INSTRUCTION MANUAL

441

RATEMETER

Serial No. ______________________________

Purchaser ______________________________

Date Issued ______________________________

ORTEC
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AN EG&G COMPANY

Printed in U.S.A.

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ORTEC warrants its nuclear instrument products, other than preamplifier FET input transistors, vacuum tubes, fuses, and batteries, to be free from defects in workmanship and materials for a period of twenty-four months from date of shipment provided that the equipment has been used in a proper manner and not subjected to abuse. Repairs or replacement, at ORTEC option, will be made on in-warranty instruments, without charge, at the ORTEC factory. Shipping expense will be to the account of the customer except in cases of defects discovered upon initial operation. Warranties of vacuum tubes and semiconductors made by their manufacturers will be extended to our customers only to the extent of the manufacturers' liability to ORTEC. Specially selected vacuum tubes or semiconductors cannot be warranted. ORTEC reserves the right to modify the design of its products without incurring responsibility for modification of previously manufactured units. Since installation conditions are beyond our control, ORTEC does not assume any risks or liabilities associated with methods of installation or with installation results.

QUALITY CONTROL

Before being approved for shipment, each ORTEC instrument must pass a stringent set of quality control tests designed to expose any flaws in materials or workmanship. Permanent records of these tests are maintained for use in warranty repair and as a source of statistical information for design improvements.

ORTEC must be informed in writing of the nature of the fault of the instrument being returned and of the model and serial numbers. Failure to do so may cause unnecessary delays in getting the unit repaired. Our standard procedure requires that instruments returned for repair pass the same quality control tests that are used for new-production instruments. Instruments that are returned should be packed so that they will withstand normal transit handling and must be shipped prepaid via Railway Express or United Parcel Service to the nearest ORTEC repair center. Instruments damaged in transit due to inadequate packing will be repaired at the sender's expense, and it will be the sender's responsibility to make claim with the shipper. Instruments not in warranty will be repaired at the standard charge unless they have been grossly misused or mishandled, in which case the user will be notified prior to the repair being done. A quotation will be sent with the notification.

DAMAGE IN TRANSIT

Shipments should be examined immediately upon receipt for evidence of external or concealed damage. The carrier making delivery should be notified immediately of any such damage, since the carrier is normally liable for damage in shipment. Packing materials, waybills, and other such documentation should be preserved in order to establish claims. After such notification to the carrier, please notify ORTEC of the circumstances so that we may assist in damage claims and in providing replacement equipment if necessary.

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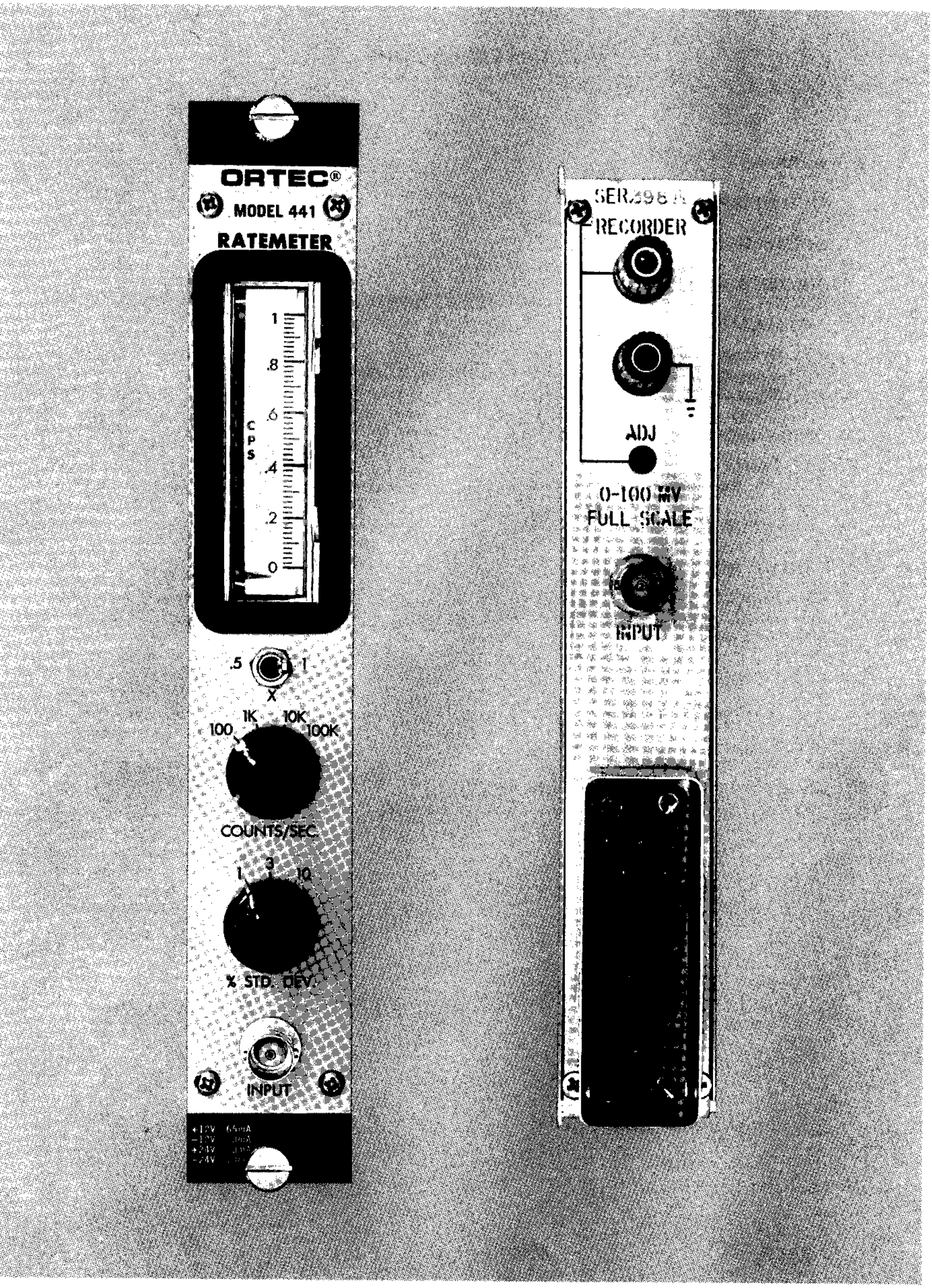

ORTEC®
MODEL 441
RATEMETER
CPS
COUNTS/SEC.
% STD. DEV.
INPUT
RECORDER
ADJ
0-100 MV
FULL SCALE
INPUT

ORTEC 441 RATEMETER

1. DESCRIPTION

The ORTEC 441 Ratemeter is a simple, high accuracy linear count ratemeter that is contained in a single width NIM package. The 441 accepts a wide range of input counting rates and provides statistical accuracy selectability. The use of Standard Deviation rather than "time constant" allows the operator to obtain the fastest possible time response for a desired accuracy. Long term stability and reliability are assured by the use of integrated circuit amplifier and logic circuits and matched field-effect transistors in the circuit design of the 441. The recorder output span is adjustable over a wide range and the input pulse requirements are easily met by almost all nuclear instruments.

2. SPECIFICATIONS

RANGES 100, 1000, 10K, and 100K counts per second with a multiplier of 1 and 0.5 for total ranges of 50, 100, 500, 10^3, 5 x 10^3, 10^4, 5 x 10^4, and 10^5 counts per second full scale.

PERCENT STANDARD DEVIATION Nominally 1%-3%-10% at full scale.

LINEARITY Better than ±0.5% of full scale.

STABILITY Better than ±0.05% of full scale per day at constant temperature.

TEMPERATURE COEFFICIENT 0.05% of full scale per °C.

INPUT PULSE REQUIREMENTS

Amplitude +2 V to operate.
±100 V maximum pulse amplitude.
±30 V maximum average.

Rise Time Less than 1 millisecond per volt at +2 V level.
Width No maximum limit, minimum width of 200 nsec, input dc-coupled with impedance of approximately 2500 ohms.

RECORDER OUTPUT Binding post connectors on rear panel with rear panel adjustment for recorder full scale output; full scale adjustment from 0-100 mV.

METER 2-inch edge reading meter with 2% meter movement.

OPERATING TEMPERATURE 0-50°C.

POWER REQUIREMENTS +12 V, 65 mA; -24 V, 10 mA.

SIZE Standard single width NIM module (1.35 in. wide).

3. INSTALLATION

3.1 GENERAL INSTALLATION CONSIDERATIONS

The 441, used in conjunction with a 401A/402A Bin and Power Supply, is intended for rack mounting; therefore, it is necessary to ensure that vacuum tube equipment operating in the same rack with the 441 has sufficient cooling air circulating to prevent any localized heating of the all-transistor circuitry used throughout the module. The temperature of equipment mounted in racks can easily exceed the recommended maximum unless precautions are taken. The 441 should not be subjected to temperatures in excess of 120°F (50°C).

3.2 CONNECTION TO POWER – MODULAR SYSTEM BIN, ORTEC 401A/402A

The 441 contains no internal power supply; therefore, it must obtain power from a Nuclear Standard Bin and Power Supply such as the ORTEC 401A/402A. Turn power off for the bin power supply before inserting or removing modules. The ORTEC 400 Series is designed so that it is not possible to overload the bin power supply with a full complement of modules in the bin; however, this may not be true when the bin contains modules other than those of ORTEC design, and in such instances the power supply voltages should be checked after the insertion of modules. The ORTEC 401A/402A has test points on power supply control panel to monitor the dc voltages. When using the 441 outside the 401A/402A Bin and Power Supply, be sure that the jumper cable used properly accounts for the power supply grounding circuits set forth in the recommended AEC standards of TID-20893 (Rev.). Both high quality and power return ground connections are provided to ensure proper reference feedback into the power supply, and these must be preserved in remote cable installations. Be careful to avoid ground loops when the module is not physically in the bin.

3.3 SIGNAL CONNECTIONS TO THE 441 INPUT

The input circuit is compatible with the standard NIM slow logic signal and the 441 will operate with any device whose output signals meet these specifications. The standard signal input requirement is such that the device must respond to signals of +3 V in amplitude and 500 ns wide while it must not accept signals of 1.5 V or less. The 441 meets these requirements, or it will accept signals that are larger in amplitude and narrower.

Typically, the input signal to a ratemeter is supplied by a discriminator which is monitoring the output of a linear amplifier such as the ORTEC 410, 435A, or 440A. The discriminator can be either an integral discriminator which produces an output each time the input crosses the discrimination level, or it can be a "window" discriminator (single channel analyzer).

4. OPERATING INSTRUCTIONS

4.1 GENERAL CONSIDERATIONS

To operate the 441 Ratemeter, first insert the module into an ORTEC 401A/402A Bin and Power Supply or any NIM bin which supplies the standard voltages. Connect a signal from a discriminator or pulse generator to the 441 INPUT connector. The rate of the input signal is read directly from the front panel meter. Note that two range switches change the meter scale. For example:

1. A meter reading of 0.8 with the range switches at 1K and X1 indicates a rate of 800 cps.

2. A meter reading of 0.8 with the range switches at 1K and X.5 indicates a rate of 400 cps.

4.2 STANDARD DEVIATION AND TIME CONSTANTS

The front panel control labeled % STANDARD DEVIATION is equivalent to the "time constant" control found on other ratemeters. These are two ways of expressing the same thing, since statistical accuracy at a given input rate depends only upon the time constant. The design of the 441 provides a selectable full scale statistical fluctuation independent of the rate. However, the user should bear in mind that these are for steady state conditions, and that for transient conditions it takes longer to achieve 1% statistics than 3% statistics at a given rate, and it takes longer to achieve a selected statistical accuracy at a low rate than at a high rate.

Equivalent Time Constants (Seconds) for Combined Range and % Std. Dev. Settings of the ORTEC 441 Linear Ratemeter

	%Std. Dev. at Full Scale		
Range	1%	3%	10%
100	50 sec	5 sec	0.5 sec
1K	5 sec	0.5 sec	0.05 sec
10K	0.5 sec	0.05 sec	0.005 sec
100K	0.05 sec	0.005 sec	0.0005 sec

If we assume a step function increase in count rate from an initial value of zero to a final value of full scale, and if we assume that a steady state condition exists when enough time has elapsed for the average value of the output to come within the selected % standard deviation of the true final value, we can calculate some meaningful times for the ratemeter response. The ratemeter response, on the average, follows the response of a classical low pass RC filter network. Thus, it takes 2.3 time constants to be within 10% of the final value, 3.5 time constants for 3%, and 4.6 time constants to be within 1% of the final value. For example, if the 441 Range were set for 100 cps full scale and the rate of input pulses changes abruptly from 0 to 100 cps, the meter indication would be within statistical accuracy after 1.15 seconds for 10% Std. Dev., or after 17.5 seconds for 3% or after 230 seconds for 1%.

5. THEORY OF OPERATION

The ratemeter operates by applying a fixed amount of charge onto a capacitor for each input signal, and by draining this charge off at a rate proportional to the amount of charge. This is most easily accomplished by means of an operational amplifier with an RC parallel feedback network. By referring to the block diagram at the end of this manual, this operation will be clearer.

The input signal, if it is larger than the input threshold (~2 V), will produce an output at the discriminator which will cause the binary to change states so that alternate input signals trigger the monostable. The monostable output causes a negative signal at the collector of Q5. The negative transition of the signal at the collector of Q5 passes through C4 and D7 to the input of the amplifier to produce a positive output signal. When the signal at Q5 goes positive, the signal path is through C4 and D6 to ground, with D7 being cut off so that the output is not changed by this positive transition.

The response of the output to a single input is:

$$e = \frac{VC_4}{C_f} \epsilon^{-t/R_fC_f} \qquad (1)$$

so that the amplitude initially "steps up" by an amount equal to VC_4/C_f and falls with an exponential time constant of R_fC_f.

The average value of the output is obtained when the current through R_f is equal to the current supplied from Q5. If n represents the average input rate, then the input current is:

$$i = nQ \text{ or } i = nVC_4 \quad (2)$$

and the current through R_f is simply:

$$i_R = \frac{E_o}{R_f}$$

where E_o is the average value of the output voltage. Since these two currents must be in equilibrium,

$$E_o = nVC_4 R_f \quad (3)$$

The statistical fluctuations of the output for a random input rate can be derived by the use of Campbell's† theorem which says that

$$e_o^2 = n \int_0^\infty \epsilon f(t)^2 \, dt \quad (4)$$

where e_o^2 = mean squared value of the output

$$f(t) = \text{time response of output} = \frac{VC_4}{C_f} \epsilon^{-t/R_fC_f}$$

n = average rate of input

so that

$$e_o^2 = \frac{n (C_4)^2 V^2}{(C_f)^2} \int_0^\infty \epsilon^{-2t/R_fC_f} dt \quad (5)$$

$$= \frac{n (C_4)^2 V^2 R_f}{2C_f} \quad (6)$$

The rms of the output is

$$e_o \text{ (rms)} = \frac{C_4 V}{C_f} \sqrt{\frac{nR_fC_f}{2}} \quad (7)$$

Using equations 3 and 7, the % standard deviation of the rms to the average output can be obtained as

$$\% \text{ Std. Dev.} = \frac{100 \times e_o}{E_o} = \frac{100}{\sqrt{2nR_fC_f}} \quad (8)$$

At full scale in the 441 these values can be calculated easily for n = 100, $R_f = 5 \times 10^6$, and C_f.

(a) $C_f = 10\mu F$ % Std. Dev. = 1%
(b) $C_f = 1\mu F$ % Std. Dev. = $\sqrt{10} \cong 3\%$
(c) $C_f = .1\mu F$ % Std. Dev. = 10%

Note in the calculations given above that n is taken as 100, whereas in the actual circuit a divide-by-2 is employed for full scale readings of 100, 1000, 10K, and 100K.

The use of a prescaler in front of the charge dump circuit does not change the average value of the output, as long as each time that the input rate is decreased the charge dumped per event is increased by the same amount. On the other hand, the prescaling smoothes out the random input rate to cause less statistical fluctuation in the output. The calculation above, based upon a random input rate of 100 cps, is conservative, in that a random rate of 100 would cause a larger percent fluctuation at the output than would be caused by the same input rate after it has been divided by 2.* The use of the binary circuit also eliminates pile-up losses in the ratemeter itself due to the finite time duration of the pulse at the collector of Q5.

†Campbell, N. R., "The Study of Discontinuous Phenomena," *Proc. Camb. Phil. Soc.*, 15:117 (1908).

*R. D. Evans, ***The Atomic Nucleus***, pp. 794-8, McGraw-Hill, 1955.

6. CIRCUIT DESCRIPTION

6.1 INPUT DISCRIMINATOR

The input circuit consists of a discrete component Schmitt Trigger circuit. This circuit is preceded with a pair of back to back diodes biased so that the base of Q1 cannot be driven more than ±3 V. In the quiescent state, the base of Q2 is about +2 V, which fixes the input threshold. When the input exceeds 2 V, Q1 turns on, which turns Q2 off. This causes Q3 to also turn off and the signal at pin 2 of IC-1 drops from about 1.7 V to 0 V. The signal at pin 2 exists for approximately the same time that the input stays above +2 V.

6.2 BINARY DIVIDER AND MONOSTABLE

The binary divider (IC-1) is an integrated circuit JKFF which changes state each time the input goes negative. In the X1 position, alternate input signals cause a positive transition at pin 7 of IC-1 which triggers the monostable circuit made up of the two halves of IC-2. These are two input positive NOR gates. The positive signal at pin 6 of IC-2 is fed back to pin 2 to provide regeneration in the monostable, and in the X.5 multiplier position is used to reset the binary. Thus, in the .5 multiplier position, each input signal produces a signal from the binary which triggers the monostable which resets the binary so that the next pulse will repeat the sequence. The input rate in the .5 multiplier position is not divided by 2 and a larger meter deflection is obtained.

6.3 INTEGRATING CIRCUIT

Each positive signal from the monostable circuit (IC-2, pin 6) saturates Q5, producing a negative pulse at the collector of Q5. The leading edge of this pulse is transmitted through D7 to the amplifier input to produce a positive signal at the amplifier output. As indicated in Section 5 of this manual, the output signal has an amplitude of VC_4/C_f, where C_f is the feedback capacitor (C11, C12, or C13). In this term, V is the voltage at the collector of Q5 ***before*** the pulse is generated. The adjustable resistor, R20, provides the calibration adjustment for the 441.

The amplifier in the 441 consists of a matched pair of field effect transistors (FET) operated as a differential amplifier to provide a high input impedance with very low offset current. The FET pair is followed by a high gain differential comparator (μA710) operated as an amplifier. This combination provides a high input impedance, high gain amplifier that requires low input currents over a wide temperature range. The amplifier has a dc balance control located between the "sources" of the two FET's. This control, R25, adjusts the output of the amplifier to zero volts when the input count rate is zero.

The feedback resistors, with the exception of the 5 megohm resistor used in the 100 cps range, are 0.1% devices. The use of such precision devices assures long term stability and eliminates the need for adjustments on each range. The low temperature coefficient of these devices also improves the overall temperature stability of the 441.

The feedback capacitors (C11, C12, and C13) are always "precharged" through R35. This provides a means of obtaining faster readings of very low input rates. For example, it takes approximately 110 seconds on 100 cps range and 1% Std. Dev. to reach 90% of the final reading, but only 11.5 seconds on the 3% position and 1.15 seconds on the 10% position. Therefore, to obtain a faster answer, start the measurement at 10%, then switch to 3% and finally to 1%. Since the capacitors are precharged, the large capacitors do not have to start charging from zero volts.

7. MAINTENANCE AND ADJUSTMENTS

There should be almost no maintenance problems with the 441 because all devices used in the instrument are operated far below their ratings. With the exception of the matched FET's, the transistors used could be replaced with a large number of different devices without any problems. The devices which are not so familiar are:

(a) D8 – MSD 6100 – Motorola
(b) IC-1 – μL 923 JKFF – Fairchild (RTL)
(c) IC-2 – μL 914 Gate – Fairchild (RTL)
(d) Q6 and Q7 – INT3242 – International (matched FET's)
(e) IC-3 – μA710 Comparator – Fairchild

7.1 ADJUSTMENTS

1. DC Balance Adjustment. With no signals applied to the input, the dc level at pin 7 of IC-3 should be zero volts. Adjust R25 to obtain this condition.

2. Meter Calibrate. With a known input rate (preferably periodic) of value above 100 cps, adjust R20 until the output at pin 7 of IC-3 reads the rate directly in millivolts. For example, a rate of 900 cps on the 1K range should produce an output of 0.900 V. Always check the dc balance (1 above) before attempting to change the meter calibrate.

3. 100 cps Range. The 100 cps range is trimmed to read correctly by adjusting R41 after adjustments 1 and 2 are checked for correctness. To make the adjustment use a signal of a known rate below 100 cps--a line frequency pulse is often convenient. Adjust R41 until the output at pin 7 of IC-3 reads the rate directly. For example, a 60 cps input rate should produce a 0.600 V output reading. Take care to allow enough time for the reading to stabilize before changing the value of R41. It takes about four minutes for a stable reading at 60 cps and 1% Std. Dev.

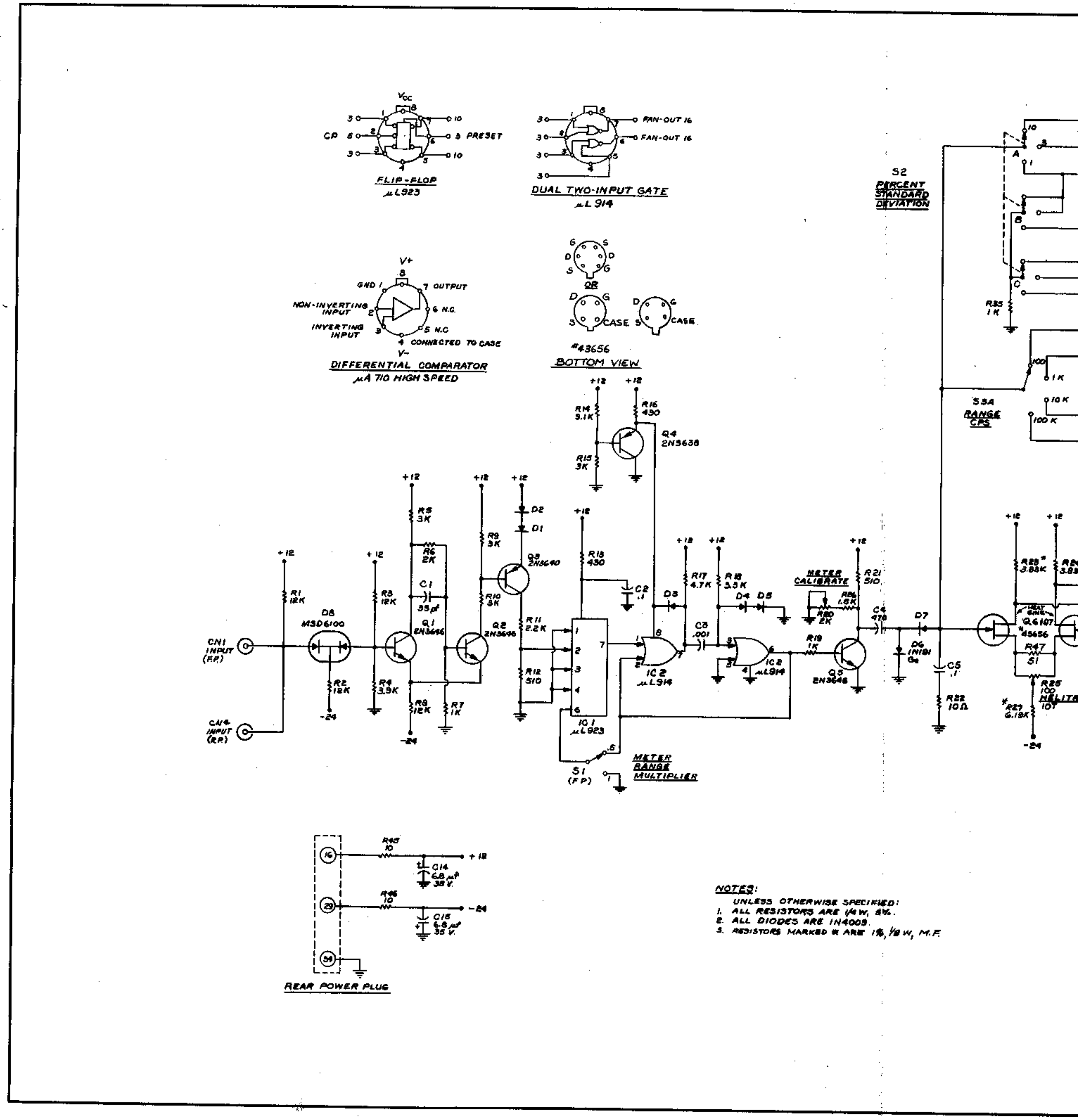
4. Meter Zero. With the instrument inserted in a bin and under power, the meter can be manually zeroed. A lever located at the right side of the meter provides the adjustment.

BIN/MODULE CONNECTOR PIN ASSIGNMENTS
FOR AEC STANDARD NUCLEAR INSTRUMENT MODULES
PER TID-20893

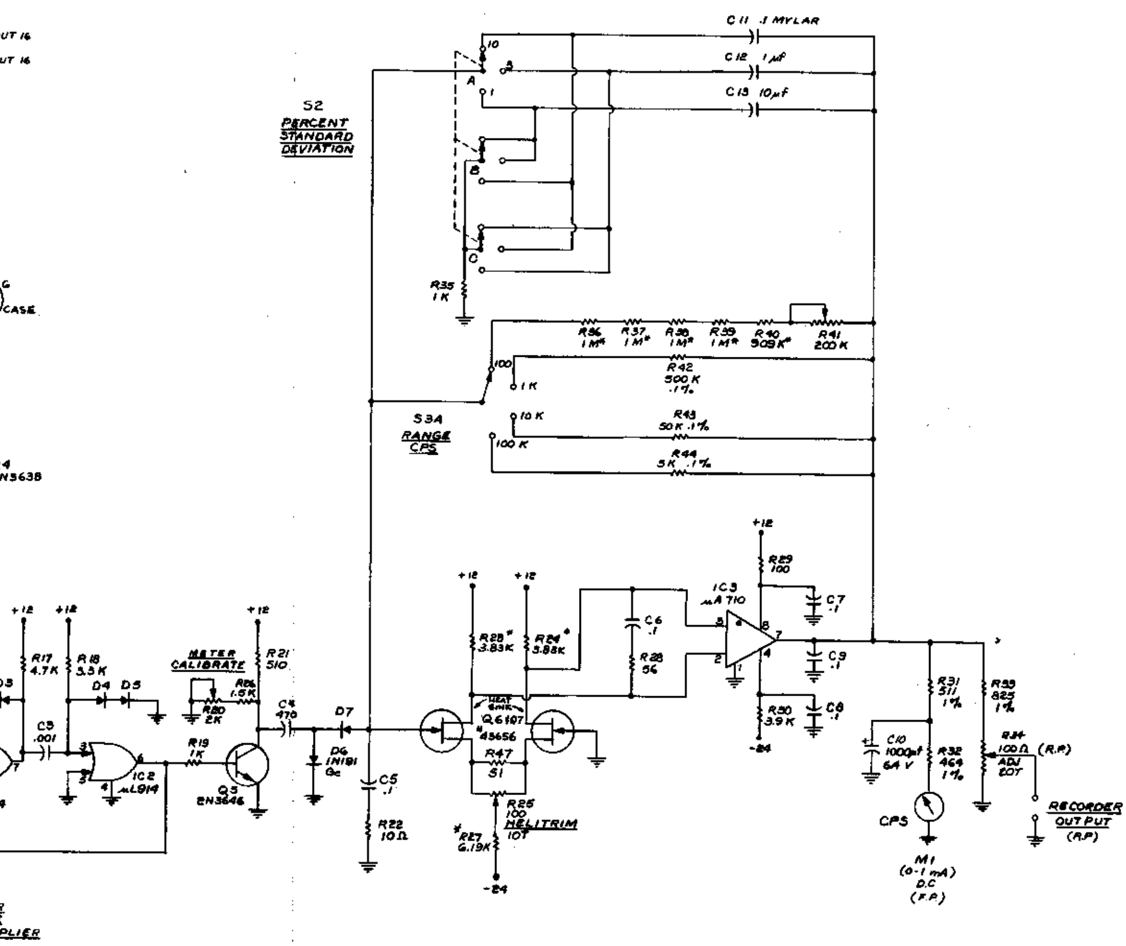
Pin	Function	Pin	Function
1	+3 volts	23	Reserved
2	- 3 volts	24	Reserved
3	Spare Bus	25	Reserved
4	Reserved Bus	26	Spare
5	Coaxial	27	Spare
6	Coaxial	*28	+24 volts
7	Coaxial	*29	- 24 volts
8	200 volts dc	30	Spare Bus
9	Spare	31	Carry No. 2
*10	+6 volts	32	Spare
*11	- 6 volts	*33	115 volts ac (Hot)
12	Reserved Bus	*34	Power Return Ground
13	Carry No. 1	35	Reset
14	Spare	36	Gate
15	Reserved	37	Spare
*16	+12 volts	38	Coaxial
*17	- 12 volts	39	Coaxial
18	Spare Bus	40	Coaxial
19	Reserved Bus	*41	115 volts ac (Neut.)
20	Spare	*42	High Quality Ground
21	Spare	G	Ground Guide Pin
22	Reserved		

**These pins are installed and wired in parallel in the ORTEC 401A Modular System Bin.*

The transistor types installed in your instrument may differ from those shown in the schematic diagram. In such cases, necessary replacements can be made with either the type shown in the diagram or the type actually used in the instrument.



FLIP-FLOP
μL923
VCC
CP
PRESET
DUAL TWO-INPUT GATE
μL914
FAN-OUT 16
FAN-OUT 16
V+
GND
OUTPUT
NON-INVERTING INPUT
INVERTING INPUT
N.C.
CONNECTED TO CASE
V-
DIFFERENTIAL COMPARATOR
μA 710 HIGH SPEED
OR
CASE
CASE
#43656
BOTTOM VIEW
S2
PERCENT STANDARD DEVIATION
S3A
RANGE CPS
R35 1K
R14 9.1K
R15 3K
R16 430
Q4 2N3638
R5 3K
R6 2K
C1 33pf
Q1 2N3646
R3 12K
R4 3.9K
R8 12K
R7 1K
R9 3K
R10 3K
Q2 2N3646
Q3 2N3640
D2
D1
R11 2.2K
R12 510
R13 430
C2 .1
IC1 μL923
IC2 μL914
D3
R17 4.7K
R18 3.3K
C3 .001
D4 D5
METER CALIBRATE
R36 1.6K
R20 2K
R19 1K
Q5 2N3646
R21 510
C4 47
D7
D6 1N191 Ge
C5 .1
R22 10Ω
Q6107
43656
R47 51
R26 100
R27 6.19K
HELITRIM
R1 12K
D8 MSD6100
R2 12K
CN1 INPUT (FP)
CN4 INPUT (RP)
S1 (FP)
METER RANGE MULTIPLIER
R45 10
C14 6.8μf 35V.
R46 10
C15 6.8μf 35V.
REAR POWER PLUG
NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL RESISTORS ARE 1/4W, 5%.
2. ALL DIODES ARE 1N4003.
3. RESISTORS MARKED * ARE 1%, 1/8W, M.F.



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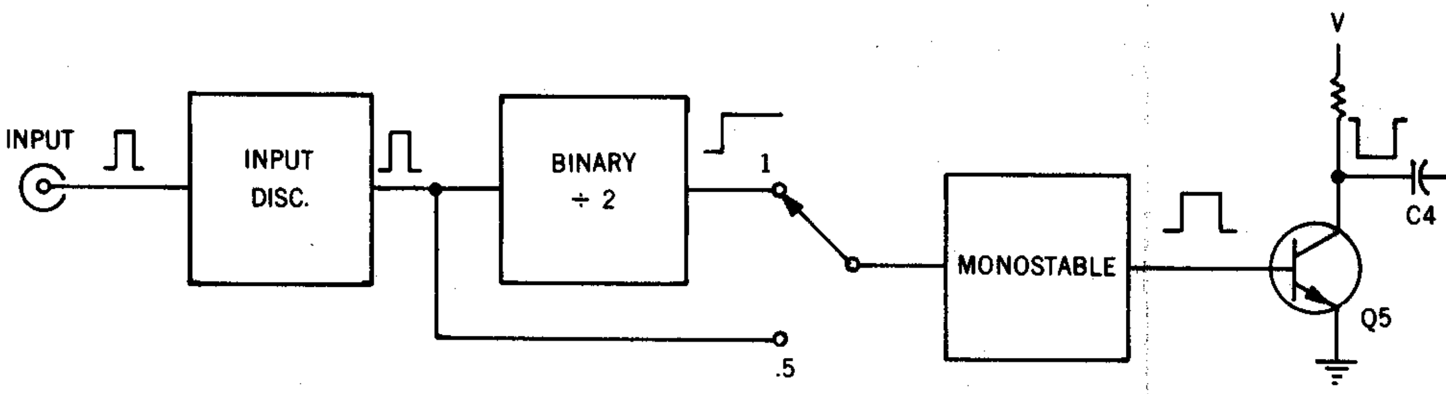
2. ALL DIODES ARE 1N4003.
3. RESISTORS MARKED * ARE 1%, 1/8 W, M.F.

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES
FRACTION ±
DECIMALS ±
ANGLES ±
SURFACE FINISH
APPLIED PRACTICES

ORTEC
OAK RIDGE TECHNICAL ENTERPRISES CORPORATION
OAK RIDGE TENNESSEE

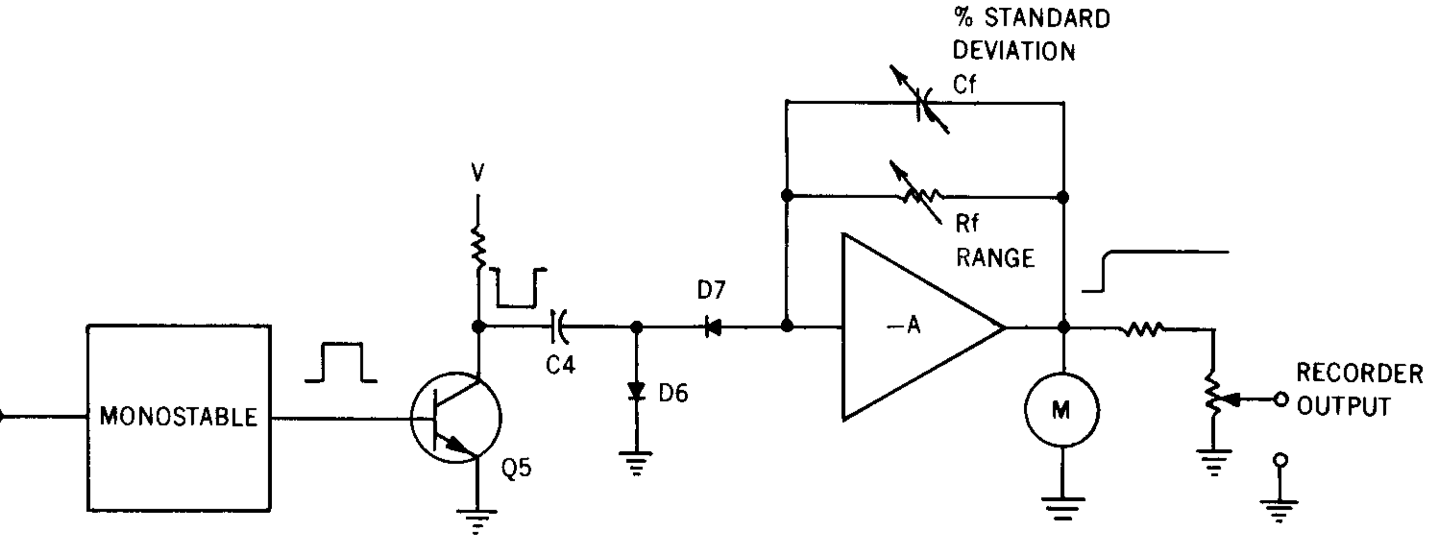
TITLE: MODEL 441 RATE METER

DRAFTSMAN: Ryder 11-10-67
CHECKED: MGN 11-13-67
B. J. MOORE
DRAWING NO. 441-0101-S1



ORTEC
200157

441 BLOCK DIAGRAM



441 BLOCK DIAGRAM