

MODEL 155 DIGITAL VOLTMETER

OPERATION MANUAL

印刷表紙使用のこと

KIKUSUI ELECTRONICS CORP.

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1 GENERAL

Kikusui Electronics Model 155 Digital Voltmeter measures

DC voltage within a range from ± 0.000 to 1000 volts at high accuracy by the use of a pulse width conversion system of integration type. It has the following features:

- * The dynamic range is wide, and measurement can be counted up to "2500" in four decimal digits without switching the range. When a voltage higher than 100% over the range preset is applied to the input, a lamp lights to indicate it.
- * Compact and lightweight, the Model 155 requires a minimum bench space. Operating procedure is very simple.
- * The measuring speed is as high as 10 samplings/sec. Polarity switching is automatic. Because of the memory circuit, indication has little flicker.
- * The measuring accuracy is as high as $\pm (0.1\% + 1 \text{ digit})$ of the indicated value. The input resistance is 10 megohms for all measuring ranges. The input terminals are floated from the case.
- * The circuitry does not involve any electromagnetic mechanical parts, but employs silicon transistors and integrated circuits to a great extent for high-reliability performance.

2 SPECIFICATIONS

| | | |
|-----------------------|--|---|
| System | Integration type pulse width conversion system | |
| Measuring Range | $\pm 0.000 - 1000$ V (maximum) | |
| Ranges | 4 ranges: $\pm 1, 10, 100$ and 1000 V | |
| Over-range | 150% (count 2500 max.) | |
| Accuracy | $\pm (0.1\% + 1 \text{ count})$ within temperature range of 15 - 35°C | |
| Maximum Sensitivity | 1 mV/digit | |
| Polarity | + and -, automatic indication | |
| Sampling Rate | 10 samplings/sec | |
| Input Resistance | 10 M Ω constant for all ranges | |
| Input Terminal | Floating with respect to the case is possible; DC 250 V max. | |
| Display Time | 0.4 sec constant | |
| Over-range Indication | Higher than count 2000 | |
| Hold | Operable by a pushbutton on the front panel | |
| Power Requirement | ----- V $\pm 10\%$, 50 or 60 Hz, approx. 14 VA | |
| Dimensions and Weight | 130 (width) x 160 (height) x 265 (depth) mm, approx. 4 kg | |
| Maximum Dimensions | 130 (width) x 180 (height) x 290 (depth) mm | |
| Accessories | Operation manual | 1 |
| | Test data | 1 |

3 OPERATING PROCEDURE

3.1 Parts on front and rear panels (Refer to Fig. 3-1)

- ① POWER Pushbutton for turning on and off line power.

When first pressed, the button is depressed and locked, and the Model 155 is energized. When re-pressed, the depressed button unlocks and comes up, then power supply is discontinued.
- ② RANGE The knob located in the center on the front panel.

Rotated clockwise to select one of the \pm 1, 10, 100 and 1000 V ranges.
- ③ VOLTS,
H and L Input terminals for applying the voltage to be measured. The high-impedance side of the voltage should be connected to the "H" terminal (red); the low-impedance side, to the "L" terminal (white).
- ④ HOLD Pushbutton used to hold the indicated value regardless of the input voltage. The indication is held when the button is depressed and locked. When the button is re-pressed, the normal measuring condition resumes.
- ⑤ OVER Over-range lamp. Lights when the indication exceeds count 2000 for the range preset.
- ⑥ + and - Automatically indicate the polarity of the voltage measured.
- ⑦ Indicator Indicator tubes are used for 4-digit decimal indication. Decimal points are built in.
- ⑧ Stand When setting the Model 155 on a bench, pull the

stand forward, if needed, for easy reading of the indication.

- ⑨ Cord hook When storing the Model 155, wind the power cord around the cord hooks.
- ⑩ Fuse holder A 0.3-ampere slow-blow fuse is contained.
- ⑪ Case fixing screw Screw that fixes the case. When the four screws are removed, the case can be detached.

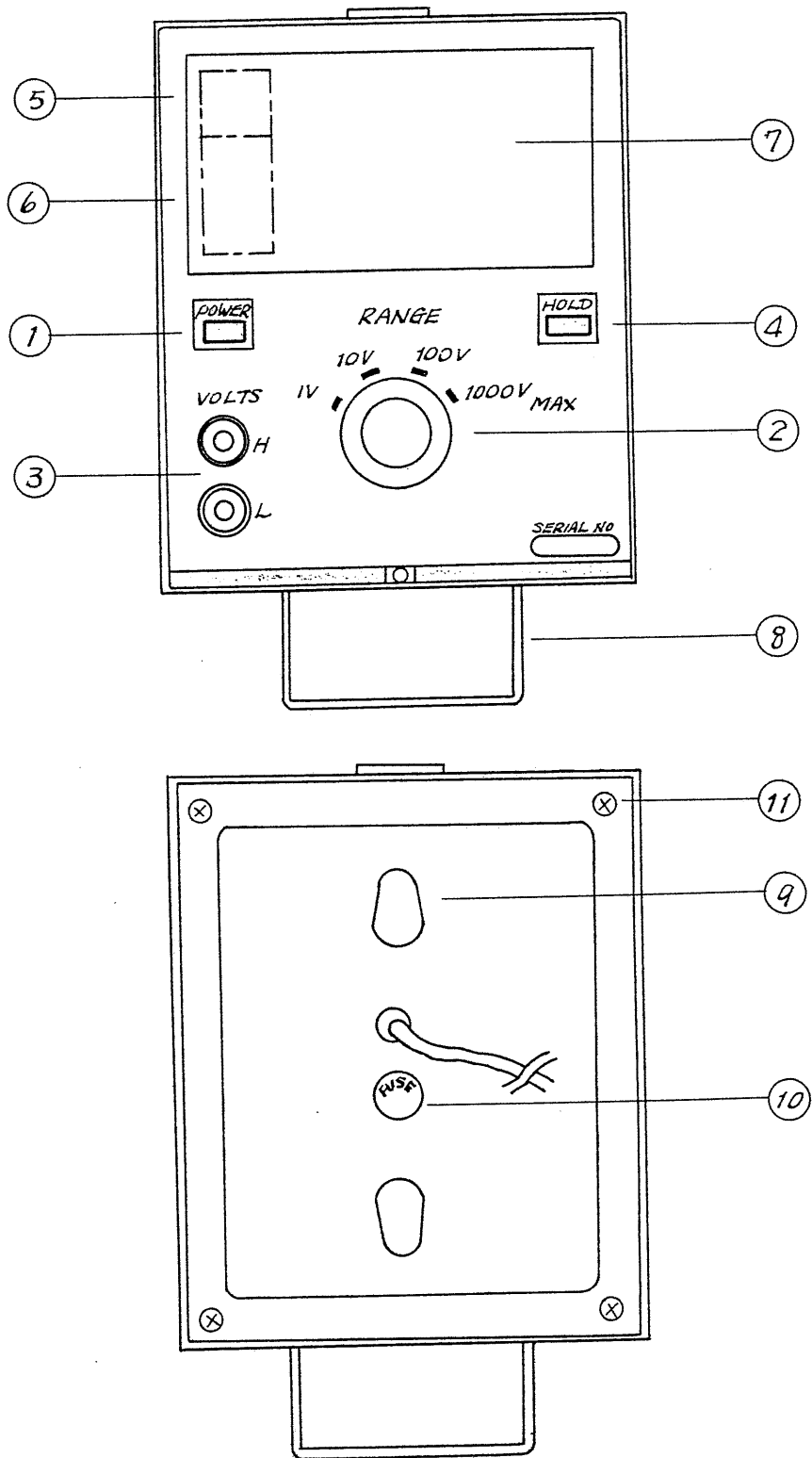


Fig. 3-1

3.2 Preparation

- (1) Connect the power cord to an outlet of _____ V, 50 or 60 Hz commercial power source.
- (2) Turn on the power switch. The indication varies for about several decades minutes after the power switch is turned on. This is the transient phenomenon caused by the power turned on. It is not a faulty condition of the Model 155.
- (3) Performance of the Model 155 becomes stable in about five minutes after the power switch is turned on.
- (4) Set the HOLD button to the unlocked condition. Otherwise, measurement cannot be conducted.
- (5) Connect the high-impedance side of the voltage source to be measured to the VOLTS H terminal (red) and the low-impedance side to the VOLTS L terminal (white). When long wire leads are needed for this connection, it is desirable to use well-insulated shielded wires.

3.3 Operation

- (1) When the approximate value of the voltage to be measured is known beforehand, select the range referring to Table 3-1. When unknown, first set the 1000 V range, then change it to lower voltage ranges until the indicated count becomes below "2500".

The Model 155 is kept from damage by a built-in protective circuit even if 1000 V max. is accidentally applied to the equipment while the range is set to the 1 V range. However, avoid applying an overvoltage as much as possible.

| Range | Voltage to be measured (V) |
|--------|----------------------------|
| 1 V | 0.000 - 2.500 |
| 10 V | 2.50 - 25.00 |
| 100 V | 25.0 - 250.0 |
| 1000 V | 250 - 1000. |

Table 3-1

- (2) When desiring to hold the indication of the voltage measured, press the HOLD button (until it is locked depressed). To hold the indication correctly, press the HOLD button approximately one second after the voltage is applied to the input terminals, considering the response time of the Model 155.

4 OPERATION PRINCIPLE

4.1 Outline

The Model 155 Digital Voltmeter converts input voltage into current, integrates it together with the reference power source, converts it into a pulse width proportional to the input voltage, and counts the pulse width by a counter. This integration type pulse conversion system is good at elimination of the noise component superimposed on the input voltage, resulting the stable measurement.

Fig. 4-1 shows the block diagram of the Model 155.

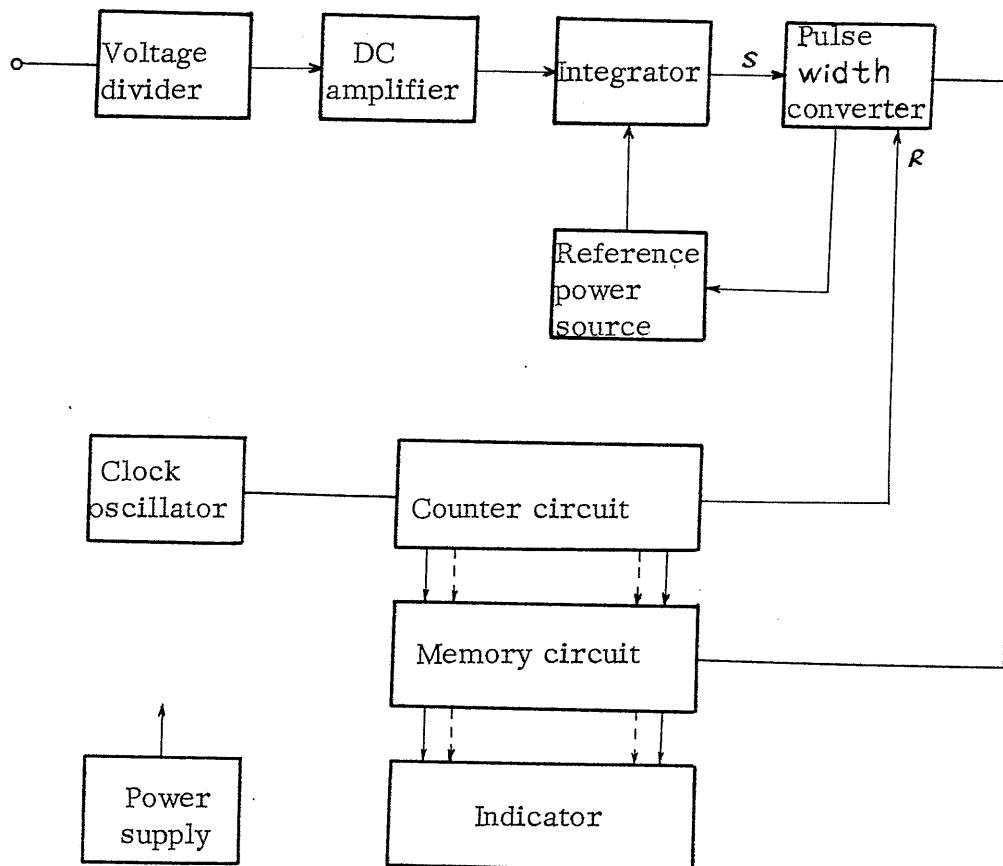


Fig. 4-1

The voltage applied to the input terminals is divided according to the range preset, fed into the DC amplifier of high input impedance, and converted into a current source having a high output impedance. This current source which is proportional to the input signal, and the reference power source are integrated. A pulse width accurately proportional to the input is then generated by a pulse converter. The ratio of the pulse width to the reference pulse width is obtained and sent to the indicator through the memory circuit for four-digit decimal indication.

4.2 Voltage divider

The voltage divider has an input resistance of $10\text{ M}\Omega$ constant. Its output resistance is made approximately equal for all the four ranges of 1, 10, 100 and 1000 V. The output of the voltage divider is designed to be 2.5 V when the count on the digital voltmeter is "2500".

The voltage division ratios are set to 1/10, 1/100 and 1/1000 by adjusting R_8 , R_9 and R_{10} on the voltage divider printed-circuit board (A2).

4.3 DC amplifier

This amplifier consists of a modulation-type amplifier and a DC amplifier. The modulation-type amplifier uses an MOS FET chopper and a source follower in the first amplification stage for obtaining a high input impedance and excellent stability.

Chopper Q_1 of the modulation-type amplifier has its gate excited with 200-Hz square wave for switching. The DC voltage is converted into AC there, and impedance conversion is effected by source follower Q_2 .

The output is then amplified in three stages.

Transistor Q_6 is the synchronous rectifier which converts the AC into

the DC corresponding to the polarity of input.

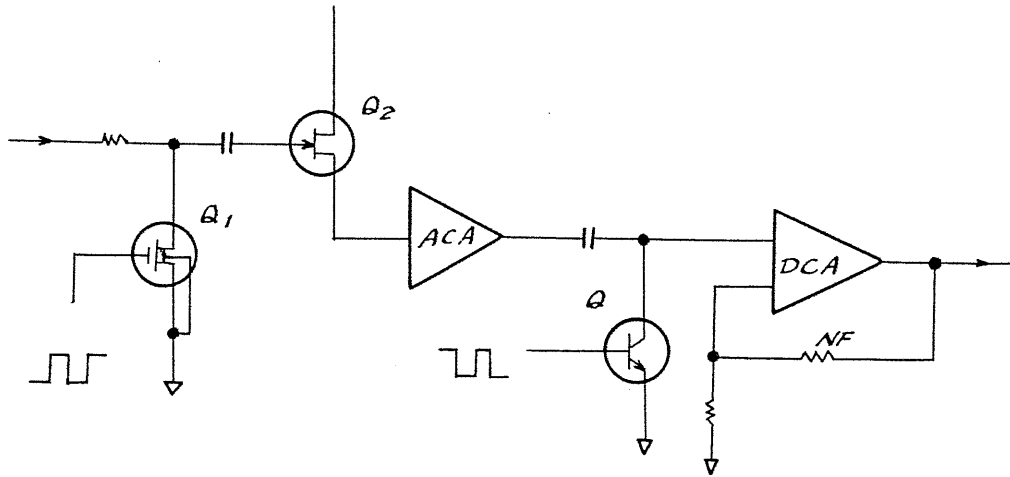


Fig. 4-2

DC amplifier DCA is a differential amplifier using Q_7 and Q_8 .

The voltage gain is stabilized by applying negative feedback from the output of Q_{10} .

The circuitry is composed as shown in Fig. 4-3 to take out the above-mentioned DC amplifier output as a constant current source. A (1) represents the entire amplifier shown in Fig. 4-2; A (2), the amplifier using Q_{16} .

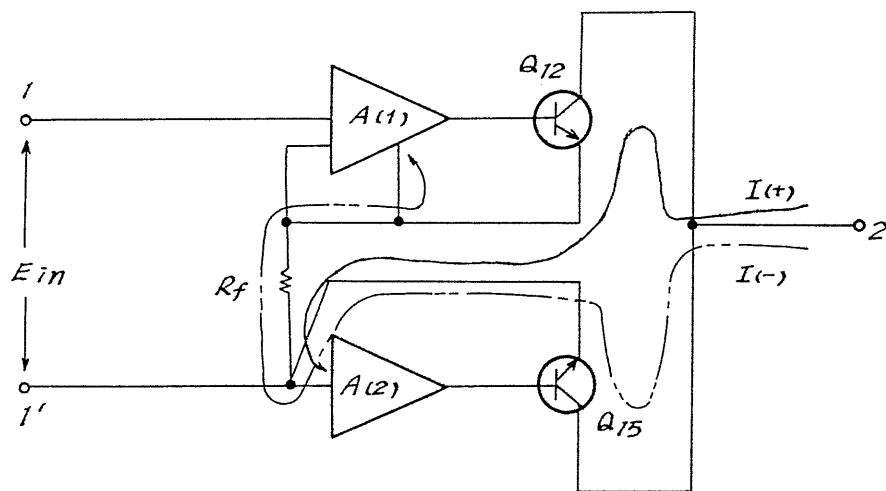


Fig. 4-3

When E_{in} is applied to input terminals 1 and 1', with the positive to terminal 1 and the negative to terminal 1', the emitter of Q_{12} will be about the same in potential as terminal 1. To R_f current $I (+)$ flows from output terminal 2 through Q_{12} as indicated with a solid line. The amount of this current is made accurately proportional to the amount of E_{in} by current feedback. A (2) is in the saturated condition then, cutting off the collector current of Q_{15} .

When E_{in} is opposite in polarity to the above, A (2) assumes the working condition. Then Q_{15} becomes conductive, current $I (-)$ flows as indicated with a broken line, and Q_{12} is cut off. This makes a current proportional to the absolute value of E_{in} flow from terminal 2.

4.4 Integration and pulse width conversion

The pulse width converter uses reference power source I_R , level detector A (3) and phase compensation type flip-flop FF as shown in Fig. 4-4.

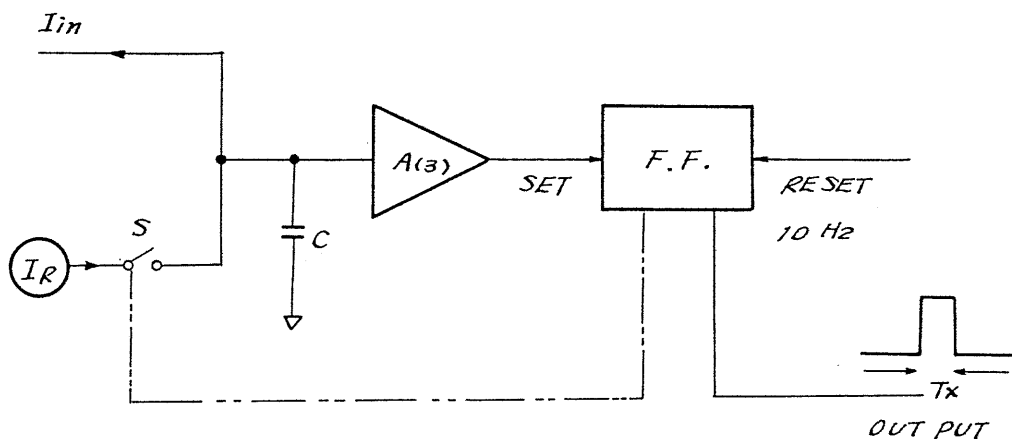


Fig. 4-4

As mentioned in Item 4.3 above, I_{in} represents the current source accurately proportional to the input voltage. The 80 kHz pulse from the clock oscillator is frequency-divided by a counter and the reset pulse thus produced is always applied to the FF at a cycle of 0.1 sec. When this FF is in the reset condition, switch S of reference power source I_S closes; when in the set condition, the switch opens.

When the FF is in the reset condition, switch S closes, difference current I between I_{in} and I_R flows in integrating capacitor C, and the potential of C rises within a range of $I_{in} < I_R$. When this potential reaches the value preset, the FF is set through the operation of the level detector. When the FF is set, S is released, only I_{in} is integrated until the FF becomes the succeeding reset condition, and the potential of C decreases to the original value. The above operation repeats 10 times within one second, and the output having a pulse duration proportional to the amount of I_{in} is obtained from the FF. If the FF takes a period of T_x to change from reset to set and a period of T from set to reset,

$$\frac{I_R - I_{in}}{I_{in}} = \frac{T - T_x}{T_x} \quad (1)$$

From equation (1),

$$\frac{I_{in}}{I_R} = \frac{T_x}{T} \quad (2)$$

Therefore, the pulse width T_x to be converted will be

$$T_x = I_{in} \cdot \frac{T}{I_R} \quad (3)$$

Equation (3) verifies that pulse width T_x is converted in proportion to I_{in} .

The counter indicates "0" for all digits when the FF is reset. It counts 80 kHz pulses, overflows with 8000 pulses, and returns to "0000".

The counter repeats this operation. When the FF generates a set pulse during the counting operation, the value on the counter is instantaneously transferred to the memory for four-digit decimal indication. The time chart of the above operation is shown in Fig. 4-5.

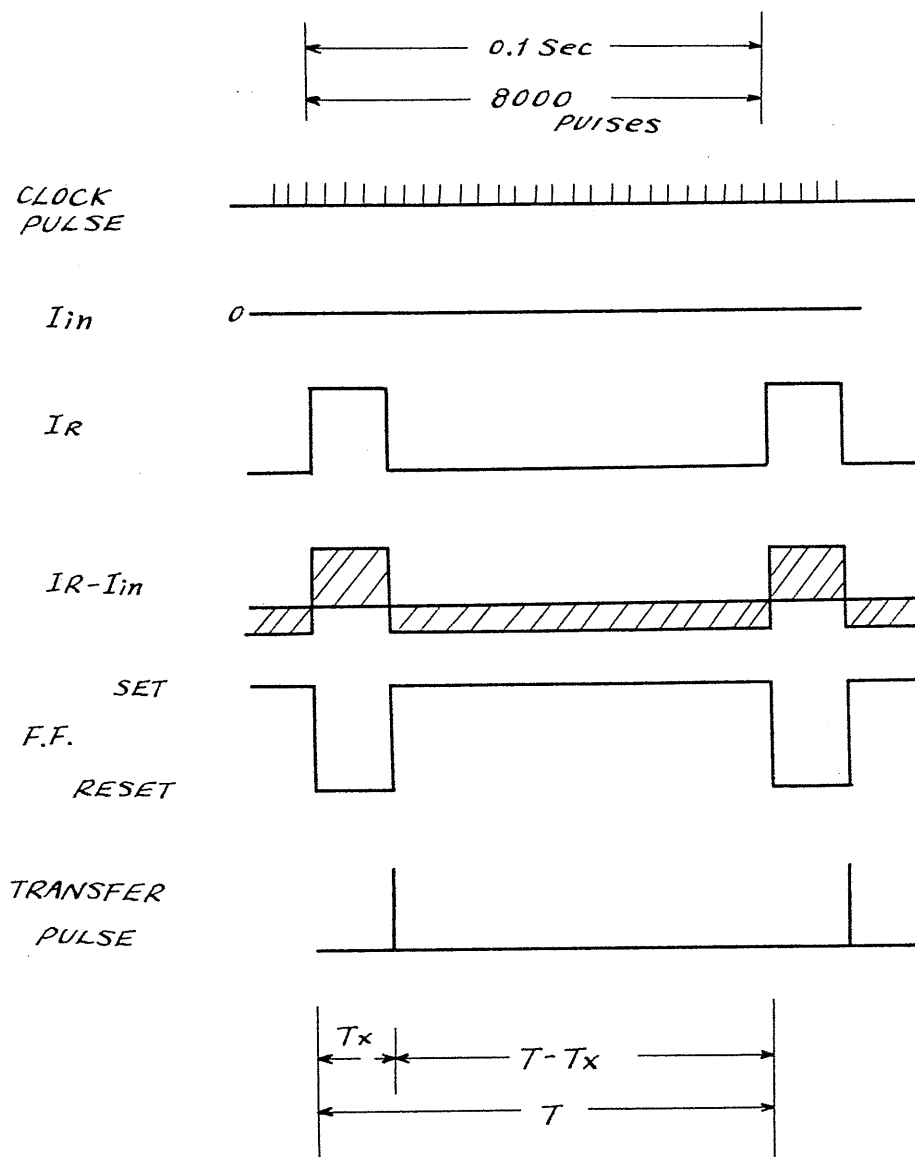


Fig. 4-5

4.5 Counter and its peripheral circuits

Composition of the counter and its peripheral components is shown in Figs. 4-6 and 4-7.

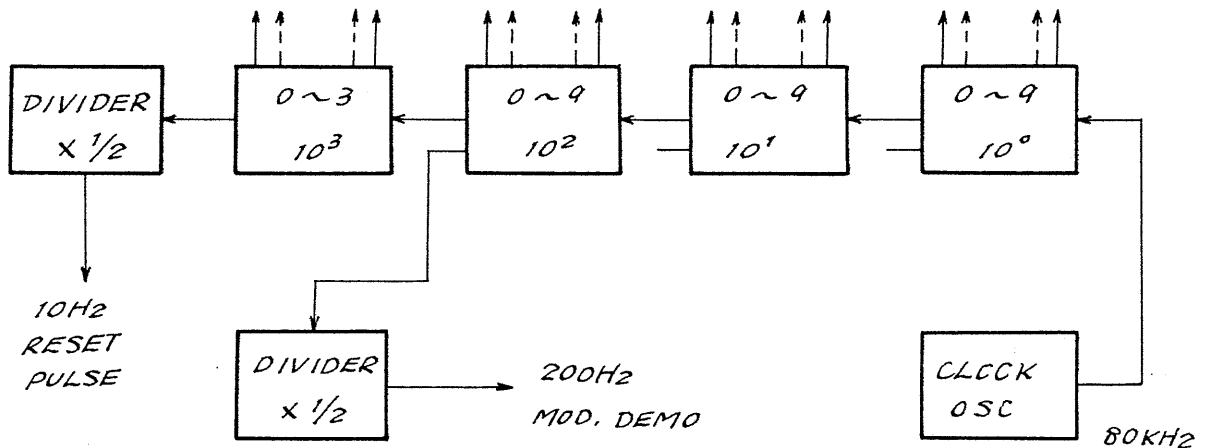


Fig. 4-6

The clock oscillator in Fig. 4-6 is an astable multivibrator which generates 80 kHz as the counting signal. The counter uses identical circuits for the decimal digits from units digit to hundreds digit. For the thousands digit, count is from 0 to 3. The 10 Hz FF reset pulse is obtained from the frequency of the thousands digit counter output. The 200 Hz chopper and synchronous rectifier driving signals are obtained by halving the 400 Hz of the hundreds digit. The counter for each digit is connected to a transfer gate, memory circuit, diode matrix and indicator circuit as shown in Fig. 4-7. If a transfer pulse is applied to the gate when the counter reaches a certain value during measurement, the count at that moment is stored in the memory circuit. Since this count is expressed by the binary 8-4-2-1 code, it is converted into a decimal value by the matrix circuit, and lights the indicator tubes by transistor switches.

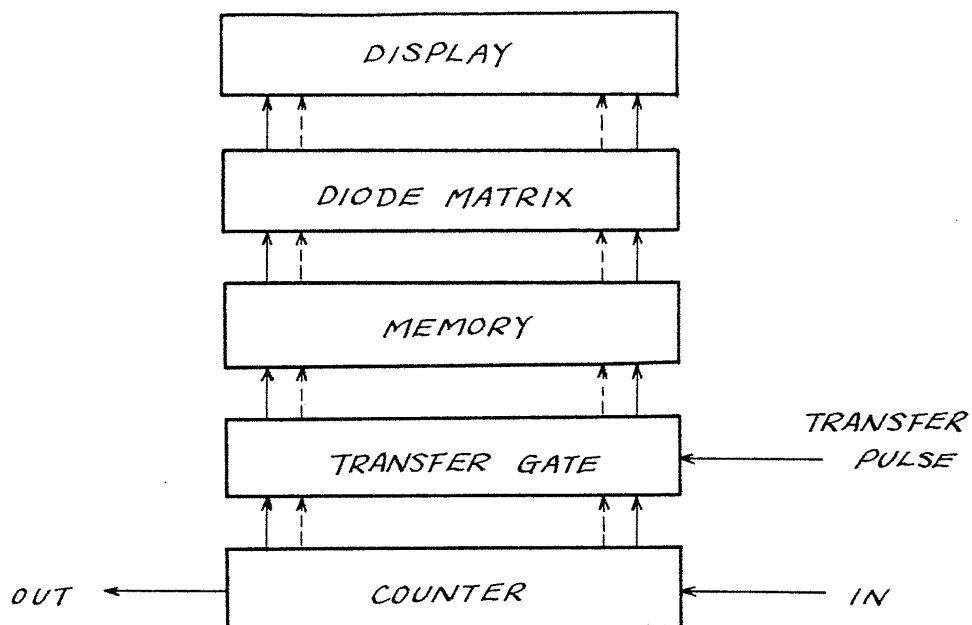


Fig. 4-7

The 8-4-2-1 code counter has four FF stages connected in cascade, as shown in Fig. 4-8, to compose a decimal counter through feedback from FF (D) to terminal J of FF (B). Table 4.1 shows the output of each FF.

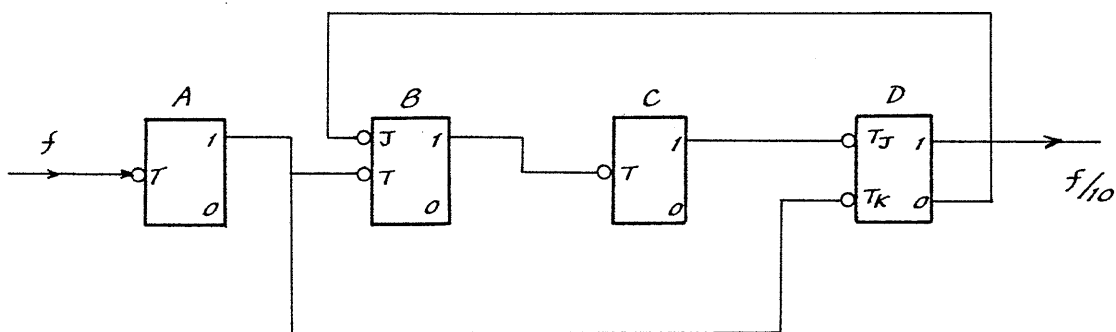


Fig. 4-8

| Decimal Number | FF | A | B | C | D |
|----------------|----|---|---|---|---|
| | | 1 | 2 | 4 | 8 |
| 0 | | 0 | 0 | 0 | 0 |
| 1 | | 1 | 0 | 0 | 0 |
| 2 | | 0 | 1 | 0 | 0 |
| 3 | | 1 | 1 | 0 | 0 |
| 4 | | 0 | 0 | 1 | 0 |
| 5 | | 1 | 0 | 1 | 0 |
| 6 | | 0 | 1 | 1 | 0 |
| 7 | | 1 | 1 | 1 | 0 |
| 8 | | 0 | 0 | 0 | 1 |
| 9 | | 1 | 0 | 0 | 1 |

Table 4-1

4.6 Power supply

The power sources used in the Model 155 are for +200 V (not regulated), and regulated voltages of +25 V, +5.5 V and -10 V. The circuitry is composed as in Fig. 4-9.

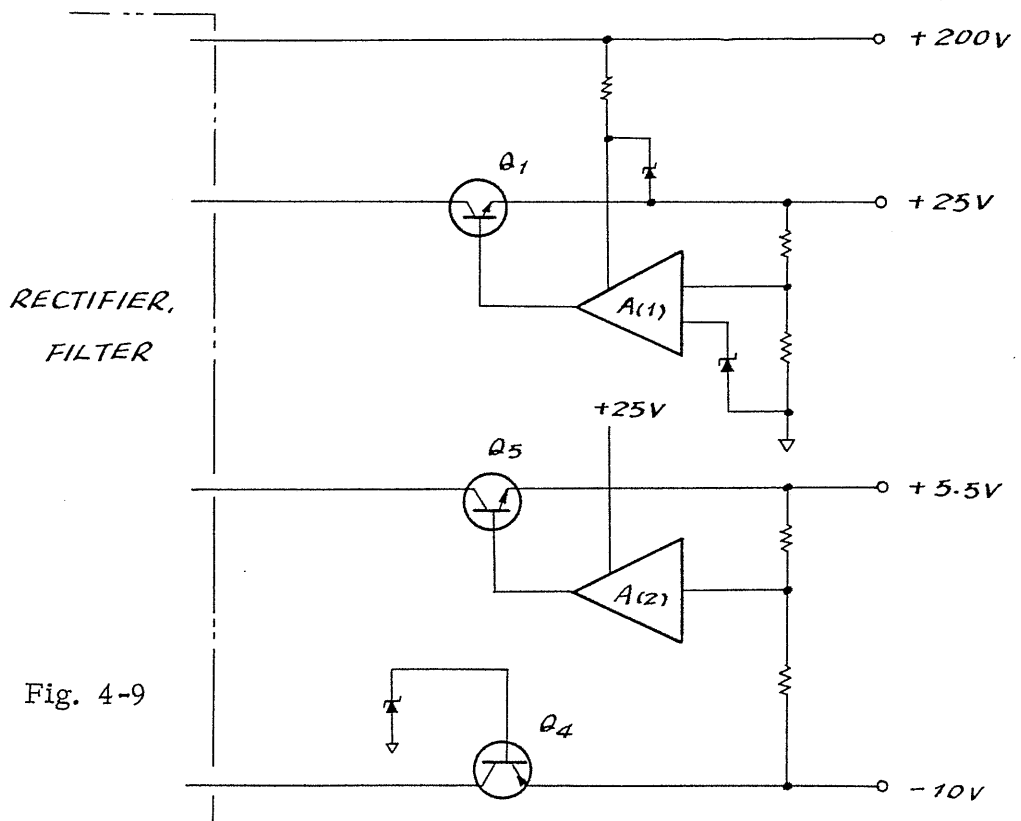


Fig. 4-9

Each of the +200 and -10 V power supply circuits is working independently, while the +25 and +5.5V circuits are related to the operation of the other power supply circuits. The bias voltage of the error amplifier A (1) for the +25 V power supply is supplied from the +200 V circuit. The +25 V power supply receives the reference voltage from the -10 V circuit, and the bias of the amplifier from the +25 V circuit.

5 MAINTENANCE

5.1 Removal of instrument case

Turn off the power switch, confirm safety, and remove the truss head screws in the four corners on the rear of the case. Gently pull the case from the front panel side.

5.2 Parts location

Main component parts of the Model 155 are located as shown in Fig. 5-1.

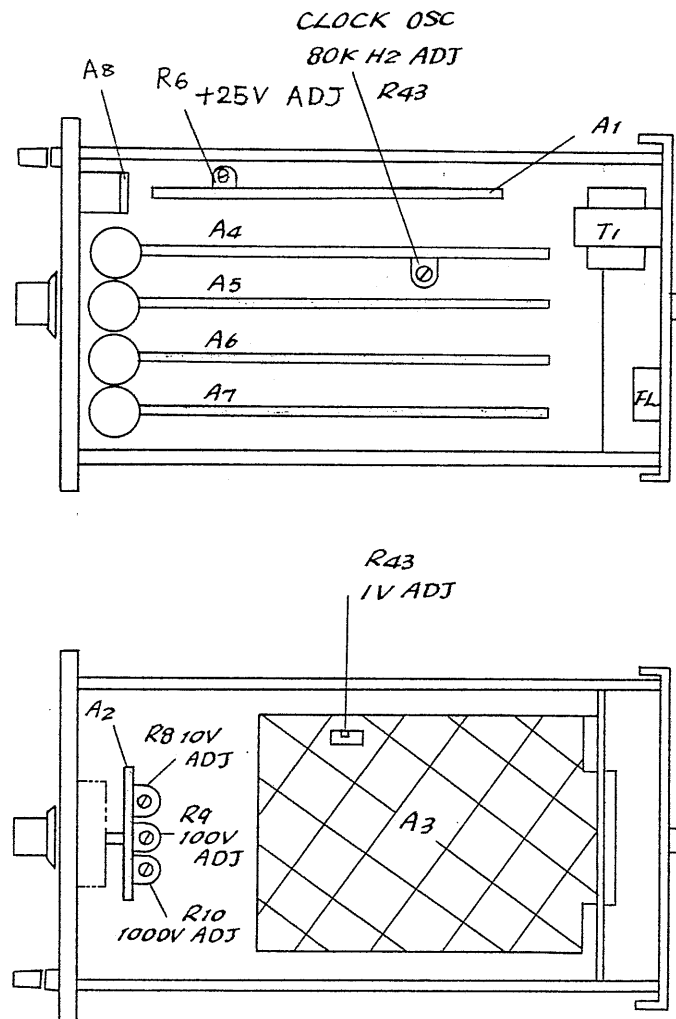


Fig. 5-1

The Model 155 uses a total of eight printed-circuit boards A1 through A8. Printed-circuit boards A5, A6 and A7 are of the same type. The eight boards are used as follows:

| | |
|----|---|
| A1 | +200, +25, +5.5 and -10 V power supplies |
| A2 | Voltage divider |
| A3 | DC amplifier and integrated pulse width converter |
| A4 | Counter and indicator, thousands digit (0 to 3) |
| A5 | " " hundreds digit (0 to 9) |
| A6 | " " tens digit (0 to 9) |
| A7 | " " units digit (0 to 9) |
| A8 | Polarity and over-range indicators |

5.3 Adjustment

Frequency adjustment of clock oscillator:

Connect an electronic counter to connector pin No. 20 of printed-circuit board A4, and adjust R_{43} so that the frequency may be within a range of $80 \text{ kHz} \pm 0.1 \%$. Even if this frequency is slightly inaccurate, it does not adversely affect the performance of the Model 155. However, it deteriorates rejection against commercial power line frequency.

Adjustment of +25 V power supply:

Connect a DC voltmeter across connector pin No. 6 and ground terminal pin No. 7 of printed-circuit board A1. Adjust R_6 so that the voltage may be within a range of $+25 \text{ V} \pm 1 \%$. Be sure to conduct this adjustment before calibrating the Model 155.

5.4 Calibration

To maintain the measuring accuracy of the Model 155, periodical check

and calibration are recommended.

From the viewpoint of calibration accuracy, conduct calibration at about 25°C and at a place where the ambient temperature varies little.

Fig. 5-2 shows an example connection for calibration. The DC voltage standard should have an accuracy of 0.02 % or better.

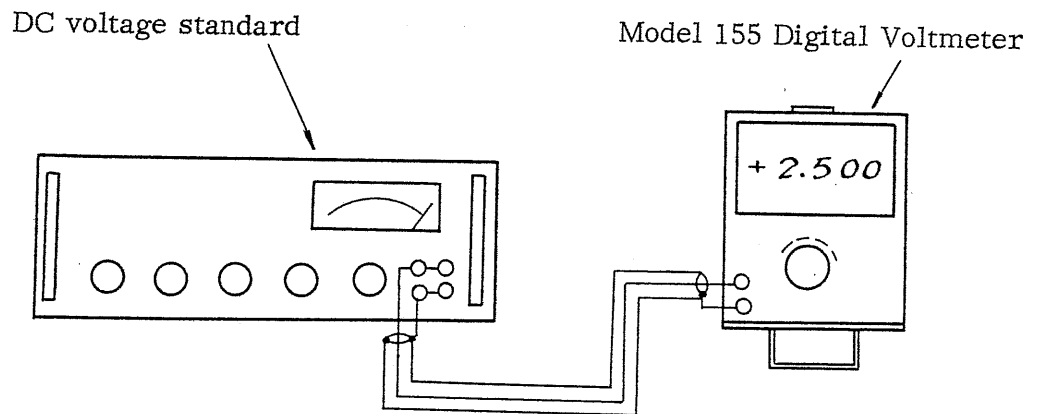


Fig. 5-2

Calibration procedure follows:

1. Turn on the power switch of the Model 155 and leave it for more than one hour for warmup.
2. Check the voltages of power supply circuits and other components (referring to Item 5.5) to confirm their normal operation.
3. Connect the output terminals of the DC voltage standard to the input terminals of the Model 155.
4. Set the output of the voltage standard to +2.500 V, and the range of the Model 155 to "1 V".
5. Adjust R_{43} of printed-circuit board A3 to set the indication to "+2.500".
6. Set the range of the Model 155 to "10 V". Adjust R_8 of printed-circuit board A2 to set the indication to "+25.00".

7. Set the range to "100 V", and adjust R₉ for indication of "+250.0".
8. Set the range to "1000 V", and adjust R₁₀ for indication of "+1000".
9. Set the range to "1 V" again, apply -2.500 V, and confirm that indication is within an error range of 0.1 % ± 1 digit.

5.5 Check and repair

Conduct check and repair referring to Item 4 "OPERATION PRINCIPLE".

The voltages noted below are measured with respect to the ground of power supply unless specified otherwise. For voltage measurement, set the range to "1 V", short-circuit the input, and keep the HOLD button in the unlocked condition.

Power supply (printed-circuit board A1):

| Test Point | DC Voltage | Ripple |
|-------------------|------------|-----------|
| 1 | + 39 V | 1.8 V pp |
| 2 | - 23 V | 0.37 V pp |
| 3 | + 9.5 V | 1 V pp |
| <hr/> | | |
| Connector Pin No. | | |
| 2 | + 192 V | 15 V pp |
| 6 | + 25.0 V | 4 mV pp |
| 9 | - 11 V | 4 mV pp |
| 14 | + 5.5 V | 10 mV pp |

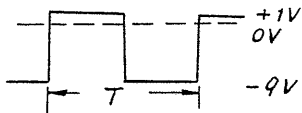
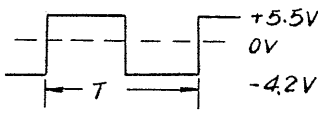
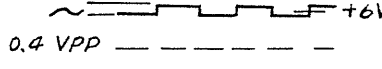
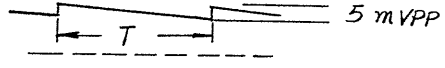
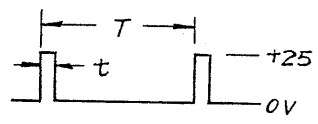
NOTE: The above voltages are measured by using the following instruments:

Oscilloscope, DC - 15 MHz, with low-capacitance probe (10 MΩ, 7 pF)

Voltmeter, DC voltage, 11 MΩ in input resistance

DC amplifier and integrated pulse duration converter (printed-circuit board A3):

Test Point

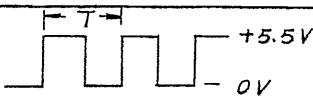
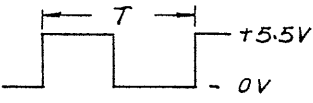
| | | |
|---|--|---|
| 1 |  | $T = 5 \text{ ms}$ |
| 2 |  | $T = 5 \text{ ms}$ |
| 3 |  | |
| 4 |  | $T = 100 \text{ ms}$ |
| 5 | +12.5 V | |
| 6 |  | $T = 100 \text{ ms}$ $t = 8 \mu\text{s}$ |

Connector Pin No.



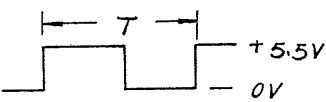
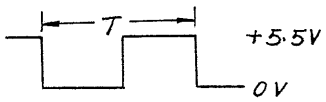
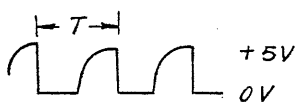
| | | | | |
|----|-----------------------------|---------|-----------------------------|--|
| 1. | 14 | 0 V | | |
| | 4 | +5.5 V | | |
| | 5 | -11 V | | |
| 7 | At +10 mV input (1 V range) | +21 V | At -10 mV input (1 V range) | +0.03 V |
| 8 | " | +0.06 V | " | +11.7 V |
| 10 | | | | $T = 0.4 \text{ sec}$ $t = 1 \mu\text{s}$ |
| 6. | 13 | +25.0 V | | |

Counter (thousands digit) and clock oscillator (printed-circuit board A4):

Test Point

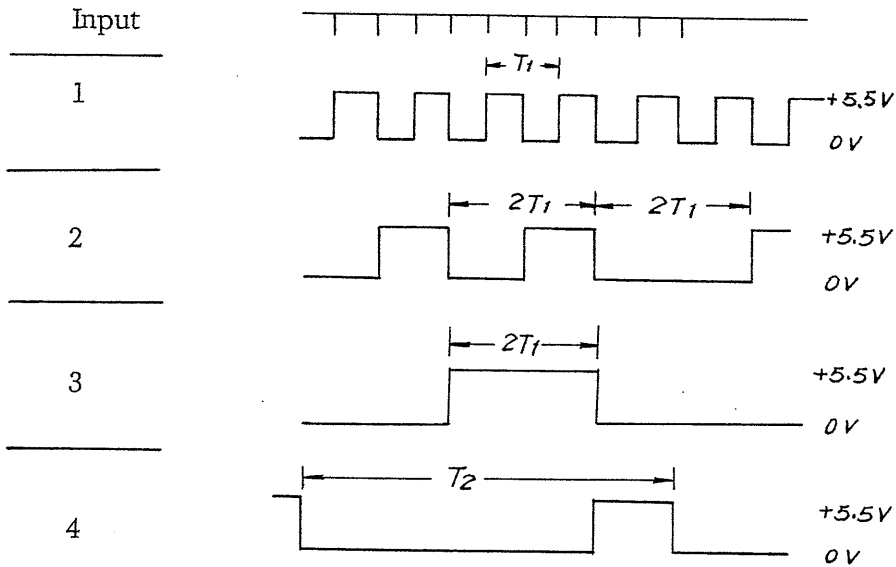
| | | |
|---|---|-----------|
| 1 |  | T = 25 ms |
| 2 |  | T = 50 ms |

Connector Pin No.

| | | |
|-------|---|-------------|
| 4 | +102V | |
| 5 |  | T = 12.5 ms |
| 6. 22 | 0 V (GND) | |
| 8 | +6 V | |
| 9 |  | T = 25 ms |
| 10 |  | T = 5 ms |
| 11 |  | T = 5 ms |
| 20 |  | T = 12.5 μs |

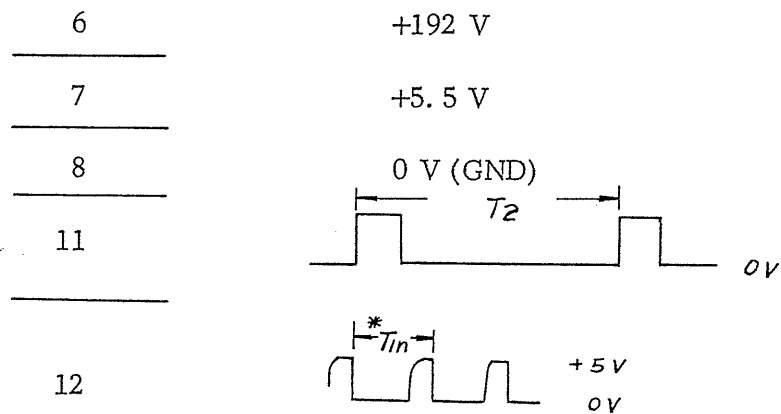
Counters (hundreds, tens and units digits) (printed-circuit boards A5, A6 and A7):

Test Point



| Digit | T_1 | T_2 | * T_{in} |
|--------|-------------|-------------|--------------|
| 10^0 | 25 μ s | 125 μ s | 12.5 μ s |
| 10^1 | 250 μ s | 1.25 ms | 125 μ s |
| 10^2 | 2.5 ms | 12.5 ms | 1.25 ms |

Connector Pin No.



NOTE: The above-illustrated waveforms are model waveforms with the rise time disregarded.