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-TR-3788C

FREQUENCY COUNTER  
INSTRUCTION MANUAL

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Regional Engineers.  
District Engineers.

Radio Inspectors Equipment: Frequency Counter, Takeda Riken  
TR3788C

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... Attached to this memorandum are copies of a draft Engineering Instruction for the operation and use of the Takeda Riken TR3788C frequency counter. These instructions should be followed while using the counter, and any suggested amendments to the methods described, or to the accessories supplied, should be submitted to this Office before 30 September 1971.

It should be noted that the counter accuracy stated in paragraph 4.2 is a figure based on the worst expected drift rate of the counter standard oscillator. After several counters have had calibration checks effected, see paragraph 6.2, the accuracy figure may be altered according to the average drift rate.

*R. W. Becker*

Encl.

for Superintending Engineer (Radio)

THE UNIVERSITY OF CHICAGO

1961-1962

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2. The second part is devoted to a discussion of the

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FREQUENCY MEASURING EQUIPMENT

FREQUENCY COUNTER - TAKEDA RIKEN - TR3788C

1. CANCELLATIONS. Nil.

2. GENERAL.

2.1 This Instruction describes the use of Takeda Riken TR3788C frequency counters issued to Radio Inspectors for frequency measurement of radio apparatus operating on frequencies up to 500 MHz.

3. ACCESSORIES.

3.1 The following accessory items are provided with the counter.

- ✓ (a) 230 volt power cord.
- ✓ (b) Set of battery cords.
- ✓ (c) 20dB attenuator.
- ✓ (d) Co-axial cord, BNC to BNC.
- ✓ (e) Co-axial cord, BNC to r.f. coupling loop.
- ✓ (f) 12/24 volt inverter power supply.
- ✓ (g) Counter instruction manual.
- ✓ (h) Inverter instruction manual.
- ✓ (i) Spare fuses.

Item (f) is housed in the protective lid for the counter. All other items are contained in a plastic satchel.

4. CONDITIONS OF USE

4.1 The instruction manual provided describes the method of setting up the instrument. These instructions should be followed along with additional requirements included in this Instruction.

4.2 Before a measurement is attempted with this Instrument, allow a warm up time of 15 minutes so that the required accuracy may be obtained. After this warm-up time, the basic measuring accuracy of the counter will be better than 2 parts in  $10^{-6}$  for one year.

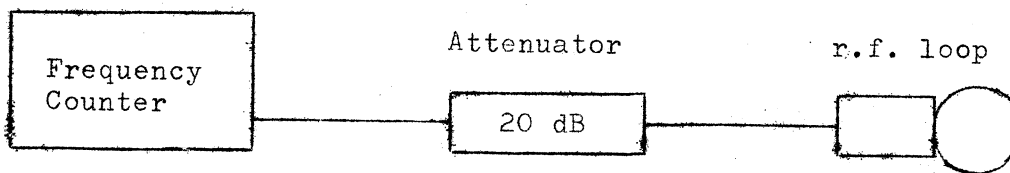
4.3 Because this instrument may be easily damaged with excessive signal (max 2 volts), the following procedure should be used to achieve a stable display of frequency.

4.3.1 Some transmitters, such as in TV translators, have r.f. monitoring points for connecting test receivers or frequency counters. Where possible, these points should be used. The counter should be connected to the test point with the 20dB attenuator in circuit, and the frequency measured. Should the level be insufficient to produce a stable display on the counter, remove the attenuator and connect as before.

4.3.2 When suitable, measure the frequency of 0 to 25 watt transmitters terminating the transmitter output into a Marconi TF1065A Output Test Set. Connect the frequency counter with the 20dB attenuator in circuit, to the BNC socket marked LO on the Output Test Set. When the transmitter is triggered, the frequency will be displayed.

With power below one watt, the 20dB attenuator may have to be removed from the input circuit, but only if a stable display can not be obtained with the attenuator in circuit.

4.3.3 Where measurement can not be made using methods 4.3.1 and 4.3.2, coupling of signal to the counter must be made with the r.f. loop provided. Initially, the counter should be set up as in fig 1. The 20dB attenuator must be in circuit to prevent excessive input signal.



4.3.4 Move the loop progressively closer to the aerial, or aerial feeder wire, until a stable display is obtained. Increase the coupling by moving the loop slightly closer to the aerial than the threshold point. Take care that an arc, or contact with the aerial, is not possible.

4.3.5 Should there be insufficient coupling to obtain a stable display on the counter with the arrangement as above, withdraw the loop from near the aerial, or aerial feeder wire. Remove the 20dB attenuator from the input and proceed with the method in 4.3.4.

4.3.6 When measuring the frequency of very low output transmitters, it may become necessary to wrap an insulated wire around the aerial or aerial feeder wire to obtain sufficient coupling. This should never be attempted until methods 4.3.4 and 4.3.5 have proved unsatisfactory.

4.4 Whenever using the inverter power supply to power the counter, always ensure that the voltage switch on the inverter matches the supply voltage. This switch is provided to allow operation on 12 or 24 volts.

## 5. MEASUREMENT

5.1 The measurement of different types of emission requires different measuring conditions. The following methods should be used:-

(a) A3 + Measure with carrier only.

- (b) A3H - Measure with carrier only.
- (c) A3A - Measure with carrier only.
- (d) A3J - Modulate the transmitter with a sinewave of known frequency.  
The carrier frequency will then be:  
  
for USB: Measured freq. - Modulating freq.  
for LSB: Measured freq. + Modulating freq.
- (e) Frequency Modulated emissions - Measure either modulated or unmodulated.

In cases (a), (b) and (c), the power output of the transmitter will increase when modulation is applied. Should this happen when the counter is coupled, the increase in power could produce an excessive signal at the input circuits of the counter. It is important to ensure that the transmitter is not capable of being readily modulated while measurements are made.

5.2 Difficulty may be experienced in measuring the frequency of some pulse modulated carrier and interrupted carrier forms of emissions as may be found in tele-control transmitters and ship's lifeboat transmitters. In such instances, the measurement displayed may bear little relation to the operating frequency. Should trouble be experienced, little further can be done to obtain an absolute frequency check and nothing further should be attempted with this counter.

## 6. MAINTENANCE

6.1 Under no circumstances is this instrument to have maintenance attempted by anyone other than staff of the Radio Laboratory, Radio Section, Wellington East Post Office Building. No other establishment has the necessary accurate equipment to maintain this instrument.

6.2 To ensure that the frequency standards in these counters remain accurate, each instrument will be recalled for calibration checks once a year. The counter should be sent to the Radio Laboratory, at the beginning of the first week of the month according to the roster below.

February:	Wanganui and Invercargill.
March:	Auckland and Dunedin.
April:	Hamilton and Timaru.
May:	Rotorua and Christchurch.
June:	Gisborne and Greymouth.
July:	Napier and Nelson.
<u>August:</u>	New Plymouth and <u>Masterton.</u>
September:	Whangarei and Palmerston North.
October:	Wellington.

6.3 In the event of failure of a counter, one spare instrument is available while repairs are being effected. This spare counter is not available to districts when their instrument is required for calibration checks.

6.4 Transport of the counter to the Radio Laboratory will be by NAC airfreight. The instrument should be well packed and be housed in a sturdy box so that the possibility of damage during transit is reduced to a minimum.

6.5 Under no circumstances should the r.f. pick-up loop be adjusted or should any new loop be made for use with the counter except as detailed in paragraph 4.3.6.

7. REFERENCE. E.I. Power General K 0001..

END



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## 1. DESCRIPTION

### 1.1 General

This instruction manual covers the specifications, operating procedure, theory, and maintenance of the -TR-3788C FREQUENCY COUNTER.

- |                               |   |
|-------------------------------|---|
| 1. DESCRIPTION                | A description of the counter and its features.  |
| 2. SPECIFICATIONS             | A detailed description of the counter's functions and specifications.   |
| 3. OPERATING PROCEDURE        | Preparation and precautions prior to operating the counter, panel description (with the aid of illustrations), associated equipment and their connection, and operating procedures.   |
| 4. THEORY OF OPERATION        | Principles of construction centered around block diagrams, theory of basic circuits, etc. (with the aid of diagrams).   |
| 5. MAINTENANCE AND INSPECTION | Instruments necessary for maintenance and inspection and troubleshooting procedures if malfunctions should occur. The circuit diagrams and parts list at the end of this section should be referred to during troubleshooting, maintenance, and inspection. |

The -TR-3788C FREQUENCY COUNTER is completely transistorized, compact, and lightweight frequency counting equipment capable of frequency measurement in the 10 Hz - 500 MHz range. Up until now, measurements in the 500 MHz frequency band required a frequency converter or other similar equipment; however, this requirement does not exist with this counter (direct display of the count is possible).

Since the counter possesses a function which permits variation of the input level as desired, frequency measurement is possible even if the level of the measured signal varies. A specific feature of this counter is the high reliability of its crystal oscillator. The oscillator has a stability of  $3 \times 10^{-9}$ /day under aging conditions and is installed in the counter only after subjection to various severe tests and aging data checked against a strictly managed standard frequency, as well as exhaustive quality control.

The operation of these counters is fast, simple, and accurate. Measurement is automatically performed and the measured result displayed in bright, clear digits.

The -TR-3788C employs TAKEDA RIKEN's original memory display system and its rationally designed controls and automatic switching of the units and decimal point by means of a switch make it extremely easy to use. In addition, the use of all silicon semiconductor components and integrated circuits not only facilitates maintenance and inspection but also makes the counter highly resistant to such ambient conditions as humidity, temperature and external noise.

The major features of the -TR-3788C ELECTRONIC COUNTER are as follows:

- a) Frequency measurement up to 500 MHz.
- b) 8 digit decimal numerical display tube registration.
- c) Gate times of 4 mS, 40 mS, 0.4 S, and 4 S.
- d) Internal time base frequency having extremely high accuracy (better than  $3 \times 10^{-9}$ /day).
- e) Memory display possible by means of simple switch operation.
- f) Units display and decimal point automatically set by ganging to various switches.
- g) Small, lightweight.

## 2. SPECIFICATIONS

### 2.1 Specifications

Measuring system	Prescaler, direct reading decimal display system
------------------	--

#### Frequency measurement (Input)

Measuring range	10 Hz ~ 500 MHz
Gate time	4 mS, 40 mS, 0.4 S, <u>4</u> S
Accuracy	$\pm \frac{1}{f \cdot G} \pm$ internal time base accuracy (f: measured frequency, G: Gate time)
Read in	kHz, MHz Decimal point automatically set when gate time switched.
Min. read in frequency	1 kHz, 100 Hz, 10 Hz, 1 Hz
Signal input	Front panel BNC connector

#### Time Base

Internal time base frequency	1 MHz
Frequency stability	$3 \times 10^{-9}$ /day (constant ambient conditions, after 48 hours of continuous operation)
Time base adjustment	Rear panel adjustment Adjustable range: $5 \times 10^{-8}$

#### Internal time base output

Frequency	1 MHz
Output level	1 Vp-p ~ 6 Vp-p (unloaded)
Output impedance	Below 1 k $\Omega$
Connectors	BNC type (rear panel)
Signal stability	Corresponds to internal time base accuracy

#### External time base input

Frequency	1 MHz
Input voltage	1 Vrms ~ 10 Vrms
Input impedance	Greater than 10 k $\Omega$
Connectors	BNC type (rear panel)

#### General specifications

Counting capacity	8-digit decimal
Counting speed	500MHz, 2 nS resolution
Display system	Numerical display tube registration Count display and memory display (can be switched at the rear panel)

#### Display time

Count display	Min. longer than 80 mS, max longer than 5 S. Continuously variable and infinite.
Memory display	(Count display time + gate time) and infinite
Infinite	Measurement made once and continuously displayed until manually reset

#### INPUT

Input level	Level continuously variable
Input mode	AC
Input impedance	Approximately 50 $\Omega$
Max. input sensitivity	100mVrms (10 Hz ~ 100 Hz) 10 mVrms (100 Hz ~ 500 MHz)
Trigger level variation range	$\pm 15$ mV
Max. input voltage	2 Vrms
Safe input voltage	$\pm 2$ V
Pulse input	Resolution 2 nS, sensitivity $\pm 50$ mVp

Self-check	The time base circuit, counting circuit, and various gates can be checked at a count (gate) time of 0.4 S and 1 MHz internal time base.
Operating temperature range	0°C ~ +40°C
Storage temperature range	-20°C ~ +70°C
Power supply	
Voltage	220 VAC, $\pm 10\%$ , 50/60 Hz Can be modified for 100, 115, 230 V (optional)
Power	Approx 65 VA
Insulation resistance	Between one AC input terminal and case Greater than 50 M $\Omega$ (100 VDC)
Dimensions	Approx 250 (wide) x 149 (high) x 345 (deep) mm (Does not include stand, rubber feet at the rear panel, and front panel cover)
Front panel cover	Approx 250 (wide) x 149 (high) x 93 (deep) mm

## 2.2 Components

The -TR-3788C consists of the following components:

1) -TR-3788C FREQUENCY COUNTER	1
2) AC power cord	1
3) Input cable	2
4) Ground cable	1
5) Tubular glass fuse ( 1 A )	3
6) Screwdriver ( 3 mm)	1
7) Allen wrench ( 3 mm, 4 mm)	2 each

8 )	Instruction manual	2
9 )	Test report	2
10)	Attenuater ( 20 dB )	1

### 3. OPERATING PROCEDURE

#### 3.1 General

This section covers preparations and precautions prior to operating the counter, panel description (with the aid of illustrations), and operating procedure.

#### 3.2 General Preparations and Notes

- 1) Use an AC power source within the rated  $220\text{ V} \pm 10\%$ .
- 2) Since a ventilation fan is not employed, pay careful attention to ambient air flow.
- 3) Ambient operating temperature range is  $0^{\circ}\text{C} \sim 40^{\circ}\text{C}$ .
- 4) Absolute storage temperature range is  $-20^{\circ}\text{C} \sim +70^{\circ}\text{C}$ .
- 5) Since a crystal oscillating element is employed, do not subject the counter to extreme mechanical shock. Handle the counter carefully.
- 6) If considerable power line noise is present, use a noise filter.
- 7) Since the internal signal may leak out, ground the counter.
- 8) When highly accurate measurements are necessary, calibrate the internal crystal oscillator. (Refer to the precautions pertaining to maintenance of TAKEDA RIKEN Counters)
- 9) All functions begin to operate as soon as power is applied.
- 10) The constant temperature oven heater operates, even if the power switch is turned off, unless the power cord is unplugged. (Since 48 hours after the OVEN heater is set to ON is required before the crystal oscillator reaches its rated stability. It is recommended that the power cord remain connected when making highly accurate measurements over a long period of time.



### 3.3 Panel Description (Refer to Fig. 3.1.)

#### -Front Panel-

##### 1) GATE IND

This neon tube indicates the opening and closing of the gate. The lamp lights when the gate opens.

##### 2) SAMPLE RATE

a) The time between counting operations can be varied from 80 mS to more than 5 S by turning this control clockwise.

b) Manual counting can be performed by depressing the RESET button (4) with this button set to HOLD.

##### 3) POWER - OFF

Controls the power to all circuits except the OVEN heater of the crystal oscillator. Power is applied when this switch is set to the POWER side and removed when set to the OFF side.

##### 4) RESET

The primary counting circuit and time base are set to the zero state and counting operation immediately performed at the next GATE signal when this button is depressed.

##### 5) GATE TIME

Switches the counting time when making frequency measurements or performing the CHECK operation. When set to CHECK, the counting time is constant at 0.4 A. When making frequency measurements, this control is used to select the desired gate time (4 mS, 40 mS, 0.4 S, or 4 S can be selected).

##### 6) PROBE POWER

Power supply connection when using a high input impedance probe. The input impedance of INPUT is 1 MΩ.

7) INPUT

Input terminal for frequency measurement.

8) LEVEL

Varies the input signal trigger level. Its variation range is  $\pm 15$  mV.

-Rear Panel-

9) NON-STORAGE/STORAGE

When this switch is set to STORAGE, the count display is accumulated and the previous counted results continuously displayed up to the end of the next counting operation.

Only those digits of the previous display which differ from the results of the following count change.

When set to NON-STORAGE, the accumulating function is lost. The displayed results are reset to "0" prior to initiation of the next counting operation, and the next counting operation performed.

When reading the counted results and this switch is set to STORAGE, SAMPLE RATE is turned fully counterclockwise.

When set to NON-STORAGE, set SAMPLE RATE to a middle position and then make the reading.

10) GROUND

Ground terminal for the counter case, when external noise, induction, etc. are considerable, connect this terminal to an earth ground with the cables supplied.

11) FREQ STD ADJ

This screw is used to adjust the internal time base (crystal oscillator).

12) EXT and INT

When set to INT, all the gate functions are performed by the crystal oscillator housed inside the counter.

At this time, a 1 MHz time base signal appears at terminal (13). When set to EXT, the gate functions of the internal crystal oscillator are lost. The gate functions are performed by applying an external time base signal (1 MHz) to terminal (13).

13)

14) FUSE 1 A

Power fuse for the counter. A 1 A fuse is required.

15) AC 220V

AC power connector. Rated power is 220 VAC  $\pm 10\%$ , 50/60 Hz.

The counter can be modified for use with 100, 115, or 230 VAC by changing the internal connections.

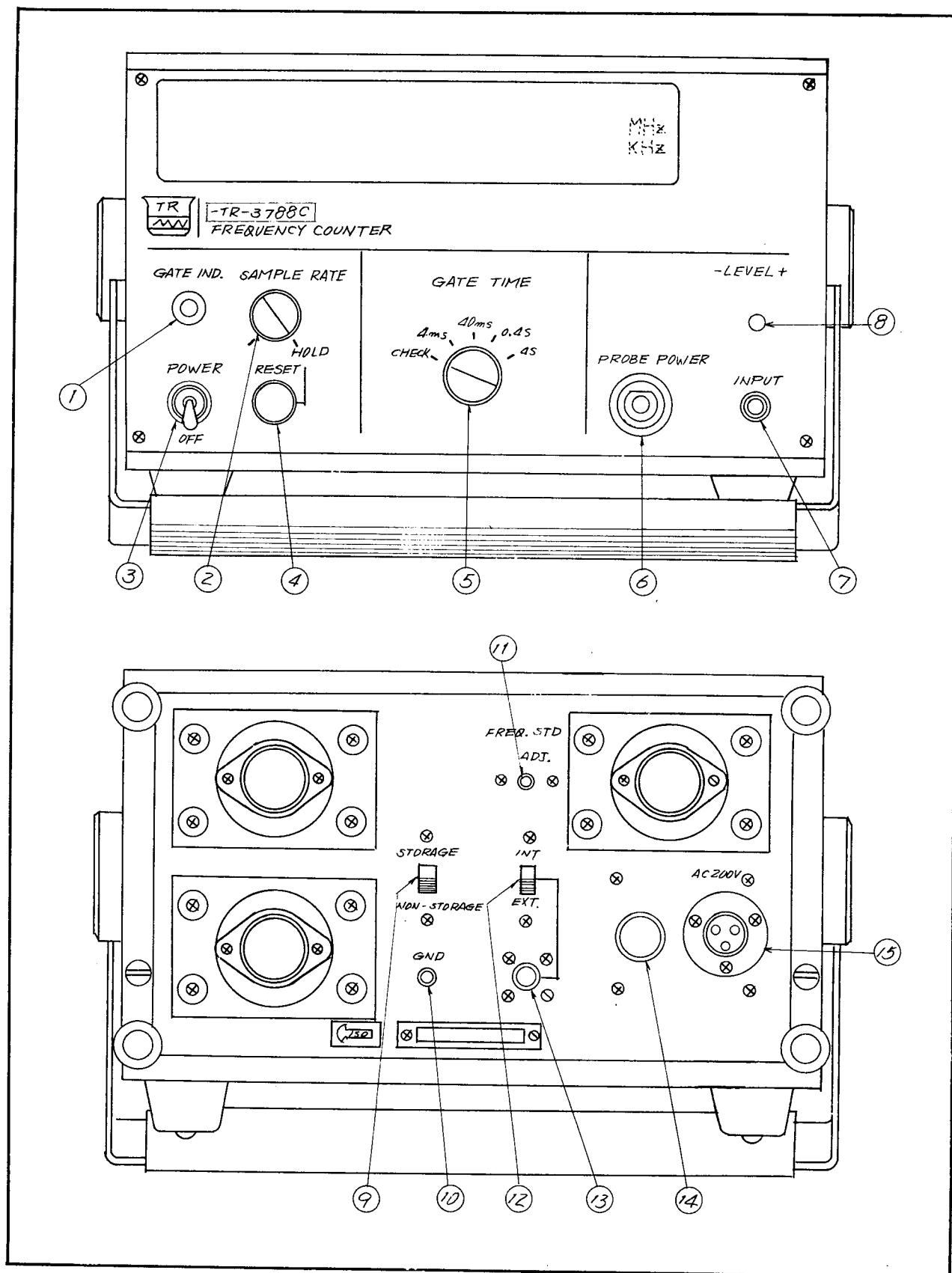


Fig. 3.1 Panel description

### 3.4 Self-Check Operation

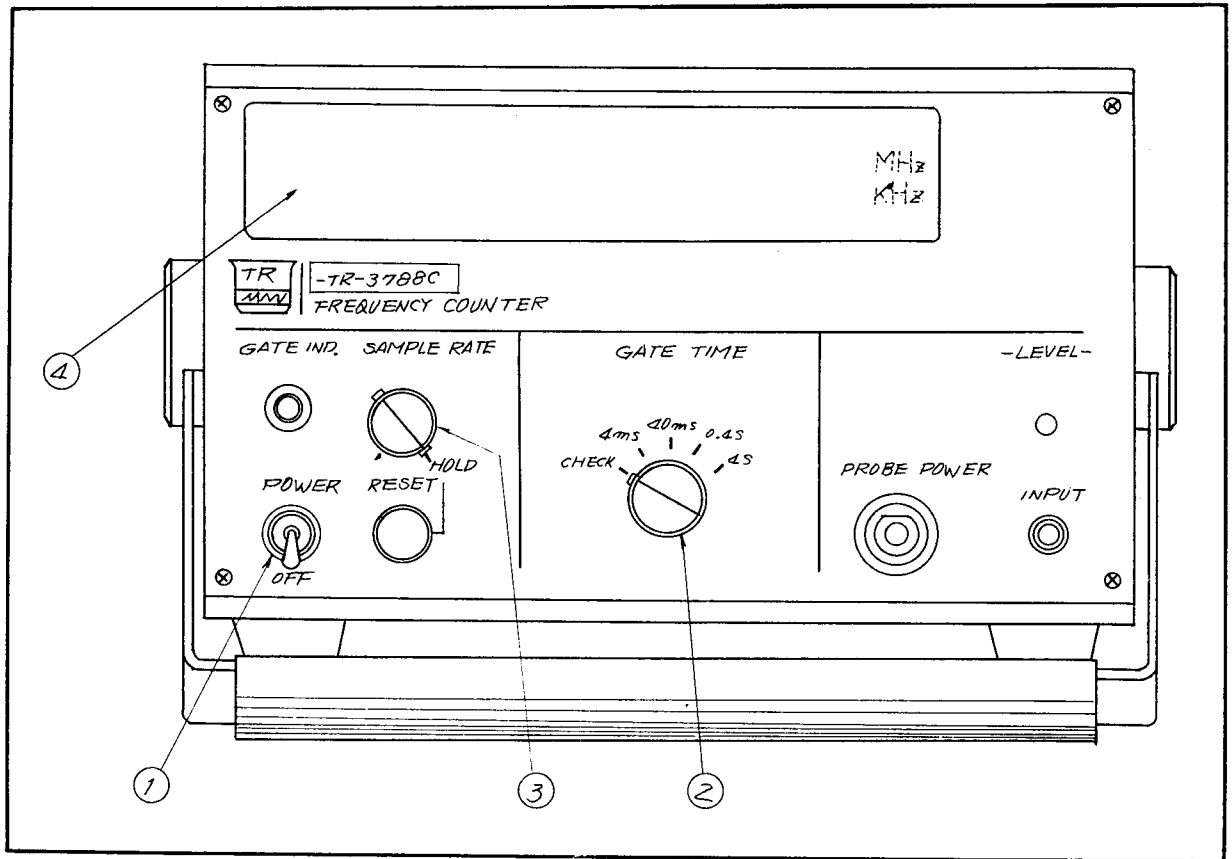


Fig. 3.2 Self-check operation

Conduct the self-check operation by referring to the numbers in Fig. 3.2 and those below.

- (1) Set POWER - OFF to OFF.

NOTE: Connect the power cord to the AC connector only after confirming that the POWER switch is set to OFF.

Pay careful attention to power cord to the power supply voltage; the rated value is 220 VAC  $\pm 10\%$ , 50/60 Hz.

- (2) Set GATE TIME to CHECK.
- (3) Turn SAMPLE RATE fully counterclockwise.

At this time, set STORAGE/NON-STORAGE at the rear panel to STORAGE.

- (4) Check to see if the displayed value is 001000.00 kHz or not.
- (5) Change STORAGE/NON-STORAGE at the rear panel and check if the display value changes or not.

### 3.5 Frequency Measurement

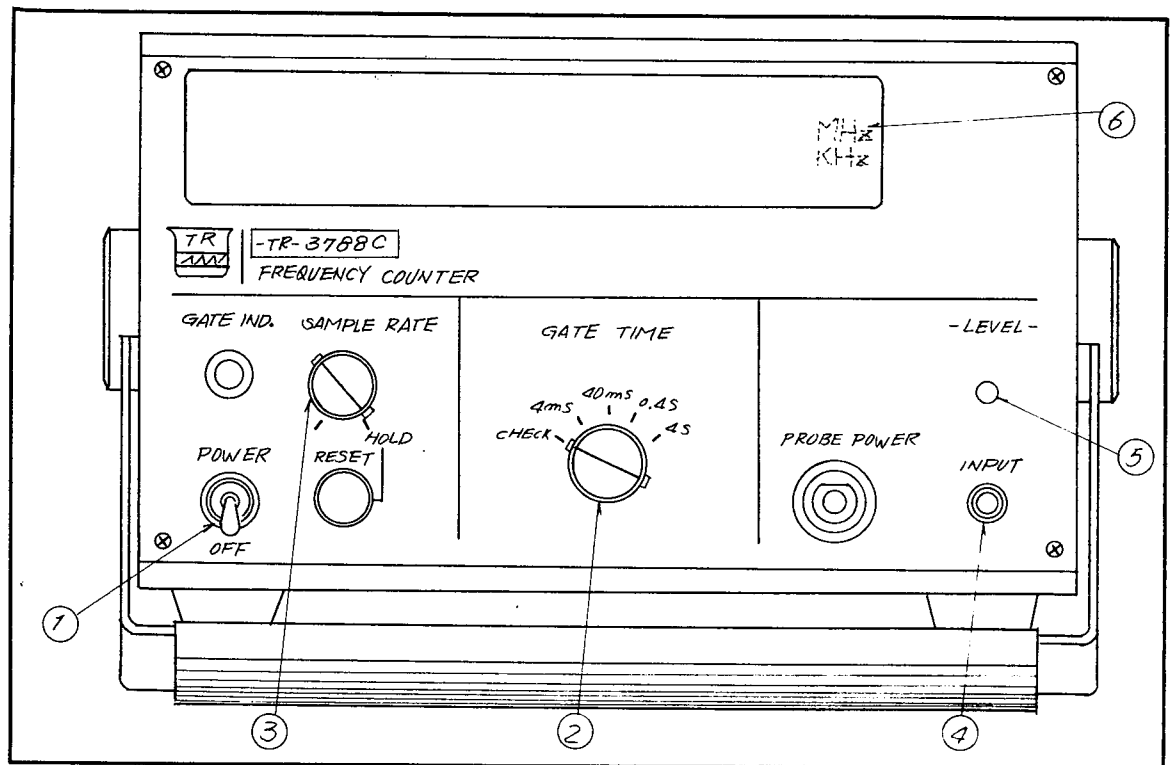


Fig. 3.3 Frequency measurement

Conduct frequency measurement by referring to the numbers in Fig. 3.3 and those listed below.

- 1) Set POWER - OFF to POWER.

NOTE 1: Connect the power cord to the AC connector only after confirming that POWER - OFF is set to OFF.

- 2: Pay careful attention to the power supply voltage.

The rated value is 220 VAC  $\pm 10\%$ , 50/60 Hz.

- 2) Set GATE TIME to 0.4 A.

Set STORAGE/NON-STORAGE at the rear panel to STORAGE.

- 3)

- 4) Apply the signal to be measured to the INPUT terminal.

NOTE: Apply the input signal only confirming that it is within the rated value of 10 mV ~ 2 Vrms.

- 5) Adjust LEVEL (8) in accordance with the waveform. When the waveform is a pulse, adjust the level to correspond to its polarity.

When it is a dc signal, operation will be performed if the level is set to a nearly middle position; however, there are times when the operating point will be changed a little by noise, waveform distortion, etc.

- 6) Read the counted value. The decimal point position is kHz or MHz units. Measurement accuracy will be increased 10 times if GATE TIME is set to 4 S.

When GATE TIME is set to 0.4 mS, measurement accuracy is low but measuring speed fast. When STORAGE/NON-STORAGE switch is set to NON-STORAGE, make measurements by turning SAMPLE RATE fully clockwise.

When making highly accurate measurements, set INT - EXT at the rear panel to EXT and apply a highly accurate 1 MHz external clock signal to the terminal.

### 3.6 Guaranteed Measurement Accuracy and Product Quality

Generally, there are two factors which limit the measurement accuracy of frequency counters. One is the accuracy of the 1 MHz crystal oscillator used to produce the internal time base (in the case of the -TR-3788C this is  $\pm 3 \times 10^{-9}$ /day) and the other the inherent  $\pm 1$  count error of counter systems.

Measurement error due to the crystal oscillator accuracy can be reduced to a small value; however, the  $\pm 1$  count error is caused by the comparative phase relationship between the measured signal and the gate time and is an error inherent in counter systems. (Refer to 4.3.)

The relationship between the measured signal and measurement accuracy is shown in Fig. 3.4 (for the -TR-3788C).

Measurement accuracy in frequency measurement is expressed by the following formula:

$$\text{Measurement accuracy} = \pm \frac{1}{f \cdot G} \pm \text{internal time base accuracy}$$

where:  $f$  = measured frequency

$G$  = Gate time

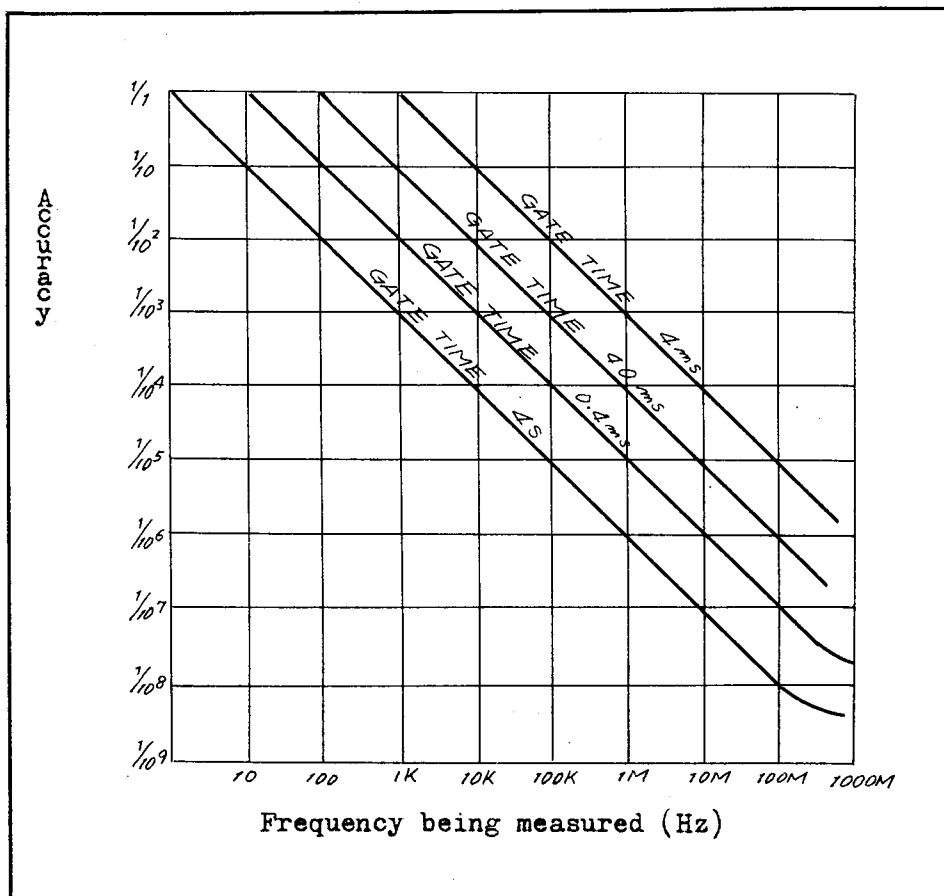


Fig. 3.4 Frequency measurement accuracy (typical characteristics)



The accuracy of -TR-3788C frequency measurements gradually deteriorates in the neighborhood of approximately 100 MHz. When the measured frequency reaches a certain high frequency, the  $\pm 1/f \cdot G$  in the formula in section 1 can be almost completely disregarded; however, the accuracy of the internal time base has a considerable affect on the counted results. Therefore, since the -TR-3788C has an accuracy of  $3 \times 10^{-9}$ , accuracy cannot be greater than  $3 \times 10^{-9}$  even at a 4 S GATE TIME.

High measurement accuracy can be obtained in high frequency measurements by using an internal time base (crystal oscillator) having high accuracy. At TAKEDA RIKEN, the accuracy of the internal time base of all digital counter series is guaranteed by an atomic standard frequency using the resonant frequency of cesium atoms.

Highly accurate frequency standards are emitted as general radio waves as national standards.

The national standard in Japan is JJY whose accuracy is maintained to within  $3 \times 10^{-9}$ . Moreover, if astronomical time is demanded of the standard, accuracy becomes  $1 \times 10^{-7} \sim 1 \times 10^{-8}$  due to multiple transmission paths, doppler effect, and fading. The TAKEDA RIKEN cesium atom frequency standard has a permanent stability of  $\pm 1 \times 10^{-11}$  and an absolute cesium time accuracy of  $\pm 1 \times 10^{-10}$ . This standard is used as a primary standard to guarantee the accuracy of the crystal oscillator used as a secondary standard to guarantee the accuracy of the internal time base of digital counters.

## 4. THEORY OF OPERATION

### 4.1 Basic Theory

Electronic counters generally have the basic construction shown in Fig. 4.1.

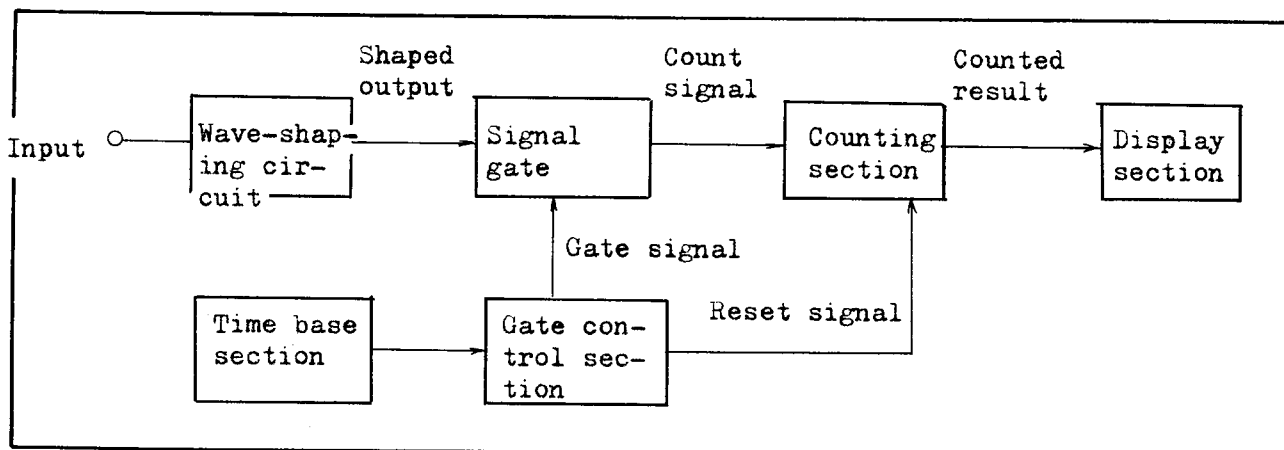


Fig. 4.1 Basic electronic counter construction

The input signal is shaped into a signal having a constant waveform, passed through the signal gate at a set time (count time), counted by the counting section, and the counted result displayed. This relationship is shown in Fig. 4.2. The 100 Hz, 10 Hz, and 1 Hz gate signal (counting signals) are obtained by dividing the accurate 1 MHz from the internal time base crystal oscillator by 10:1, 100:1, etc. and opens/closes the signal gate by controlling the gate control section with these signals.

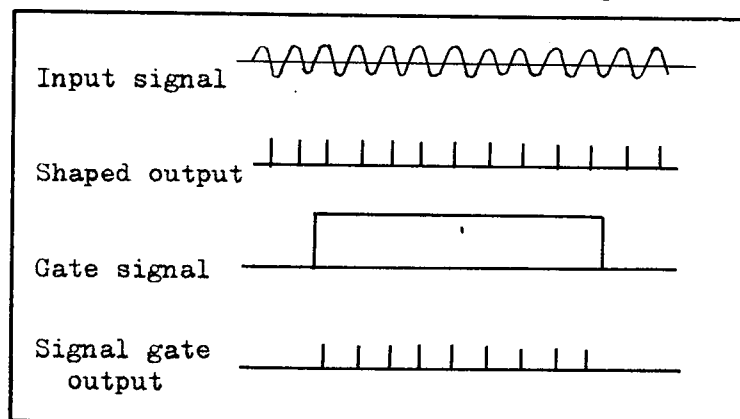


Fig. 4.2 Time chart

The 500 MHz input frequency is reduced to 125 MHz by dividing it by 4 and the 125 MHz then employed in the decimal counting circuit.

The counted results are not displayed as 1.4, even though the input frequency is divided by 4. Direct readout of the frequency is obtained by multiplying the counting time by 4.

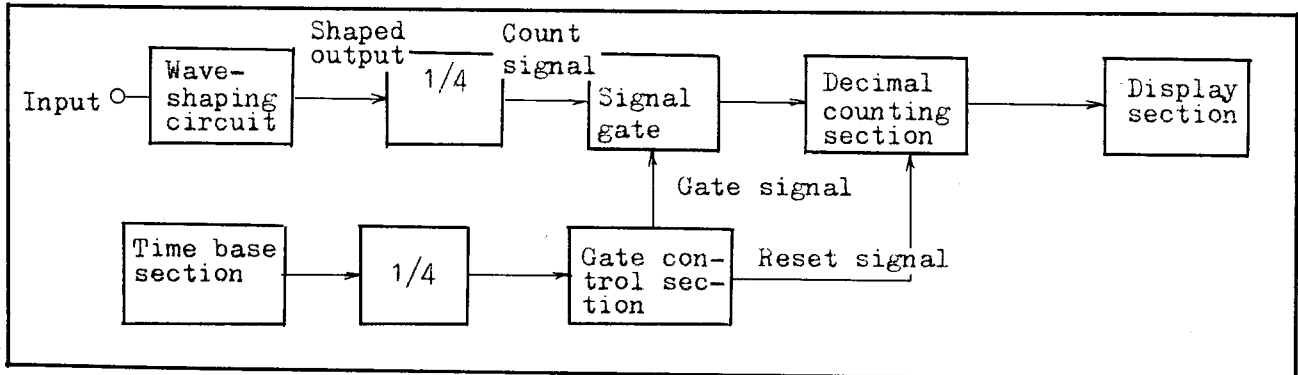


Fig. 4.3 Basic construction of the -TR-3788C

At this time, the clock signals are 25 Hz, 2.5 Hz, and 0.25 Hz in respect to 100 Hz, 10 Hz, and 1 Hz.

The operation cycle is; the gate opens once, the count is made, the counted value is fed to the display section, and all circuits except the display section then reset and returned to the next measurement state. The repetition speed of this operation is varied by adjusting SAMPLE RATE on the panel. Both automatic and manual sampling are possible.

#### 4.2 Frequency Measurement

The accurate 1 MHz signal from the crystal oscillator is amplified, shaped, and then divided by the divider to product the clock signal.

The accurate 4 mS (250 Hz), 40 mS (25 Hz), 0.4 S (2.5 Hz), and 4 S (0.25 Hz) clock signals produced in this manner are selected by means GATE TIME on the front panel, fed to the counting control circuit as the gate time, and used to control the opening/closing of the signal gate.

The signal to be measured is applied to the INPUT terminal on the other panel, amplified, shaped, and fed to the signal gate. The signal is then fed to the counting circuit (SCALER) only during the count time selected at GATE TIME. The counted result is displayed simultaneously with counting.

When the gate is closed, the gate signal is fed to the sample rate control circuit. This circuit is delayed by this signal for the desired period of time selected by means of SAMPLE RATE on the panel. A different date signal is fed to the gate control circuit to open the gate.

The above has been a description of this counter's automatic sampling operation at the same time the gate opening signal is produced, all circuits are reset and the next count performed. During memory display (set to STORAGE), the previously counted value is continuously displayed during the next count operation. The results of the next counting operation are then displayed after the gate closes and the count completed. In this process, only those digits of the following counted results which differ from the display of the previous count changed. The display does not flicker but remains steady.

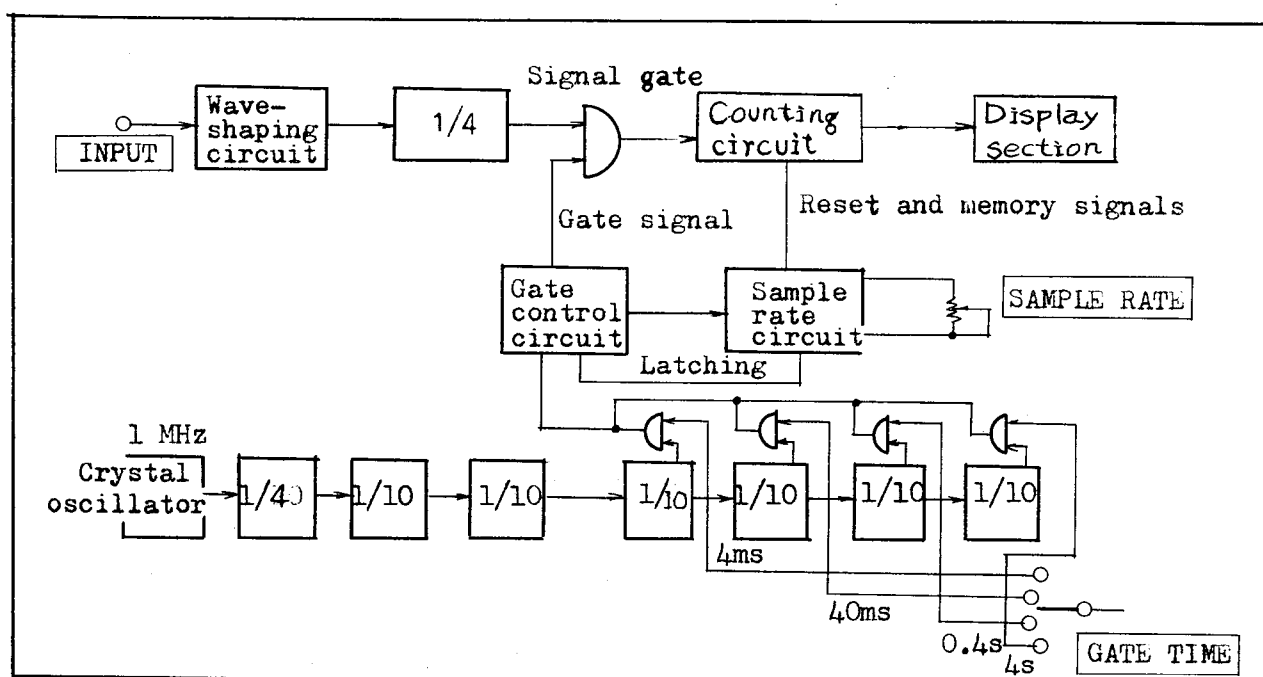


Fig. 4.4 Block diagram of frequency measurement

### 4.3 Frequency Measurement Accuracy

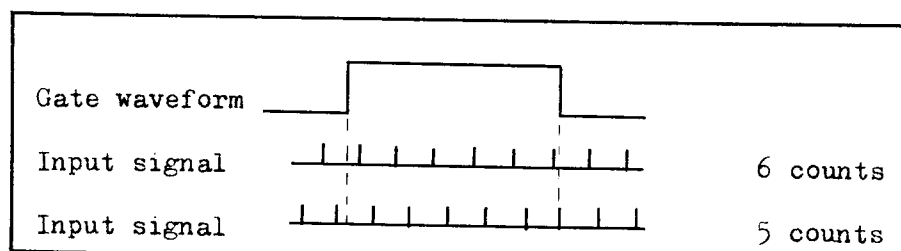
Frequency measurement accuracy is determined by the  $\pm 1$  count error inherent in the digital system and the accuracy of the internal time base.

Error is also generated when noise is included in the signal; however, when making frequency measurements by counting the input signal pulse pulses, error will not occur if the noise is lower than the trigger level (input sensitivity). Frequency measurement accuracy can be obtained with the following formula when the gate time is added.

$$\text{Frequency measurement accuracy} = \frac{1}{\text{full count}} \pm \text{internal time base accuracy}$$

However, the full count is [Measured frequency x gate time].

The  $\pm 1$  count error inherent in digital systems cannot be avoided, and is caused by the increase or decrease of the full count by 1 count due to the phase relationship between the signal pulse (measured signal after shaping) and the gate waveform as shown in Fig. 4.5.



When conditions are as shown in Fig. 4.5, the count should be 5.7 if measured with an analog system; however, due to the inherent quantization in the digital system, the 0.7 component will be either discarded or raised and the count will become either 5 or 6.

The 1 MHz internal time base signal is obtained by means of a crystal oscillator. All of the internal time base times are produced from this signal. For this reason, since the 1 MHz output of the crystal oscillator is an important factor controlling the measurement accuracy of the counter, it is necessary to maintain it at a high accuracy. Therefore, timely calibration is necessary.

#### 4.4 Self-Check

The 1 MHz crystal oscillator output is amplified, shaped, and fed to the divider to produce the 250 kHz, 25 kHz ... 2.5 Hz, and 0.2 Hz clock signals.

The 0.4 S (2.5 Hz) clock signal produced in this manner becomes the signal which opens/closes the gate. The signal pulse of the measured signal is fed to the counting section only when this signal is present. At this time, if the clock signal is applied instead of the signal to-be-measured, the counted results can be anticipated if the gate time is set because the time or frequency of the gate time and counted signal are known.

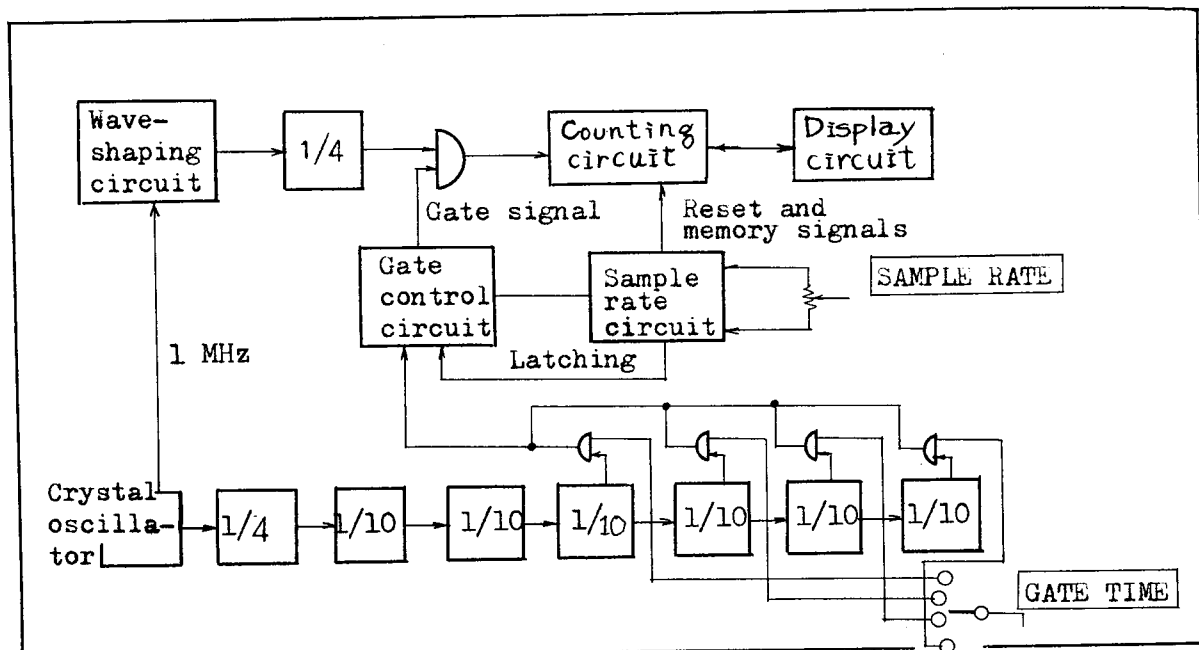


Fig. 4.6 Block diagram of self-check

#### 4.5 Active Elements and Their Construction

The basic circuit construction of the counter will be described by describing the active elements. This will make it easier to fully understand its theory of operation and circuit construction.

This counter employs all semiconductor components as active elements. Various semiconductor diode and transistors, as well as integrated circuits, are employed in the counter.

##### (A) Diodes

Semiconductor diodes are employed in the counter for power supply rectification and constant voltage applications, as well as in various gate circuits, trigger circuits, clamping circuits, and wave-shaping circuits. Typical examples of their use in gate circuits, trigger circuits, and constant voltage circuits will be given here.

Refer to (B) for information concerning wave-shaping circuits.

Fig. 4.7 is a typical gate circuit.

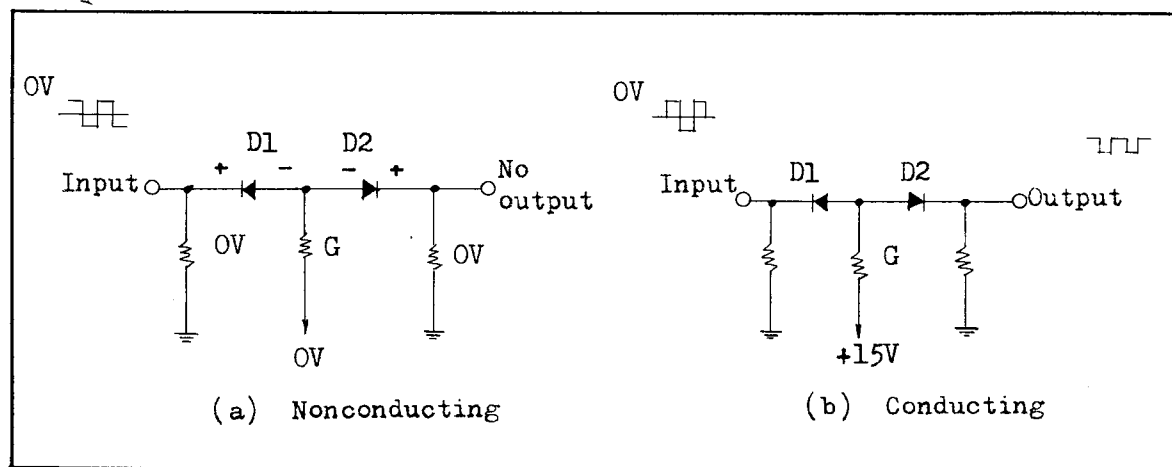


Fig. 4.7 Typical gate circuit

When point G in Fig. 4.7 (a) is 0 V (ground), D1 is in the conducting state (ON) in respect to the input voltage load and D2 is not conducting (OFF). In respect to a positive input D1 is OFF (nonconducting) and no output appears at the output terminals. When point G is clamped at -15 V as shown in (b), there is a range of voltage at which D1 and D2 are both ON (conducting) and the input signal passes through.

A gate which opens and closes is formed by the circuit shown in Fig. 4.7. Since gate circuit controls the amplitude of the input signal, it is called a limiter (or clipper) circuit.

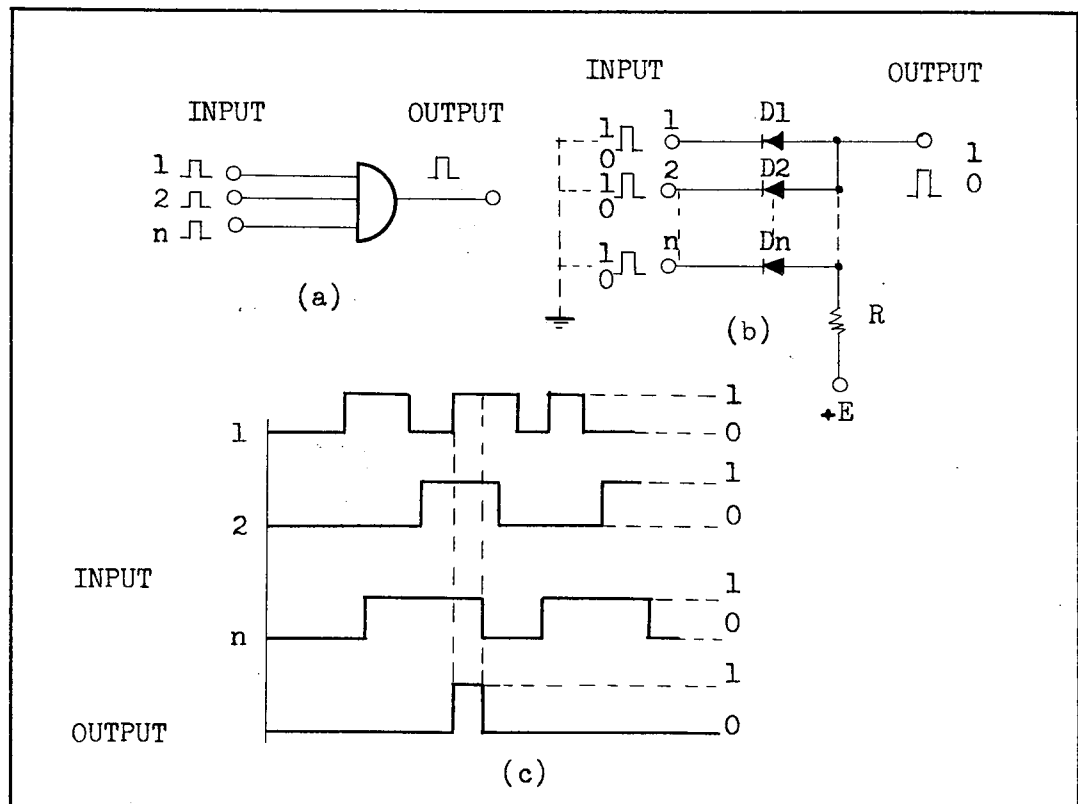


Fig. 4.8 Diode AND circuit

A circuit in which a "1" signal is generated at the output terminals only when there is a "1" (+ voltage) signal at 2 or n input terminals, as shown in Fig. 4.8, is called an AND circuit. The symbol generally used to denote and AND circuit is shown in (a). An example of an actual diode AND gate is shown in (b). Terminals 1, 2, ... n in the figure are grounded through the pulse source.



If a "0" (zero voltage) signal is simultaneously applied to terminals 1, 2, ... n, the dc source circuit is  $R \rightarrow D1, D2, \dots Dn \rightarrow$  internal impedance of the pulse source, a positive bias is applied to the diodes and forward current flows.

If R is large compared to the impedance of the pulse source and the forward resistance of the diodes, OUTPUT is nearly at ground potential and an output does not appear.

When a "1" (+ voltage) is applied to INPUT, the diodes will conduct even if the "1" voltage is lower than +E; however, since the internal impedance of the pulse source is low, the OUTPUT will generally be almost the same as the INPUT voltage.

When the "1" voltage is greater than +E, the output will be +E regardless of the input voltage since the diodes are then cutoff.

Since output only appears when all the inputs are "1", this circuit is called an AND gate.

The waveforms of this circuit are shown in Fig. 4.8 (c).

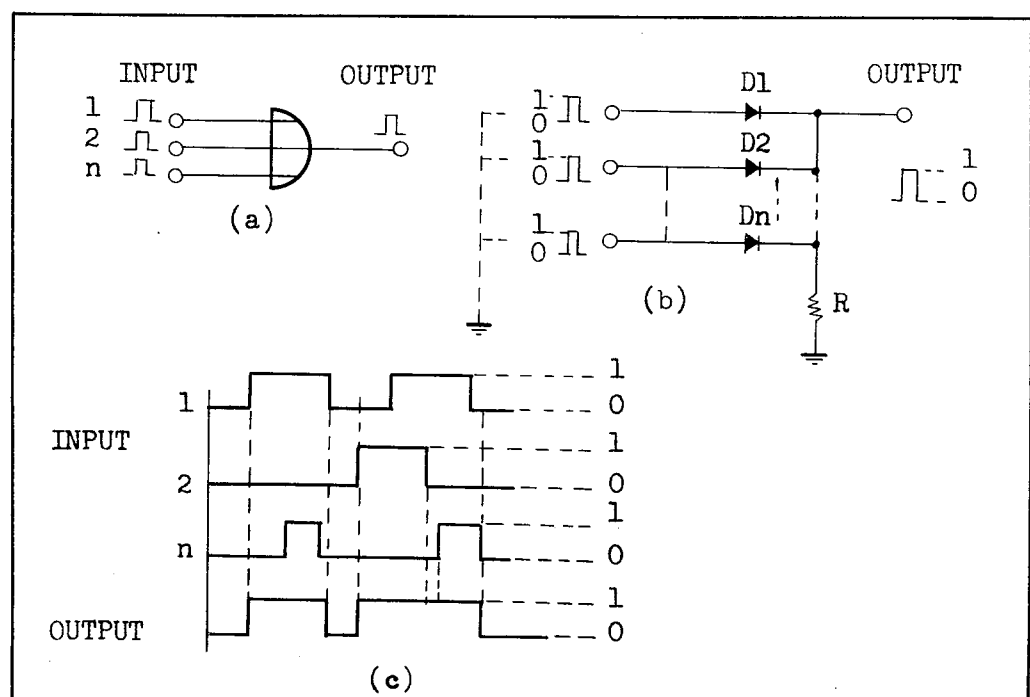


Fig. 4.9 Diode OR circuit

A diode OR circuit is shown in Fig. 4.9. The circuit in Fig. 4.9 is called an OR circuit because a "1" output is generated if a "1" signal is applied to any one of the input terminals (1, 2, or n).

The symbol generally used for the OR circuit is shown in Fig. 4.9 (a). An example of an actual OR circuit is shown in (b).

Terminals 1, 2, ... n in Fig. 4.9 (b) are grounded through the pulse source.

When terminals 1, 2, ... n are all "0", the diodes are reversed biased and, since all the diodes are cutoff, an output does not appear at OUTPUT.

If a "1" signal is applied to any one of the terminals, an output will appear at OUTPUT during the time that the signal is applied since that diode will be forward biased during the period the signal is applied.

Since an output will appear at OUTPUT if a "1" signal is applied to any of the input terminals, this circuit is called an OR circuit. When a signal appears at the output terminal from one of the input terminals, the other terminals are not affected since all the terminals are independent.

Fig. 4.10 is a comparison of a limiter type differentiator circuit employing a diode and conventional RC differentiator circuit.

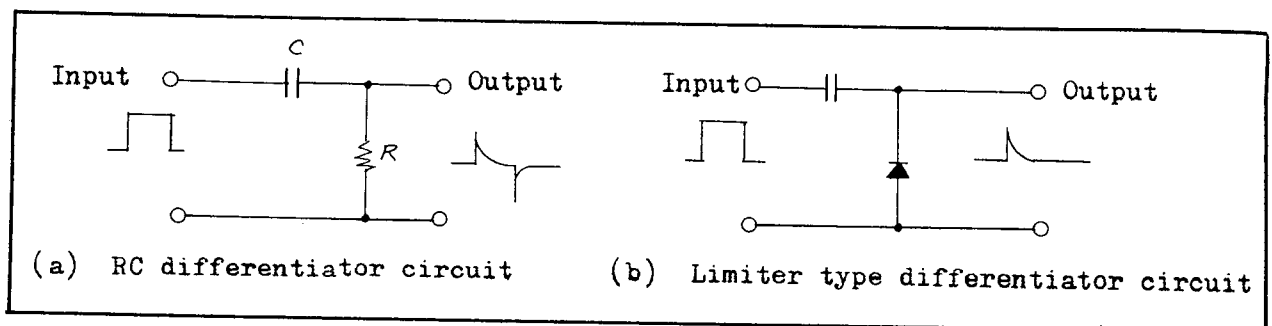


Fig. 4.10 Limiter circuit

When a square-wave is differentiated with a conventional RC differentiator circuit as shown in (a), positive and negative differentiated waveforms appear. This is not favorable for use in counters. When a diode is used as in (b), it is a limiter differentiator circuit and either the positive or negative waveform, whichever is unnecessary, is eliminated. Wide use is made of limiter differentiator circuits in this counter to prevent

erroneous counting and division in the counting circuits, dividing circuits, etc.

When a diode is used as a constant voltage circuit, both its forward voltage drop and its reverse zener voltage (zener diode) can be employed. A constant voltage circuit employing a zener diode is shown in Fig. 4. 11.

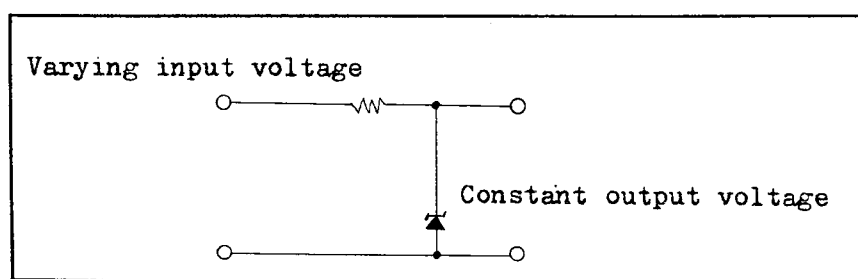


Fig. 4. 11 Constant voltage circuit employing a zener diode

The voltages of the various power supplied in this counter are made constant by a combination of zener diodes and transistors.

A circuit employing the forward direction of a diode is employed to make low voltages constant since voltages of 0.5 ~ 0.8 V can be obtained if a silicon diodes is used.

#### (B) Transistors

This counter employs various types of transistors in the wave-shaping circuit and as Schmitt circuits, flip-flop circuits, and amplifier circuits corresponding to the purpose of the circuit.

There are three basic transistor configurations, grounded emitter, grounded collector, and grounded base as shown in Fig. 4.12.

The features of these basic configurations are listed in Table 4.1.

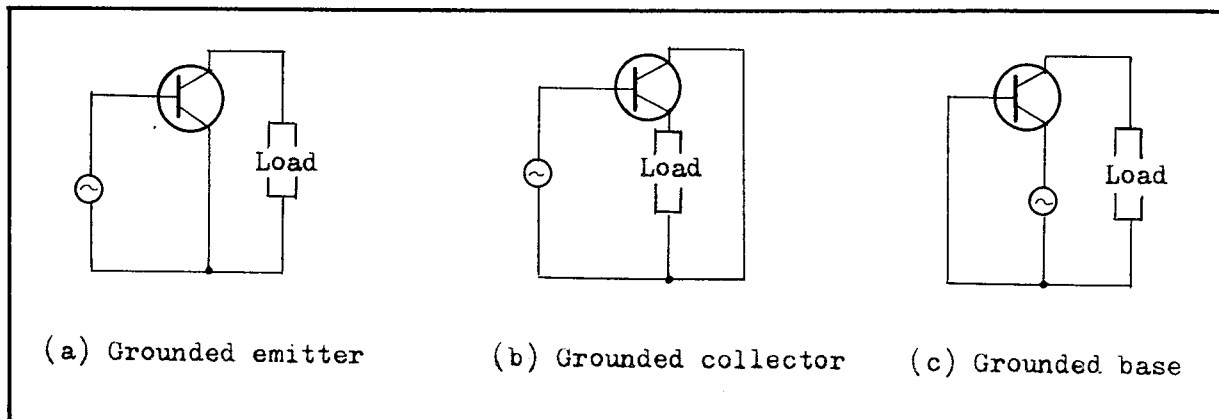


Fig. 4.1 Features of basic transistor configurations

Configuration	Input impedance	Output impedance	Voltage gain
Grounded emitter	Medium	Medium	High
Grounded collector	High	Low	None
Grounded base	Low	High	Medium

The above is for NPN type transistors; however, everything is the same for PNP type transistors except that current flow is in the reverse direction. This counter employs the grounded emitter in the majority of circuits; only a very small portion employs the grounded collector.

The grounded collector has no voltage gain; however, since its input impedance is high and its output impedance low it is used as an impedance converter.

This type of circuit is called an emitter follower.

#### 1) Amplifier

Circuit board WA92 is a 10 Hz ~ 500 MHz wideband, fixed gain amplifier. For this reason, transistors having superb high frequency characteristics are employed.

## 2) Wave-shaping circuit

When counting, it is necessary to shape the input signal and other signals into a waveform having short raise and fall times in order to amplify, transfer, count, and divide them.

The wave-shaping circuit widely employed to accomplish this is the emitter coupled binary circuit. This circuit is called a Schmitt circuit after the inventor.

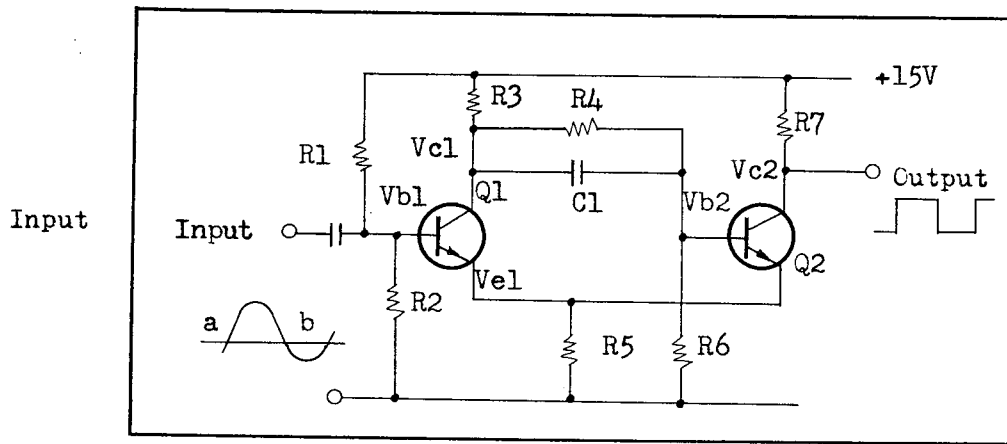


Fig. 4.13 Typical Schmitt circuit

An example of this circuit is shown in Fig. 4.13. If  $R_1$  and  $R_2$  are selected so that  $Q_1$  base voltage  $V_{b1}$  is lower than the voltage drop across  $R_5$  ( $Q_1$  emitter voltage  $V_{e1}$ ), bias voltage  $V_{b1}$  will be applied.

This cuts off  $Q_1$ . If  $R_4$  and  $R_6$  are large,  $Q_1$  collector voltage  $V_{c1}$  will be almost equal to the +15 V supply voltage.

If  $R_4$  and  $R_6$  are selected so that  $Q_2$  base voltage  $V_{b2}$  is slightly higher than  $V_{e1}$ ,  $Q_2$  conducts (ON) and the output voltage at  $Q_2$  collector  $V_{c2}$  will be almost proportional to the values of  $R_5$  and  $R_7$ .

This stable state will continue ( $Q_1$  OFF and  $Q_2$  ON) until an input signal is applied. The input signal applied is shown in the figure. When the input signal is large (as shown by (a) in the figure),  $V_{b1}$  exceeds  $V_{e1}$  and  $Q_1$  conducts (ON state). In this state,  $Q_1$  current starts to flow,  $V_{c1}$  drops,  $V_{b2}$  rises, and  $V_{e1}$  drops. The base to emitter voltage of  $Q_1$  becomes large,  $V_{c1}$  steadily

drops, and  $V_{b2}$  drops. The loop gain becomes greater than 1 by this action, and positive feedback is present until Q2 suddenly turns OFF (Q1 and Q2 OFF).

Next, the input voltage starts to drop as shown by (b) in the figure.

$V_{b1}$  drops, the current flowing through Q1 decreases, and  $V_{c1}$  starts to drop.

When  $V_{b1}$  rises, it eventually turns Q2 ON.

When Q2 is on, current starts to flow through it,  $V_{e1}$  becomes high, and, as a result, the base-to-emitter voltage of Q1 drops,  $V_{c1}$  steadily rises, and  $V_{b1}$  becomes high.

In this way, positive feedback is applied, Q1 suddenly turns OFF, and the original stable state is reached (Q1 OFF and Q2 ON).

The above was a description of the theory of operation of the Schmitt circuit. Since a fixed output having a rise time, fall time, and amplitude, in respect to various input signals can be obtained, it is used as a wave-shaping circuit.

One characteristic of a Schmitt circuit is that input voltage  $E^+$  (when Q1 is ON and Q2 is OFF) and input voltage  $E^-$  (when Q1 is OFF and Q2 ON) do not coincide.  $E^+$  is higher than  $E^-$ ;  $E^+ - E^- = E_h$ , called the hysteresis voltage, becomes the input sensitivity of the Schmitt circuit. The cause of hysteresis is that after Q1 turns ON and Q2 turns OFF,  $E^+$  exceeds the input voltage and Q2 does not turn on since voltage  $V_{b2}$  becomes extremely low despite the fact that  $V_{e1}$  is the same as the original voltage even when  $E^+$  drops below the input voltage. It is necessary to make  $V_{b2}$  large by dropping the input voltage in order to turn Q2 ON and  $E^-$  becomes lower than  $E^+$ .

The above is shown in diagram form in Fig. 4.14. Since erroneous operation will occur if noise in the signal is greater than  $E_h$ , careful attention is required. (Refer to Fig. 4.15.)

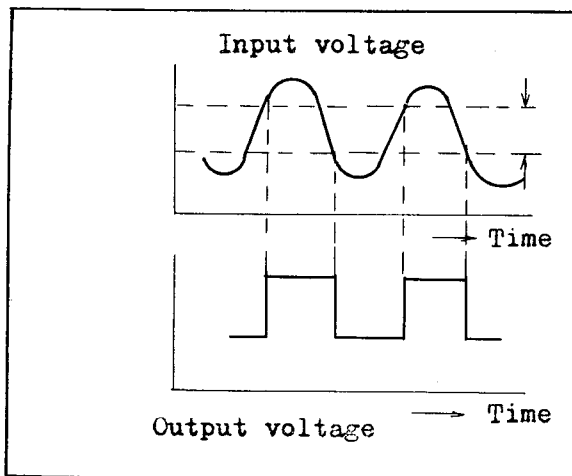


Fig. 4.14 Schmitt circuit output voltage

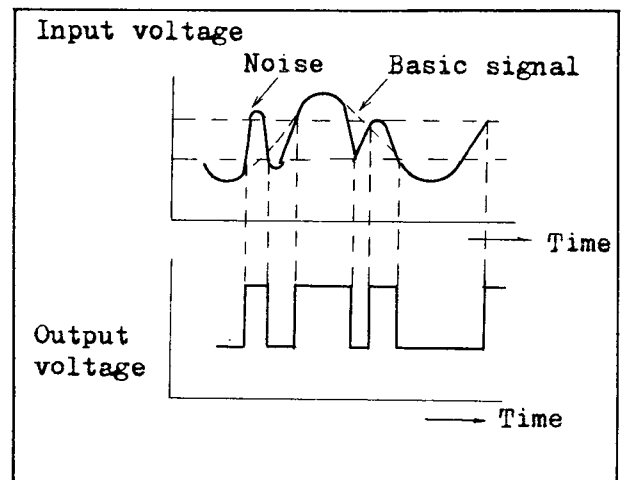


Fig. 4.15 Erroneous operation due to noise

### 3) One-shot multivibrator

When counting, the accurate internal time base must be divided to a low frequency in order to be used as a TIME UNIT and TIME GATE.

Phantastron circuits, one-shot multivibrator circuits, and flip-flop circuits are typical system widely employed to accomplish this.

A description of the one-shot multivibrator will be given here. Unlike the Schmitt circuit described previously and the flip-flop circuit to be described later which have two stable states, this circuit has only one stable state.

The major point of difference between this circuit and Schmitt and flip-flop circuits is that the output waveform can be changed to have any desirable pulse amplitude even when the amplitude of the trigger pulse is small.

A typical one-shot multivibrator is shown in Fig. 4.16.

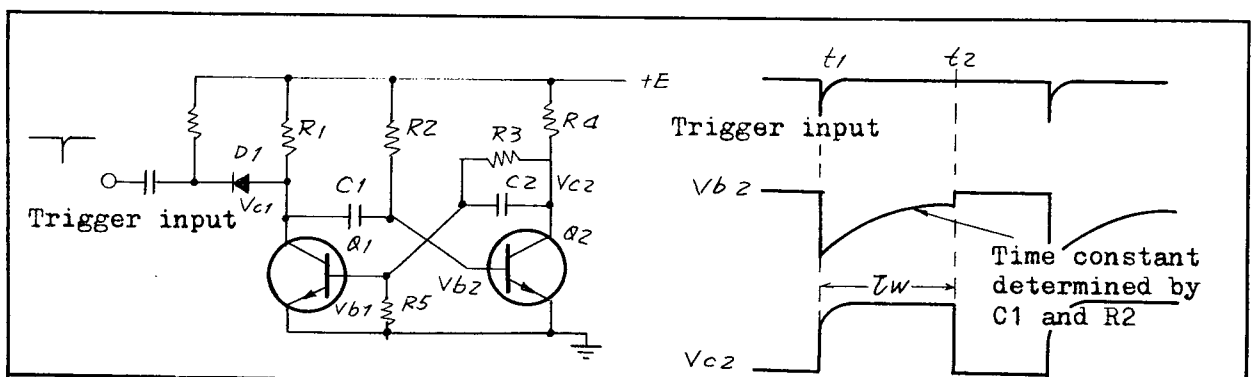


Fig. 4.16 One-shot multivibrator

When +E is applied in Fig. 4.16, Q1 is cutoff (nonconducting) and Q2 conducts (ON state). That is, current flows through Q2 and R2 turns ON, and, as a result, Q1 base voltage (Vb1) drops and Q1 turns OFF.

This is the state prior to t1. If a negative trigger pulse is applied at t1, the base of Q2 is triggered through D1.

This makes voltage Vb2 drop, Vc2 rise, and Vb1 rise. Vc1 drops due to the rise in Vb1, and Vb2 rises through C1.

The t1 state in (b) is the result of this regenerative action. The stable state continues through this period; however, since Vb2 is the voltage charged across C1, C1 discharges through this period; however, since Vb2 is the voltage charged across C1, C1 discharges through R2 (time constant of C1 and R2), as time approaches t2 from t1, Q2 shifts from the OFF state to the ON state at exactly t2, Vb1 drops through R3 and C2, and Vc1 rises. The circuit is shifted to the Q1 OFF, Q2 ON stable state during this instant at t2 by means of this regenerative action. The pulse width  $\tau_w$  at this time is essentially determined by the time constant of C1 and R2 and can be expressed as  $\tau_w = 0.7 C1 \cdot R2$ .

The above has been an explanation of the theory of operation of the one-shot multivibrator. Since any desired pulse width can be obtained by changing the time constant of C1 and R2, this circuit is employed for time division, in addition to circuit delay and voltage control.

3) The flip-flop circuit is the same as the previously described Schmitt circuit in that it is a binary circuit having two stable states.



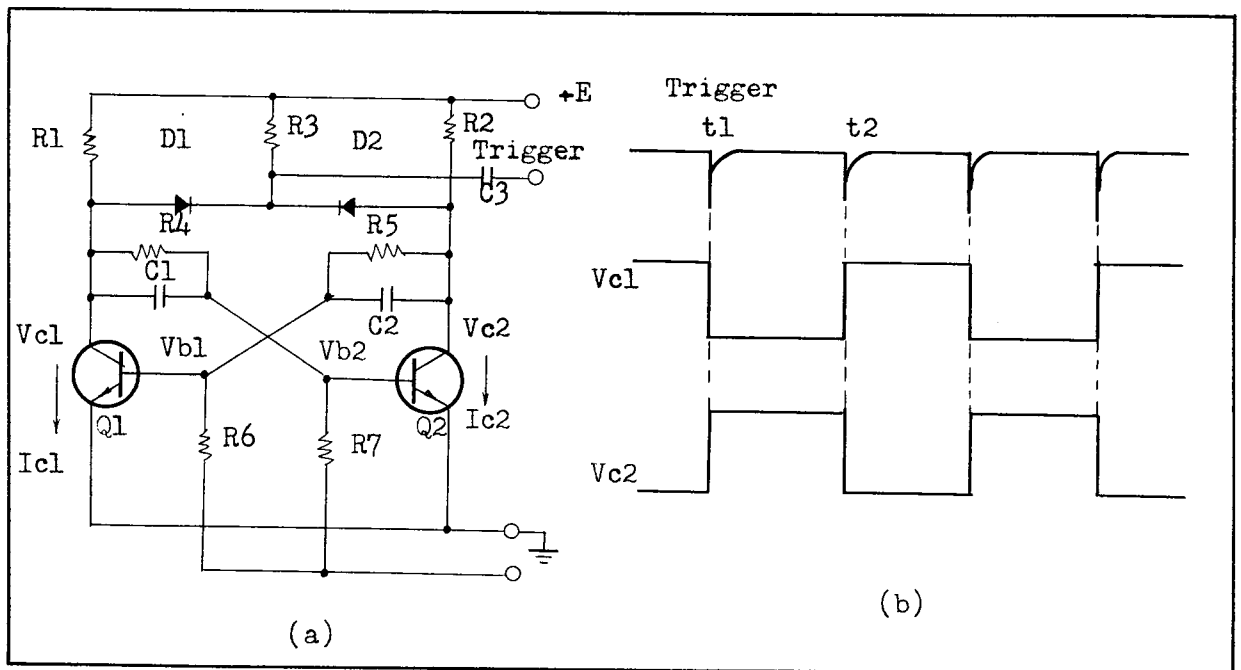


Fig. 4.17 Flip-flop circuit

As shown in the figure, since one output signal is obtained in respect to two input signals, the flip-flop circuit is employed as frequency divider.

The circuit in the figure is a binary divider; however, division to the required order can be obtained by connecting several of them in cascade and applying suitable feedback. Refer to 4.6 for information concerning the decimal divider (counting) circuit. Since the construction in the figure is completely symmetrical, which transistor (Q1 or Q2) enters the ON state when the switch is turned on cannot be predicted. Assume that Q2 is ON. If this is the case, Vc2 becomes 0 V, bias from -E is applied to Q1, and Q1 turns OFF.

This is the stable state prior to t1 in (a) of the figure. If a negative trigger is applied at this time (t1), the pulse cannot pass through D2 since D2 is reverse biased and Vc2 is almost zero since Q2 is ON.

Since Q1 is in the OFF state, the trigger pulse passes through D1, and the Q2 bias voltage drops through D1 and C1.

Hence,  $I_{c2}$  decreases  $\rightarrow V_{c2}$  rises  $\rightarrow V_{b1}$  rises  $\rightarrow I_{c1}$  starts to flow  $\rightarrow V_{c1}$  rises and Q1, Q2 ON OFF are switched by the regenerative action of the drop in  $V_{b2}$ .

This is the second stable state.

If a trigger pulse is applied at  $t_2$ , the pulse enters at D2 and Q1 and Q2 return to the state they were in prior to time  $t_1$ .

#### 4.6 Decimal Counting Circuit Operation

There are various types of pulse counting circuits; however, a binary circuit is generally employed because of its counting speed and other factors.

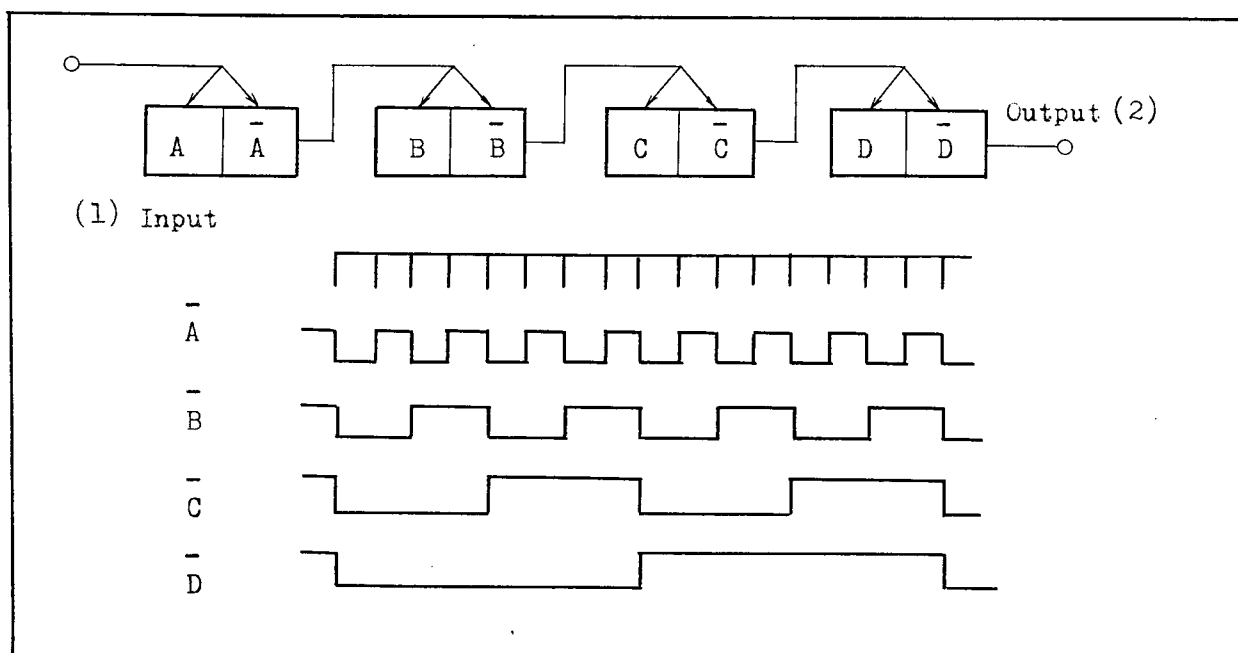


Fig. 4.18 Base 16 counting circuit

This base 16 counting circuit is converted into a decimal counting circuit by applying a suitable gate and feedback.

Refer to 4.7 concerning the integrated circuit employed as the decimal counting circuit.

#### 4.7 Description of the Operation of Each Block

This counter employs a module system and, since it is divided into blocks having various functions, a description of each block will now be given.

##### 1) Time base section (3D45, 3D12)

The time base section is the heart of the counter. The time base section of this counter is 3D45 and 3D12.

The time base section is broadly classified into a 1 MHz crystal oscillator circuit, a wave-shaping circuit for its output or for an external time base signal, and dividing circuits down to 0.25 Hz.

Its form when 4 flip-flops are connected in cascade is shown in Fig. 4.18. If this construction is employed since one output pulse is obtained in respect to two input pulses, in the so-called base 16 circuit, 1 output pulse will be obtained for every 16 input pulses. As shown in Fig. 4.19, flip-flops J - K are used to obtain a decimal divider. That is, the transistor in the ON state shifts to the OFF state and the transistor in the OFF states inverts to the ON state. The action following the second stage is shown in the time chart at the bottom of Fig. 4.19. This forms a decimal divider having 1 output pulse for every 10 input pulses.

In the dividing circuit (5D45, 5D12), the 1 MHz from the crystal oscillator is divided to 25 Hz, 2.5 Hz, etc. by the use of 6 decimal divider stages and a base 4 divider circuit.

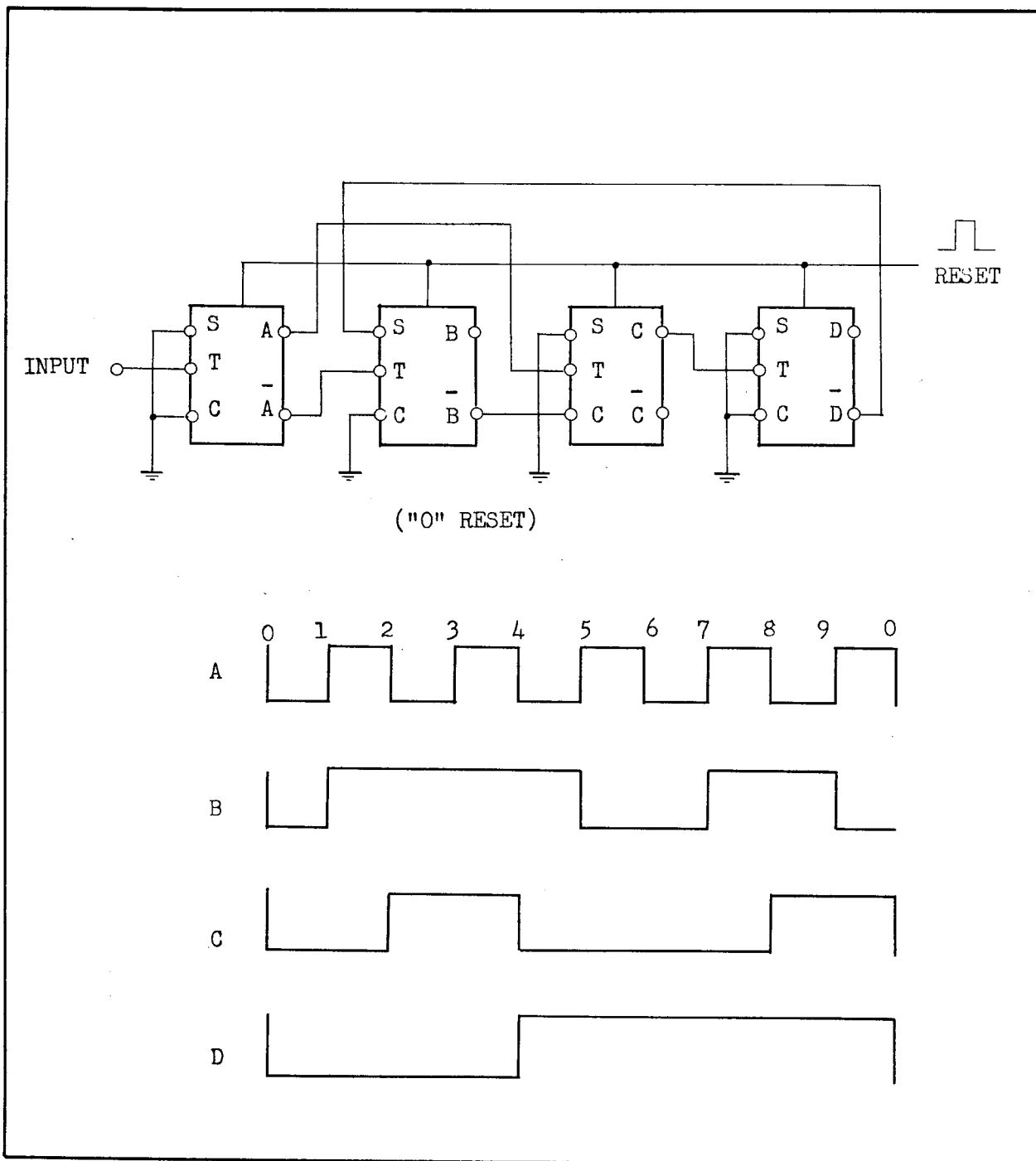


Fig. 4.19 Decimal divider formed from flip-flops J and K

## 2) Gate control circuit (3B30, 3B12)

The gate control circuit (3B40, 3B12) controls the opening and closing of the signal gate at a set time interval. In addition, it also controls the sampling time after counting or at any desired time, generates a reset pulse to manually reset all circuits to their original zero state, generates a memory pulse to instruct the memory during memory display, and is the circuit which lights the neon tube during the period when the gate is open.

Fig. 4.20 is a block diagram of 3B40 and 3B12. Binary in the diagram is a special name for a flip-flop. A one-shot circuit is employed.

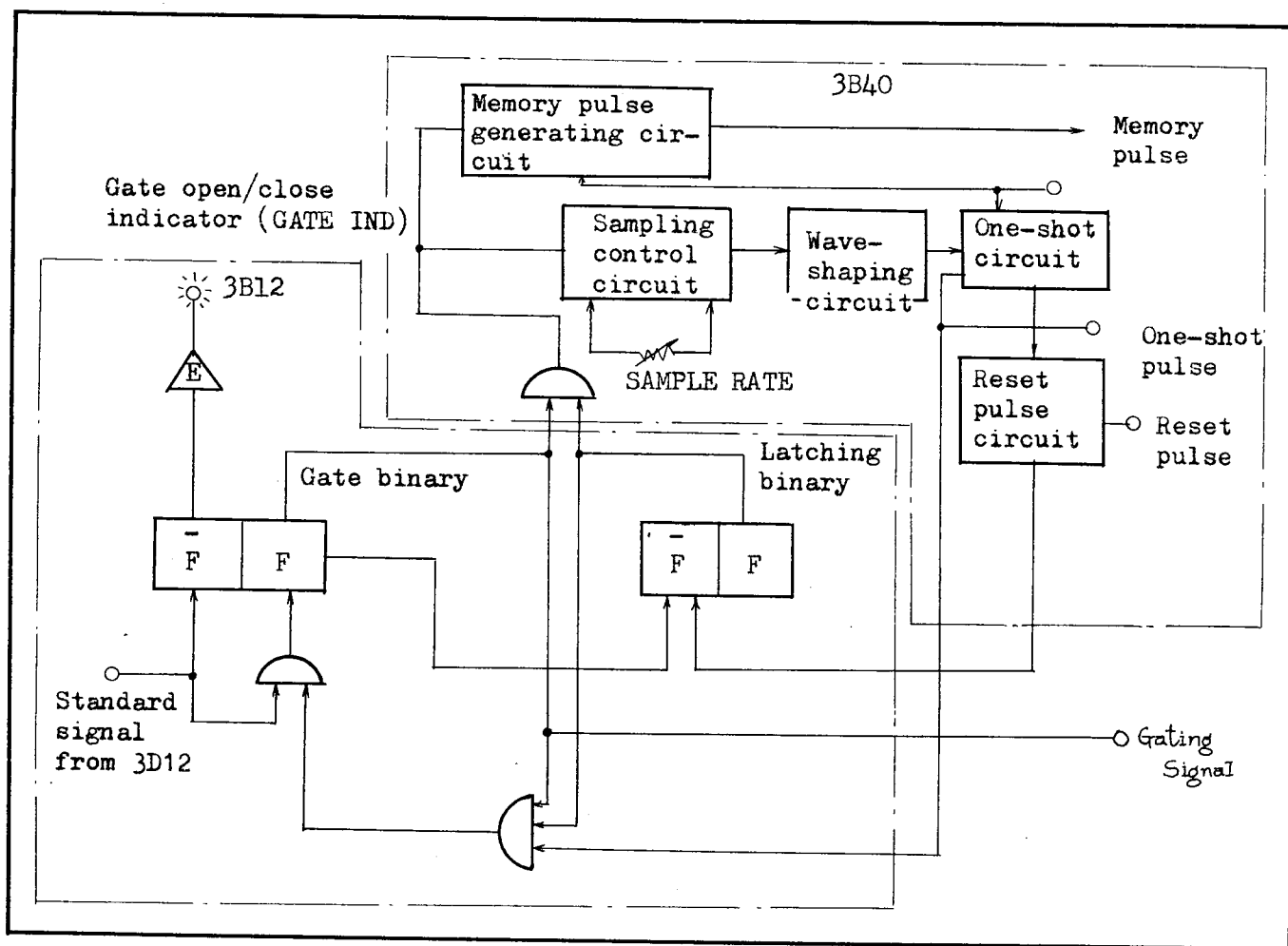


Fig. 4.20 3B40, 3B12 block diagram

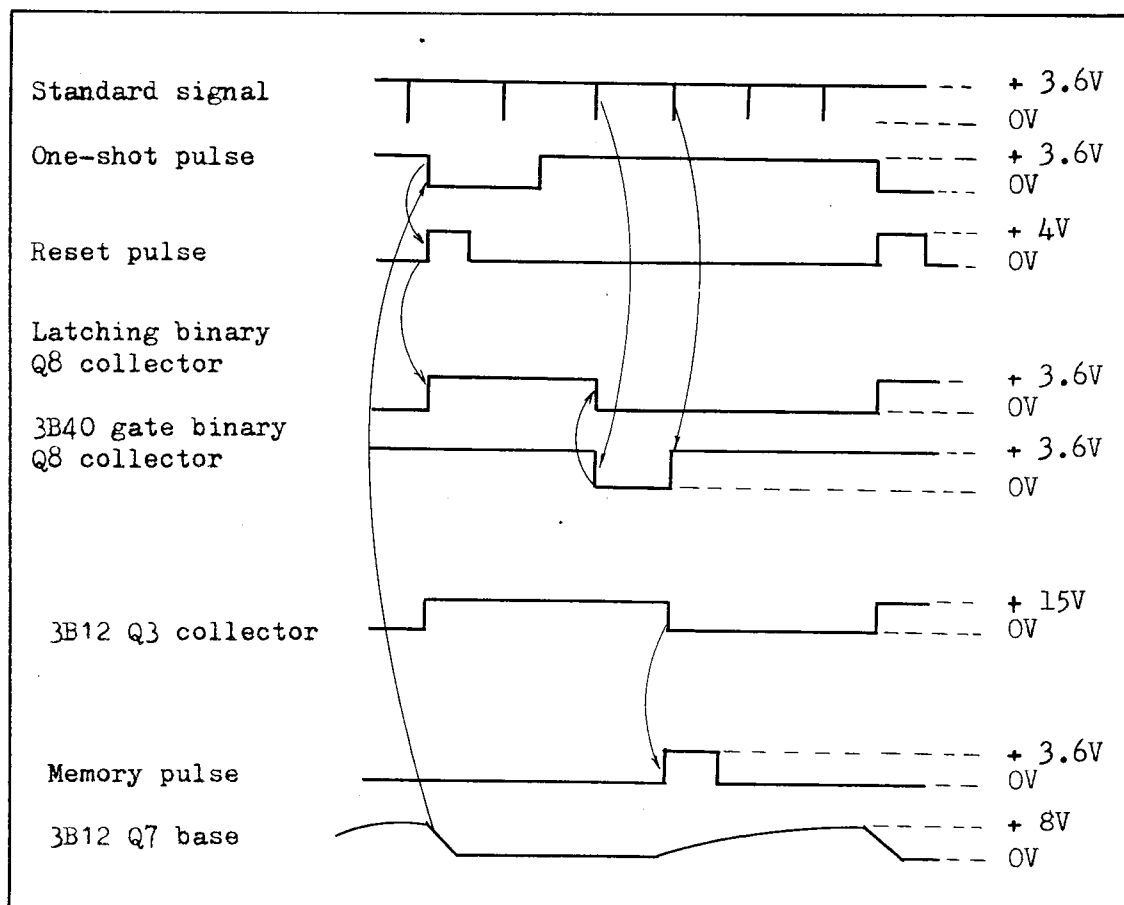


Fig. 4.21 3B40, 3B12 timing chart

### 3) 15 MHz counting circuit (~~3B40~~)

This circuit divides a wide range of frequencies (0.25 Hz ~ 15 MHz) by 10:1. This circuit is called a counting circuit not because it divides in the manner of a dividing circuit but because it displays the counted result.

This is the same as the dividing circuit described previously; however, as shown in Fig. 4.22, there is no feedback but it is changed into a decimal counting circuit by means of the gate circuit. This is done to obtain high resolution since there is a phase delay when feedback is employed.

Fig. 4.22 shows the operating waveforms in various points in the circuit.

#### 4) Other circuits

In addition to the blocks (circuits) already described in the above, there are blocks which shape the output of the wideband amplifier, a 40: 1 dividing circuit, 2 MHz counting circuit (3C40), display circuit (3C10), and power supply circuit (3E14).

3C40 is the 2 MHz counting circuit which contains the display circuit and memory circuit.

3C10 is the count display circuit and memory circuit for the counted result.

#### 5) General

The above has been a description of the individual circuits employed in this counter. The various circuits are combined in the instrument to satisfy all the specifications in section 2.

A general block diagram of the counter appears in Fig. 4.23.

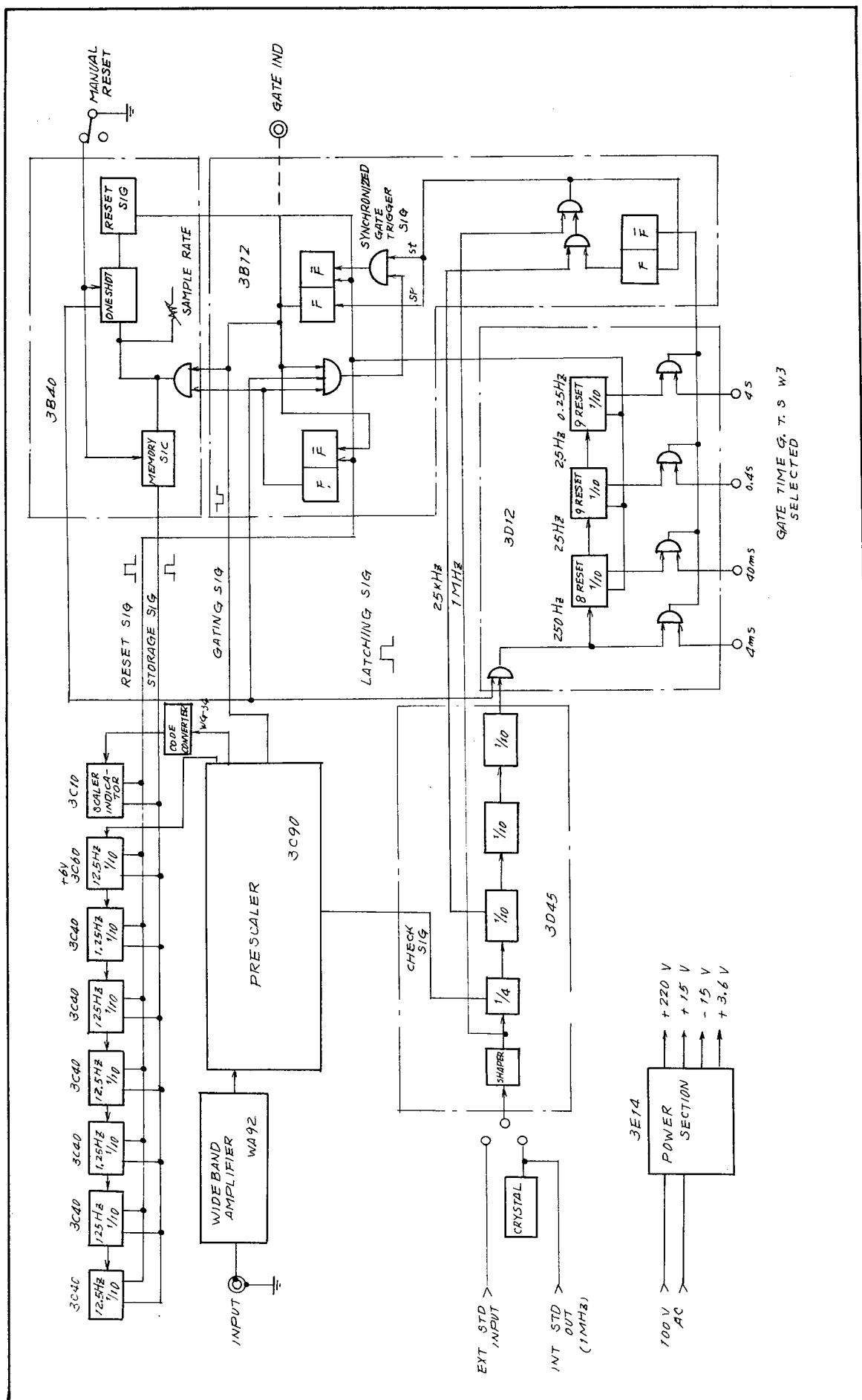


Fig. 4.23 General block diagram of the -TR-3787/3788



## 5. MAINTENANCE AND INSPECTION

### 5.1 Introduction

This section covers various important points relating to maintenance, maintenance procedures, instruments necessary for maintenance, performance checks, and adjustment procedures for the -TR-3788C FREQUENCY COUNTER. This is accomplished with the use of diagrams and charts. Assembly procedures, simple inspection, and repair procedures to be followed in the event of trouble are also described. When conducting maintenance and inspection, refer to the circuit diagrams and parts list appended to the end of this section.

### 5.2 Important Points Relating to Maintenance

Pay careful attention to the following points to obtain stable, highly accurate measurements over a long period of time.

- 1) Always wear white gloves when conducting maintenance, inspection, or adjustment on the counter.
- 2) Use a power source within the specified value (220 V  $\pm 10\%$ , 50/60 Hz).  
NOTE: Connect the power cord to the AC input terminal only after confirming that the power switch is set to the OFF position.
- 3) Cooling air is fed in from the side of the counter.

Therefore, always pay careful attention to avoid blocking the air flow around the counter.

- 4) The ambient temperature range in which the counter can be used is  $0^{\circ}\text{C} \sim +40^{\circ}\text{C}$ .
- 5) Its storage temperature range is  $-20^{\circ}\text{C} \sim +70^{\circ}\text{C}$ .
- 6) Since a crystal oscillating element is employed, never subject the counter to extreme shocks or vibrations. Always handle the counter carefully.
- 7) Use a noise filter when there is a considerable amount of noise in the AC power source.
- 8) Since the internal signals in the counter can leak out, ground the case.

9) When highly accurate measurements are required, calibrate the internal crystal oscillator.

10) The internal heater operates when the constant temperature oven power switch is set to OVEN even if the power switch (POWER) is set to OFF.

11) The warm-up time for this counter is 48 hours.

12) Refer to section 2 for input voltage specifications; do not apply excessive input.

13) When disassembling the counter, be sure not to loose any of the screws.

### 5.3 Instruments Necessary for Maintenance and Inspection

The instruments required to check the performance, troubleshoot, repair, and adjust the counter are listed in Table 5.1.

Other test equipment having the same specifications, performance, etc. as that of those below can also be used.

Table 5.1 Instruments required for maintenance and inspection

Instrument	Ratings	Remarks
Slidac	220 VAC use 0 ~ 260 V Greater than 150 VA	Checking individual points and power supply voltage changes
VTVM	DC input impedance Greater than 10 MΩ Accuracy 5% 0.1 ~ 300 V AC input impedance Greater than 1 MΩ Accuracy 5% 0.1 ~ 500 Vrms	Measurement of power supply voltage and other voltages
DC voltmeter	0.1 ~ 300 V Accuracy 0.5%	Power supply voltage adjustment
Oscilloscope	Frequency range DC ~ 500 MHz Voltage sensitivity 0.1 ~ 200 V	Observation and measurement of voltage waveforms in each section measurement of external input waveforms and internal signals

Instrument	Ratings	Remarks
Signal generator	Frequency range 10 Hz ~ 10 MHz Output voltage 5 mV ~ 10 V	As input signal for measurements and performance checks
Signal generator	Frequency range 10 MHz ~ 100 MHz Output voltage 5 mV ~ 10 V	Measurements and performance checks
Signal generator	Frequency range 100 ~ 700 MHz Output voltage 5 mV ~ 10 V	
High-frequency, high accuracy voltmeter	Frequency range 10 Hz ~ 700 MHz Detection sensitivity Better than 1 mV	Input, output, signal voltage measurements, frequency band measurements
Ohmmeter	Input impedance Greater than 10 MΩ Measuring range Greater than 0.1 Ω	Circuit resistance measurements
Variable attenuator	Frequency range 10 Hz ~ 700 MHz Attenuation Better than 0 ~ 40dB	Performance checks
Frequency standard	1 MHz sine-wave Accuracy $1 \times 10^{-10}$	Measurement of internal time base accuracy

#### 5-4 Performance Check

Performance checks to determine whether or not all the circuits and functions of the counter operate normally should be performed at the following times.

1. As part of the check of counter specifications when first received.
2. Periodically to maintain maximum reliability.
3. As part of troubleshooting to ascertain the location of the faulty circuit.
4. To return the counter to its normal state after repair and adjustment.

- 1) Checking the self-check operation (refer to 3.4)
  - a. GATE TIME CHECK
  - b. SAMPLE RATE Fully counterclockwise
  - c. STORAGE/NON-STORAGE STORAGE or NON-STORAGE  
(Confirm that the display does not change at this time)

Check to see whether or not 001000.00 kHz is displayed when the controls are set as shown above.

- 2) Checking the frequency measurement operation (Refer to 3.5)
  - a. GATE TIME 0.4 S
  - b. SAMPLE RATE Fully counterclockwise
  - c. STORAGE/NON-STORAGE STORAGE
  - d. Connect a signal from the signal generator to the INPUT terminal of the counter with the input cable. Make the input signal voltage greater than 10 mVrms at this time.
  - e. Measure the 10 Hz ~ 10 MHz signal generator frequency with the counter at a constant 10 mVrms.
  - f. Measure the 10 MHz ~ 100 MHz and 100 MHz ~ 500 MHz frequencies in the same manner as in the above at a constant 10 mVrms.

NOTE: Conduct measurements with a 50  $\Omega$  termination when noise is present in the cable or when the cable must be long in frequently measurement.

- 3) Switch STORAGE/NON-STORAGE at the rear panel and confirm that both memory display and count display are normal.
- 4) The display time can be varied from approximately 80 ms ~ 5 S by turning SAMPLE RATE clockwise. When set to HOLD, the counted result is maintained.
- 5) GATE TIME establishes the count time for self-checking and frequency measurement.

There are only four times (4, 40 mS, 0.4, 4 S); however, all of these are produced by the internal crystal oscillator.

6) Input level

The input sensitivity of INPUT is 10 mVrms.

The maximum input voltage at INPUT is 2 Vrms.

Pulse input sensitivity is  $\pm 30$  mVp.

7) Reading units

The kHz, MHz, and decimal point position are automatically activated by the GATE TIME switch.

8) Power supply voltage variations

Since the counter specifications are 220 VAC  $\pm 10\%$ , 50/60 Hz, confirm that counter operation is normal within this range.

In addition, confirm that power consumption at this time is approximately 65 VA.

9) Internal time base signal

Frequency	1 MHz, sine-wave
Voltage	1 Vrms below 10 Vrms
Impedance	Approx 10 k $\Omega$

The counter can be operated by an external 1 MHz signal.

Set the INT - EXT switch at the rear panel to EXT and connect a 1 MHz sine-wave signal greater than 1 Vrms to the BNC terminal.

Operation is performed by producing the time base signal of the counter by means of an external signal. This is used as the time base for frequency measurement and when high accuracy is required at the same time.

### 5.5 Troubleshooting

This counter employs all transistors and a circuit board system. Since strict product quality control is effectively conducted, trouble should almost never occur. However, if trouble should occur, it can almost

Always be corrected by merely changing circuit boards. Refer to section 4 for a description of the theory of operation of the counter.

Table 5.2 is a list of the circuit boards and a description of their functions. Various symptoms and their troubleshooting procedures are shown in Table 5.3. Perform inspection by checking the analysis numbers. In addition, refer to the attached circuit diagram, circuit waveforms diagram, and parts layout diagram when troubleshooting.

Table 5.2 Circuit boards and their functions

Circuit board	Circuit diagram	Function
3E14	POWER SUPPLY	Power supply circuit, control circuit
WA92	INPUT AMPLIFIER	Input circuit
3C90	1/40 SCALER	Base 40 counting circuit
WG34	CODE CONVERTER	Code converter circuit
3C10	DECIMAL SCALER	Decimal counting circuit
3C60	DECIMAL SCALER	Decimal counting circuit
3C40	DECIMAL SCALER	Decimal counting circuit
3B40	GATE CONTROL	Gate control section, Gate control circuit
3B12	GATE CONTROL	Gate control section 4:1 - 10:1 sample rate circuit
3D45	DIVIDER	Time base section, wave-shaping circuit, 10:1 - 10:1 dividing circuits
3D12	DIVIDER	Time base section, 10:1 - 10:1 - 10:1 dividing circuits

Table 5.3 Troubleshooting and repair

Symptom and location	Trouble location and cause	Corrective action
(1) Power lamp does not light when the power switch (POWER) is set to POWER.		
A. Check to see if the fuse at the rear panel is blown	A) Abnormal AC power supply B) Internal wiring is shorted C) Shorted to ground due to defective part	Check to see if it is the specified value Check the individual power supplies Correct the faulty point and replace the defective part
B. Power supply check 1) No output voltage	POWER SECTION: A) Power transformer T1 open B) Defective S1 a-d contacts C) Rectifier is open D) Defective electrolytic capacitor  3E14 A) Defective zener diode B) Q1-Q4 in the POWER SECTION or Q1 - Q9 in 3E14 are defective C) Check individual components	Replace defective parts " " "  Replace defective parts " "
2) Measure various voltages +15 V -15 V +3.6 V +220 V (These are voltages to ground)	Defective transistor or diode	Replace the defective part
(2) 1000 kHz is not displayed at the self-checking operation		
A. Check the time base section (3D45)	When oscillations cease, either the crystal is defective or the FREQ ADJ variable capacitor is defective.	Replace the defective parts
B. Dividing circuits (3D45, 3D12) and counting circuits (3C60, (1) Use an oscilloscope to make sure the relationship between the input and output of each decimal circuit in the counting circuits and dividing circuits is 10:1.	The same type boards are mutually interchangeable; when a board is defective verify whether the board or the wiring is defective by always changing the board.	Replace the defective board

2) Check for a defective board	Make your judgement by the waveforms of each decimal circuit (4 flip-flops) and locate the defective part in the defective flip-flop.	Replace the defective part
C. Check the display circuit (Check this when the trouble is only in the display and not any of the abnormalities described thus far.) (Check the display section of each counting circuit)	Observe the waveforms at each section of each display section board and relocate the faulty point or defective part.	Replace the defective parts
D. Check the signal gate (3C90), gate control, sample rate (3B40, 3B12) 1) Check by observing the circuit boards with an oscilloscope and referring to the circuit diagram.	Do not perform this check until thoroughly understanding the operating functions covered in 4.7 (2).	
2) The IND lamp on the abnormal states described previously are present)	Defective 3C90 signal gate section, transistor, or circuit part	Replace the defective parts
3) IND lamp on the panel does not light	3B40, including Q7 - Q14, circuit is faulty or defective part	Replace the defective parts
4) The display time is abnormal when SAMPLE RATE at the front panel is turned.	3B12, including Q3 - Q8, circuit is faulty or defective part	Replace the defective parts
(3) The self-check operation is normal but measurements cannot be made.		
A. Check the input circuit wiring 1) Measurement is absolutely impossible	Check the connection between input AMP 3C90 and the input cable and between AMP 3C90 and the front panel with a VTVM. (Check for open wiring in the cable. This is especially necessary when the cable has been used for a long time.)	Replace the defective parts Repair the wiring Replace the input cable



## 5.6 Replacement and Repair Procedure for Circuit Board Components

### 1) Replacement of transistors, diodes, and integrated circuits

When removing defective semiconductor components, hold the leads of the component with tweezers having good heat conductivity, quickly melt the solder at the rear surface with a soldering iron made especially for transistor use (below 30 W), and remove the leads by pulling them out with the tweezers.

If the soldering iron is permitted to contact the printed board for a long time, not only may the printed copper conductor be damaged but the parts may also be damaged. The installation procedure is exactly the reverse of removal procedure; the leads of the part are polished with sandpaper or tweezers and then inserted into the installation holes in the printed board. The leads of the part are attached to the rear of the printed board with tweezers and installed by quickly applying a small amount of solder.

### 2) Parts replacement procedure

This is the same as described above; the part is held with tweezers and removed quickly. Careful attention must be given to styrol capacitors since they are covered with a coating and are susceptible to heat.

### 3) Wiring procedures

Wiring is performed in accordance with the color coding (signal system, power system, etc). Special care must be taken to avoid induction between the AC power lines and

signal system. When soldering the lead wires, wrap the lead approximately 1 ~ 2 turns around the connection and solder it quickly so as not to damage the wire covering.

#### 4) Replacement of the crystal oscillator

A defective crystal oscillator can be replaced by removing the screws which hold the oscillator at the rear and removing the oscillator from the socket. Since the crystal oscillator is precisely calibrated with TAKEDA RIKEN's standard, please inform TAKEDA RIKEN when its replacement becomes necessary.

#### 5) Replacement parts

Replacement parts must satisfy the specifications of the circuit in which they are to be used. It is necessary to use replacement parts which are the same as the original parts. When a part cannot be repaired, another type may be used (except for semiconductors) as long as it has the same ratings as the original part.

Semiconductor parts must be replaced with parts that are identical to the original.

#### 6) Cleaning and inspection after replacement and repair

Always perform the following cleaning after parts replacement or repair.

a) Remove any oxidation from soldered sections with highly volatile or oil thinner.

b) Remove any pieces of cut wiring, solder particles, etc.

These can be effectively removed with high pressure air from a compressor.

c) After cleaning check for short circuits between circuits boards and parts.

## 5.7 Assembly Procedure

After replacement or repair of boards or parts, assemble the counter back into its original form; however, do not place it into the case at this time.

Securely fasten it with screws and lock washers while at the same time paying careful attention not to damage the slot in the heads of the screws.

Always apply lock paint to the screws after tightening them. Insert the circuit boards firmly to insure a good connection at the connector section.

## 5.8 Internal Time Base (Crystal Oscillator) Calibration

Counter reliability cannot be overstressed even when talking about the accuracy of measured results.

Measurement accuracy of a counter is determined by two factors: (1) the  $\pm 1$  count error inherent in the counter system, and (2) the accuracy of the internal time base. Of these, serious consideration must be given to the accuracy of the internal time base, which can be considered the heart of the counter system. The internal time base must therefore be calibrated with a standard which guarantees its complete accuracy. TAKEDA RIKEN has installed an atomic frequency standard employing the resonant frequency of cesium atoms to guarantee this accuracy standard employing the resonant frequency of cesium atoms to guarantee this accuracy. National standards are generally transmitted as highly accurate frequency standards. The national standard in Japan is JJY which maintains an accuracy within  $-3 \times 10^{-8}$ . When an astronomical time standard is received, error  $1 \times 10^{-7}$  is generated due to the doppler effect, multipath reception, etc. The TAKEDA RIKEN Standard employing the resonant frequency of cesium atoms has an absolute atomic accuracy of  $\pm 1 \times 10^{-10}$  and a long term stability of  $\pm 1 \times 10^{-11}$ . The internal time base of all frequency counters are calibrated by a crystal

oscillator secondary time base of all frequency counters are calibrated by a crystal oscillator secondary standard which is calibrated by this standard as the primary standard. The specifications of the primary standard are listed below.

Output frequency	100 kHz, 1 MHz
Warm-up time	30 mins
Stability	$\pm 1 \times 10^{-11}$ /long term
Accuracy	$1 \times 10^{-10}$
Output signal level	10 ~ 20 mW, 50Ω
Operating temperature range	$\pm 10^{\circ}\text{C} \sim +30^{\circ}\text{C}$

#### Secondary Standard Specifications

Output frequency	100 kHz, 1 MHz, 2.5 MHz
Stability	$1 \times 10^{-10}$ /day (after one month warm-up)
Short term stability	$4 \times 10^{-11}$ /sec

The internal time base of the -TK-3788C is produced by a 1 MHz crystal oscillator. The 0.4 S, 4 S, etc. times are then produced by multiplying and dividing its frequency.

There is a method of calibrating the crystal oscillator by using a standard.

#### 3) Method using a standard

In this calibration method, the calibrated signal from the standard is directly connected to the input of the counter and measurement performed. At this time, the GATE TIME switch is set to 4 S (the longest gate time position). For example, when the external standard is 10 MHz, adjust the FREQ STD ADJ until the displayed value of the measured result reads 010000.00 kHz.

Calibration makes measurements at an accuracy of  $1 \times 10^{-8}$  possible with the counter. The accuracy of the external standard used at this time must be greater than  $1 \times 10^{-10}$ .

When calibrating with the method described above, allow the counter to warm-up for 48 hours after power is applied before performing calibration. Ambient temperature variations, shock, and vibration should be avoided when making measurement after calibration.