

**BK PRECISION<sup>®</sup>**

**Instruction Manual**

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**Model 1856C 2.4GHz Counter**

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## Section I

## INTRODUCTION

The 2.4GHz Frequency Counter is a highquality, lightweight counter capable of frequency measurements from 5 Hz to 2.4 GHz. The 2.4 GHz Frequency Counter features a special 50  $\Omega$ -terminated input for use in high frequency VHF/UHF/microwave/cellular telephone systems, as well as a standard 1 M $\Omega$  input for frequency measurements to 100 MHz.

The counters utilize an eight-digit display which provides up to 10 Hz resolution to 2.4 GHz (Channel B). 1 Hz resolution to 100 MHz, and 0.1 Hz to 10 MHz (Channel A).

In period mode, the unit measures the period required (in microseconds) for one cycle, over the range of 5 Hz to 2M MHz. At low frequencies, much greater accuracy can be achieved by period measurement than by frequency measurement.

Totalize mode permits counting of individual events. The counting process can be gated, either manually by a front panel switch, or by a gating signal applied to a rear panel jack, for more exact electronic control.

Operating mode and one of four decades of resolution are selected by front panel pushbutton switches. Easy-to-interpret readouts are provided by large bright digits, automatic decimal point placement, leading zero blanking, and LED display of proper measurement units. Overrange and GATE function (in-

dication of a measurement in progress) are also shown on front panel indicators.

A front panel HOLD switch is provided which "freezes" the display at the present reading, as well as a RESET button which clears the counter display and initiates a new measurement when released.

A selectable x 10 attenuator and selectable 100 kHz low-pass filter are incorporated at the standard frequency input jack, for lessened susceptibility to noise and (in low frequency measurements) undesirable high frequency components.

The 10 MHz CH.A and 3.90625MHz CH.B time base is generated by a crystal controlled oscillator for good stability with regard to temperature (  $\pm 10$  ppm, 0  $^{\circ}$ C to 40  $^{\circ}$ C ) and Line voltage variation (  $\pm 1$  ppm for 10% variation).

Other features include universal ac capability, a multi-position carrying handle/tilt stand for portability, and internal RF shielding.

The exceptional accuracy, sensitivity, and range of these counters make them extremely valuable instruments for the scientist, engineer, and communications technician.

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## **Section II**

## **SAFETY SUMMARY**

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- Read this manual carefully to ensure your personal safety and to prevent damage either to the instrument or to equipment connected to it.
- Always operate from a power source that does not apply more than 250 Vrms between protective ground connection, through the grounding conductor in the power cord, is essential for safe operation.
- To avoid electric shock, plug the power cord into a properly wired receptacle where earth ground had been verified by a qualified service person. Due to this unit is grounded through the power cord, do this before making any connections to the input terminals of the meters.
- Make sure that the power cord and the fuse are in good condition before use. When servicing, use only the power cord and fuse specified for the counters.
- To avoid personal injury, never operate the instrument without the panels or covers.
- Do not work alone. Trained person should be nearby to render aid if necessary.

# Section III

# CONTROLS AND INDICATORS

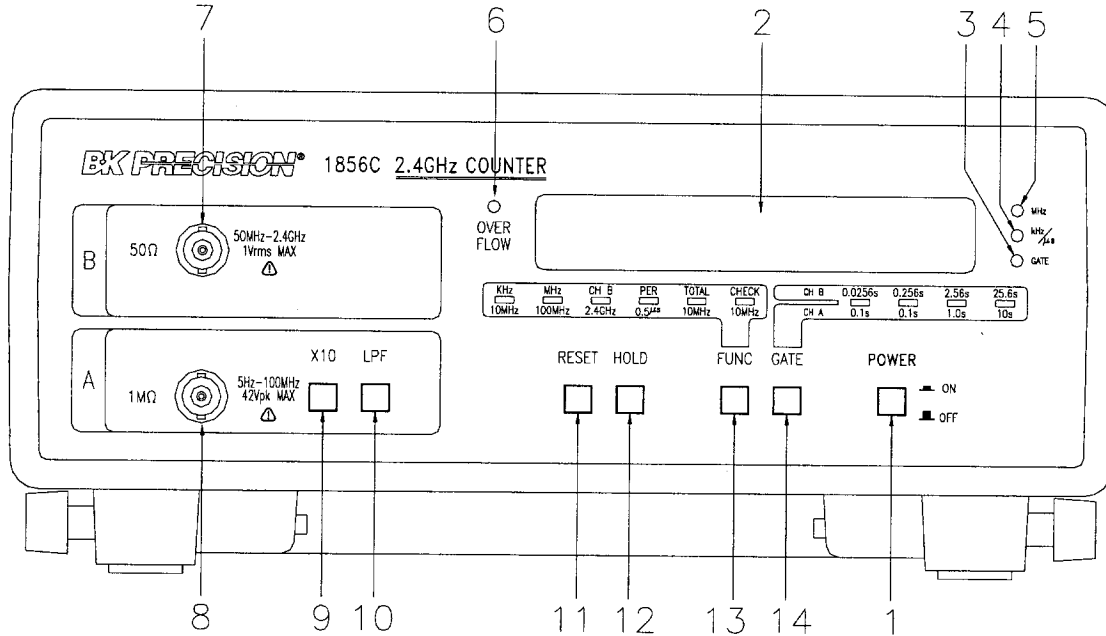


Figure 1. Front Panel

## CONTROLS AND INDICATORS

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**FRONT PANEL.** Refer to Fig. 1.

1. **POWER Switch.** Turns the unit on and off.
2. **Display.** Eight-digit display used for all readings.
3. **GATE Indicator.** Lights whenever a measurement is being taken.
4. **kHz/ $\mu$ s Indicator.** In kHz Frequency or CHECK mode, indicates that the frequency displayed is in kilohertz. In PERiod mode indicates that the period displayed is in microseconds. Not used in TOTALize mode.
5. **MHz Indicator.** In MHz Frequency or CH B (PRESCALE) mode, indicates that the frequency displayed is in megahertz. Not used in TOTALize mode.
6. **OVERFLOW Indicator.** Lights whenever the range of the display is exceeded. One or more most significant digits are not displayed.
7. **Channel B Input Jack.** Female BNC connector terminated in a 50 ohm input resistance.
8. **Channel A Input Jack.** Female BNC connector terminated in a 1 megohm input resistance, shunted by  $\leq 40$  pF capacitance.
9. **x10 Attenuator Switch.** When this switch is pushed in, the Channel A input is attenuated 10:1 before application to the counter. With the switch released (out), the signal is applied unattenuated.
10. **LPF (Low-Pass Filter) Switch.** With this switch pushed in, the Channel A input is routed through a low-pass filter with a  $-3$ dB point of approximately 100 kHz. When it is released (out), the input is applied directly.
11. **RESET Switch.** In all modes, pushing this momentary switch resets the counter to zero. When it is released, the measurement starts again.
12. **HOLD Switch.** Functions as follows:
  - a. All modes except TOTALize: Setting this switch to on "freezes" the display at the existing reading and resets the counter. Releasing the switch starts a new measurement; the display is updated when this measurement is completed.
  - b. TOTALize mode: Setting the switch to on "freezes" the display at the existing reading and halts the totalizing process. When the switch is released, counting resumes, provided that the gating signal at the rear panel **TOTALIZE START/STOP INPUT** jack (18) is high (or jack is open).
13. **FUNCTION Switch.** Pushing this momentary switch selects the six counter operating modes and lights the corre-

## CONTROLS AND INDICATORS

sponding mode indicators as follows:

- a. **kHz Frequency Mode Indicator.** When selected, the unit measures the frequency of the signal at the **Channel A Input** (8). Readings are in kHz as indicated by the **kHz/μs** indicator (4). Resolution is selected by the **GATE** switch (14). This mode is automatically selected when the counter is powered ON.

**Note:**

Guaranteed frequency measurement range in kHz Frequency mode is 5 Hz to 10 MHz (above 10 MHz, display may show zero with no **OVERFLOW** indication); sine wave sensitivity: 20 mV rms, 5 Hz to 10 MHz.

- b. **MHz Frequency Mode Indicator.** When selected, the unit measures the frequency of the signal at the **Channel A Input** (8). Readings are in MHz as indicated by the **MHz** indicator (5). Resolution is selected by the **GATE** switch (14).

**Note:**

Guaranteed frequency measurement range in the MHz frequency mode is 5 Hz to 100 MHz.

- c. **CH B (PRESCALE) Frequency Mode Indicator.** When selected, the unit measures the frequency of the signal

at the **Channel B Input** (7). Readings are in MHz as indicated by the MHz indicator (5). Resolution is selected by the **GATE** switch (14).

- d. **PERiod Mode Indicator.** When selected, the unit measures the period of the signal at the Channel A input. Readings are in μs as indicated by the **kHz/μs** indicator (4). Cycles Averaged; 1, 10, 100, or 1000 are selected by the **GATE** switch (14).

- e. **TOTALize A Mode Indicator.** When selected, the unit counts cycles of the Channel A input and continuously displays that count. Totalization can be controlled by a gate signal at the rear panel **TOTALIZE START/STOP** jack (18).

- f. **CHECK Mode Indicator.** When selected, the unit displays the frequency of the internal time base, providing a general check of performance.

14. **GATE Switch.** Pushing this momentary switch selects the degree of display resolution in all modes except **TOTALize** as follows;

- a. **1/0.01s Indicator.** When selected, the unit measures kHz or MHz Frequency with a 0.01s Gate Time, CH B Frequency with a 1 Gate Time, and **PERiod** for one cycle between display updates. This Gate Time is automatically selected when the unit is powered on.
- b. **10/0.1s Indicator.** When selected, the unit measures

## CONTROLS AND INDICATORS

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kHz or MHz Frequency with a 0.1s Gate Time, CH B Frequency with a 10 Gate Time, and PERiod for 10 cycles averaging between display updates.

c.**100/1.0s Indicator.** When selected, the unit measures kHz or MHz Frequency with a 1.0s Gate Time, CH B Frequency with a 100 Gate Time, and PERiod for 100 cycles averaging between display updates.

d.**1000/10s Indicator.** When selected, the unit measures kHz or MHz Frequency with a 10s Gate Time, CH B Frequency with a 1000s Gate Time, and PERiod for 1000 cycles averaging between display updates.

### Remark

For 2.4 GHz counter, Gate switch selections of 1/10/100/1000 are 25.6ms/256ms/2.56s/25.6s.

### Note:

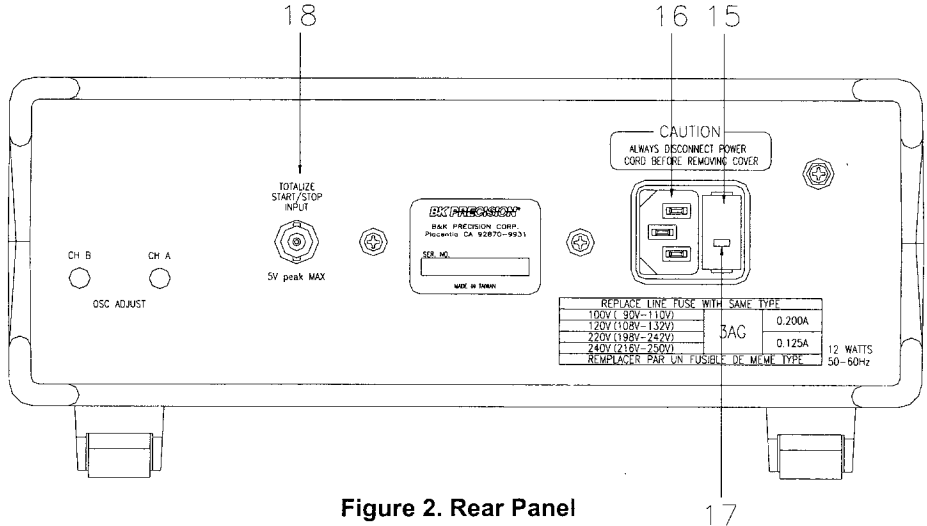
Measuring the PERiod of low frequencies such as 10 Hz with 100 or 1000 cycles averaging will result in extremely long display update times.



**REAR PANEL.** Refer to Fig. 2.

- 15. Fuseholder.
- 16. Line Cord Receptacle.
- 17. **LINE VOLTAGE SELECT** Indicator. Settings allow Universal Power Operation: 100/120/220/240 VAC, 50/60 Hz.

18. **TOTALIZE START/STOP** Input Jack. Input jack used to control the totalization function, if desired. Unit stops totalizing whenever the signal applied at this jack goes to a TTL low level (or is connected to chassis ground).



**Figure 2. Rear Panel**

## Section IV

## SPECIFICATIONS

### FUNCTIONS

Frequency.	Period Average.
2.4 GHz Frequency	Totalize.
Prescaler.	Check (Self Test).
100 MHz Frequency	
Period.	

### FEATURES

8 Digits, 0.56".	2-Position Attenuator.
Low Pass Filter.	Remote Stop-Start.
Display Hold.	

### FREQUENCY CHARACTERISTICS

<b>Channel A:</b>	5 Hz to 10 MHz sinewave, kHz mode.
	5 Hz to 100 MHz sinewave, MHz mode.
<b>Channel B:</b>	50 MHz to 2.4 GHz (2400 <b>(PRESCALE)</b> MHz)sinewave.

**Accuracy:**  $\pm A \times$  Time base Error

$\pm 1$  count.

**Resolution:** 0.1 Hz to 100 Hz, kHz  
mode.

**Channel A:** 1 Hz to 1000 Hz, MHz  
mode.

**Channel B:** 10 Hz to 10kHz.

**(PRESCALE)**

**Display:** Input signal frequency with  
decimal point positioned by  
GATE switch.  
Units of measurement (kHz,  
MHz) indicated on front panel  
by LED indicators and selected  
by front panel switches.

Number of Digits Displayed See Tables 1 and 2.

## SPECIFICATIONS

Gate Time	Number Of Significant Digits Displayed							
	10 SEC		1 SEC		0.1 SEC		0.01SEC	
Resolution	.1 Hz	1 Hz	1 Hz	10 Hz	10 Hz	100 Hz	100 Hz	1000 Hz
Function Typical Frequency	kHz	MHz	kHz	MHz	kHz	MHz	kHz	MHz
100 MHz	—	8*	—	8	—	7	—	6
10 MHz	8*	8	8	7	7	6	6	5
1 MHz	8	7	7	6	6	5	5	4
100 kHz	7	6	6	5	5	4	4	3
10 kHz	6	5	5	4	4	3	3	2
1 kHz	5	4	4	3	3	2	2	1
100 Hz	4	3	3	2	2	1	1	—
10 Hz	3	2	2	1	1	—	—	—
5 Hz	2	1	1	—	—	—	—	—

\* = Overflow

**Table 1. Number of Significant Digits Displayed for Typical Frequencies  
for Channel A Input and kHz or MHz Frequency Modes.**

## SPECIFICATIONS

Gate Time	Number Of Significant Digits Displayed			
	25.6 SEC	2.56 SEC	0.256 SEC	0.0256 SEC
Resolution	10 Hz	100 Hz	1kHz	10 kHz
Typical Frequency				
50 MHz	7	6	5	4
150 MHz	8	7	6	5
520 MHz	8	7	6	5
2.4 GHz	8*	8	7	6

\*=Overflow

Table 2. Number of Significant Digits Displayed for Typical Frequencies for Channel B (PRESCALE)

## PERIOD CHARACTERISTICS

<b>Range:</b>	0.5 $\mu$ s to 200,000 $\mu$ s.	<b>Display:</b>	$\mu$ s with decimal point.
<b>Frequency Range:</b>	5 Hz to 2 MHz sine wave.	<b>Minimum Pulse</b>	
<b>Accuracy:</b>	$\pm 1$ count $\pm A$ x time base error $\pm A$ x trigger error*	<b>Width:</b>	250 ns.
<b>Resolution:</b>	100 ps to 100 ns, switch selectable in four decade steps.	<b>Number of Digits Displayed:</b>	See Table 3.

\*Note: Trigger error is typically  $\pm 0.3\%$  of reading divided by the number of cycles averaged, for input signals having better than 40 dB S/N ratio and greater than 100 mV amplitude.

A: Display reading.

## SPECIFICATIONS

	Gate (CHA)	Number Of Significant Digits Displayed			
		0.01 s	0.1 s	1.0s	10s
	Resolution	0.1 $\mu$ s	0.01 $\mu$ s	0.001 $\mu$ s	0.0001 $\mu$ s
Typical Period	Corresponding Frequency	(1 Period Average)	(10 Period Average)	(100 Period Average)	(1000 Period Average)
0.5 $\mu$ s	2 MHz	1	2	3	4
1.0 $\mu$ s	1 MHz	2	3	4	5
10 $\mu$ s	100 kHz	3	4	5	6
100 $\mu$ s	10kHz	4	5	6	7
1000 $\mu$ s	1 kHz	5	6	7	8
10,000 $\mu$ s	100 Hz	6	7	8	8*
100,000 $\mu$ s	10 Hz	7	8	8*	8*
200,000 $\mu$ s	5Hz	7	8	8*	8*

\* = Overflow

Table 3. Number of Significant Digits Displayed for Typical Periods.

### TOTALIZE CHARACTERISTICS

**Range:** 5 Hz to 10 MHz sine wave.

**Capacity:** 0 to 99,999,999 plus overflow LED.

**Control:**

Manual reset and hold from the front panel. Normally enabled, except when signal at back panel START/STOP jack is low.

## SPECIFICATIONS

### CHANNEL A INPUT CHARACTERISTICS (5Hz to 100 MHz input)

Impedance:	1M $\Omega$ resistance, shunted by 40 pF capacitance.
Connector:	BNC on front panel.
Coupling:	AC.
Sinewave:	20 mV rms, 5 Hz to 30 MHz.
Sensitivity:	50 mV rms, 30 MHz to 100 MHz.
Maximum Input:	See Fig 3.
Attenuator:	x1/x10, switch selectable.
Filter:	Low pass filter, - 3 dB point of 100 kHz, switch se-lectable.

### PERSCALE INPUT CHARACTERISTICS (50 MHz to 2.4 GHz input )

Impedance:	50 ohms.
Connector:	BNC on front panel.
Coupling:	AC.

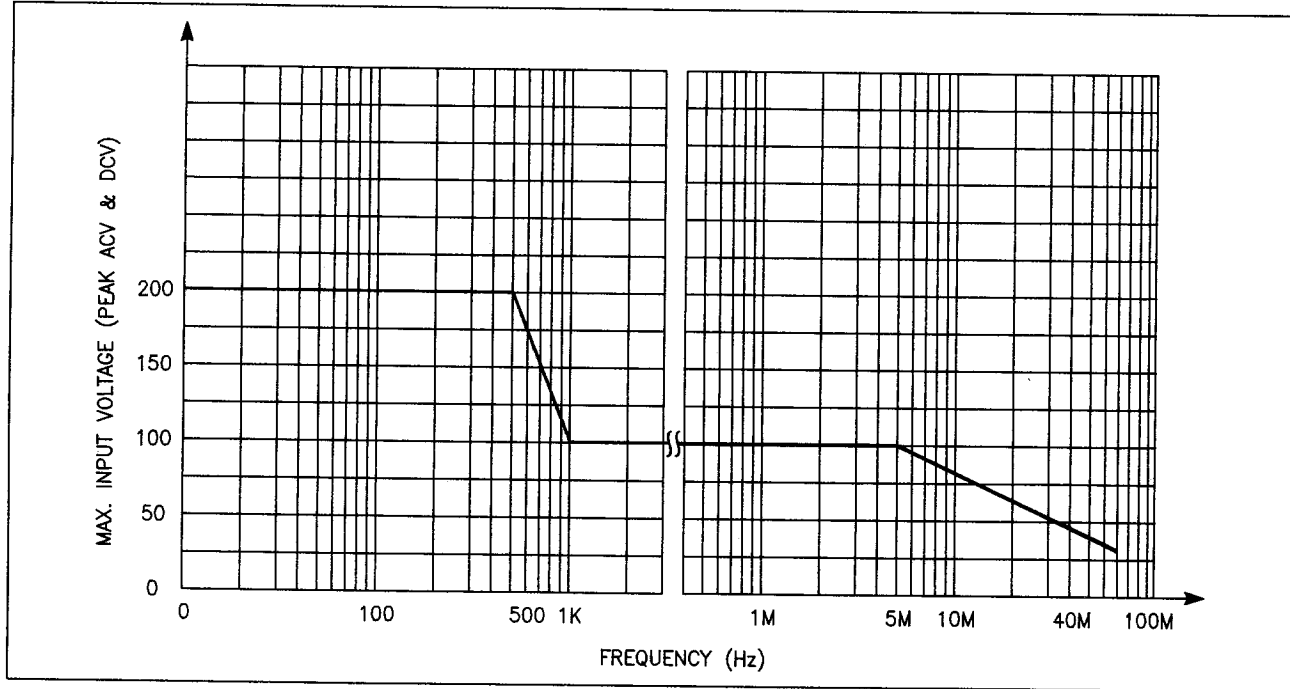
<b>Sinewave</b>	10 mV rms, 50 MHz to 600 MHz.
<b>Sensitivity:</b>	25 mV rms 601 MHz to 1.3 GHz. 50 mV rms, 1301 MHz to 2.4 GHz.
<b>Maximum Input:</b>	1 V rms.

### TOTALIZE START/STOP INPUT

<b>Logic Levels:</b>	Standard TTL levels; low level inhibits totalizing, high level enables it.
<b>Loading:</b>	One standard TTL gate.
<b>Maximum Input:</b>	5V DC peak.

### TIME BASE CHARACTERISTICS (STANDARD):

<b>Type:</b>	crystal-controlled oscillator
<b>Frequency:</b>	10 MHz.(CH. A) 3.90625MHz(CH.B)
<b>Temperature Factor Stability:</b>	$\leq 0.001\%$ ( $\pm 10$ ppm from 0 $^{\circ}$ C~40 $^{\circ}$ C ambinet)
<b>Maximum Aging Rate:</b>	$\pm 5$ ppm/yr.



**Figure 3 Maximum Input Protection Derating Curve.**

**(Channel A Input)**

## SPECIFICATIONS

### DISPLAY CHARACTERISTICS

**Visual Display:** Eight 0.56" seven-segment digits with kHz, MHz,  $\mu$ s, GATE, and OVERFLOW LED indicators.

**OVERFLOW Indication:** LED indicator lights when count exceeds 99,999,999 during any selected gate time.

- Display Update Time:**
1. KHz and MHz FREQUENCY Mode: User selected gate time plus fixed 200 ms interval.
  2. Pre-scale Mode: User selected gate time plus fixed 640 ms interval.
  3. PERiod Mode: User selected cycles averaging plus fixed 200 ms interval.
  4. TOTALize Mode: Continuous.

**Resolution:** Selectable in four steps as

follows:

GATE Time:	Period	kHz	MHz	
		Frequency	Frequency	Prescale
0.01s	0.1 $\mu$ s	100Hz	1000Hz	10kHz
0.1s	0.01 $\mu$ s	10Hz	100Hz	1kHz
1.0s	0.001 $\mu$ s	1Hz	10Hz	100Hz
10s	0.0001 $\mu$ s	0.1Hz	1Hz	10Hz

### RESET and HOLD Switches

**RESET:**

Resets the display to zero.

**HOLD:**

In FREQUENCY and PERiod modes, measurement in progress is stopped, and the last complete measurement is displayed. When HOLD is released, a new measurement begins. In TOTALize mode, counter is stopped but not reset, and the last count is displayed. When HOLD is released, count continues from where the counter stopped.



**GENERAL**

- Power Requirements:** 100/120/220/240 VAC  
( $\pm 10\%$ ), 50/60 Hz; 12W. (at normal line voltage)
- Dimensions (HxWxD):** 267(W)x114(H)x298(D)mm  
(10.5"x4.5"x11.8")
- Weight:** 2.2kg (4.85 lbs).
- Temperature and Humidity:**
- Operation:** 0°C to + 40°C  $\leq$  80% R.H.
  - Storage:** - 20°C to + 60°C  $\leq$  70% R.H.
- Standard Accessories:** Operator's manual, power cord.
- Optional Accessories:** EB-10: 3 feet, 50 $\Omega$  BNC to BNC coaxial cables  
EB-11: 3 feet, 50 $\Omega$  BNC to alligator clip coaxial cables

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## **Section V**

## **PREPARATION FOR USE**

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### **Line Voltage Selection**

This product is intended to operate from a power source that does not supply more than 250 Vrms between the supply conductors or between either supply conductor and ground. Before connecting the power cord to a power-input source, verify that the line voltage indicator on the rear panel is corrected (see Figure 2).

### **Grounding the Equipment**

A protective ground connection, the third wire in the power cord, is necessary for safe operation. To avoid electrical shock, plug the power cord into a properly wired receptacle before making any connections to the equipment input terminals. Do not remove the ground lug from the power cord for any reason. Use only the power cord and connector specified for this equipment.

### **Fuses**

To avoid fire hazard, use only a fuse of the specified type, voltage rating and current rating for this equipment. See Controls, Connectors, and Indicators in Section III.

## Section VI

## OPERATING INSTRUCTIONS

### PRELIMINARY

Numbers in parentheses refer to items in "CONTROLS AND INDICATORS" section and Fig 1, and 2.

1. Connect the unit to ac power.
2. Set the POWER switch (1) to on (pushed in).

### CAUTION

1. *Application of input voltages higher than the limits listed in the "SPECIFICATIONS" section may damage the counter. Before applying any signal to the inputs, make certain that it does not exceed these specified maximums.*
2. *Engaging the x10 Attenuator switch (9) does not alter these upper limits.*
3. *Counter ground points are connected to earth ground through the counter's ac power cord. Always connect counter (probe) ground only to ground points or isolated points in the circuit under test.*

### FREQUENCY MEASUREMENTS

#### Using Channel A Input (5 Hz to 100 MHz)

1. Apply the signal to be measured to the Channel A input jack (8).
2. Select measurement units of kHz Frequency with the FUNCTION switch (13). The kHz/ $\mu$ s or MHz indicator (4,5) lights accordingly.

#### Note:

In kHz mode, maximum guaranteed frequency is 10 MHz. Maximum frequency in MHz mode is 100 MHz. Exceeding these ranges may produce unpredictable results, such as a display of zero, with no OVERFLOW indication.

3. Select the degree of resolution desired, using the GATE switch (14). The actual Gate Times of 0.01s, 0.1s, 1.0s, and 10s are given by the CH A labels below the LED indicators.
4. Frequency is given by the display (2). The GATE indicator (3) lights while each measurement is in progress, and the

## OPERATING INSTRUCTIONS

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display is updated at the end of each measurement interval (when GATE goes off).

### Note:

Some measurement delay and display instability may be encountered; see "Display Interpretation".

5. The OVERFLOW indicator (6) lights whenever the range of the display is exceeded.
6. If necessary, engage the x10 Attenuator switch (9). When set to x10 (pushed in), this switch attenuates the Channel A signal by a factor of approximately 10 before application to the counter. This helps prevent mis-counting caused by noisy or improperly terminated high-amplitude signals.
7. If necessary, engage the LPF (Low-Pass Filter) switch (10). This routes the Channel A input through a low-pass filter (− 3 dB frequency of approximately 100 kHz) before application to the counter. This helps eliminate counting errors in low frequency measurements by minimizing effects of high-frequency noise present on the input.
8. Engaging the HOLD switch (12) during frequency measurements causes the display to "freeze" at the existing reading. When HOLD is released, a new measurement begins, but the display continues to hold the old reading

until the new measurement is completed.

9. Pushing RESET (11) in frequency measurements resets the display to zero. When the button is released, a new measurement begins, but the display remains at zero until the new measurement is completed.

### Using Channel B (PRESCALE) input (50 MHz – 2.4 GHz)

1. Apply the signal to be measured to the Channel B (PRESCALE) input jack (7).

#### CAUTION

*The maximum input limit to this jack is 1.5V rms maximum over the input frequency range. The input impedance is 50 ohms.*

2. Engage the CH B (PRESCALE) Frequency mode with the FUNCTION switch (13).
3. Select the degree of resolution desired, using the GATE switch (14). The actual Gate Times of 1, 10, 100 and 1000 are given by the CH B labels above the LED indicators.
4. Frequency is given by the display (2). The GATE indicator (3) lights while each measurement is in progress, and the display is updated at the end of each measurement interval (when GATE goes off).

### Note:

Some measurement delay and display instability may be encountered; see "Display Interpretation".

5. The OVERFLOW indicator (6) lights whenever the range of the display exceeded.
6. Engaging the HOLD switch (12) during frequency measurements causes the display to "freeze" at the existing reading. When HOLD is released, a new measurement begins, but the display continues to hold the old reading until the new measurement completed.
7. Pushing RESET (11) in frequency measurements resets the display to zero. When the button is released, a new measurement begins, but the display remains at zero until the new measurement is completed.
8. The x10 Attenuator and LPF switches (9,10) have no effect in CH B (PRESCALE) Frequency mode.

### PERIOD MEASUREMENTS

In period mode, the unit displays the period, or time required for one cycle of the input signal to occur. The actual measurement is made by averaging over 1, 10, 100, or 1000 cycles. Maximum frequency is 3.5 MHz.

1. Apply the signal to be measured to the Channel A input jack (8).
2. Engage the PERiod mode with the FUNCTION switch (13). The kHz/ $\mu$ s indicator (4) lights to indicate that readings are in microseconds.
3. Select the degree of resolution desired, using the GATE switch (14). (The GATE switch determines how many cycles are averaged in the measurement: 1, 10 100, or 1000, respectively, from left to right.)
4. Period is given by the display (2). The GATE indicator (3) lights while each measurement is in progress, and the display is updated at the end of each measurement interval (when GATE goes off). (At higher frequencies, the GATE indicator may flash too quickly to be seen).

### Note:

Some measurement delay and display instability may be encountered; see "Display Interpretation".

5. The OVERFLOW indicator (6) lights whenever the range of the display is exceeded.
6. If necessary, engage the x10 Attenuator switch (9). When set to x10 (pushed in), this switch attenuates the Channel

## **OPERATING INSTRUCTIONS**

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A signal by a factor of approximately 10 before application to the counter. This helps prevent mis-counting caused by noisy or improperly terminated high-amplitude signals.

7. If necessary, engage the LPF (Low-pass Filter) switch (10). This routes the Channel A input through a low-pass filter (− 3 dB frequency of approximately 100 kHz) before application to the counter. This helps eliminate counting errors in low frequency measurements by minimizing effects of high-frequency noise present on the input.
8. Engaging the HOLD switch (12) during period measurements causes the display to "freeze" at the existing reading. When HOLD is released, a new measurement begins, but the display continues to hold the old reading until the new measurement is completed.
9. Pushing RESET (11) in period measurements resets the display to zero. When the button is released, a new measurement begins, but the display remains at zero until the new measurement completed.

### **TOTALIZE MEASUREMENTS**

The TOTALize mode is used to count the total number of events occurring during a specific time period. This time period can be defined manually by front panel switch action, or for better accuracy, by a gating signal applied to the rear panel.

Because of capacitive coupling of the counter input, events should occur at least five times per second for accurate counting. Maximum frequency is 10 MHz.

1. Engage the TOTALize mode with the FUNCtion switch (13). Any GATE (14) setting is ignored.
2. If the counting is to be controlled electronically, connect the gating signal to the rear panel TOTALIZE START/STOP jack. A TTL high at this input enables the totalizing process; a TTL low disables it, holding the display at the accumulated value. If no signal is connected, the jack is pulled high internally so counting occurs.
3. Depress the RESET switch (11) to zero the counter. If no gating signal is connected to the TOTALIZE START/STOP jack, the unit starts counting as soon as the RESET switch is released. If a gating signal is connected, counting starts when RESET is released and the gating signal goes high.
4. As the unit totalizes, it displays the count continually. Maximum count is 99,999,999. If this is exceeded, the OVERFLOW indicator (6) lights, and the count continues.
5. Counting is halted by one of three methods:
  - a. If the gating signal at the TOTALIZE START/STOP jack goes low, counting stops and the display is held at the accumulated total. Counting resumes when the gating

## OPERATING INSTRUCTIONS

signal again goes high.

- b. If the HOLD switch (12) is engaged, counting stops and the display is held at the accumulated total. Counting resumes when the switch released.
  - c. Pressing RESET (11) at any time clears the counter and resets the display to zero.
6. If necessary, engage the x10 Attenuator switch (9). When set to x10 (pushed in), this switch attenuates the Channel A signal by a factor of approximately 10 before application to the counter. This helps prevent mis-counting caused by noisy or improperly terminated high-amplitude signals.
  7. If necessary, engage the LPF (Low-Pass Filter) switch (10). This routes the Channel A input through a low-pass filter ( $-3$  dB frequency of approximately 100 kHz) before application to the counter. This helps eliminate counting errors in low frequency measurements by minimizing effects of high-frequency noise present on the input.

### DISPLAY INTERPRETATION

#### Display Formats

Sample displays are given in Fig. 4. In Fig. 4, a value of 1234.567 is displayed, and the kHz/ $\mu$ s indicator is lit. This may represent either a frequency or a period reading; a glance at the mode switches indicates which is correct.

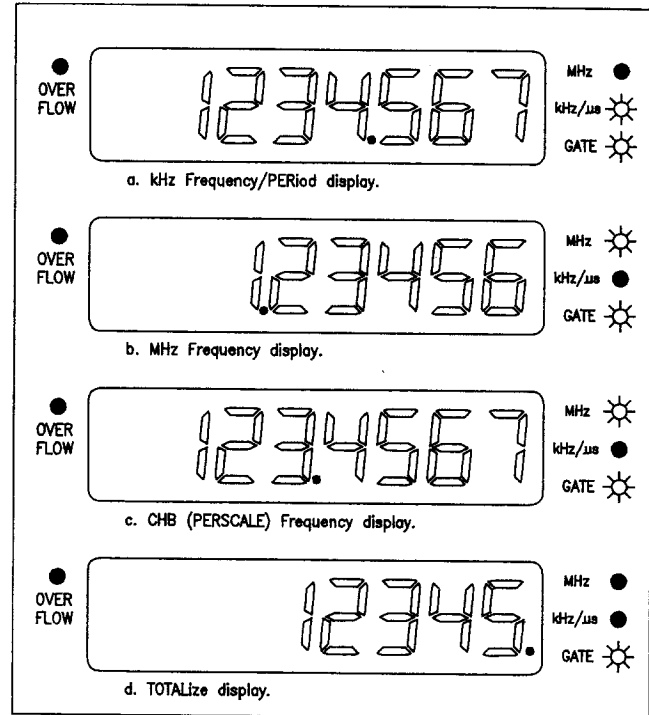


Figure 4. Samples of Various Displays.

## OPERATING INSTRUCTIONS

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Assuming that Fig. 4 represents a frequency reading, the resolution displayed is .001 kHz, or 1 Hz;. If the MHz Frequency mode is engaged with the FUNCTION switch, leaving all else unchanged, the display changes to that of Fig. 4. This is the same frequency as in Fig. 4, but given in megahertz. Note that the resolution is now .00001 MHz, or 10 Hz, even though a different Gate Time was not selected with the GATE switch. The display resolutions vary with the FUNCTION and GATE selections.

The frequency displays of Fig. 4 and b are obtained by engaging the 1.0s Gate Time with the GATE switch. A typical Channel B (PRESCALE) reading using this same Gate Time setting is shown in Fig. 4. Note that the resolution is now .0001 MHz, or 100 Hz.

Fig. 4 gives a typical totalize display. Totalizations have no units, and are always integers (no digits to right of decimal point). At higher totalizing frequencies, the least significant display digits tend to fade due to their rapid rate of change.

### Display Instability

An uncertainty of  $\pm 1$  least significant digit is inherent in all digital measurements. However, greater display uncertainties can result from other factors, as follows:

Noise or ringing on the input can cause false triggering. In some cases the display may be unstable, whereas in others it may appear stable but at an incorrect reading. For Channel A measurements, this type of error can be reduced by using the attenuator and filter. Similar errors introduced by standing waves may be avoided by using proper terminations and cable lengths when appropriate. The Channel B (PRESCALE) input jack is provided with an internal  $50 \Omega$  termination, to void standing wave difficulties for measurements in  $50 \Omega$  systems.

Uncertainty may be introduced by instability of the input frequency. This is common with LC oscillators; crystal-controlled oscillators are much more stable.

In period measurements, uncertainty is introduced by trigger error (see "SPECIFICATIONS"). This uncertainty can be reduced by taking the measurement over a greater number of cycles.

Period and frequency are reciprocals of each other. At low frequencies, more digits can be obtained (lessening the effects of instability) using period mode. Similarly, high frequency accuracy is enhanced by using frequency mode. The "crossover" point between the two modes is 10 kHz.



**Measurement Delays**

In all measurements (except totalize), the display is updated at the end of a finite measurement interval. The GATE indicator lights during this interval, which varies in length according to operating mode and resolution selected. For some conditions, the delay can become significant. This should be kept in mind when changing resolution or operating mode, or when using HOLD or RESET, because each of these actions initiates a new measurement. Measurement delays for each mode are discussed here.

**Frequency**

In frequency measurements, each GATE setting establishes a set time during which the measurement is made and results in a different display resolution. Gate Times settings for kHz, MHz, and CH B (PRESCALE). Frequency modes and their resulting display resolutions are as follows:

<b>FUNCTION mode</b>	<b>GATE Time setting</b>	<b>Display Resolution</b>
kHz	0.01s	100 Hz
kHz	0.1s	10 Hz
kHz	1.0s	1 Hz
kHz	10s	0.1 Hz
MHz	0.01s	1 kHz
MHz	0.1s	100 Hz
MHz	1.0s	10 Hz
MHz	10s	1 Hz
CH B	0.0256s	10 kHz
CH B	0.256s	1 kHz
CH B	2.56s	100 Hz
CH B	25.6s	10 Hz

**Table 4. Gate time and measurement resolution in Frequency mode.**

## OPERATING INSTRUCTIONS

As observed in the table, smaller GATE Times result in lower resolutions. They are useful when quicker updates are desired, for example, while tuning an oscillator. Better resolutions require longer update intervals.

### Period

Period measurements are made by averaging over a set number of cycles. That number is determined by the GATE switch as follows:

<b>GATE Setting</b>	<b>Number of cycles averaged</b>
0.0256/0.01s	1
0.256/0.1s	10
2.56/1.0s	100
25.6/10s	1000

The time required for a period measurement to be completed can be found by the formula:

$$\text{Time} = \left[ \begin{array}{c} \text{Number of} \\ \text{cycles} \\ \text{averaged} \end{array} \right] \times \left[ \begin{array}{c} \text{Average} \\ \text{cycle} \\ \text{length} \end{array} \right]$$

Where time units are same (seconds, milliseconds, etc.) on both sides.

For a constant input frequency this is:

$$\text{Time} = \frac{\text{Number of cycles averaged}}{\text{Input frequency (Hz)}}$$

Note that two GATE switch settings select 100 and 1000 cycle averaging. Because of this, significant delays may occur between display updates at low frequencies.

### Inter-Measurement Interval

The inter-Measurement interval is fixed at 200 milliseconds in all modes except CH B (PRESCALE) and TOTALize. In CH B mode it is 640 ms, and in TOTALize, counting is continuous.

This fixed interval is independent of gate time, number of cycles, or input frequency.

## GENERAL CONSIDERATIONS

### **Use of Attenuator Probes**

Channel A input resistance (1 M  $\Omega$ ) and input capacitance (40 pF max) are independent of the x10 Attenuator switch. To decrease loading, a high-impedance oscilloscope probe may be used with Channel A.

### Note:

When using a 10:1 probe make certain that the signal amplitude is large enough to provide at least the minimum required signal to the counter after probe attenuation (see "Channel A Sensitivity" in "SPECIFICATIONS").

### Note:

Do not use a 10:1 probe with the CH B (PRESCALE) input. The probe is designed for 10:1 attenuation with a counter input resistance of  $1\text{ M}\Omega$ . The  $50\ \Omega$  termination of the CH B jack would result in unacceptably high (180,001/1) attenuation.

### Cable Considerations

Accuracy of radio frequency measurements can be affected by connections between signal source and counter. Main considerations are standing waves and shunt cable capacitance.

Standing waves are usually present due to reflections when a transmission line is not terminated in its characteristic impedance. These standing waves may cause damage to the signal source or produce inaccurate measurements, and their effects increase as cable length reaches one-fourth of the wave-

length for the frequency being measured.

Standing waves can be minimized by keeping cable lengths short, and, more importantly, providing a proper termination. The cable's characteristic impedance and the terminating impedance should match the source impedance. For example, for a source impedance of 50 ohms, use 50 ohm coaxial cable terminated with a 50 ohm resistive load. Use a dc blocking capacitor in situations where bias voltage or other dc voltages could be affected by the termination resistor.

Shunt cable capacitance, which can cause undesirable signal attenuation, increases with increased cable length. It is recommended that for radio frequency measurements, the cable be no longer than three feet (90 cm), to keep shunt capacitance within acceptable limits.

In  $50\ \Omega$  systems the internal  $50\ \Omega$  input termination of the CH B (PRESCALE) jack minimizes reflections and the resulting standing waves. Thus, the need for an external termination is eliminated. Also, shunt capacitance has a much lesser effect at this jack than at the Channel A input, and the above restriction on cable length is reduced. However, CH B measurements must always be taken from a  $50\ \Omega$  point in the circuit under test.

## OPERATING INSTRUCTIONS

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### FUNcTION or GATE Time Changes

When switching gate times or function modes, note that such a change initiates a new measurement; the display is not updated until the new measurement is completed. Even though the decimal point and leading zeroes are adjusted immediately, appearance of the correct value may be significantly delayed depending on measurement interval (see "Display Interpretation - Measurement Delays").

### Line Frequency Measurement

#### WARNING

*Use caution in measuring the line frequency of an ac outlet. Using the probe tip only, measure both sides of the line. The ground side will give a zero reading and the hot side will provide the desired measurement. Do not use the "ground" lead of the probe. Remember that the chassis of the counter and the "ground" lead of the probe are already at earth ground (via the 3-wire power cord of the instrument). Touching the "ground" lead to the "hot" side of the line would place a direct short on the power line through the probe cable, resulting in possible*

*injury and damage to the probe cable.*

Use of the attenuator, filter, and/or a x10 probe is advisable when measuring line frequency, because of the high amplitude signal, and because noise is usually present and can cause mis-counting.

### CHECK (SELF TEST)

The CHECK mode provides a quick, general self test of instrument operation.

1. Engage the CHECK Mode with the FUNcTION switch (13). This connects the counter input internally to the time base oscillator.
2. Engage each GATE Time Mode with the GATE switch (14) and check that the results match the following:

GATE setting*	Ddisplay reads
0.01s	10000.0 kHz
0.1s	10000.00 kHz
1.0s	10000.000 kHz
10s	0000.0000 kHz, OVERFLOW lit

## OPERATING INSTRUCTIONS

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3. Pressing the HOLD switch (12) should hold the display value and keep the GATE indicator off for as long as the button is pushed in. When HOLD is disengaged, GATE should resume flashing. (If a new GATE Time has been selected, the display is updated to its proper value after the first GATE interval.
4. Pressing the RESET switch (11) should clear the display. The GATE indicator should stay off as long as RESET is pushed. Upon release of the button, GATE should resume flashing and the display should be updated at the end of the first GATE interval.

\*GATE indicator lights during this interval; time between measurement is 200 ms.

## Section VIII

## MAINTENANCE AND CALIBRATION



### WARNING

*The following instructions are for use by qualified personnel only. To avoid electrical shock, do not perform any servicing other than contained in the operating instructions unless you are qualified to do so.*

### FUSE REPLACEMENT

If the primary line fuse FS5 blows, the display and the FUNCTION or GATE LED indicators will not light and the counter will not operate. The fuse should not normally open unless a problem has developed in the unit. Try to determine and correct the cause of the blown fuse, then replace only with a fuse of the correct rating. For 100 or 120 V operation a 0.2 A, 250 V, 3AG fuse should be used and for 220 or 240 V operation a 0.1A, 250 V, 3AG fuse should be used. The primary line fuse, FS5, is located on the rear panel (see Fig. 2).

If replacement of the primary line fuse does not alleviate the problem, then one of the four transformer secondary fuses, FS1/FS2/FS3/FS4, may be open. The four fuses are located

on the main circuit board (see Fig. 11). Replace only with a 0.5A, 125 V or 250 V 5x20 mm for each.

### LINE VOLTAGE CONVERSION

The primary winding of the power transformer is tapped to permit operation from 100, 120, 220, or 240 VAC, 50/60 Hz line voltage. Conversion from one line voltage to another is done by simply replacing the fuse holder with voltage selector located on the rear panel (see Fig. 2-12).

To convert to a different line voltage, perform the following procedure:

1. Make sure the power cord is unplugged.
2. Reset the Fuse holder with voltage selector for the desired line voltage as shown on the rear panel.
3. A change in line voltage may also require a corresponding change of fuse value. Install the correct fuse value as listed in the **FUSE REPLACEMENT** section.

## MAINTENANCE AND CALIBRATION

### ADJUSTMENTS

This unit was accurately adjusted at the factory before shipment. Readjustment is recommended only if repairs have been made in a circuit affecting adjustment accuracy, or if you have a reason to believe the unit is out of adjustment. However, adjustments should be attempted only if the following equipment is available:

1. 10MHz Standard with an accuracy of at least  $\pm 0.1$  PPM ( $1 \times 10^{-7}$ ) and an output level of at least 100 mV rms.
2. RF Generator (Wavetek 3001 or equivalent).
3. RF Millivoltmeter (Boonton 92BD or equivalent).

The following adjustments require the removal of the case top; unplug the power cord, turn the unit over and remove the four Phillips screws, two holding the rear rubber feet and the two next to the front rubber feet. Locations of the electrical adjustments are shown in Fig. 11.

ADJUSTMENT	FUNCTION OF ADJUSTMENT
SVR1	Channel A Sensitivity
SVR2	Totalize Sensitivity

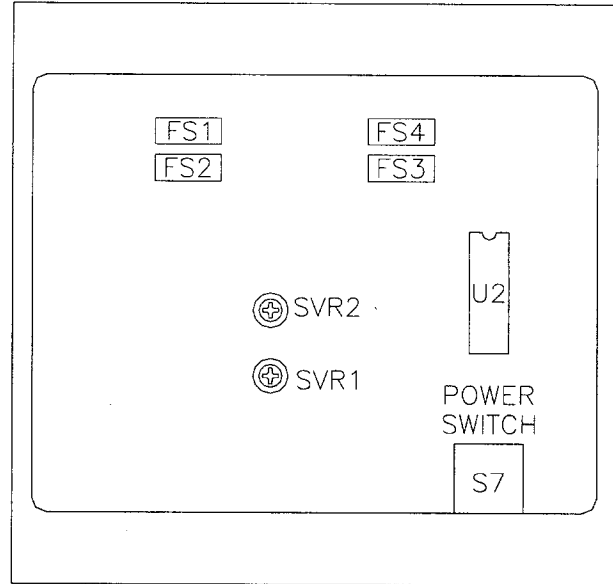


Figure 11 Main board Adjustments, Component Side

### Time Base Adjustment

This adjustment should be performed after a one hour warmup with the top case on but not screwed down, allowing the heat rise inside the unit to stabilize. The top case is then lifted off and the adjustment made.

1. Set the unit for **kHz** mode with the **FUNC** switch and **1.0s** Gate Time with the **GATE** switch.
2. Connect the 10 MHz standard frequency source to **Channel A Input**.
3. Using a small non-metallic slotted screwdriver, adjust the trimmer SC1 for a reading of **10000.000 ± 1 Hz** on the unit display.
4. Set the unit for **CH.B** mode with the **FUNC** switch and **2.56s** Gate Time with the **GATE** switch.
5. Connect the 1000MHz standard frequency source to channel B input.
6. Using a small non-metallic slotted screwdriver, adjust the trimmer SC2 for a reading of **1000,0000 ± 100Hz** on the unit display.

### Channel A Sensitivity Adjustments

1. Set the unit to **MHz** mode with the **FUNC** switch and **0.01s** Gate time with the **GATE** switch.

2. Connect the RF Generator and the RF Millivoltmeter with a BNC Tee to the **Channel A Input**. Set the RF Generator frequency output to read 100.000 MHz and set its level for a reading of 50 mV rms on the RF Millivoltmeter. The counter display should read  $100.000 \pm 1$  count.
3. Slowly decrease the RF Generator output level until the counter's least significant digit varies by more than 3 counts. The counter will typically start to read lower.
4. Adjust the **Channel A Sensitivity Trimmer SVR1** (through the hole in the metal shield) so that the counter display reads  $100.000 \text{ MHz} \pm 1$  count.
5. Repeat steps 3 and 4 until trimmer SVR1 no longer can give a stable  $100.000 \text{ MHz} \pm 1$  count on the display. The typical range of the RF level required would be approximately 20 mV to 30 mV rms.

### TOTALIZE Adjustments

1. Set the unit for **TOTAL** mode with the **FUNC** switch.
2. Connect the RF Generator and RF Millivoltmeter with a BNC Tee to the Channel A Input. Set the RF Generator frequency output to 10.000 MHz and its level for a reading of 35 mV rms on the RF Millivoltmeter.
3. Adjust Trimmer SVR2 until the display just starts to change the second digit from the left.



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## Section IX

## TROUBLESHOOTING

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The following troubleshooting steps provide a logical procedure for fault isolation. If the procedure cannot, of course, guarantee to pinpoint every possible problem, it will in most cases localize the problem to a certain area.

Most of these troubleshooting steps require removal of the top cover as described previously.

### General Fault Isolation

1. **Performance test** Test each operating mode by applying an appropriate signal to Channel A and Channel B as directed in Table 4. Frequency accuracy of the signal isn't critical, but amplitude should be adequate to produce stable readings (use caution not to exceed the maximum Channel B input ratings). On Channel A, the filter, and/or attenuator may be used to stabilize the reading.
2. **Fault Isolation** Proceed as follows according to the results of the test:
  - a. If no display can be obtained at all, follow the procedure for "**No Display**".
  - b. If display shows abnormalities such as missing decimal

points or unlit segments or digits, follow the procedure for "**Abnormal Display**".

- c. If display appears normal, but value is incorrect or unstable (in Channel B, Channel A, or both), follow the procedure for "**Incorrect or Unstable Display Value**".
- d. If problem is not adequately described by any of the above, start at "**No Display**" and proceed through each step until the difficulty is isolated.

**Table 5 Operational Test**

Input Frequency	Operation Mode	RESOLUTION	Normal (Ideal) Display
10 kHz	FREQUENCY kHz	100 Hz 10 Hz 1 Hz .1 Hz	10. 10.00 10.000 10.0000 **
10 kHz	FREQUENCY MHz	1 kHz 100 Hz 10 Hz 1 Hz	.010 .0100 .01000 .010000 *
100 MHz	FREQUENCY CH B	10 kHz 1 kHz 100 Hz 10 Hz	100.00 100.000 100.0000 100.00000 **
10 kHz	PERiod	.1 $\mu$ SEC .01 $\mu$ SEC .001 $\mu$ SEC .0001 $\mu$ SEC	100.0 100.00 100.000 100.0000
10 kHz	TOTALize	not applicable.	Display a accumulates, with fifth digit from right changing at approximately 1 Hz.
not required input	CHECK	100 Hz 10 Hz 1 Hz .1 Hz	10000.0 10000.00 10000.000 0000.0000* over lit

Input Frequency	Operation Mode	RESOLUTION	Normal (Ideal) Display
Less than 100 Hz	PERiod	.0001 $\mu$ SEC	over lit ***

**NOTE:**

\* :Measurement delay of 10 seconds.

\*\* :Measurement delay of 25.6 seconds.

\*\*\* :Measurement delay of at least ten seconds.

## TROUBLESHOOTING

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### NO Display.

1. Check supply voltage at U2 pin 25 for approximately +5 volts. If this voltage isn't present, check ac input, fuse and + 5V (VA) power supply circuit (D17, D18, C31,UP1). Otherwise proceed to "**Abnormal Display**".

### Abnormal Display.

1. **Digit Strobes and time base** Set the unit to any operating mode and check for the digit strobe waveforms of page 8 at U2 pins 22-24 and 26-30. If these are normal, proceed to step 2. If not, check the output of the time base oscillator at pin 38 for a waveform of frequency 10 MHz and peaks of 0 and 2.4 V. If normal, check U2 and display digits; if no output is obtained, check oscillator components, U2 and + 5V (VCC) power supply (D19, D20, C35, UP2).
2. **Display test** Enable display self-test by connect U2 pins 1 and 22 to each other via a 1s355 diode ( anode to pin 22 ). Display should be all " eights " with all decimal points and OVERFLOW indicator on. If not, check displays and U2 segment driver pins 8-11 and 13 - 16. Waveform at each of these pins should approximate a dc level of about 1.0 V, with negative spikes of about 4 kHz . Waveforms shown are with

display digits connected.

3. **Decimal points** If the problem involves decimal points in MHz or Channel B modes, check the mode selection logic as in "step 5" of "**Incorrect or Unstable Display Value**".
4. **MHz or kHz/  $\mu$ SEC indicators** For problems involving these (D24, D25), check the mode selection logic as in "**Incorrect or Unstable Display Value**", step 5.
5. **GATE indicator** If the GATE indicator, D26, does not function properly, check D26, Display U7 and U2 pin 3. D26 is connected via Display U7 to pin 3, which goes low whenever a measurement is being taken. (If this pin shows no activity, check for proper mode selection as in "**Incorrect or Unstable Display Value**", step 5).
6. **Function indicator** If the Function indicators kHz, MHz, CH B, PER, TOTALize, and CHECK square LEDs, does not function properly, check LED1-LED6, U5 and U2.
7. **Gate time indicator** If the Gate time indicator .01/ 0.0256s, .1/0.256s, 1/2.56s, and 10/25.6s square LEDs does not function properly, check LED7-LED10, U11 and U12.

**Incorrect or Unstable Display Value.**

1. **Half-splitting: Channel A** Apply an appropriate signal to Channel A and check the waveform at the collector of Q4. Waveform should be a square wave (0-2.8V) of same frequency and polarity as the Channel A input signal. If the waveform is normal, proceed step 3; otherwise, check for a problem in the Channel A analog circuitry; see the next step.
2. **Channel A analog circuits** Table gives waveforms for the Channel A input buffer and signal shaping circuits, along with input conditions required for obtaining them. The order of table entries is from input to output, permitting either sequential or half-splitting troubleshooting techniques, as desired by the user.
3. **Half-splitting: Channel B** Apply an appropriate signal to the Channel A jack. Check the output of the ECL-to-TTL converter, collector of Q7. A TTL level waveform should be observed; its frequency should be 1/320 of input frequency. Note that because of the high frequency, shape irregularities in this waveform can be expected.  
If the waveform is correct, proceed to step 5. If not, check the Channel B circuits.

4. **Channel B input amplifier** With signal still applied at the Channel B input, check for presence of signal at the input of IC4, and the output of Q7 and Q8. If not detected, check IC5A, IC5, A IC4 and associated components.

**Table 6 Channel a analog circuit waveform**

Test Point	Waveform (See Note 1 next page)
A. Gate of Q1.	Identical to input.
B. Gate of Q1, but with ATTEN set to x10.	1/10 amplitude of input.
C. Source of Q1 Connection point of C7, C9, C10, R8.	1Vp-p, 10 kHz sine wave centered at + 1.3V.(see Note 2 next page)
D. U1 pin 10.	1Vp-p, 10 kHz sine wave centered at + 3.8V.
E. U1 pin 9, 11.	DC level of + 3.8V.
F. U1 pin 4 or 7.	1Vp-p, 10 kHz rounded square wave centered at + 3.8V.
G. U1 pin 5 or 6.	Same as F, but inverted.
H. U1 pin 3 or 12.	Same as F, with squarer edges.
I. U1 pin 2.	Same as H, but inverted.
J. U1 pin 13.	0.7Vp-p, 10 kHz square wave centered at + 3.8V.
K. U1 pin 15, or base of Q3.	1Vp-p, 10 kHz square wave centered at + 3.8V.
L. U1 pin 14, or base of Q4.	Same as K, but inverted.

**7. Channel A/Channel B Select**

a. See table 8 for reference.

**8. Reset** Check that all readings are cleared to zero when RESET switch is pushed. If not, check S4.

**Table 8 Check of Function Logic**

Function Engaged	Test Points	Waveform
Frequency kHz	U2 pin 4 U7 pin 1,3 D25 U10 pin 3	U2 strobe D1 (pin 30). Logic high. Lit. Logic high.
Frequency MHz	U2 pin 4 U14 pin 5 U14 pin 3 U2 pin 20  U7 pin 4 U10 pin 2	U2 strobe D1 (pin 30). Logic high. Same as U9 pin 4 (U2 digit strobe selected by Gate switch, see Table 3). Logic high. Logic high(see other entries for U7 pin 6).
Frequency CH B	U2 pin 4 U14 pin 12,13 U14 pin 2 U2 pin 20  U14 pin 9,10 U7 pin 5 U7 pin 6  U10 pin 4	U2 strobe D1 (pin 30). Logic high. Same as U14 pin 1 (u2 digit strobe selected by Gate switch, see Table 3). See last entry in this table. Logic high. Logic high (see other entries for U7 pin 6). Logic high.

Function Engaged	Test Points	Waveform
PERiod	U2 pin 4 U7 pin 11,12 D25 U10 pin 7	U2 strobe D8 (pin 22). Logic high. Lit. Logic high.
TOTALize	U2 pin 4 U7 pin 6 U10 pin 10	U2 strobe D4 (pin 27).  Logic high.
CHECK	U2 pin 4 U7 pin 13 U10 pin 1	U2 strobe D3 (pin 28). Logic high. Logic high.
Either Frequency MHz or Frequency CH B	U7 pin 6 D24 U14 pin 6	Logic high. Lit. Logic high.

## Section X FUSE REPLACEMENT AND VOLTAGE SELECTION

This instrument is the universal line voltage operation; 100V, 120V, 220V and 240V. The below is explaining the user how to replace fuse.

1. Extract the fuse drawer from the AC socket with the aid of a screwdriver (The extra safe fuse drawer can only be extracted with the aid of a tool. Eg. screwdriver.)
2. Only then the fuse holder with voltage selector can be removed from the fuse holder.

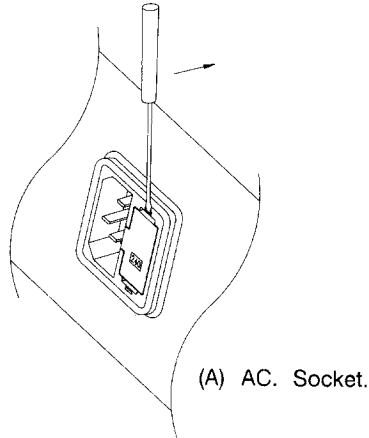


Figure 12-1. Fuse replacement and voltage selection

3. Pull out the fuse link from the fuse holder with voltage selector and then replace a new fuse rated voltage in accordance with specific required fuse or select the voltage according to the user's local line source.
4. When finish the replacement, install the equipments follow up as figured steps D,C and B. The equipments can be easily installed by hands.

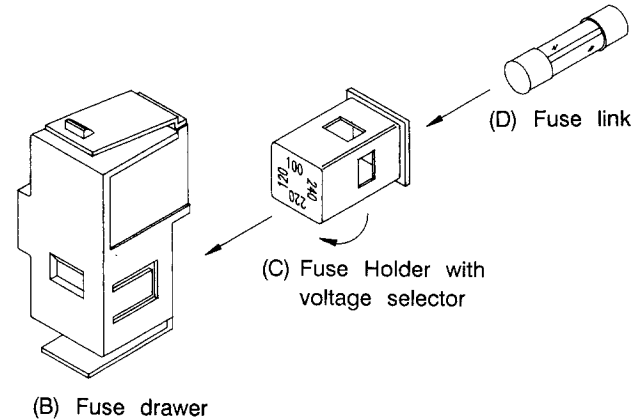


Figure 12-2. Fuse replacement and voltage selection

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