3 and diodes D4, D8, D9, D10, D11, and D12. Diodes D4, D8, and D9 are fast recovery, conventional diodes, and D10, D11, and D12 are 5.2 v Zener diodes. When Q2 is on, its collector current forward biases D4, which turns Q3 hard off. The collector of Q3 is caught at approximately -17 v by the series string of D8, D9, D10, D11, and D12. When Q2 is turned off, D4 is brought out of clamp and Q3 is driven into saturation by base drive through R4. Thus, the collector swing of Q3 is from -17 v to essentially 0 v. With this scheme, the current of Q2 is sampled rather than its collector voltage, and amplification is not achieved in the usual sense. However, the method used does not load the flip-flop, permitting it to operate at maximum speed.

The two fast-recovery diodes in series with the Zener diodes isolate the large capacity of the Zener diodes from the collector of Q3, permitting fast rise and fall times. One fast diode is adequate, but two diodes give better temperature compensation for the diodes in the pump circuit.

2.2.3 Pump Driver

Transistors Q4 and Q5 are a complementary pair emitter-follower which isolates the low impedance of the diode pump from the limiting amplifier stage. The necessity of complementary design over that of a single emitter follower can be explained if we momentarily include the pump circuit. The negative-going step of the 17-v pulse from the limiting amplifier stage charges the feed capacitor of the pump (C8, C9, and C10, depending on range) through diode D13 to nearly 17 v with conduction through Q4. On the positive-going edge of the pulse (or return to ground), this capacitor must now be discharged quickly to 0 v to be prepared for the next pulse. This discharge path must proceed through the second diode of the pump D14 into the smoothing capacitor (C12, C13, and C14, depending on time constant) for proper action of the pump. At this time, Q4 is biased off and cannot provide this discharge. Q4 is off since its base is near ground and its emitter close to -17 v, because the feed capacitor is behaving as a battery. With Q5 in the circuit as the NPN complement, it will be biased "on" and will permit the feed capacitor to discharge.

2.2.4 Pump Circuit

The operation of the pump circuit was partially covered in the preceding section and will be extended here. Figure 1B represents the conventional circuit of a linear count-rate meter. Either i_o or v_o can be sensed

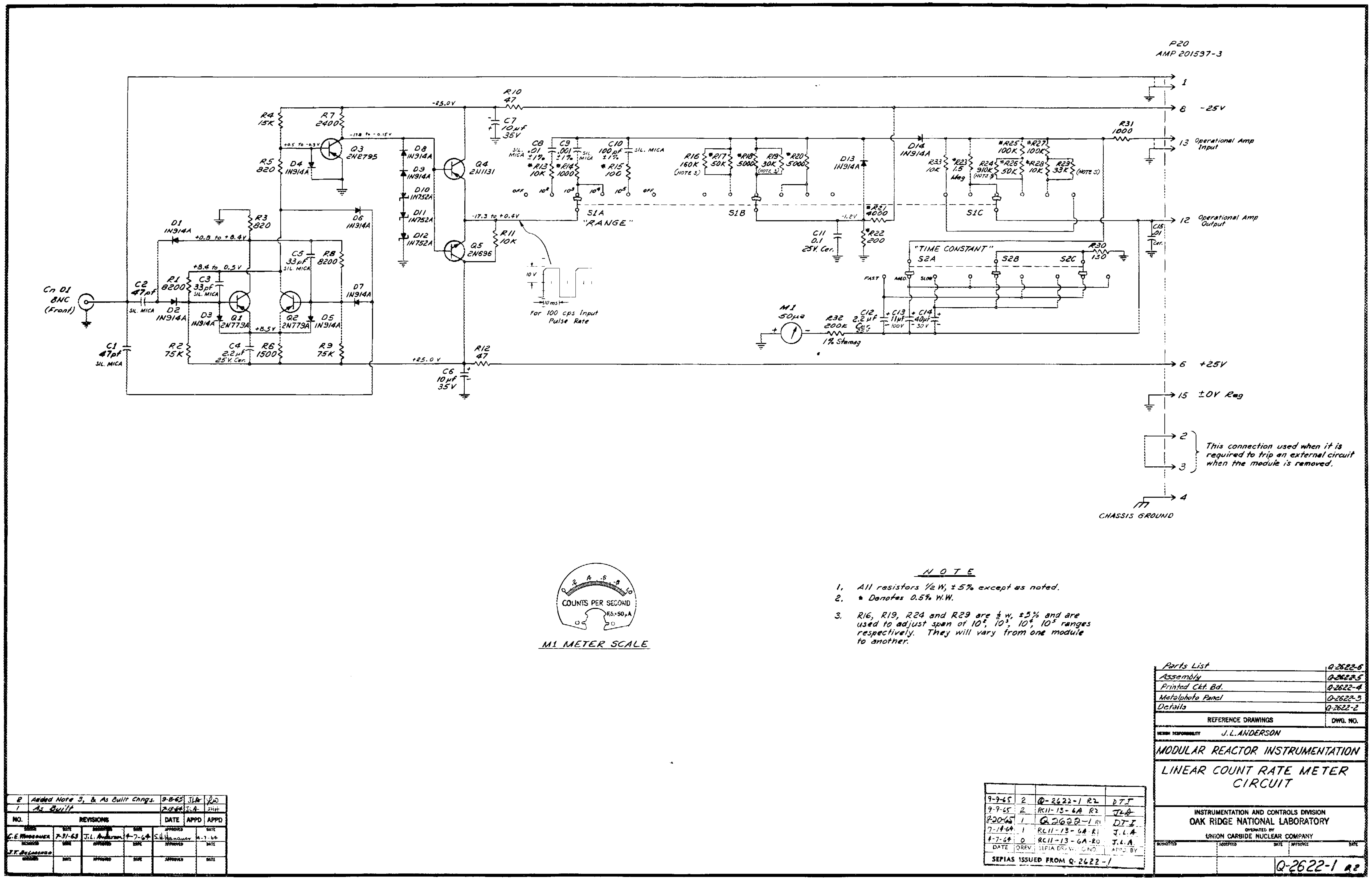

Fig. 2. Linear Count-Rate Meter Circuit.

as the output signal. As charge from the feed capacitor C_f is transferred to the smoothing capacitor C_s, the voltage v_o is developed, causing i_o to flow. At a steady count rate, there is an equilibrium condition established where the rate of charge inflow i_i is equal to the current outflow i_o.

At high count rates, v_o will be large enough to significantly influence the charge delivered by each pulse, and nonlinearity will result. This can be seen mathematically in the following expression for v_o when the product nR_sC_f approaches unity:

$$v_o = \frac{v_i \, n \, R_s \, C_f}{1 + n \, R_s \, Cf} ,$$

where

v_i = input pulse amplitude,

n = input count rate,

C_f = capacity of feed capacitor,

R_s = shunt resistance across smoothing capacitor.[2]

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[2] v_o is derived as follows:

$$v_o = i_o R_s ,$$

where

$$i_o = \frac{\Delta Q}{\Delta t} = \frac{(V_i - v_o) \, C_f}{\frac{1}{n}} = (v_i - v_o) \, n \, C_f .$$

Thus,

$$v_o = (V_i - v_o) \, n \, C_f \, R_s ,$$

and solving for v_o,

$$v_o = \frac{V_i \, n \, R_s \, C_f}{1 + n \, R_s \, C_f} .$$

If an external operational amplifier is connected as shown in Fig. 1A, and with R_s as the feedback resistor of the amplifier, this source of non-linearity is reduced. Since the input to the amplifier will remain at virtual ground regardless of the amplitude of v_o (within limitations of the amplifier), the charge delivered by each pulse will be a constant. Note the difference in polarity of v_o for the two cases.

The output from the diode pump contains spikes at the leading and trailing edges of the input pulses. These spikes may cause paralysis or damage in the early stages of the operational amplifier if not suppressed. Resistors R13, R14, and R15 spoil the leading and falling edges of the input pulse and reduce the amplitude of these spikes without seriously reducing the resolution of count-rate meter. R31 is in series with the input of the operational amplifier and also limits the magnitude of the spikes. C15, which is connected across the output of the operational amplifier, suppresses spikes that are transmitted directly to the output through the smoothing capacitor (C12, C13, or C14 depending on the time constant selected).

The range switch is a three-pole, six-position switch which has four range positions and two off positions. Section C selects the value of R_s to be placed across the amplifier. Section A selects the appropriate spoiler resistor, and Section B selects a shunt resistor for diode D13. This shunt resistor improves the linearity of the unit at the higher counting rates by shortening the discharge time of the feed capacitor (C8, C9, or C10) as the impedance of diode D14 becomes very high when the feed capacitor voltage is below 0.5 v.

The spoiler resistor and the diode shunt resistor influence the magnitude of the output current from the diode pump. On the discharge cycle of the feed capacitor, these two resistors behaving as a voltage divider reduce the effective voltage and thereby the amount of charge transferred to the smoothing capacitor. The diode shunt resistor is trimmed to adjust the span for the 100 and 1000 count/sec ranges. R16, which is in parallel with R17, is trimmed for the 100 count/sec range, and R19 in parallel with R18 is used for the 1000 count/sec range.

The span adjustment for the 10^4 and 10^5 count/sec ranges is made by trimming the values of R_s. R24 is used for this purpose for the 10^4 count/sec range and R29 for the 10^5 count/sec range.

The time-constant switch is so arranged that the capacitors not in use are charged to the full output voltage of the external amplifier. Thus, when the switch is operated to change the time constant, no significant transient is created. Resistor R30 in series with these capacitors limits the peak turn-on currents, which can damage the output stage of the external amplifier, and also prevents oscillation that normally will occur if the outputs of these amplifiers are loaded with large capacitors.

Resistors R21 and R22 provide the necessary bias voltage for the diode pump. This insures that D14 is sufficiently back biased during the charging time of the feed capacitor to avoid a leakage of charge from the smoothing capacitor.

Temperature effects in the diode pump are primarily due to changes in two diodes D13 and D14. The effect of the variation of the diode potentials is equivalent to a variation of the amplitude of the input pulse. The effect is such that at higher temperatures the input pulse appears bigger and there is greater output from the pump. More clearly, as the forward drop of D13 reduces with a temperature increase, the feed capacitor charges to a larger voltage. Also, the forward drop across D14 is less, and more charge is transferred. The two diodes in series with the three 5.2-v Zener diodes have a tendency to compensate for this. As the temperature rises, the forward drop of these two diodes will be less, and the result will be a reduced pulse amplitude.

The leakage of the smoothing capacitors and diode D14 (a 1N914A) behaves as additional shunt resistance across R_s. The 1N914A is specified to have a maximum leakage current of 0.025 μa at a reverse bias of 20 v at 20°C and can be considered negligible. The electrolytic smoothing capacitors were purchased with a specified leakage not to exceed 0.2 μa at 25°C and, in the worst case, a 30% change in this leakage is needed to cause a 0.1% of full-scale change in the output on the 100 and 1000 count/sec ranges. There would be negligible effect on the two upper ranges, since R_s is only 1/10 as large.

The other critical components, such as the feed capacitor and resistors, are high-quality, high-stability ±1% components, or better.

3. OPERATING INSTRUCTIONS

3.1 Installation

The Linear Count-Rate Meter, model Q-2622, is a module in the ORNL Modular Reactor Instrumentation series. Like the other modules of the series, this module has standard connectors and dimensions and has a pin- and hole-code on the rear plate to prevent insertion of the module in a wrong location in a drawer. The module is installed by firmly inserting it in the proper location and tightening the thumb screw. The module may be plugged in with power on without damage.

3.2 Operating Controls

3.2.1 Panel Meter

The panel meter is calibrated to read from 0 to 1.0 count/sec with the appropriate multiplier as determined by the range switch. The meter will not indicate properly unless the Linear Count-Rate Meter Module is connected to an external operational amplifier.

3.2.2 Range Switch

The range switch is mounted on the front panel and permits the selection of any one of four ranges: 100, 1000, 10^4, or 10^5 counts/sec. "Off" positions are available at either extremity of the switch.

3.2.3 Input Connector

A BNC-type connector is available on the front panel for an input signal. There is no cable termination in the module.

3.2.4 Time Constant Switch

The time constant switch is mounted internally and is accessible when the drawer containing the module is withdrawn.

3.2.5 Connections

All connections including a second input connection with a coaxial type contact are made through rear connector P20 when the module is inserted. A jumper between pins 2 and 3 of P20 is provided so that the presence of the module in its proper drawer location can be monitored if desired.

4. MAINTENANCE INSTRUCTIONS

4.1 General

This module is used in conjunction with an external operational amplifier. In the event of any apparent malfunction, check the external amplifier before removing the unit from service.

Many of the resistors and capacitors used in this module have been selected because of their high accuracy and stability. Consult the Replaceable Parts List, Sect. 5, before replacing any defective components.

4.2 Periodic Maintenance

None is required.

4.3 Calibration Procedure

All calibration procedures are covered in Sect. 7, Acceptance Test Procedure.

4.4 Calibration Instruments

Refer to Sect. 6.

4.5 Troubleshooting

In the event of a failure, check the external amplifier. Visually inspect the module, and if no failure is apparent, check the input signal for proper shape and amplitude. If this is normal, measure the voltages and compare them with Table 1 or Fig. 2. Waveforms can be compared with those in Fig. 2.

Table 1. Transistor Voltage Chart[1]

Transistor No.	Emitter (v)	Base (v)	Collector (v)
Q1, 2N779	+8.8/+8.5	+9.3/+8.9	+0.8/+8.4
Q2, 2N779	+9.0/+8.5	+8.5/+9.0	+8.9/+0.4
Q3, 2N2795	0.0	+0.7/-0.3	-17.1/-0.1
Q4, 2N1131	-16.5/+0.5	-17.1/-0.1	-24.3
Q5, 2N696	-16.5/+0.5	-17.1/-0.1	+24.4

[1] All measurements were made with supply voltages adjusted to +25 ± 50 mv and -25 ± 50 mv with input signal removed. All voltages were measured with a vacuum-tube voltmeter with greater than 10 megohms input impedance. A 20,000 ohm/v voltmeter can be used with somewhat less accuracy. Some elements can have two voltage values, depending on the state of the flip-flop Q1 and Q2.

5. REPLACEABLE PARTS LIST

A description and an ORNL Stores number for all replaceable parts are given in Table 2.

Table 2. Replaceable Parts List

Part No.	ORNL Stores No.	Description
C3, C5	06-807-3470	Capacitor, 33 pf, ±5%, 500 v dc w, sil. mica, Elmenco DM-15-330.
C1, C2	06-807-3480	Capacitor, 47 pf, ±5%, 500 v dc w, sil. mica, Elmenco DM-15-470.
C10		Capacitor, 100 pf, ±1%, 500 v dc w, sil. mica, Elmenco DM-15-101.
C9		Capacitor, 0.001 mf, ±1%, 500 v dc w, sil. mica, Elmenco DM-16-102.
C8		Capacitor, 0.01 mf, ±1%, 500 v dc w, sil. mica, Elmenco DM-30-103.
C15	06-802-0084	Capacitor, 0.01 mf, ±20%, 25 v dc w, ceramic, monolithic, Sprague No. 3C3.
C4, C12	06-802-0091	Capacitor, 2.2 mf, ±20%, 25 v dc w, ceramic, monolithic, Sprague No. 5C15.
C11	06-802-0087	Capacitor, 0.1 mf, ±20%, 25 v dc w, ceramic, monolithic, Sprague No. 3C21.
C6, C7	06-816-3240	Capacitor, 10 mf, ±10%, 35 v dc w, tantalum, Sprague No. 150D106X9035R2.
		Capacitor, tantalum electrolytic for derating to 20 v dc w, leakage current shall be less than 0.2 μa from 10°C to 45°C, leakage current shall not exceed 0.2 μa after 10,000 hours operation at 45°C and rated working voltage. Capacitance shall not vary more than 10% of rated value at 25°C over 10°C to 45°C, Sprague Electric Co. The following values are specified at 25°C.
C14		40 mf, ±10%, 30 v dc w.
C13		11 mf, ±10%, 100 v dc w.
		The following wire-wound precision resistors to be temperature aged at 150°C for 48 hours. Final resistance value to be within tolerance when measured at 25°C. Standard lead spacing.
R15		Resistor, 100 ohms, ±1/2%, 0.25 w, at 125°C, Daven type 1273.

Table 2 (continued)

Part No.	ORNL Stores No.	Description
R22		Resistor, 200 ohms, ±1/2%, 0.25 w, at 125°C, Daven type 1273.
R14		Resistor, 1000 ohms, ±1/2%, 0.25 w, at 125°C, Daven type 1273.
R21		Resistor, 4000 ohms, ±1/2%, 0.25 w, at 125°C, Daven type 1273.
R18, R20		Resistor, 5000 ohms, ±1/2%, 0.25 w, at 125°C, Daven type 1273.
R13, R28		Resistor, 10 kilohms, ±1/2%, 0.25 w, at 125°C, Daven type 1273.
R17, R26		Resistor, 50 kilohms, ±1/2%, 0.25 w, at 125°C, Daven type 1273.
R25, R27		Resistor, 100 kilohms, ±1/2%, 0.25 w, at 125°C, Daven type 1273.
R23		Resistor, 1.5 megohm, ±1/2%, 0.40 w, at 125°C, Daven type 1358.
R10, R12		Resistor, 47 ohms, ±5%, 1/2 w, Allen-Bradley.
R30		Resistor, 130 ohms, ±5%, 1/2 w, A-B.
R7		Resistor, 2400 ohms, ±5%, 1/2 w, A-B.
R3, R5		Resistor, 820 ohms, ±5%, 1/2 w, A-B.
R31		Resistor, 1000 ohms, ±5%, 1/2 w, A-B.
R6		Resistor, 1500 ohms, ±5%, 1/2 w, A-B.
R1, R8		Resistor, 8200 ohms, ±5%, 1/2 w, A-B.
R11, R33		Resistor, 10 kilohms, ±5%, 1/2 w, A-B.
R19		Resistor, 30 kilohms, ±5%, 1/2 w, A-B.
R4		Resistor, 15 kilohms, ±5%, 1/2 w, A-B.
R29		Resistor, 33 kilohms, ±5%, 1/2 w, A-B.
R2, R9		Resistor, 75 kilohms, ±5%, 1/2 w, A-B.
R16		Resistor, 160 kilohms, ±5%, 1/2 w, A-B.
R24		Resistor, 910 kilohms, ±5%, 1/2 w, A-B.
R32	06-932-0199	Resistor, 200 kilohms, ±1%, 1/2 w, carbon film, Stemag type SLAK, double high-temperature varnish impregnated. Vendor: H.E. Priester Corp., Scarsdale, New York.
Q1, Q2, Q3	06-996-1640	Transistor, PNP, germanium, type 2N779A, Philco.
Q5	06-996-1610	Transistor, NPN, silicon, type 2N696, Texas Instr. Co.

Table 2 (continued)

Part No.	ORNL Stores No.	Description
Q4	06-996-1710	Transistor, PNP, silicon, type 2N1131, Texas Instr. Co.
Q3		Transistor, PNP, germanium, type 2N2795, Sprague.
D1, D2, D3, D4, D5, D6, D7, D8, D9, D13, D14	06-995-6280	Diode, silicon, type 1N914A, Texas Instr. Co.
D10, D11, D12	06-995-6230	Diode, Zener, type 1N752A, 5.6 v, ±5%, Motorola.
M1	06-050-1835	Meter, microammeter, 0-50 μa, dc, 1175 ohm coil, 50 division scale, Weston No. 206-5061101, mark scale per Q-2622-1.
S1		Switch, subminiature, rotary, 3-pole, 6-position, 6 active contacts per pole, positive shorting, 30° indexing, 1/2 in. diam x 1.00 in. deep behind panel, 1/4-32 thread bushing x 1/4 in. long, 1/8-in. diam shaft 3/4 in. long from mounting surface, complete with internal teeth lockwasher and hex nut, Oak type 1/2 in.
S2		Switch, subminiature, rotary, 3-pole, 3-position, 3 active contacts per pole, positive shorting, 30° indexing, 1/2 in. diam x 0.593 in. deep behind panel, 1/4-32 thread bushing x 1/4 in. long, 1/8-in. diam shaft 3/4 in. long from mounting surface, complete with internal teeth lockwasher and hex nut, Oak type 1/2 in.

6. ACCEPTANCE TEST PROCEDURES

6.1 Test Equipment

The following test equipment is required:

1. An oscilloscope, Tektronix 541 with type L or CA plug-in. Type L is preferred because of its greater sensitivity.

2. A digital, direct-current voltmeter, differential input, four digit, 0.01% accuracy with 1 mv resolution on the most sensitive range.

3. A direct-current, vacuum-tube voltmeter, 10 megohms or greater input impedance; a Dynamics model 1362 is recommended.

4. A pulse generator, crystal controlled, ORNL Q-2167 or equivalent.

5. A transistor tester, current amplification measured at 1 kc, collector saturation current measured with 50-μa meter with 25 small divisions. Baird-Atomic model KT-1 is recommended.

6. Power supplies, positive 25 v, negative 25 v, 0.05% regulation for line and load changes, less than 1 mv rms noise and ripple.

7. An operational amplifier and all required power supplies; ORNL Q-2605 is recommended.

8. A resistance bridge, 1% accuracy, 10 ohms to 1 megohm.

9. Potentiometers, composition, carbon, 2 w, linear, 100 kilohms and 1 megohm.

6.2 General Test Procedures

Prior to any testing, all transistors should be checked for current amplification h_{FE} and collector saturation current I_{CBO}. The Baird-Atomic, model KT-1 tester or its equivalent is recommended. Reject all transistors that do not fall within the ranges specified in Table 3. Observe the operating voltages of the various transistors to avoid damage from excessive dissipation.

Preadjust the supply voltage outputs to within ±50 mv of the 25-v value and connect to the module. The digital voltmeter should be used for this measurement. Permit at least a 15-min warm-up for all modules, power supplies, and test instruments before making any adjustments and measurements. The power supplies may require readjustment after this warm-up interval.

Table 3. Transistor Specification Chart

Transistor	Current Amplification			Collector Saturation Current		
	V_{CE} (v)	I_C (ma)	h_{FE}	V_{CB} (v)	I_E (emitter open)	I_{CBO} (μa)
2N1131 (PNP)	-7.5	5	20 to 60	-7.5	0	< 1
2N696 (NPN)	+7.5	5	20 to 60	+7.5	0	< 1
2N779 (PNP)	-4.5	5	75 to 150	-4.5	0	< 1
2N2795(PNP)	-7.5	5	50 to 100	-7.5	0	< 1

Preadjust the supply voltage outputs to within ±50 mv of the 25-v value and connect to the module. The digital voltmeter should be used for this measurement. Permit at least a 15-min warm-up for all modules, power supplies, and test instruments before making any adjustments and measurements. The power supplies may require readjustment after this warm-up interval.

6.3 Adjustments and Calibration

6.3.1 Preliminary

Figure 3 shows the equipment for adjustment and calibration of the module. Note the grounding. It is important that the common (±0 v) ground for all dc supplies associated with the model Q-2605 operational amplifier be tied to the common (±0 v) ground of the +25 v and -25 v supplies of the model Q-2622 module. The power ground of one of these supplies (-25 v or +25 v) should be made the power ground for the entire system.

The digital voltmeter shall be connected between the operational amplifier output and the high-quality (HQ) ground of the operational amplifier. An RC filter consisting of a 1-kilohm resistor and a 2-μf capacitor should be used between the operational amplifier and the digital voltmeter.

The output of the crystal-controlled pulse generator must be attenuated before connecting it to the module input. A resistive network consisting of two 510-ohm resistors is sufficient. This will give 4-v pulses when connected as shown in Fig. 3.

The adjustment of the four ranges of the modules is as follows: switch the time-constant switch to the "fast" position, and balance the operational amplifier.

6.3.2 10^5 Count/sec Range

Disconnect R29 and replace it with a 100-kilohm carbon potentiometer. Switch the pulse generator to a 10^5 count/sec rate. Adjust the 100-kilohm potentiometer until a reading of 10.00 v is obtained on the digital voltmeter. The front panel meter should indicate 1.00 ± one small division. Switch the pulse generator to a 5 x 10^4 count/sec rate. The digital voltmeter should read 5 v ± 10 mv. The panel meter should read 0.5 ± 1 small division.

Remove the 100-kilohm potentiometer and bridge it. Replace it with the nearest ±5%, 1/2-w, carbon resistor. The value of this resistor should not be less than three times the value of R28. Install the resistor, taking care not to overheat it.

The following calibration check should be made at the frequencies indicated in Table 4.

Table 4. Calibration Check

Pulser Frequency (cps)	Output Voltage (v)	True Output Voltage (v)	Deviation From True Output[1] (v)	Error (% of Reading)[2]
(1)	(2)	(3)	(4)	(5)
0		0.000		
10^4		1.000		
2.5×10^4		2.000		
5.0×10^4		5.000		
10^5		10.00		

[1] Deviation is computed as value in col 2 - value in col 3.

[2] Error is computed as (col 4/col 3) x 100.

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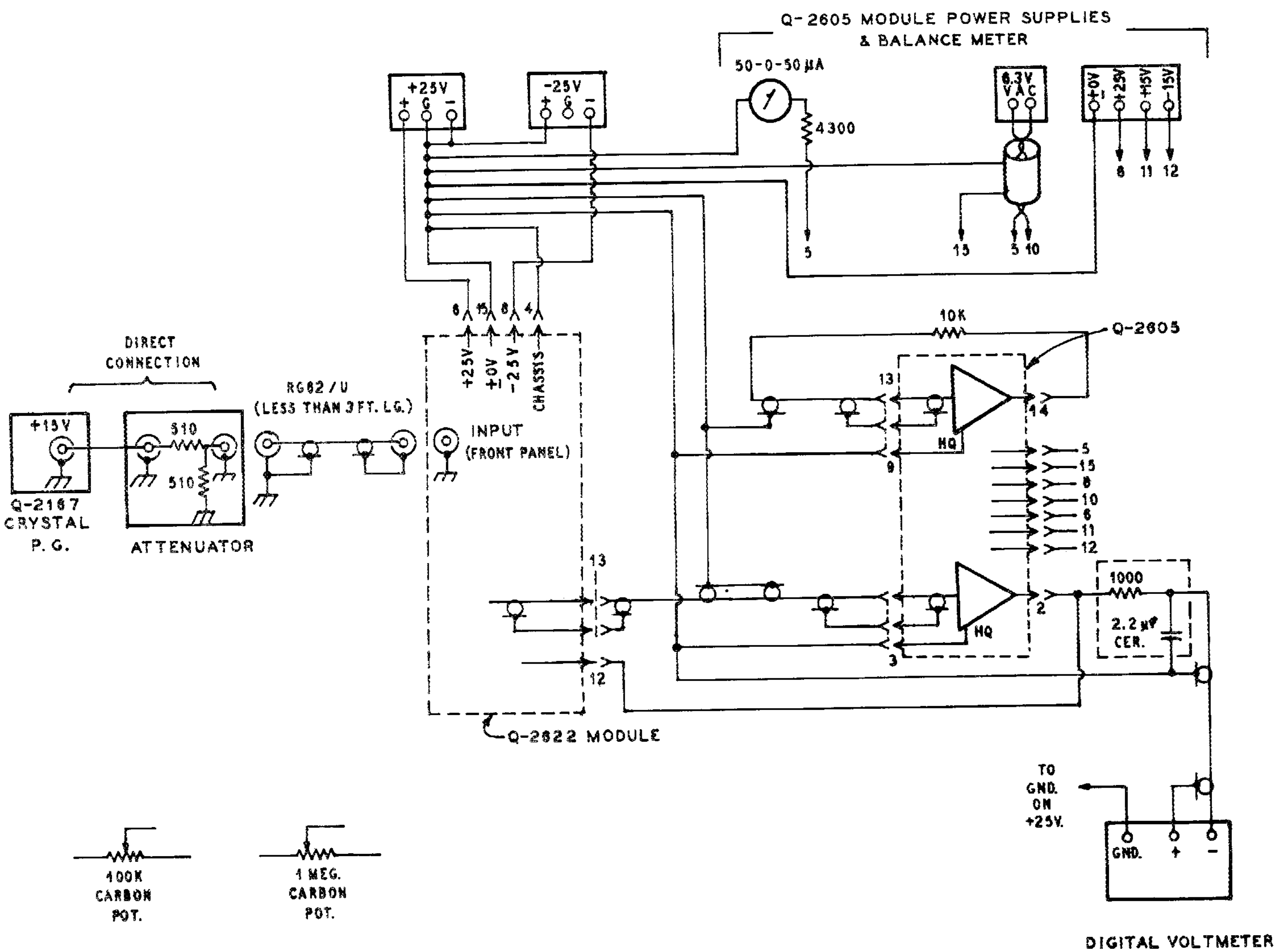

Fig. 3. Equipment for Testing and Adjusting the Linear Count-Rate Meter Module, ORNL Model Q-2622.

6.3.3 10^4 Count/sec Range

Disconnect R24 and replace it with a 1-megohm carbon potentiometer. Switch the pulse generator to a 10^4 count/sec rate. Adjust the 1-megohm potentiometer until a reading of 10.00 v is obtained on the digital voltmeter. The front-panel meter of the module should indicate 1.00 ± one small division. Switch the pulse generator to a 5000 count/sec rate. The digital voltmeter should read 5 v ± 10 mv. The panel meter should read 0.5 ± 1 small division.

Remove the 1-megohm potentiometer and bridge it. Replace it with the nearest ±5%, 1/2-w, carbon resistor. The value of this resistor should not be less than three times the value of R26. Install the resistor, taking care not to overheat it.

Check the calibration of the module on this 10^4 count/sec range at 0, 1000, 2500, 5000, and 10^4 counts/sec. Complete Table 4. The true output will be 10.00 v at 10^4 counts/sec.

6.3.4 10^3 Count/sec Range

Disconnect R19 and replace it with a 100-kilohm carbon potentiometer. Switch the pulse generator to a 1000-count/sec rate. Adjust the 100-kilohm potentiometer until a reading of 10.00 v is obtained on the digital voltmeter. The front-panel meter on the module should indicate 1.00 ± one small division. Switch the pulse generator to a 500 count/sec rate. The digital voltmeter should read 5 v ± 10 mv. The panel meter should read 0.5 ± 1 small division.

Remove the 100-kilohm carbon potentiometer and bridge it. Replace it with the nearest ±5%, 1/2-w, carbon resistor. The value of this resistor should not be less than three times the value of R18. Install the resistor, taking care not to overheat it.

Check the calibration of the module on the 10^3 count/sec range at 0, 100, 250, 500, and 1000 counts/sec. Complete Table 4. The true output will be 10.00 v at 1000 counts/sec.

With a 1000 count/sec input, switch the time-constant switch to the "medium" and then to the "slow" positions. There should be no change in reading.

6.3.5 10^2 Count/sec Range

Disconnect R16 and replace it with a 1-megohm carbon potentiometer. Switch the pulse generator to the 100 count/sec rate. Adjust the 1-megohm potentiometer until a reading of 1.00 v is obtained on the digital voltmeter. The front panel of the module should indicate 1.00 ± one small division. Switch the pulse generator to 50 counts/sec. The digital voltmeter should read 5 v ± 10 mv. The panel meter should read 0.5 ± 1 small division.

Remove the 1-megohm potentiometer and bridge it. Replace it with the nearest ±5%, 1/2-w, carbon resistor. The value of this resistor should not be less than three times the value of R17. Install the resistor, taking care not to overheat it.

Check the calibration of the module on the 10^2 count/sec range at 0, 10, 25, 50, and 100 counts/sec. It may be necessary to increase the smoothing time-constant at the 0, 10, and 25 count/sec points. If this is so, repeat the readings at all points with the new time constant. There should be no change in reading as the time constant is changed. It will be necessary to take a little more time between readings for the longer time-constants. Complete Table 4. The true output will be 10.00 v at 100 counts/sec.

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Part 22

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