527E
FREQUENCY DIFFERENCE
METER

OPERATION AND
SERVICE MANUAL

79645 H

SERIAL NO. ______________

REVISED
DECEMBER 1991

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TREMETRICS™
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INTRODUCTION

This manual contains the information necessary to operate and maintain the Frequency Difference Meter Model 527E, assembly number 79635-0001, manufactured by TREMETRICS Inc. This information includes physical description, installation and preliminary adjustment procedures, operating procedures, theory of operation, procedures for calibration and alignment, a parts list, and applicable drawings and diagrams required to provide adequate manual support.

This manual is to be used by all personnel operating or servicing the Frequency Difference Meter.

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SECTION I

GENERAL DESCRIPTION

1-1. SCOPE OF SECTION.

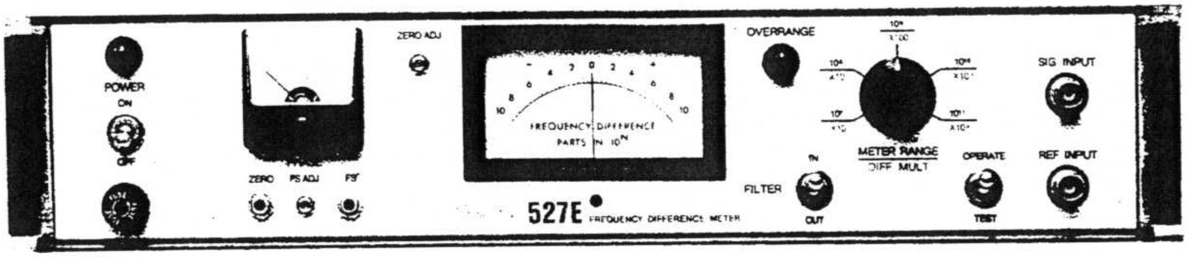
1-2. This section describes the purpose and physical characteristics of the TREMETRICS Inc., all-silicon solid state Model 527E Frequency Difference Meter (FDM) and provides a brief description of the operating controls and connectors.

1-3 PURPOSE OF EQUIPMENT.

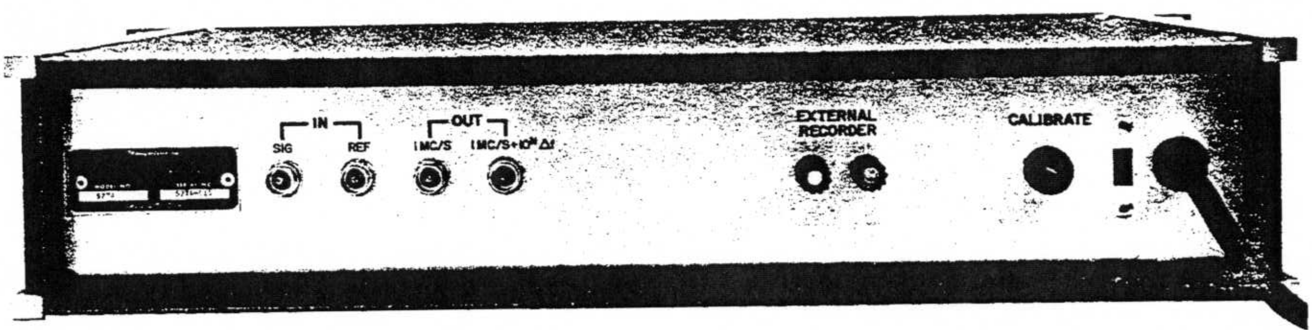
1-4. The Model 527E FDM is used to determine the fractional frequency difference between two stable oscillators, to adjust two oscillators to the same frequency, to offset one oscillator from another by a specified frequency, and to analyze short and long term frequency stability at nominal frequencies of 100 kHz, 1 MHz, 2.5 MHz, and 5 MHz.

1-5. DESCRIPTION OF EQUIPMENT

1-6 The FDM (Figure 1-1) is 3.5 inches high, 12.75 inches deep, 16.875 inches wide, and weighs approximately 15 pounds. The rack mounted model is 19 inches wide. It contains 14 printed circuit plug-in boards: a power transistor board, a flip-flop board, 4 error multiplier boards, a reference input/9 MHz amplifier board, a 5 MHz/1 MHz divider board, a buffer amplifier board, a power supply board, a differentiator/integrator board, a single shot/phase comparator board, a crystal filter board and a phase comparator board. A PCB extender board is provided to facilitate trouble shooting and maintenance. Refer to table 1-1



Front View



Rear View

Figure 1-1. Frequency Difference Meter Model 527A.

TABLE 1-1. Frequency Difference Meter Controls, Indicators, and Connectors.

Name	Reference Designation	Function
POWER switch and lamp	S5/DS1	Applies 115 volt ac power to FDM circuitry. Lamp lights when POWER switch is in ON position and unit is connected to facility power.
ZERO ADJ potentiometer	R2	Adjusts electrical zero of meter when reference signal is applied and TEST/OPERATE switch is set to TEST.
Meter	M2	Indicates phase relationship between two nominal frequencies for conversion to fractional frequency difference.
Meter	M1	Indicates fractional difference between two nominal frequencies in parts in 10^N.
OVERRANGE lamp	DS2	Indicates when fractional frequency difference exceeds meter range or when excessively noisy input signal is applied.
METER RANGE/ DIFF MULT selector	S3	Selects fractional frequency difference range for meter in parts in 10^7, 10^8, 10^9, 10^{10}, or 10^{11}. Also indicates amount of multiplication of fractional frequency difference.
SIG INPUT connectors	J5/J6	Provides connection of unknown frequency signal on either front or back panel.

Table 1-1 (Continued)

Name	Reference Designation	Function
REF INPUT connectors	J4/J7	Provides connection of known frequency reference on either front or back panel.
TEST/OPERATE switch	S2	In TEST position, reference input is applied to error multiplier circuits, instead of unknown signal, to allow meter to be electrically zeroed.
FILTER switch	S4	Switches crystal filter into signal circuit in 10^{10} and 10^{11} meter ranges. Used when signal input is excessively noisy.
Fuse	F1	Protects FDM circuitry from excessive current overloads.
EXTERNAL RECORDER connectors	J1/J9	Provides connection of dc output voltage, proportional to fractional frequency difference indicated on meter, to external chart recorder.
ZERO pushbutton	S6	Pushed to check phase meter zero.
FS pushbutton	S7	Pushed to check phase meter full scale deflection.
FULL SCALE ADJ potentiometer	R1	Adjusts phase meter full scale deflection.

for a functional description of the FDM controls, connectors, and indicators.

1-7. ELECTRICAL SPECIFICATIONS.

1-8. The electrical specifications of the Model 527E FDM are listed in the following paragraphs.

1-9. INPUT REQUIREMENTS.

1-10. The input requirements of the FDM are as listed in the following paragraphs.

1-11. FREQUENCIES. 100 kHz (±0.25%); 1 MHz (±0.50%); 2.5 MHz (±0.50%); 5 MHz (±0.50%).

1-12. VOLTAGE. 0.5 to 10.0 volts rms.

1-13. IMPEDANCE. 1000 ohms nominal.

1-14. OUTPUT REQUIREMENTS.

1-15. The output requirements of the FDM are as listed in the following paragraphs.

1-16. FREQUENCIES. 1 MHz derived from reference input; 1 MHz + $10^N \Delta F$ derived from signal input.

1-17. VOLTAGE. 2 volts peak-to-peak.

1-18. RECORD OUTPUT. DC voltage proportional to front panel meter reading. Will drive 0.5 milliampere recorder with input impednace less than or equal to 2000 ohms.

1-19. FREQUENCY DIFFERENCE INDICATORS.

1-20. The requirements on the frequency difference indicators of the FDM are as listed in the following paragraphs.

1-21. METER. Front panel; zero center, scale from -10 to +10 parts in 10^7, 10^8, 10^9, 10^{10}, or 10^{11}. ($\pm$5% of full scale reading on all ranges.)

1-22. METER. Signal phase, with multiplied differential error, is shown by repeated excursions of meter needle.

1-23. POWER REQUIREMENTS.

1-24. The power required for the FDM is 115 volts ($\pm$15%) or 230 volts ($\pm$15%), 48-420 Hz; approximately 20 watts.

SECTION II

INSTALLATION AND ADJUSTMENTS

2-1. SCOPE OF SECTION.

2-2. This section provides instructions for installation and initial adjustment of Model 527E FDM.

2-3. INSTALLATION.

2-4. Carefully unpack and examine the FDM for possible damage during shipment. Special attention should be given to areas where the outside shipping package was damaged.

NOTE

The Model 527E FDM is, by necessity, an extremely sensitive instrument and is conservatively designed for minimum susceptability to excessive vibrations and large alternating magnetic fields. However, operation in such environments should be avoided. Problems that can arise by operating in such environments are covered in paragraph 3-9.

2-5. The FDM can be mounted in a standard 19 inch rack or located on a bench. For bench operation, rubber feet provided in accessary parts set (6355-0002) should be used. Refer to Figure 2-1 for proper installation of rubber feet.

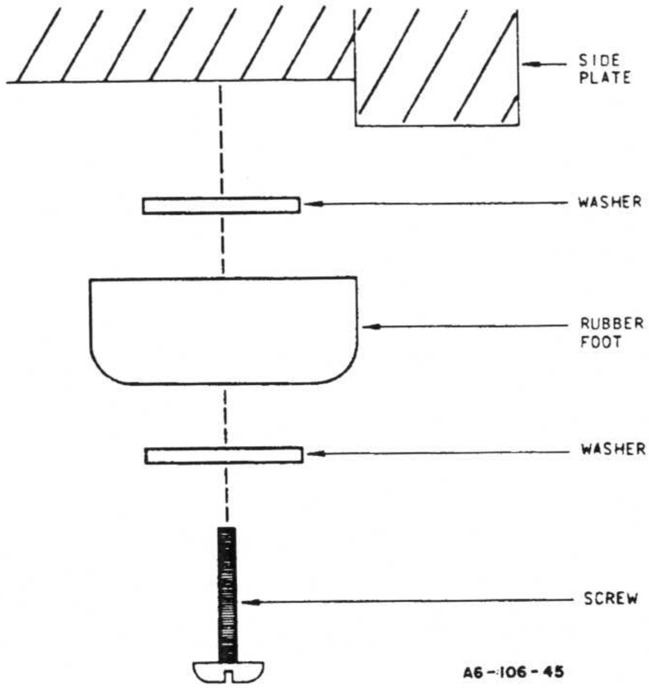


Figure 2-1. Installation of Rubber Feet.

2-6. PRELIMINARY ADJUSTMENTS.

2-7. The operator should become familiar with the controls and connectors and then perform the following preliminary adjustment procedure:

a. Check that 115/230 switch on back panel is in correct position for power source to be used.

b. Connect FDM to 115 or 230 volt, 48 or 420 Hz, single phase power source.

c. Check that front panel meter indicates zero when POWER switch is OFF. Use recessed mechanical zero adjustment just below meter, if meter does not indicate zero. Do not use ZERO ADJ potentiometer.

d. Connect reference frequency standard to REF INPUT connector on either front or back panel.

e. Set TEST/OPERATE switch to TEST.

f. Set POWER switch to ON. POWER lamp shall light.

g. Front panel frequency difference meter shall indicate zero; if it does not, adjust ZERO ADJ potentionmeter to obtain zero indication. METER RANGE selector or FILTER switch position will not affect meter zero.

h. Push phase meter zero button. If required make mechanical zero adjustment of (small) phase meter.

i. Push phase meter FS button. Adjust for full scale deflection using FS ADJ potentiometer.

SECTION III

OPERATION

3-1. SCOPE OF SECTION.

3-2. This section provides detailed procedures for operation of the Model 527E FDM to measure frequency difference, perform oscillator adjustments, offset one oscillator frequency from another, and to analyze and measure short and long term oscillator stability.

3-3. EQUIPMENT TURN ON.

3-4. The Model 527E FDM requires no special turn on procedures beyond setting the 115/230 switch to the correct position; connecting the power cord to a 115 or 230 volt, 48-420 Hz power source; and setting the POWER switch to ON. It does not require any warmup period.

3-5. OPERATION.

3-6. Prior to using the FDM, zero the meters in accordance with paragraph 2-6.

3-7. Care should be taken to avoid external ground loops and excessive cable lengths. All cabling should be properly shielded. This will minimize cross coupling between the signal and reference inputs or between the 1 MHz + 10^N ΔF output and either the reference or signal input. Cross coupling between signal and reference inputs is indicated by low frequency cycling on the front panel meter; cross coupling between the 1 MHz + 10^N ΔF output and either the signal or reference input is indicated by higher frequency cycling on the front panel meter. An oscilloscope synchronized with the reference input and connected to view the signal input can introduce sufficient cross coupling to cause the front panel meter to cycle. Phase shifts between the signal source and the FDM can also affect meter readings.

3-8. FREQUENCY DIFFERENCE MEASUREMENT.

3-9. To determine the fractional frequency difference between two stable oscillators, any one of the following methods may be used:

a. Meter readout.
b. Internal phase meter.
c. External chart recorder.
d. External oscilloscope.
e. External electronic counter with counter time base.
f. External electronic counter with external time base.

3-10. METER READOUT. The fractional frequency difference between a signal and reference input can be read directly from the meter. Determine the fractional frequency difference as follows:

a. Set METER RANGE selector to 10^7.
b. Connect reference frequency standard to REF INPUT connector.
c. Connect signal frequency to SIG INPUT connector.
d. Set TEST/OPERATE switch to OPERATE.
e. Set METER RANGE selector to position giving largest on-scale reading without causing OVERRANGE lamp to light.

NOTE

If OVERRANGE lamp remains lighted in all METER RANGE selector positions, either fractional frequency difference is beyond meter range or excessive phase noise is present. Presence of phase noise indicates that either reference or signal inputs are noisy, or instrument is being subjected to vibration or alternating magnetic fields. In 10^{10} and 10^{11} position noise can be reduced by setting FILTER switch to IN. Filter is limited to input frequencies within 5 parts in 10^7 of the standard frequencies due to filter bandwidth limitation.

f. Read fractional frequency difference directly from meter. For example, if meter reading is 6.5 and METER RANGE selector is set to 10^9 position, fractional frequency difference between signal and reference frequencies is 6.5 parts in 10^9.

3-11. PHASE METER. The rate of motion of the needle on the front panel phase meter is proportional to the fractional frequency difference between a signal and reference input. Accuracy of this method is limited only by accuracy with which needle rate, or its reciprocal, is determined. Determine the fractional frequency difference as follows:

a. Set DIFF MULT selector to 10.

b. Connect reference frequency standard to REF INPUT connector.

c. Connect signal frequency to SIG INPUT connector.

d. Set TEST/OPERATE switch to OPERATE.

e. Set DIFF MULT selector to position giving greatest, readable phase meter rate without causing OVERRANGE lamp to light.

f. If the signal frequency is slightly high with respect to the reference phase meter needle will move slowly to the right until it reaches full scale and will then suddenly return to zero and again move slowly to the right. With an error multiplication factor of 10 on the meter range switch, one full scale excursion of the phase meter per second corresponds to 1 part in $(10)^7$. One excursion in 5 seconds would represent 1/5 as much frequency offset or 2 parts in $(10)^8$. For other multiplication factors the following table applies.

Frequency Multiplication Factor	Frequency Offset Indicated By One Phase Meter Excursion Per Second
10	1 part in $(10)^7$
100	1 part in $(10)^8$
1,000	1 part in $(10)^9$
10,000	1 part in $(10)^{10}$

3-12. EXTERNAL CHART RECORDER. A ±0.5 milliampere recorder with input impedance less than or equal to 2000 ohms can be used for recording fractional frequency differences. The EXTERNAL RECORDER output on back panel is proportional to front panel meter reading. Determine fractional frequency difference as follows:

a. Set up meter indication in accordance with paragraph 3-10.
b. Set TEST/OPERATE switch to TEST.
c. Adjust recorder for zero indication at center of chart.
d. Set TEST/OPERATE switch to OPERATE.
e. Adjust CALIBRATE potentiometer on rear panel until recorder reading corresponds to meter reading.

3-13. EXTERNAL OSCILLOSCOPE. An oscilloscope can be used to measure the fractional frequency difference by displaying the signal output on the oscilloscope when it is synchronized to the reference output. Accuracy of this method is limited only by accuracy with which display movement rate, or its reciprocal, is determined. Determine fractional frequency difference as follows:

a. Connect 1 MC/S OUT signal to oscilloscope as signal to be displayed.
b. Connect 1 MC/S + 10^N Δf OUT reference to oscilloscope as synchronizing signal.

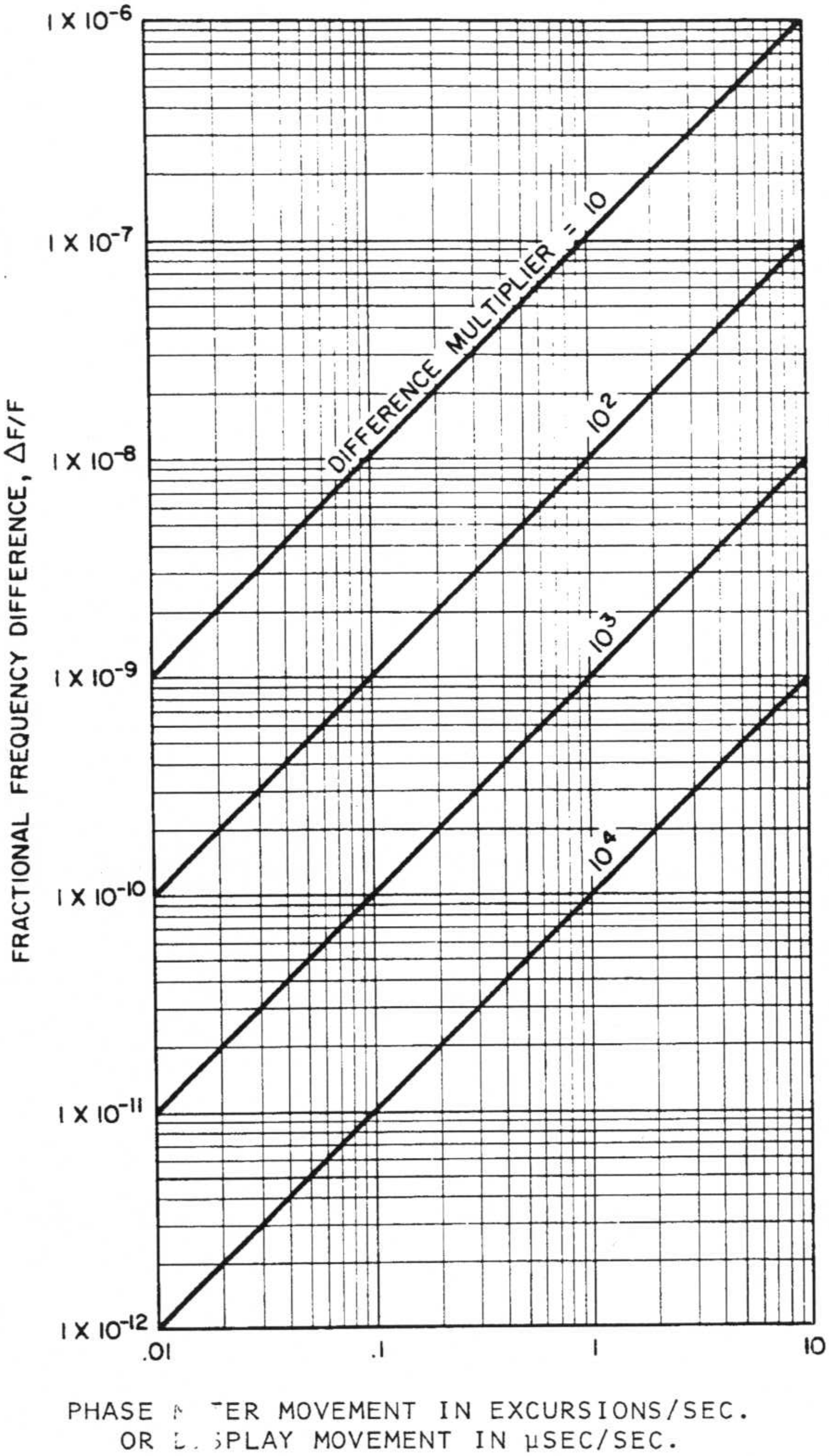


Figure 3-1. Fractional Frequency Difference vs Display Movement in μsec/sec or Phase Meter Movement in excursions/sec.

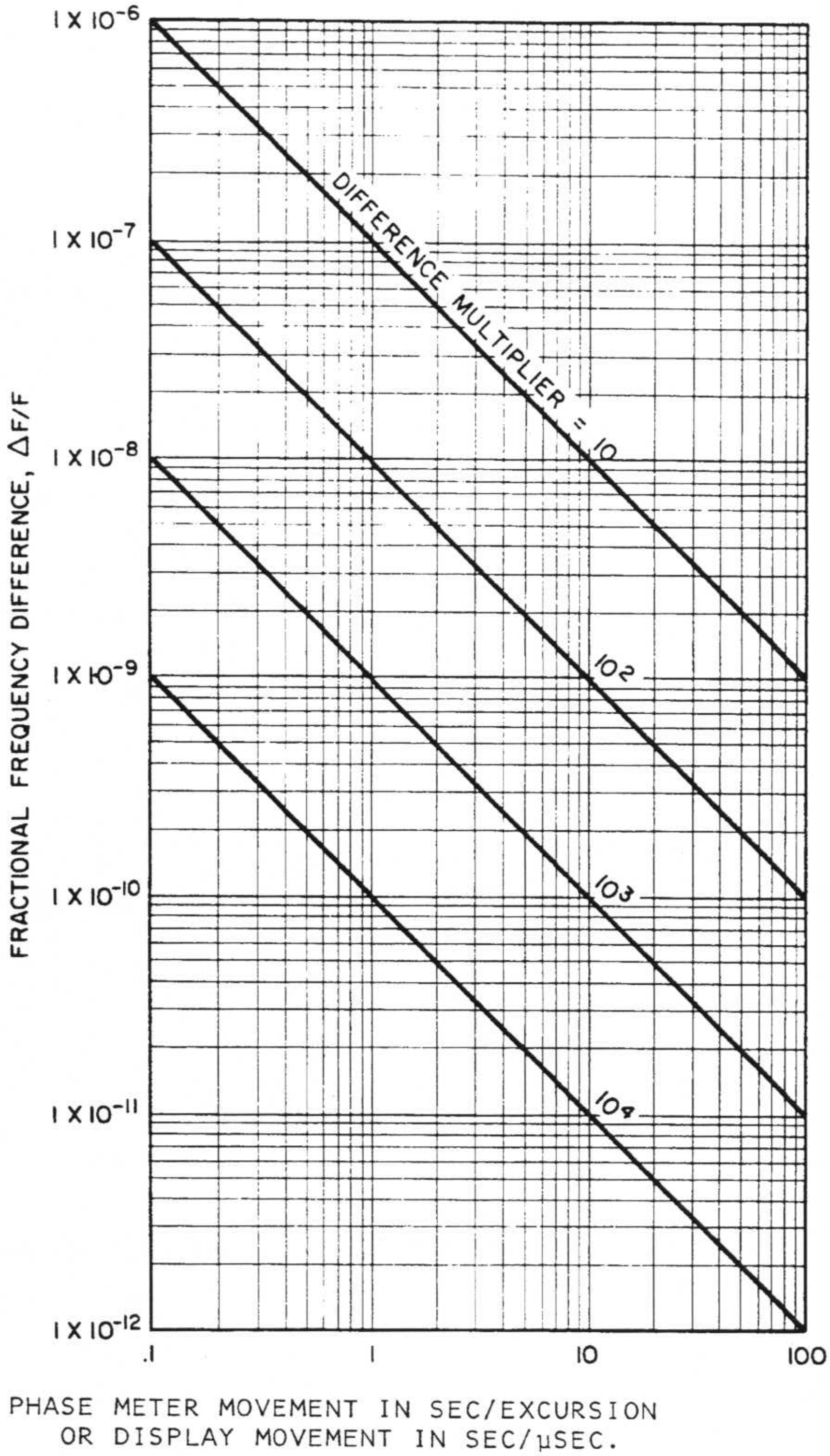


Figure 3-2. Fractional Frequency Difference vs Display Movement in sec/μsec or Phase Meter Movement in sec/excursion.

c. Use most sensitive usable scale for DIFF MULT selector.

d. Rate in microseconds per second at which oscilloscope display moves is related to fractional frequency difference between signal and reference as follows: μsec/sec = (DIFF MULT position) ($\Delta F/F$) (10^6).

After the rate at which display moves is determined, $\Delta F/F$ can be easily determined. Fo· example, if display moves right at 1.8 μsec/sec and DIFF MULT selector is set to 10^3, $\Delta F/F$ equals minus 1.8 parts in 10^9. Figures 2-1 and 2-2 may be used to help determine $\Delta F/F$ when either display movement rate or its reciprocal is known.

3-14. EXTERNAL ELECTRONIC COUNTER WITH COUNTER TIME BASE. This method is useful when the fractional frequency difference exceeds the meter readout limit of 10 parts in 10^7. This method is limited only by the FDM 10 kHz bandwidth at 1 MHz + 10^N ΔF. With the DIFF MULT selector set to 10, as large as one part in 10^3 can be measured.

3-15. The only requirements for the counter are that its frequency range include 1 MHz and that it have sufficient input sensitivity to operate from the FDM outputs. Always accour· for the counter's ±1 count ambiguity by using the longest avai..ble gate time and the most sensitive, usable DIFF MULT selector position. Determine the fractional frequency difference as follows:

a. Connect 1 MC/S + 10^N Δf OUT signal to counter input.

b. Set TEST/OPERATE switch to OPERATE. Note counter readout.

c. Set TEST/OPERATE switch to TEST. Note counter readout.

d. Calculate fractional frequency difference using the following equation:

$$\Delta F/F = \frac{\text{(TEST position readout) - (OPERATE position readout)}}{(10^6) \quad \text{(DIFF MULT selector position)}}$$

As an example, assume the counter time base is 1 MHz, its gate time is set to 10 seconds, and it has a 6 digit readout. Starting with the DIFF MULT selector set to 10, the counter readout is 1000.0776 kHz with the TEST/OPERATE switch in the OPERATE position. This readout represents the signal input frequency. The underlined digits are all that will be visible on the counter readout. This gives a frequency offset of 77 Hz (neglecting the time base offset and the ±1 count ambiguity). Since the FDM bandwidth limit is 10,000 Hz, the DIFF MULT selector can be set to 10^3. Assume the counter readout in this position is 1007.7616 kHz. This gives a frequency offset of 7,761 Hz, within the bandwidth limit. Set the TEST/OPERATE switch to TEST to measure the reference input frequency. Assume the counter readout is 1000.0003 kHz; this gives a frequency offset of 0.3 Hz (neglecting the ±1 count ambiguity). The equation given in paragraph 3-15 d., gives the following results:

$$\Delta F/F = \frac{1{,}007{,}761.6 \text{ Hz} - 1{,}000{,}000.3 \text{ Hz}}{(10^6) \quad (10^3)} = \frac{7{,}761.3}{(10^9)}$$

or 7.7613 parts in 10^6. Using this method, the time base offset is cancelled out in the subtraction. The only remaining error is the ±1 count ambiguity, which is eliminated by dropping the last digit in the answer. The correct fractional frequency difference is then 7.761 parts in 10^6.

3-16 If the signal and reference input frequency errors in paragraph 3-15 had the same absolute values, but were low instead of high, the counter readouts would have been 992.2384 kHz and 999.9997 kHz for the signal and reference outputs respectively. In this case, the fractional frequency difference would have been -7.761 parts in 10^6.

3-17. It was assumed in paragraph 3-15 that the signal and reference inputs were extremely stable and that the readouts remained constant for any number of 10 second gate intervals. Actually, phase noise will probably cause one or more readout digits to change from one gate interval to the next. These digits are unreliable and should not be used when calculating the fractional frequency difference.

3-18. EXTERNAL ELECTRONIC COUNTER WITH EXTERNAL TIME BASE. This method is basically the same as the method described in paragraph 3-14, except that no reading is taken with the TEST/OPERATE switch in the TEST position. The 1 MC/S OUT signal is used as the time base. Use the following equation to determine the fractional frequency difference:

$$\Delta F/F = \frac{(\text{OPERATE position readout}) - 1{,}000{,}000.0 \text{ Hz}}{(10^6) \quad (\text{DIFF MULT position})}$$

The results will be the same as in paragraph 3-14. The ± 1 count ambiguity and any phase noise must also be accounted for in the results.

3-19. OSCILLATOR ADJUSTMENT.

3-20. The basic procedures for oscillator adjustment are the same as specified in paragraphs 3-10 or 3-11 for frequency difference measurement. After the meter reading or oscilloscope spot is set up, increase or decrease the oscillator frequency until the desired meter reading is obtained. Always start with the METER RANGE/DIFF MULT selector in the least sensitive position, advancing it to more sensitive positions as the frequency difference is decreased.

NOTE

The two input frequencies do not have to be at the same nominal frequency. For example, the reference input frequency can be at a nominal 1 MHz and the frequency to be adjusted at a nominal 2.5 MHz.

3-21. OSCILLATOR LONG TERM STABILITY MEASUREMENT.

3-22. The basic procedures for analyzing oscillator long term stability are the same as specified in paragraphs 3-10 or 3-11 for frequency difference measurement. The rate of frequency change with respect to time can be determined by recording the frequency difference on an external chart recorder. This is also useful for studying oscillator aging behavior or studying oscillator behavior under various service conditions such as temperature changes.

SECTION IV

THEORY OF OPERATION

4-1. SCOPE OF SECTION.

4-2. This section provides a general description of the overall operation of the Model 527A FDM and detailed analysis of its individual circuits and modules. This analysis is supported by block diagrams and references to schematic diagrams as required.

4-3. FUNCTIONAL ANALYSIS.

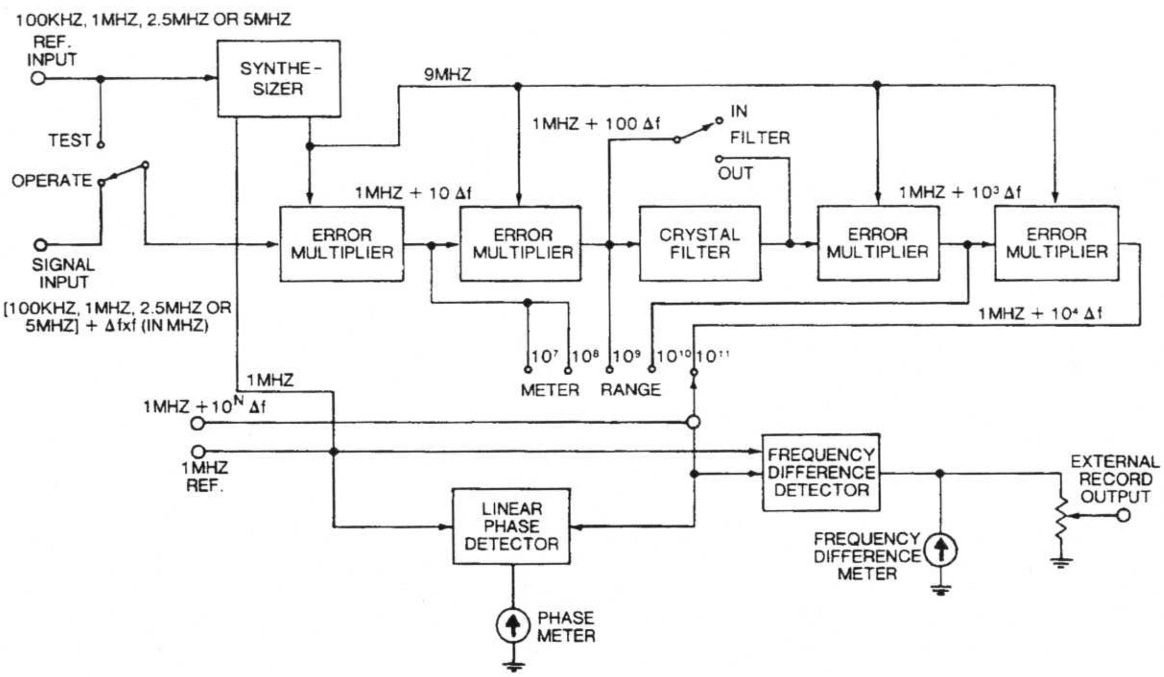
4-4. The FDM can be divided into two main operational sections; the error multiplier section and the difference detector section. Refer to figure 4-1 for a functional block diagram of the FDM.

4-5. ERROR MULTIPLIER SECTION.

4-6. The error multiplier section consists of a synthesizer, four error multipliers, and a crystal filter. The synthesizer converts the reference input signal to a 9 MHz reference signal for the error multipliers, and to a 1 MHz reference signal for the display circuits and 1 MC/S OUT reference signal. The first error multiplier converts the input signal to a 1 MHz signal with 10 times the fractional frequency offset of the input signal. The second, third, and fourth error multipliers have 1 MHz outputs with 100, 1,000, and 10,000 times the fractional frequency offset of the input signal, respectively. A crystal filter can be switched into the circuit between the second and third error multipliers to allow for better difference multiplication of noisy input signals. Table 4-1 gives the relationships between

Table 4-1. Signal Input and Error Multiplier Output Relationships.

Input Signal	DIFF MULT Selector Setting			
	10	10^2	10^3	10^4
100 kHz + ΔF_1	1 MHz + $100\Delta F_1$	1 MHz + $1{,}000\Delta F_1$	1 MHz + $10{,}000\Delta F_1$	1 MHz + $100{,}000\Delta F_1$
1 MHz + ΔF_2	1 MHz + $10\Delta F_2$	1 MHz + $100\Delta F_2$	1 MHz + $1{,}000\Delta F_2$	1 MHz + $10{,}000\Delta F_2$
2.5 MHz + ΔF_3	1 MHz + $4\Delta F_3$	1 MHz + $40\Delta F_3$	1 MHz + $400\Delta F_3$	1 MHz + $4{,}000\Delta F_3$
5 MHz + ΔF_4	1 MHz + $2\Delta F_4$	1 MHz + $20\Delta F_4$	1 MHz + $200\Delta F_4$	1 MHz + $2{,}000\Delta F_4$



Block Diagram of the Model 527E Frequency Difference Meter

Figure 4-1.

the signal inputs and the error multiplier outputs.

4-7. DIFFERENCE DETECTOR SECTION.

4-8. The difference detector section consists of a frequency difference detector, frequency difference meter, phase detector and phase meter. The frequency difference detector converts the fractional frequency difference between the synthesizer and error multiplier outputs, as selected by the METER RANGE selector, to a dc voltage for use by the front panel meter. The frequency difference detector is calibrated such that when (DIFF MULT) ($\Delta F/F$) (10^6) equals 1 Hz, the front panel meter deflects full scale.

4-9. The linear phase detector converts the phase difference between the 1 MHz reference and the error-multiplied 1 MHz to a voltage level for indication by the front panel phase meter.

4-10. DETAILED THEORY OF OPERATION.

4-11. The FDM contains 14 plug-in printed circuit boards, or modules, which are as follows; power transistor board, flip-flop, 4 error multipliers, reference input/9 MHz amplifier, 5 MHz/1 MHz divider, buffer amplifier, power supply, differentiator/integrator, single shot/phase comparator, crystal filter, and phase detector.

4-12. POWER SUPPLY.

4-13. The power supply consists of power transistor printed circuit board assembly 6153 and power supply printed circuit board assembly 6160 (see Figures 7-3 and 7-4). The power supply has three dc outputs; + 15, - 15, and + 9 volts; and operates from 115 volts ac coupled through FDM transformer T1. The + 9 volt dc power supply consists of transistors Q1, Q2, and Q6. Its output is regulated by voltage regulator VR1 with capacitor C4 across the output to reduce ripple. The + 15 volt dc power supply consists of transistors Q3, Q4, and Q5. It uses the - 15 volt dc power supply as a reference for voltage regulation. Capacitor C2 across its output reduces ripple. The - 15 volt dc power is derived directly from the diode bridge and input filter. The output is regulated by voltage regulator VR 2 with capacitor C5 across its output to reduce ripple.

4-14. SYNTHESIZER.

4-15. The synthesizer consists of reference input/9 MHz amplifier printed circuit board assembly 6157 (see Figure 7-5) and 5 MHz/1 MHz divider printed circuit board assembly 6158 (see Figure 7-6). Refer to Figure 4-2 for a functional block diagram of the synthesizer.

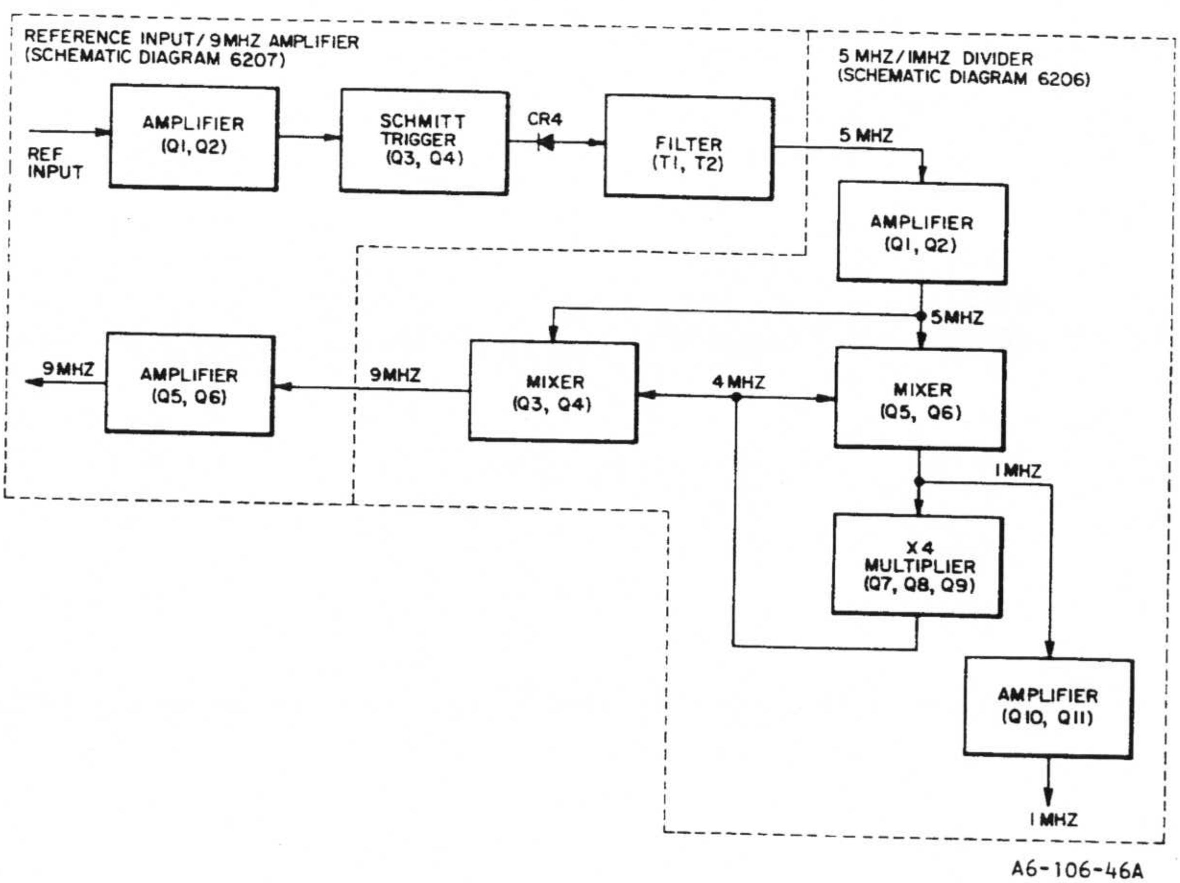


Figure 4-2. Synthesizer Functional Block Diagram.

4-16. The FDM reference input, which can be any submultible of 5 MHz, is amplified and limited by the amplifier consisting of transistors Q1 and Q2. This signal is applied to the Schmitt trigger, consisting of transistors Q3 and Q4, where it is converted to a square wave. The negative going portion of the square wave is coupled through diode CR4, which blocks the positive going portion of the square wave, to the 5 MHz filter consisting of variable transformers T1 and T2. This output goes to the 5 MHz/1 MHz divider board where it is amplified by the amplifier consisting of transistors Q1 and Q2. The amplifier output is coupled to the two mixers, or dividers, through the 5 MHz filter, variable transformer T1. The output of the mixer, consisting of transistors Q5 and Q6, is filtered at 1 MHz by variable transformer T2. This 1 MHz signal is quadrupled in frequency by the multiplier consisting of transistors Q7, Q8, and Q9. Transistor Q9 oscillates at approximately 4 MHz, when no input signal is present, to provide a starting signal for the two mixers. Once the mixer output signal is present, transistor Q9 is forced to oscillate at exactly 4 MHz. The 1 MHz output of the mixer, consisting of transistors Q5 and Q6, is amplified by transistors Q10 and Q11 to provide the 1 MHz reference signal for the FDM. The output signal of the 9 MHz mixer, consisting of transistors Q3 and Q4, is sent back to the reference input/9 MHz amplifier board, where it is filtered by variable transformers T3 and T4 at 9 MHz. This signal is amplified by transistors Q5 and Q6 to provide the 9 MHz reference signal for the error multipliers.

4-17. ERROR MULTIPLIER.

4-18.. The FDM has four error multiplier boards; three error multiplier printed circuit board assemblies 6155 and one error multiplier printed circuit board assembly 6156 (see Figures 7-7 and 7-8. The only difference between the 6155 and 6156 assemblies is that the 6156 has two additional diodes, one additional resistor, and one additional capacitor in the signal input circuit. Refer to figure 4-3 for a functional block diagram of the error multiplier.

4-19. The error multiplier converts the FDM signal input, which must be a multiple of 10 MHz, to a 1 MHz signal with ten times the fractional frequency error of the signal input. The input signal, F + ΔF (nominal frequency plus some unknown error), is amplified by transistors Q1 and Q2. ΔF/F is the fractional frequency difference between the reference and the signal inputs.

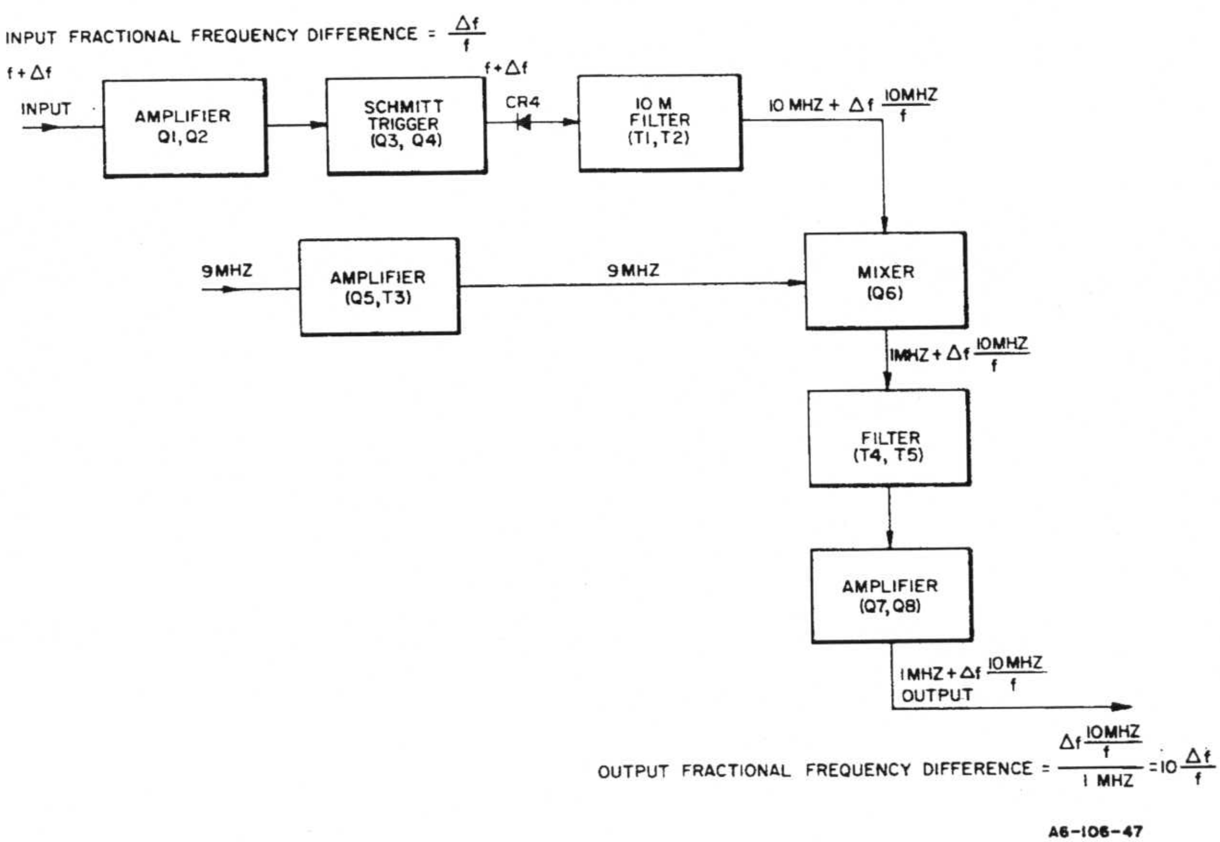


Figure 4-3. Error Multiplier Functional Block Diagram.

This signal is applied to the Schmitt trigger, consisting of transistors Q3 and Q4, where it is converted to a square wave. The negative going portion of the square wave is coupled through diode CR4, which blocks the positive going portion of the square wave, to the 10 MHz filter, consisting of variable transformers T1 and T2. The filter output is 10 MHz + ΔF (10 MHz/F). The amount of frequency multiplication from the error multiplier input to the 10 MHz filter is 10 MHz/F. The 9 MHz reference input, from the reference input/9 MHz amplifier, is amplified and filtered, at 9 MHz, by transistor Q5 and variable transformer T3. The 10 MHz + ΔF (10 MHz/F) signal is mixed with this 9 MHz reference signal by transistor Q6. The output of transistor Q6, 1 MHz + ΔF (10 MHz/F), is filtered at 1 MHz by variable transformers T4 and T5. This signal is amplified by transistors Q7 and Q8 and filtered at 1 MHz by variable transformer T6 to provide the 1 MHz + ΔF (10 MHz/F) output signal. Thus, the fractional frequency error of the output signal is $\frac{\Delta F(10\ MHz/F)}{1\ MHz}$ or 10 $\Delta F/F$, which is ten times the input error.

4-20. CRYSTAL FILTER.

4-21. The crystal filter printed circuit board assembly 6164 (see Figure 7-9) is electrically located between the second (10^2) and third (10^3) error multipliers. Under normal operating conditions, the crystal filter is shorted out by FILTER switch S4. When the filter must be used, S4 is set to IN, forcing the signal through the crystal filter. The crystal, Y1, is tuned to exactly 1 MHz by variable capacitor C2.

4-22. BUFFER AMPLIFIER.

4-23. The buffer amplifier printed circuit board assembly 6159 (see Figure 7-10) is used to buffer the 1 MHz and 1 MHz + 10^N ΔF

signals and to switch on the OVERRANGE lamp using solid state switching.

4-24. The 1 MHz reference signal from the 5 MHz/1 MHz divider, in the synthesizer, is amplified by the transistor pair (emitter follower coupled to common base) consisting of transistors Q7 and Q8. This output is buffered by emitter follower transistor Q9. The 1 MHz + 10^N ΔF signal from the error multiplier, selected by the METER RANGE selector S3, is amplified and buffered by an identical circuit consisting of transistors Q6, Q5, and Q4 respectively.

4-25. The blanking pulses, from the single shot/phase comparator (see paragraph 4-34), are filtered by the active low pass filter, consisting of transistor Q3 and associated circuitry. When this filtered signal becomes negative (an indication of excessive noise or an overrange signal) transistors Q1 and Q2 are turned on, applying approximately -15 volts dc to the OVERRANGE lamp DS2. Since the OVERRANGE lamp has +15 volts dc applied to it at all times, the negative voltage increases the potential across the lamp to approximately 28 volts dc, causing the lamp to light.

4-26. PHASE DETECTOR

4-27. The phase detector printed circuit board assembly 79736 (see Figure 7-13a) converts the frequency difference between the 1 MHz reference and the 1 MHz + 10^N ΔF signal from the buffer amplifier, to a dc voltage for use by the phase meter. Refer to Figure 4-4 for a functional block diagram.

4-28. The buffered 1 MHz + 10^N ΔF signal is converted to a square wave by limiter amplifier Q3, Q4, and U1C. This square wave is differentiated by a network consisting of C4 and R12. The 1 MHz reference is similarly converted to a square wave and differentiated.

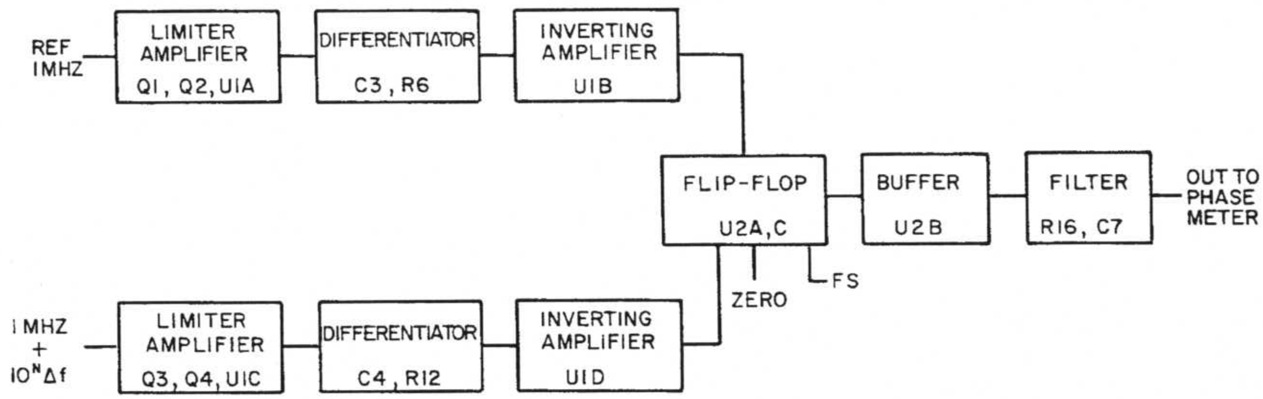


Figure 4-4. Phase Detector Functional Block Diagram.

4-29 Flip-flop U2 A&C is triggered on by the reference, off by the error-multiplied input. The on-time, and therefore the d-c component in the output is therefore a measure of the phase difference between the two inputs.

4-30 The flip flop output is filtered by R6 and C7 to provide a d-c signal for indication by the front panel phase meter.

4-31. FREQUENCY DIFFERENCE DETECTOR.

4-32. The frequency difference detector consists of flip-flop printed circuit board assembly 6154 (see Figure 7-12) single shot/phase comparator printed circuit board assembly 6162 (see Figure 7-13) and differentiator/integrator printed circuit board assembly 6161 (see Figure 7-14). Refer to Figure 4-5 for a functional block diagram of the frequency difference detector and to Figure 4-6 for the frequency difference detector pulses.

4-33. The buffered 1 MHz and 1 MHz + 10^N ΔF signals from the buffer amplifier are divided down from 1 MHz to 250 kHz by the flip-flop. These signals are phase compared by setting and resetting a phase comparator (flip-flop) circuit in the single shot/phase comparator. The signals applied to the phase comparator are also applied to an AND gate, which triggers a single shot circuit when the two input signals are coincident (within 0.5 microseconds of each other). The single shot circuit output sets one of the signal input flip-flop dividers, adding one count to that divider. This change in count causes the signals to the phase comparator to become 180 degrees out of phase, returning the phase comparator to center of its range.

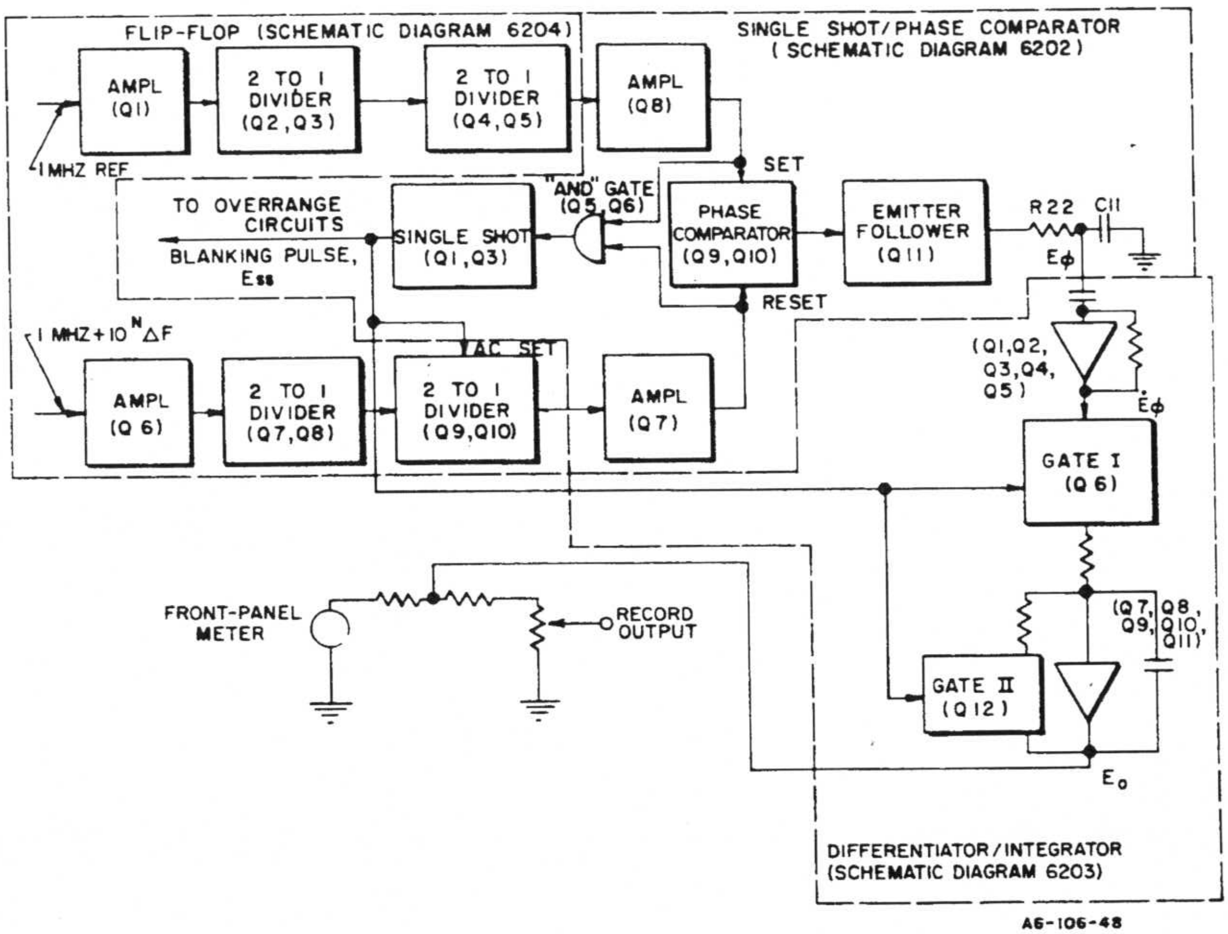


Figure 4-5. Frequency Difference Detector Functional Block Diagram.

4-34. The phase comparator measures the phase difference between the 1 MHz and 1 MHz + 10^N ΔF signals on a linear scale. Its output also steps back to center range when it reaches zero

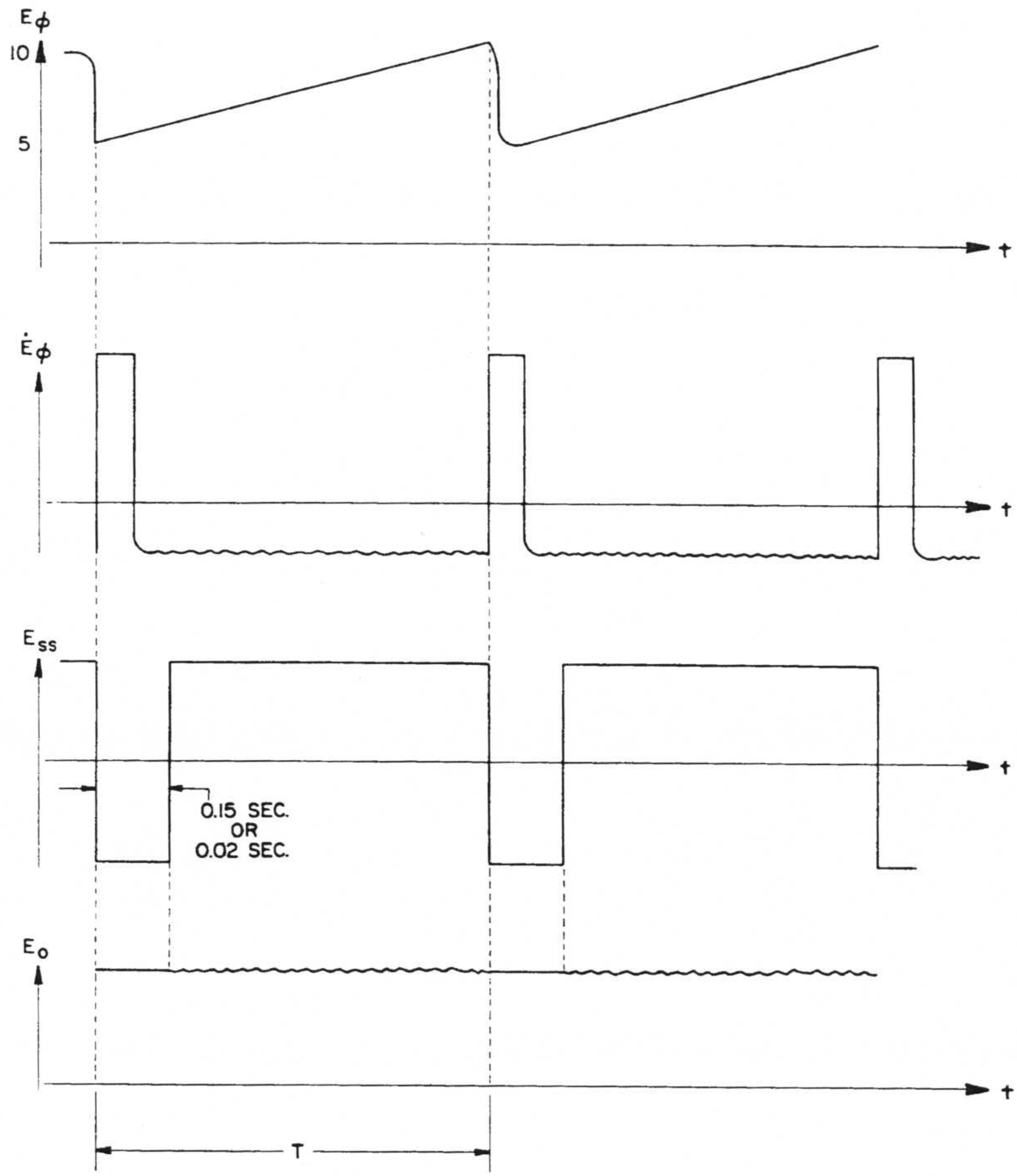


Figure 4-6. Frequency Difference Detector Pulses.

or full scale (the two input signals are coincident). The phase comparator output is differentiated to produce signal $\dot{E}_{\phi}$. The transient produced when the phase comparator steps back to center range is blanked out by GATE I, which is driven by single shot pulse E_{SS}. The differentiator output, after blanking, is filtered by an active low pass filter. During the time the single shot pulse is present, a dc feedback path is opened by GATE II to hold the output voltage at a stable level. This output voltage, E_0, is proportional to the phase rate, or frequency difference, between the 1 MHz and 1 MHz + 10^N ΔF signals.

4-35. FLIP-FLOP. The flip-flop is used as a square wave converter and a 1 MHz to 250 kHz divider for the 1 MHz and 1 MHz + 10^N ΔF signals received from the buffer amplifier.

4-36. The 1 MHz and 1 MHz + 10^N ΔF signals are converted to square wave signals by amplifiers Q1 and Q6 respectively. These amplifiers have sufficient gain to saturate the amplifier output. This causes the output to take the form of a square wave. The 1 MHz square wave is divided by two casaded binary dividers, consisting of transistors Q2 and Q3 and transistors Q4 and Q5. The output of the second divider is a 250 kHz square wave. An identical circuit is used for the 1 MHz + 10^N ΔF signal, consisting of transistors Q7 and Q8 and transistors Q9 and Q10. The second divider of each circuit receives its reset pulse from the single shot/phase comparator. The two flip-flop outputs are then sent to the single shot/phase comparator.

4-37. SINGLE SHOT/PHASE COMPARATOR. The single shot/phase comparator compares the phase of the two signals from the flip-flop and has a ramp voltage output proportional to the difference in phase between the two signals.

4-38. The 250 kHz and 250 kHz + 10^N $\Delta F/4$ square wave signals from the flip-flop are amplified by transistors Q8 and Q7 respectively. These square waves are used to set and reset the phase comparator consisting of transistors Q9 and Q10. The phase comparator output is buffered by emitter follower transistor Q11 and filtered by the RC network consisting of resistor R22 and capacitor C11. The filter output, E_ϕ, is a ramp voltage proportional to the phase difference between the 1 MHz and 1 MHz + 10^N ΔF signals.

4-39. The negative going portion of the square wave outputs from transistors Q7 and Q8 are also compared by the AND gate consisting of transistors Q5 and Q6. When the two signals are within approximately 0.5 microseconds of each other, the AND gate triggers the single shot circuit, producing a blanking pulse. The width of the single shot output pulse, E_{SS}, is determined by the setting of the METER RANGE selector. In the 10^8 through 10^{11} positions the pulse width is approximately 150 milliseconds. In the 10^7 position, resistor R3 is switched into the circuit parallel to resistor R2, reducing the pulse width to about 20 milliseconds. The pulse period, T, is determined by the phase change rate.

4-40. <u>DIFFERENTIATOR/INTEGRATOR.</u> The differentiator/integrator converts the phase comparator output ramp voltage to a stable dc voltage for use by the frequency difference meter.

4-41. The ramp voltage from the phase comparator is differentiated by an active differentiator consisting of a high gain amplifier (transistors Q1 through Q5), feedback resistor R3, and capacitors C1 and C2. Capacitor C1 is switched into the circuit only when the METER RANGE selector S3 is in the 10^7 position. The blanking switch (GATE I), transistor Q6, disconnects the differentiator output, E_ϕ, from the active low pass filter during the time the flip-flop divider is being reset. The active low pass filter, whose time constant is approximately 1 second, consists of transistors Q7 through Q11; capacitor C6; and resistors R11, R12, R13, and R18.

4-42. The blanking pulse also turns off transistor Q12. This holds the output voltage stable during the flip-flop reset time. The filter output, E_0, is proportional to the frequency difference between the 1 MHz and 1 MHz + 10^N ΔF signals. Potentiometer R12 calibrates the front panel meter for the 10^8 through 10^{11} ranges and potentiometer R13 calibrates the meter for the 10^7 range.

SECTION V

MAINTENANCE

5-1. SCOPE OF SECTION.

5-2. This section provides a list of all special test equipment required, a table of common malfunctions and probable causes, and calibration procedures for aligning the tuned amplifiers in the FDM.

5-3. TEST EQUIPMENT REQUIRED.

5-4. All special test equipment required to analyze malfunctions and perform required calibrations is as follows:

a. Frequency standard with known offset in parts in 10^7.
b. Frequency standard with known offset in parts in 10^8, 10^9, 10^{10}, or 10^{11}.
c. Stable 1 MHz reference.
d. Insulated alignment tool.
e. Oscilloscope
f. High impedance, low capacitance probe.

5-5. TROUBLE ANALYSIS.

5-6. The operator should become familiar with the operating instructions in section III and the theory of operation in section IV before performing a trouble analysis on the FDM. Table 5-1 lists the most common troubles and associated probable malfunctioning components. Table 5-2 is a cross reference list between module assembly stock numbers and the associated printed circuit board assembly stock number. This table is useful when locating boards in the FDM.

Table 5-1. Common Troubles and Probable Malfunctioning Components.

Trouble	Probable Malfunctioning Component
POWER lamp off	Indicator lamp DS1 Fuse F1 115/230 switch S1 Power switch S5 Power Transistor board, 6153 (J18) Power Supply board, 6160 (J17)
1 MC/S OUT signal not present	Buffer Amplifier board, 6159 (23) Reference Input/9 MHz Amplifier board, 6157 (J11) 5 MHz/1 MHz Divider board, 6158 (J10)
1 MC/S + 10^N Δf OUT signal not present regardless of METER RANGE selector position	Buffer Amplifier Board, 6159 (J23) First Error Multiplier board, 6156 (J12) METER RANGE selector S4
1 MC/S + 10^N Δf OUT signal present only in METER RANGE selector 10^7 and 10^8 positions	Second Error Multiplier board, 6155 (J13)
1 MC/S + 10^N Δf OUT signal present only in METER RANGE selector 10^7, 10^8, and 10^9 positions	Third Error Multiplier board, 6155 (J15)
1 MC/S + 10^N Δf OUT signal present only in METER RANGE selector 10^7, 10^8, 10^9, and 10^{10} positions	Fourth Error Multiplier board, 6155 (J16)

Table 5-1. (Continued)

Trouble	Probable Malfunctioning Component
1 MC/S + 10^N Δf OUT signal disappears in METER RANGE selector 10^{10} or 10^{11} positions with Filter switch set to IN	Crystal Filter board, 6164 (J14)
Abnormal meter indication	Flip-Flop board, 6154 (J22) Single Shot/Phase Comparator board, 6162 (J21) Meter M1
Abnormal phase meter action	Phase comparator board, (J24)
OVERRANGE lamp behaves abnormally	OVERRANGE lamp DS2 Buffer Amplifier board, 6159 (J23)

5-7. CALIBRATION.

5-8. This paragraph provides procedures for calibration of the front panel frequency difference meter, adjustment of the phase meter and alignment of the tuned amplifiers in the FDM.

5-9. METER CALIBRATION.

5-10. Any method, exclusive of meter and external chart recorder readout methods, specified in section III can be used to set in a desired fractional frequency difference to calibrate the meter. Meter calibration accuracy depends only on accuracy with which desired frequency difference can be set in.

Table 5-2. Module Assembly to Printed Circuit Board Assembly Cross Reference.

Module Assembly	PC Board Assembly	Name
-	6153	Power Transistor
6168	6154	Flip-Flop
6169	6155	Error Multiplier
6170	6156	Error Multiplier
6171	6157	Reference Input/9 MHz Amplifier
6172	6158	5 MHz/1 MHz Divider
6173	6159	Buffer Amplifier
6174	6160	Power Supply
6175	6161	Differentiator/Integrator
6193	6162	Single Shot/Phase Comparator
79736	79738	Linear Phase Detector
6195	6164	Crystal Filter

5-11. METER CALIBRATION FOR 10^8 THROUGH 10^{11} RANGES.
Calibrate the meter for the 10^8, 10^9, 10^{10}, and 10^{11} ranges, as follows:

a. Adjust frequency difference to 10 or less parts in 10^N, where N equals 8, 9, 10 or 11 depending on meter range to be used for calibration.

b. Set METER RANGE selector to corresponding meter range position (10^9 position if meter will be calibrated for 10 or less parts in 10^9).

c. Adjust potentiometer R12 on Differentiator/Integrator board 6161 until meter indication equals frequency difference set in. For example, if frequency difference set in equals 9.6 parts in 10^9, potentiometer R12 is adjusted until meter indicates 9.6 parts in 10^N with METER RANGE selector in the 10^9 position.

5-12. METER CALIBRATION FOR 10^7 RANGE. Calibrate the meter for the 10^7 range, as follows:

NOTE

Adjustment of potentiometer R12 will affect the calibration of the meter in the 10^7 range. Therefore, meter must be properly calibrated for 10^8, 10^9, 10^{10}, or 10^{11} range. Adjustment of R13 will not affect calibration of meter for 10^8, 10^9, 10^{10}, or 10^{11} range.

a. Adjust frequency difference to 10 or less parts in 10^7.
b. Set METER RANGE selector to 10^7.
c. Adjust potentiometer R13 on Differentiator/Integrator board 6161 until meter indication equals frequency difference set in. Do not, under any circumstances, adjust potentiometer R12.

5-13. PHASE DISPLAY ADJUSTMENT.

5-14. a. Push the zero button. If need be zero the PHASE METER using the meters own mechanical zero adjustment.
b. Push the FS button. Adjust FS ADJ control for full scale deflection of the phase meter.

5-15. AMPLIFIER ALIGNMENT.

5-16. The FDM will normally operate within specified limits after a defective component has been replaced, without amplifier alignment. Do not attempt to realign the amplifiers unless it is absolutely certain the FDM is not operating within specified limits.

5-17. Realign the tuned amplifier as follows:

CAUTION

Do not remove or replace any printed circuit board with power applied to the FDM. This could cause arcing which can damage the circuits.

NOTE

The printed circuit board assembly shields must be in place when any adjustment is being made.

a. Connect stable 1 MHz source to REF INPUT connector. Do not connect anything to SIG INPUT connector.
b. Set TEST/OPERATE switch to TEST.
c. Set FILTER switch to IN.

d. Remove all boards from FDM except Power Transistor board 6153 (J18), Power Supply board 6160 (J17), and Reference Input/9 MHz Amplifier board 6157 (J11).
e. Place PCB extender (located in connector J19) in connector J10 and connect 5 MHz/1 MHz Divider board 6158 to PCB extender.
f. Adjust transformers T1 and T2 on Reference Input/9 MHz Amplifier board and transformer T1 on 5 MHz/1 MHz Divider board (see Figures 7-5 and 7-6).

NOTE

Unless otherwise specified, test points referenced are on same board as transformer being adjusted.

g. Adjust transformer T2 on 5 MHz/1 MHz Divider board for minimum dc voltage at TP2 (see Figure 7-6).
h. Adjust transformer T3 on 5 MHz/1 MHz Divider board for minimum dc voltage at TP3 (see Figure 7-6).
i. Adjust transformer T4 on 5 MHz/1 MHz Divider board for minimum dc voltage at TP4 (see Figure 7-6).
j. Readjust transformers T1, T2, and T3 on 5 MHz/1 MHz Divider board for minimum dc voltage at TP1, TP2, and TP3 respectively (see Figure 7-6).
k. Set POWER switch to OFF.
l. Remove 5 MHz/1 MHz Divider board and PCB extender and insert 5 MHz/1 MHz Divider board in connector J10.
m. Set POWER switch to ON.
n. Adjust transformer T3, T4, and T5 on Reference Input/9 MHz Amplifier board for minimum dc voltage at TP1 (see Figure 7-5).
o. Set POWER switch to OFF.

p. Insert PCB extender in connector J12 and connect Error Multiplier board 6156 to PCB extender.

q. Set POWER switch to ON.

r. Set TEST/OPERATE switch to OPERATE.

s. Adjust transformer T3 on Error Multiplier board for maximum 9 MHz sine wave amplitude at TP1 (see Figures 7-7 and 7-8).

t. Set TEST/OPERATE switch to TEST.

u. Adjust transformers T1 and T2 on Error Multiplier board for maximum 1 MHz envelope amplitude at TP1 (see Figures 7-7 and 7-8).

v. Adjust transformers T6, T1, T2, T4, and T5 on Error Multiplier board for minimum dc voltage at TP2 (see Figures 7-7 and 7-8).

w. Set POWER switch to OFF.

x. Remove Error Multiplier board and PCB extender.

y. Repeat steps p. through x. for three Error Multiplier boards, 6155, using connector J12.

z. Insert Error Multiplier board 6156 in connector J12.

aa. Insert an Error Multiplier board 6155 in connector J12.

ab. Insert Crystal Filter board 6164 in connector J14.

ac. Insert PCB extender in connector J15 and connect another Error Multiplier board 6155 to PCB extender.

ad. Set POWER switch to ON.

ae. Adjust capacitor C2 on Crystal Filter board for maximum 1 MHz sine wave amplitude at pin 4 of Error Multiplier board on PCB extender (see Figures 7-7 and 7-8.)

af. Set POWER switch to OFF.

ag. Remove Error Multiplier board and PCB extender.

ah. Install Error Multiplier boards 6155 in connectors J15 and J16.

ai. Install PCB extender in connector J19.

aj. Install Differentiator/Integrator board 6161 in connector J20.

ak. Install Single Shot/Phase Comparator board 6162 in connector J21.

al. Install Flip-Flop board 6154 in connector J22.

am. Install Buffer Amplifier board 6159 in connector J23.

an. Install Phase Detector board 6163 in connector J24.

5-18. FDM is now ready for operation.

SECTION VI

REPLACEABLE PARTS

6-1. SCOPE OF SECTION.

6-2. This section provides all necessary information for quick identification of replaceable parts for the FDM. The section consists of an item/reference designation list, a list of replaceable parts, a numeric list of manufacturer codes, and ordering information.

6-3. ITEM/REFERENCE DESIGNATION.

6-4. An Index of item reference designations for the FDM is presented in Table 6-1. Information in the table includes item number, reference designation, TREMETRICS stock number, description, and assembly stock number, presented in that order.

6-5. ITEM NUMBER.

6-6. An item number is assigned to identify each part in a particular assembly from other parts within that same assembly. Identical parts within an assembly have the same Item Number.

6-7. REFERENCE DESIGNATION.

6-8. The Reference Designation is an alpha-numeric identification assigned to each assembly and to electrical components within an assembly. Reference Designations are obtained by referring to the schematic diagrams or printed circuit board illustrations in section VII or by markings on the assembly.

6-9. TREMETRICS STOCK NUMBER

6-10 A TREMETRICS Stock Number is assigned to every replaceable part in the FDM. Identical parts have identical stock numbers.

6-11. PART DESCRIPTION.

6-12. All parts are described using the noun-modifier method. For example, a 2500 ohm variable resistor is described as: RES VAR 2X5 K. The X indicates the decimal location.

6-13. ASSEMBLY STOCK NUMBER.

6-14. The Assembly Stock Number is the number assigned to a particular assembly to identify it from other assemblies within the FDM. Assembly Stock Numbers are identical to assembly drawing numbers.

6-15. USE OF ITEM/REFERENCE DESIGNATION INDEX.

6-16. The Item/Reference Designation Index is divided into subsections which correspond to each assembly in the FDM. The subsections are listed in numeric order by Assembly Stock Number. Parts are listed in each subsection as follows:

a. Parts having no Reference Designation assigned are listed first, in numeric order, by Item Number.
b. Parts having Reference Designations assigned are listed last, in alpha-numeric order, by Reference Designation.

6-17. To locate a specific part within the Item Reference Designation Index (Table 6-1), proceed as follows:

a. Obtain the number and/or name of the assembly that contains the part. (Refer to the printed circuit board illustration in Section VII.)

b. Obtain the Reference Designation or the Item Number for the part. (Refer to the schematic diagram or printed circuit board illustration in Section VII.)

c. Locate the subsection which corresponds to the assembly in the Item/Reference Designation Index.

d. Locate the part within the subsection by Item Number or Reference Designation.

NOTE

Using an opaque straight edge, ruler, or sheet or paper under the row being examined will reduce reading errors in multi-column indexes.

6-18. REPLACEABLE PARTS.

6-19. A list of replaceable parts for the FDM is presented in Table 6-2. Information in the table includes the TREMETRICS STOCK Number, part description, manufacturer code, manufacturer part number, and the total quantity and unit of measure for a given part in the complete instrument, presented in that order. The parts are listed in numerical order by TREMETRICS Stock Number.

6-20. To locate a part in the List of Replaceable Parts (Table 6-2), proceed as follows:

a. Obtain the TREMETRICS Stock Number by referring to the Item Reference Designation Index (Table 6-1). See paragraph 6-17.

6-21. FEDERAL SUPPLY CODE FOR MANUFACTURERS.

6-22. A list of manufacturers supplying parts for the FDM is provided in Table 6-3. Information in the table includes the manufacturer code number, manufacturer's name, and manufacturer's address, presented in that order. The manufacturers are listed in numerical order by code number.

6-23. To locate the manufacturer of a part, proceed as follows:

a. Obtain the manufacturer code number by referring to the List of Replaceable Parts (Table 6-2).
b. Locate the code number in the appropriate column of the Federal Supply Code for Manufacturers.

6-24. ORDERING INFORMATION.

6-25. Address orders or inquiries to either an authorized TREMETRICS Inc. Sales Representative or to:

Customer Service
TREMETRICS Inc.
2215 Grand Avenue Parkway
Austin, Texas 78728

6-26. To insure prompt service, orders must include the following information:

a. Name, model, and serial number of the instrument.
b. Assembly or sub-assembly name and/or number.
c. Reference Designation. If no reference designation is listed, include the Item Number.
d. TREMETRICS Stock Number.
e. Full description of the part.

6-27. Item a. is located on the instrument; item b. can be found on either the assembly itself or in the pertinent section of the Reference Designation Index; and items c., d., and e. are found in the Item/Reference Designation Index (Table 6-1).

6-28. The part numbers shown will change occasionally as manufacturers' items are reevaluated or as improved components become available. The component shipped will be the component used in production at the time the order is received, and will be equivalent to the component it replaces in both dimensions and performance.

6-29. The minimum billing on any order is $15.00, with a standard delivery of 30 days. All prices are FOB Austin, Texas, and are subject to change without notice.