MODEL 156L
DIGITAL VOLT OHMMETER

OPERATION MANUAL

KIKUSUI ELECTRONICS CORP.

CONTENTS

1. GENERAL DESCRIPTION

Kikusui Electronics Model 156L Digital Voltmeter measures DC voltage within a range from ±0.000 to 1000 volts and from 000.0Ω to 3.000MΩ resistance 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 "3000" in four decimal digits without switching the range. When a voltage higher than "3000" preset is applied to the input, a lamp lights to indicate it.
* Compact and lightweight, the Model 156L 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 ±(0.1% + 1 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
DC voltage Measurement	
Measureing Range	±0.000 V ~ 1000 V (maximum)
Ranges	5 ranges: ± 3,30, 300, 1000 V
Accuracy	Indication ± (0.1% + 1 digit) at 15° ~ 35°C Indication ± (0.15% + 2 digit) at 0° ~ 15°C 35° ~ 40 C
Maximum sensitivity	1 mV/digit
Polarity	Positive and negative ; automatic indication
Input Resistance	10 MΩ constant for all ranges
Resistance Measurement	
Measuring Range	000.0Ω ~ 3.000 MΩ
Ranges	5 ranges: 300Ω, 3 kΩ, 30 kΩ, 300 kΩ, 3 MΩ
Accuracy	Indication all ranges; ±(0.2% + 1 digit) at 15 C ~ 35 C Indication all ranges: ±(0.3% + 2 digit) at 0° ~ 15°C , 35° ~ 40°C 75% or less humidity

Measuring Current	300 Ω range ;	10 mA
	3 kΩ range ;	1 mA
	30 kΩ range ;	100 μA
	300 kΩ range ;	10 μA
	3 MΩ range ;	1 μA
Sampling Rate	10 samplings/sec	
Indication Time	0.4 sec	
Over-range	Count 10%	
Over range indication	More than 3000	
Input Terminal	Floatable with respect to case ; DC 250 V maximum	
Hold	Operable by switch on front panel	
Power Supply	--------V, ± 10%, 50 or 60 Hz, approx.20VA	
Dimensions	130 (W) x 160 (H) x 265 (D) mm	
(Maximum)	130 (W) x 180 (H) x 290 (D) mm	
Weight	Approx. 4 kg	
Accessories	Operation Manual	1

3. OPERATING PROCEDURE

3.1 Front panel and Rear panel descriptions

1 POWER

A push-button switch for turning on and off line power. When first pressed, th this switch is so locked as to turn on power. Power supply is turned off when i. is it is pressed again.

2 RANGE

A knob located in the center of the front panel. Its clockwise rotation selects each of ±3 V, 30 V, 300 V, and 1000 V r[illegible]s ranges in this order, and further each of 3[illegible] 300 Ω, 3 kΩ, 30 kΩ, 300 kΩ, and 3 MΩ ranges.

3 VOLTS: H and L

Input terminals for applying voltage to be measured. Connect the high- impedance side of the input cvoltage with the H terminal (red), and the low-impedance side with the L terminal (white).

4 OHMS: H and L

Terminals for connecting resistance to be measured. In the case where a re[illegible] resistance element to be measured is set in a circuit, connect the high-impedance side of the circuit with the H terminal (red), and the low-impedance side with the L terminal (white).

5 HOLD

A push-button for holding the indication of measured value regardless of the input voltage. The indication is held when the button is pressed and locked. Pressing it again allows the Model 156L to resume the measuring condition.

6 OVER

An over-range lamp. " OVER " is sidplayed when the indication becomes more than 3000 in the preset range.

7 +, -
Ω , kΩ

This indicates the polarity of voltage to be measured and also the unit of an ohmmeter. A corresponding unit is shown in accordance with range selection.

8 Digit indicator

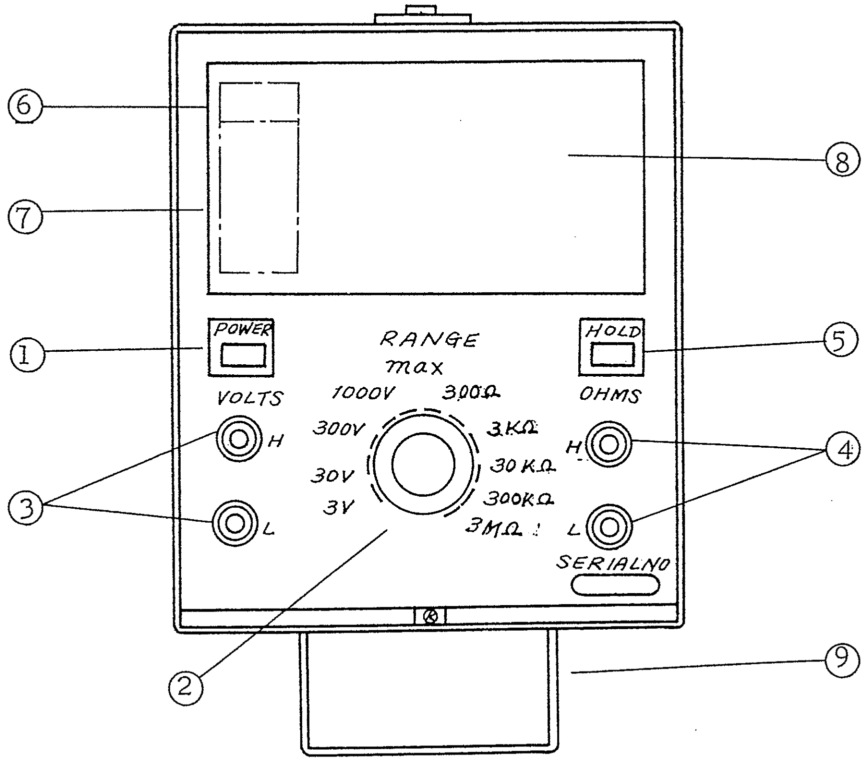
This indicator comprises discharge display tubes functioning in a decimal mode of 4 digits with built-in decimal points. A corresponding decimal point lights in accordance with range selection.

9 Inclining stand

When the Model 156L is set on a bench, use it with this stand pulled forwards if so required.

10	Cord hook	When storing the Model 156L, wind the power cord around the cord hook.
11	Fuse holder	A 0.5-ampere slow-blow fuse is contained.
12	Case fixing screws	Screws for fixing the case to the inner chassis chassis. Remove these screws when opening the case.

Front Panel



Rear Panel

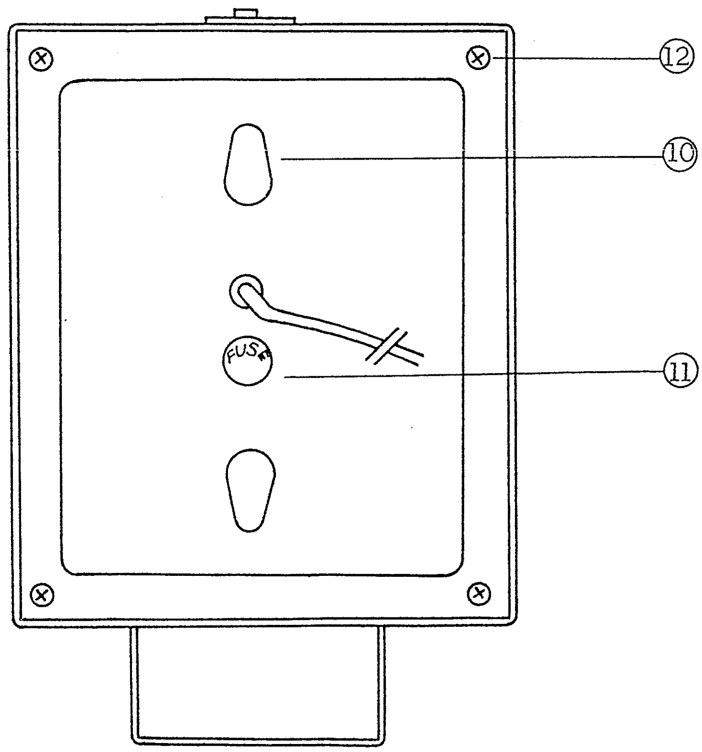


Fig. 3-1

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 156L.

(3) Performance of the Model 156L 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 "3000". The Model 156L 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)		
3 V	0.000	~	3.000
30 V	3.00	~	30.00
300 V	30.0	~	300.0
1 000 V	300.	~	1000.

Table 3-1

Measurement of resistance

1) Connect the high-impedance side of a resistance to be measured with the input terminal OHMS H (red) on the right of the front panel, and the low-impedance side with the terminal L (white). In case of a low resistance range, be careful particularly of the length of a lead wire. In case of a high resistance range, use a well-insulated lead wire.

2) When the approximate value of the resistance to be measured is known beforehand, select a range referring to Table 3-2. When it is totally unknown, first set the knob to the 3 MΩ range, and switch it sequentially to the lower ohmic ranges until the indication becomes below 3000.

Range	Resistance to be measured (kΩ, MΩ)		
300 Ω	000.0 Ω	~	300.0 Ω
3kΩ	0.300kΩ	~	3.000kΩ
30kΩ	3.00kΩ	~	30.00kΩ
300kΩ	30.0kΩ	~	300.0kΩ
1 MΩ	300. kΩ	~	3000. kΩ

Table 3-2

To hold measurement

For holding the result of measurement, press the HOLD push-button so as to lock it. In order to hold the measured value accurately, be sure to perform the holding operation after the indication becomes stable at a certain value, considering the response time of the Model 156L.

4. PRINCIPLE OF OPERATION

4.1 Outline

The Model 156L Digital Voltmeter converts input voltage into current, integrates it together with the reference power source, converts it into a a pulse width proportional to the input voltage, and counts the pulse width by a counter. This integration type pulse conversion system is good a 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 156L.

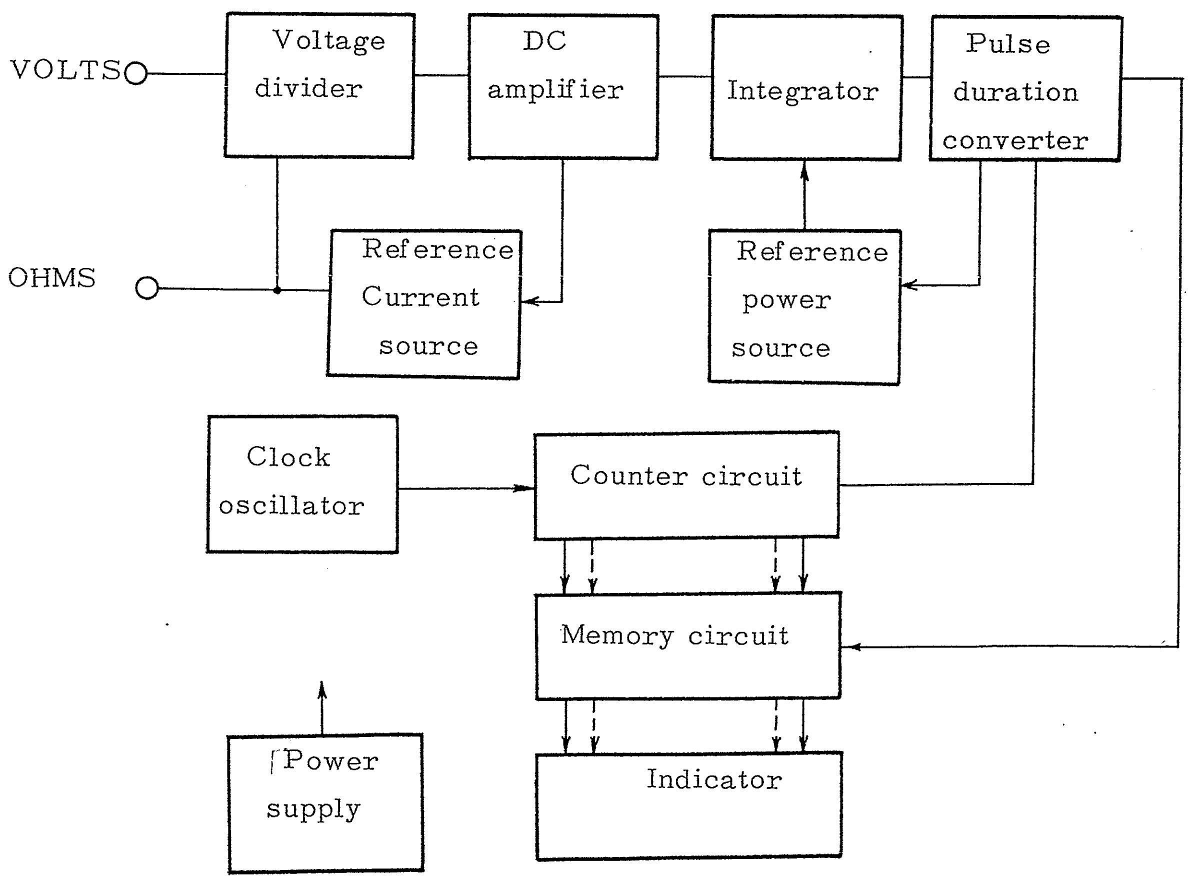


Fig. 4-1

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 propotional 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 and standard resistors

The voltage divider has an input resistance of 10MΩ constant. Its output resistance is made approximately equal for all the four ranges of 3,30,300 and 1000V. The output of the voltage divider is designed to be 3V when the count on the digital voltmeter is "3000". In resistance measurement these resistors 1kΩ,10kΩ, 100kΩ and 1 MΩ are used as standard resistors to make reference constant current.

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 sqare 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.

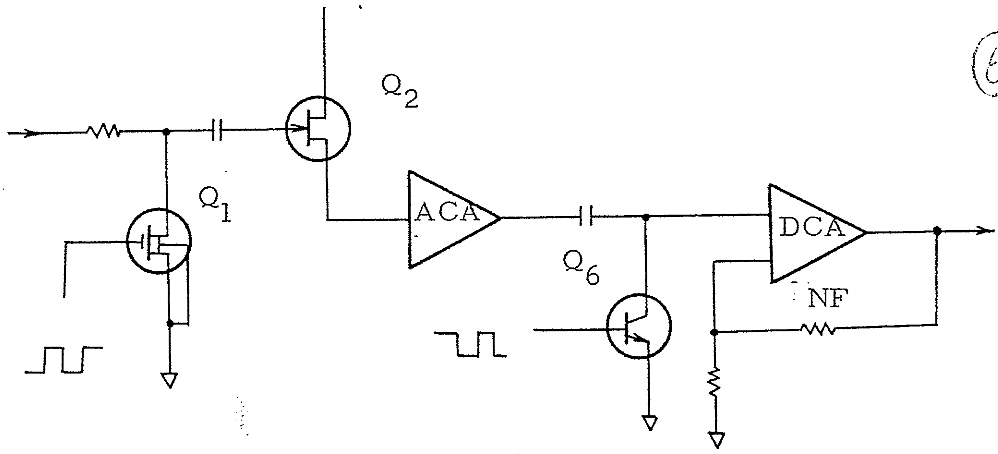


Fig. 4-2

DC amplifier DC A 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}.

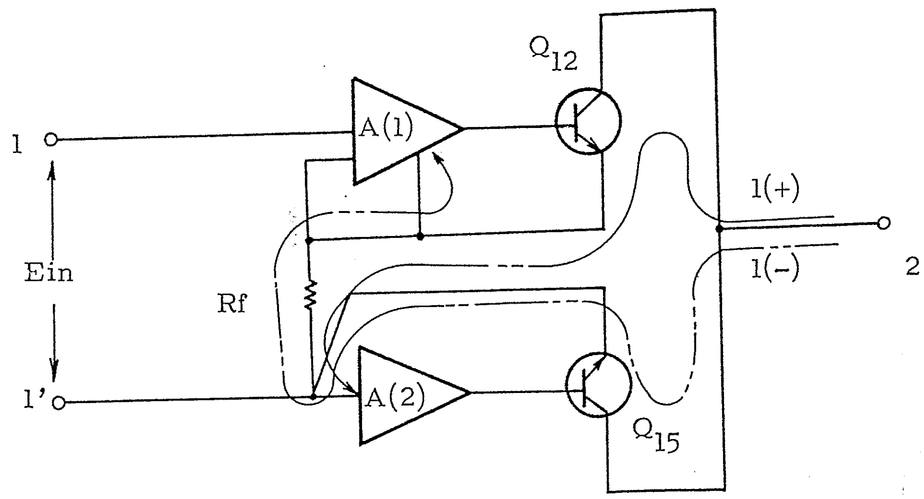


Fig. 4-3

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 Rf 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.

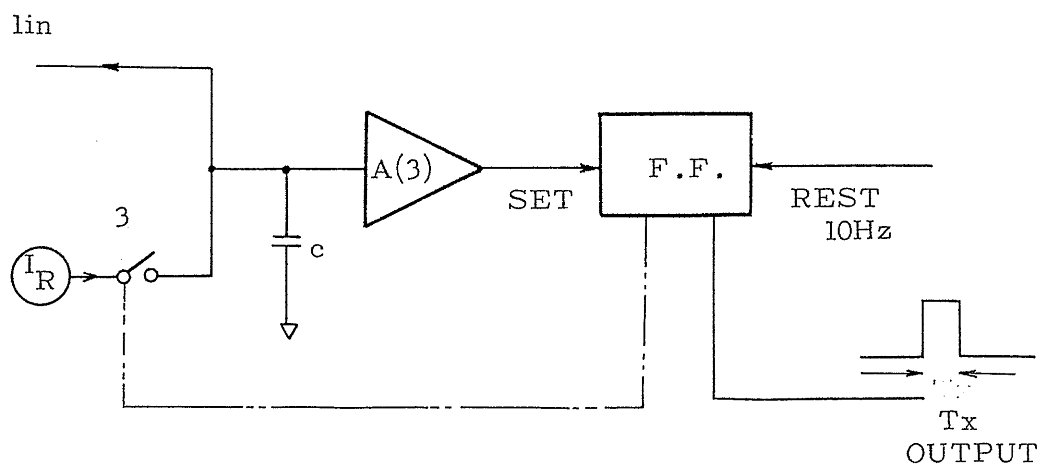


Fig. 4-4

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 this produced is always applied to the F.F. at a cycle of 0.1 sec. When this F.F. is in the reset condition, switch S of reference power source I_s closes; when in the set condition, the switch opens. When the F.F. is in the reset condition, switch S closed, 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 F.F. is set through the operation of the level detector. When the F.F. is set, S is released, only I_{in} is integra-ted until the F.F. 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 F.F. If the F.F. takes a period of Tx to change from reset to set and a period of T from set to reset.

$$\frac{I_R - I_{in}}{I_{in}} = \frac{T - Tx}{Tx} \qquad (1)$$

From equation (1),

$$\frac{I_{in}}{I_R} = \frac{Tx}{T} \qquad (2)$$

Therefore, the pulse width Tx to be converted will be

$$Tx = I_{in} \frac{T}{I_R} \qquad (3)$$

Equation (3) verifies that pulse width Tx is converted in proportion to I_{in}. The counter indicates "0" for all digits when the F.F. is reset. It counts 80 kHz pulses, overflows with 8000 pulses, and returns to "0000".

The counter repeats this operation. When the F.F. 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.

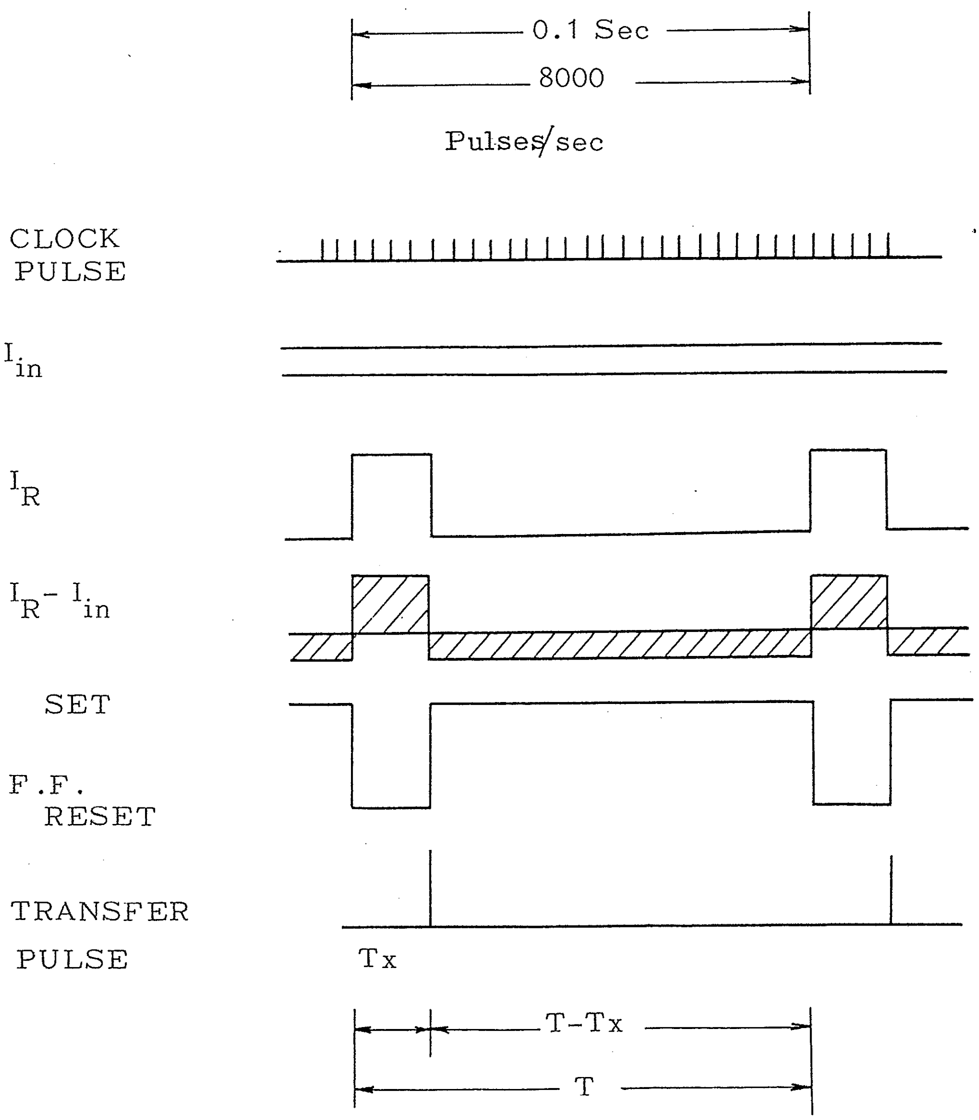


Fig. 4-5

4.5 Counter and its peripheral circuits

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

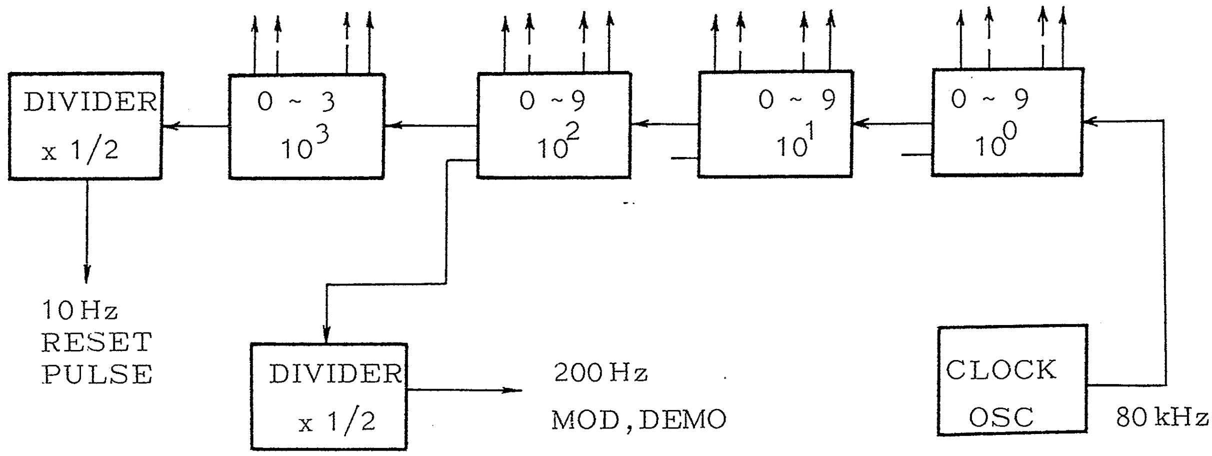


Fig. 4-6

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 F.F. 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 having 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.

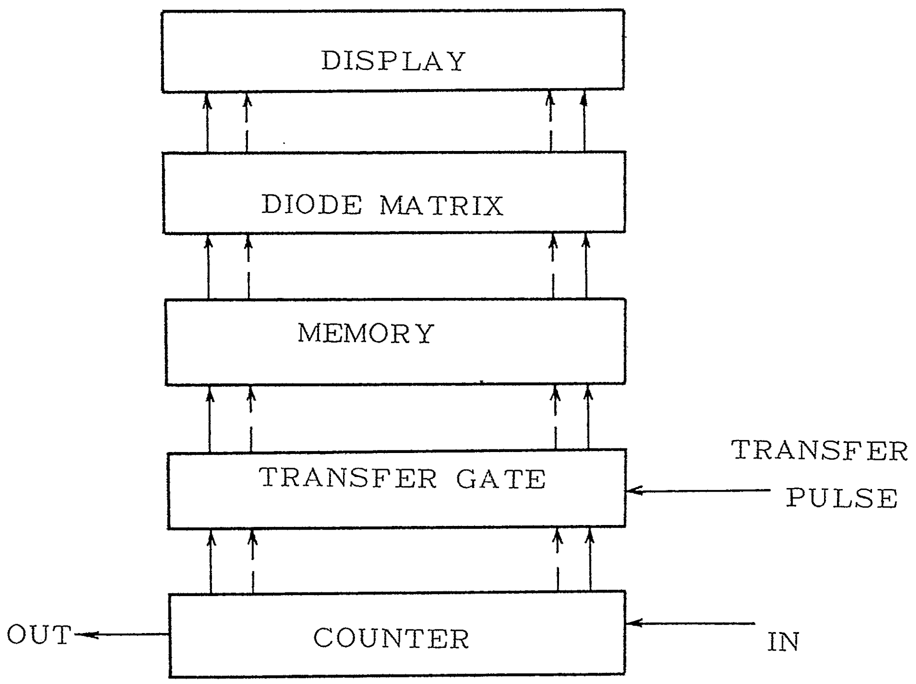


Fig. 4-7

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

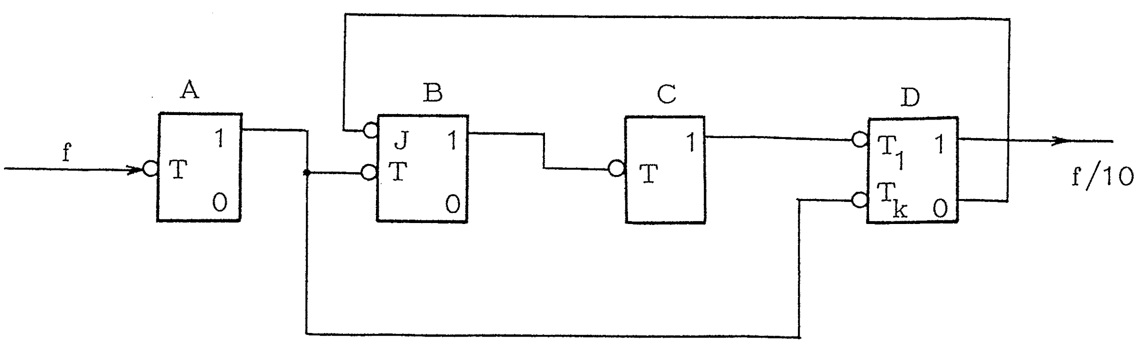


Fig. 4-8

F.F. / Decimal Number	A 1	B 2	C 4	D 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 Resistance measuring circuit

In accordance with selection of the resistance measuring ranges from 300 Ω to 3 MΩ, the resistance measuring circuit allows a current ranging from 0.1 μA to 10 mA to flow in a resistance to be measured from a constant current power source, thereby measuring a voltage at the terminal. Fig. 4-9 illustrates the principle of the measuring circuit.

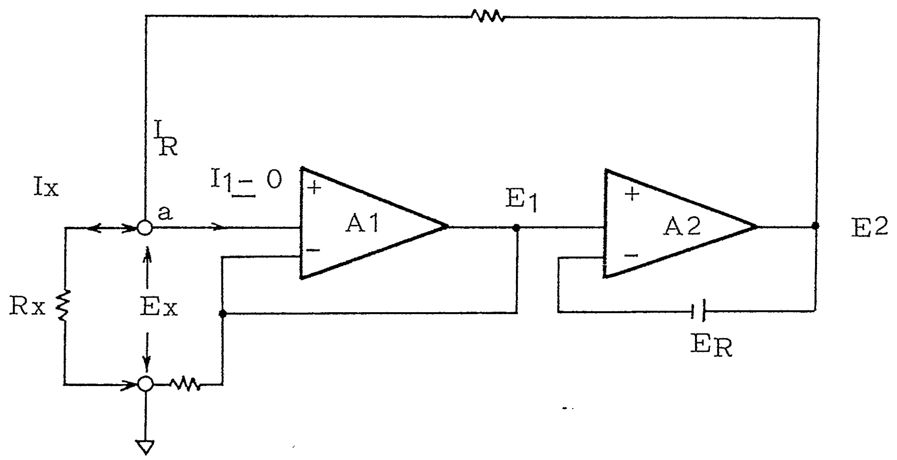


Fig. 4-9

In the above drawing, A_1 is a chopper amplifier for voltage measurement , A_2 is a DC amplifier to supply a constant current to a resistance R_X to be measured, and E_R is a reference voltage for a constant current circuit. Suppose now that a terminal voltage is E_X when the resistance R_X is connected with the resistance measuring terminal. Then the output voltage E_1 of A_1 becomes E_X. The output voltage E_2 of A_2 becomes $E_X + E_R$ by reason that a power source having such polarity as shown in Fig. 4-9 is supplied inseries from output and negative feedback is applied to A_2. Therefore, in a range where both A_1 and A_2 are linear, the voltage across the terminal of the reference resistance R_S becomes $(E_X + E_R) - E_X = E_R$, so that a current $I_R = E_R / R_S$ flows in R_S. As regards the input terminal "a" , on the other hand, $I_R = I_X + I_1$.

Since input impedance of A'_1 is so designed as to become remarkably great against R_X, I_1 is regarded as zero. M Namely, $I_R = I_X$, and $I_X = E_R/R_S$. Thus a constant current can be supplied regardless of the resistance R_X.

4.7 Power supply

The power sources used in the Model 156L are for +200 V (not regulated), and regulated voltages of +25 V, +5.5 V and -11 V.

The circuitry is composed as in Fig. 4-9.

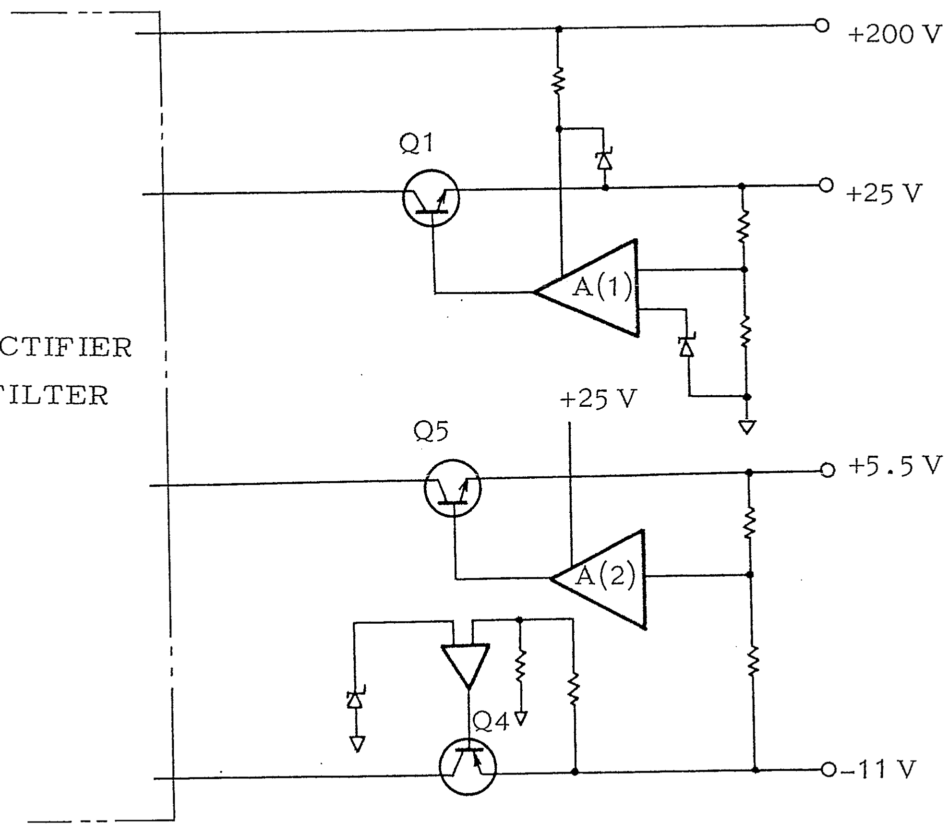


Fig. 4-9

Each of the +200 and -11 V power supply circuits is working independently, while the +25 and +5.5 V 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 -11 V circuit, and the bias of the amplifier from the + 25V circuit.

5 . MAINTENANCE

5.1 Removal of instrument case

Turn off the power switch, and after confirming safety, remove the fourtruss head screws in the corners on the rear panel of the case. Then gently pull out the case forwards with respect to the front panel.

5.2 Parts location

The main component parts of the Model 156L are located as shown in Fig. 5-1.

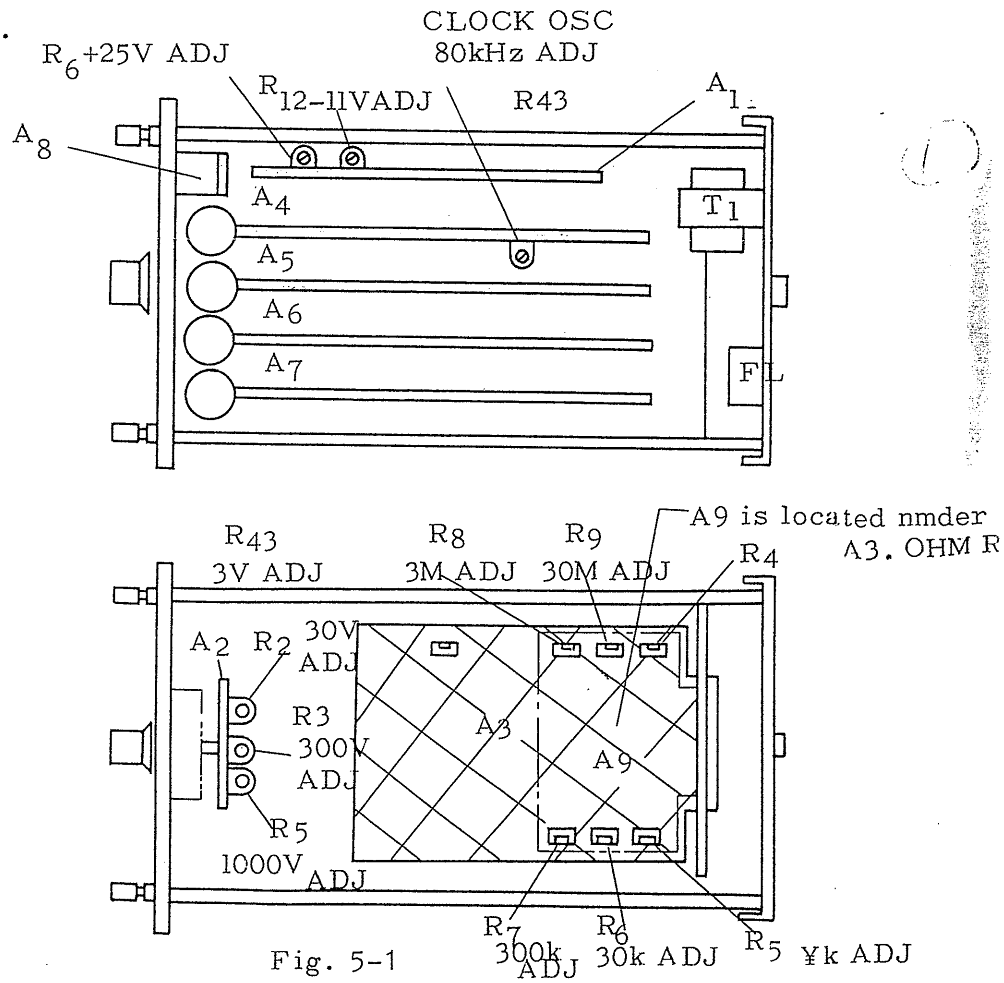


Fig. 5-1

The Model 156L 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 -11V 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 R43 so that the frequency may be within a range of 80kHz ±0.1%. Even if this frequency is slightly inaccurate, it does not adversely affect the performance of the Model 156L. However, it deteriorates rejection against commercial power line frequency.

Adjustment of +25V power supply:

Connect a DC voltmeter across connector pin No. 6 and ground terminal pin No.7 of printed-circuit board A1. Adjust R6 so that the voltage may be within a range of +25V ±1%.

Be sure to conduct this adjustment before calibration the Model 156L.

5.4 Calibration

To maintain the measuring accuracy of the Model 156L, periodical check and calibration are recommended.

From the view point of calibrationaccuracy, 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.

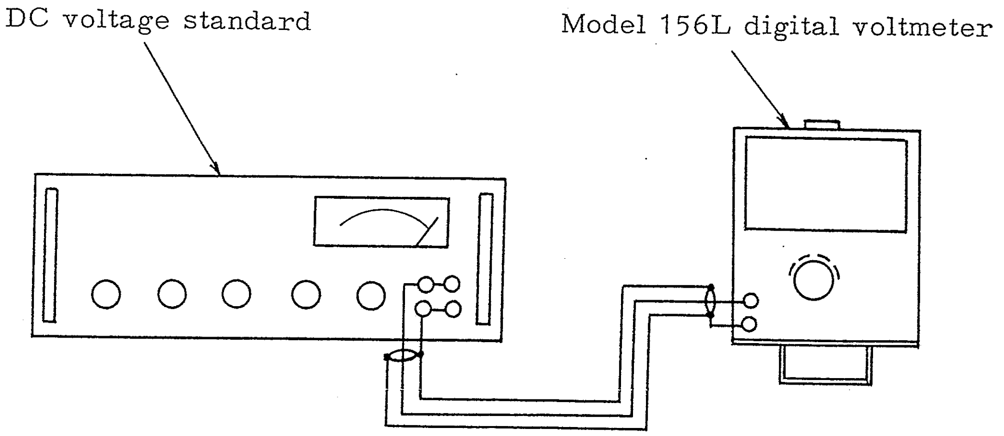


Fig. 5-2

Calibration procedure follows:

1. Turn on the power switch of the Model 156L and leave it for more than one hour for warm up.

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 156L.

4. Set the output of the voltage standard to +3.000V, and the range of the Model 156L to "3V".

5. Adjust R_{43} of printed-circuit board A3 to set the indication to "+3.000".

6. Set the range of the Model 156L to "30V". Adjust R_8 of printed-circuit board A2 to set the indication to "30.00".

7 Set the range to "300V", and adjust R_9 for indication of "+300.0".

8. Set the range to "1000V", and adjust R_{10} for indication of "+1000".

9. Set the range to "3V" again, apply -3.000V, and confirm that indication is within an error range of 0.1% ±1 digit.

Calibration of resistance range :

Calibration of the resistance ranges is to be performed in the following procedure after termination of the above-described calibration of the voltage ranges.

1. Set the range switch to 300Ω, and connect a standard resistor of 300Ω (accuracy : ±0.02%) with the measuring terminal, and adjust R5 so that indication may become 300.0Ω.

2. Next, set the switch to 3MΩ, and connect a standard resistor of 3MΩ with the measuring terminal, and adjust R9 so that indication may become 3000kΩ. When it is impossible

to obtain 3000kΩ by this method , make adjustment by means of R4, and adjust the 300Ω range again. R4 must be set to a value by which both 300Ω and 3MΩ ranges can be adjusted.

3. As for the 3kΩ, 30kΩ, and 300kΩ ranges, connect standard resistors of 3kΩ, 30kΩ, and 300kΩ respectively, and adjust R6, R7, and R8.

(Caution)

In case of calibrating the high resistance ranges, error resulting from induction is liable to occur. To avoid this, be sure to connect the low impedance side with the white terminal and the high impedance side with the **red** terminal as shown in Fig. 5-3 by using well-insulated lead wires.

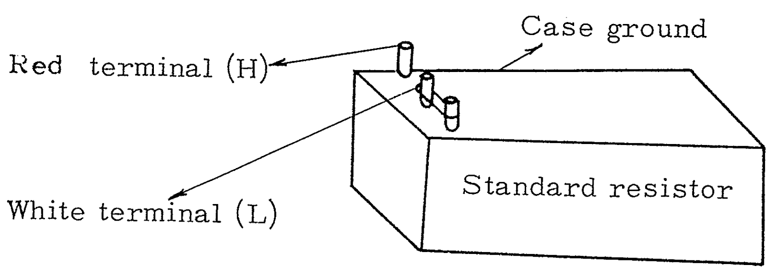


Fig. 5-3

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 "1V", short-circuit the input, and keep the HOLD button in the unlocked condition.

Power supply (printed-circuit board A1):

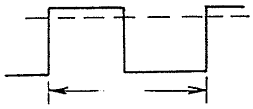
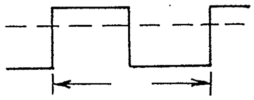
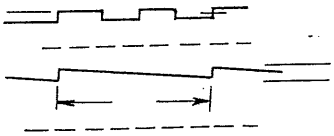
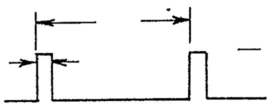
Test Point	DC Voltage	Ripple
1	+39V	3 Vp-p
3	-23V	1.5 Vp-p
2	+9.5V	1Vp-p

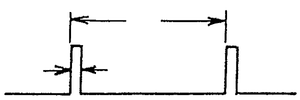
Connector Pin No.		
2	+192V	20 Vp-p
6	+25.0V	4 mVp-p
9	-11V	9 mVp-p
14	+5.5V	15 mVp-p

NOTE: The above voltages are measured by using the following instruments: Oscilloscope, DC -15MHz, with low-capacitance probe (10MΩ, 7pF)

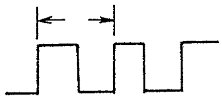
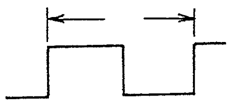
Voltmeter, DC voltage, 10MΩ in input resistance

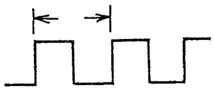
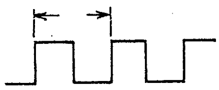
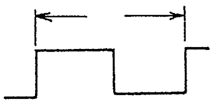
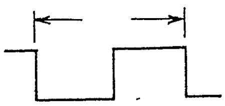
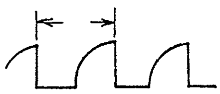
DC amplifier and integrated duration converter (printed-circuit board A3) :

Test Point		
1		T=5ms
2		T=5ms
3		
4		T=100ms
5		
6		T=100ms t=8μs

Connector Pin No.			
1, 14	0 V		
4	+5.5V		
5	-11V		
7 At +10mV input (1 V range)	+21V	At -10mV input (1 V range)	+0.03V
8 "	+0.06V	"	+11.7V
10		T=0.4sec t=1μs	
6. 13	+25.0V		

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

Test Point		
1		T = 25 ms
2		T = 50 ms

Connector Pin No.		
4 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

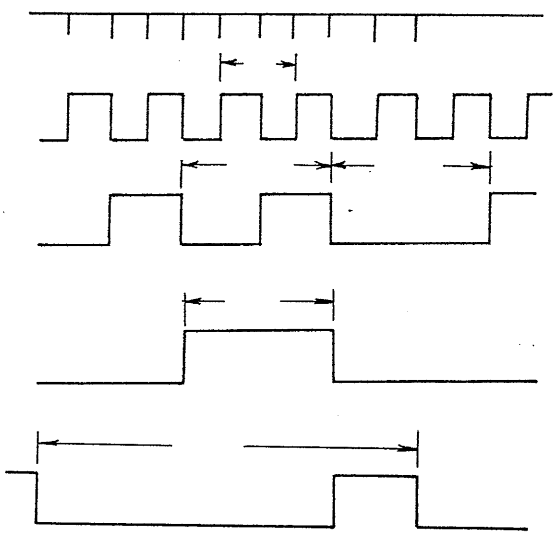
Input

1

2

3

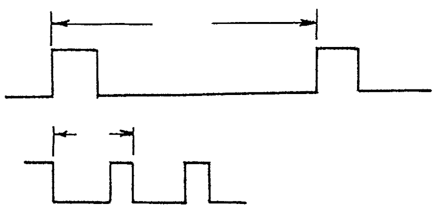
4



Digit	T1	T2	*Tin
10^0	25µs	125µs	12.5µs
10^1	250µs	1.25ms	125µs
10^2	2.5ms	12.5ms	1.25ms

Connector Pin No.

6	+192V
7	+5.5V
8	0 V (GND)
11	
12	



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

5.6 Ohm converter (printed-circuit board A9)

The voltage noted below are measured with respect to the ground (0 V) unless otherwise specified under the condition where the range switch is set to 300Ω and the measuring terminal is short-circuited.

Connector Pin No.		
1		0 V
2		+25 V
3		+0.6 V
5		+1.6 V
6		-11 V
Across 7 and 8	AC	41 V