OPERATING AND SERVICE MANUAL

(HP PART NO. 00651-90005)

MODEL 651B
TEST OSCILLATOR

SERIALS PREFIXED: 811-

Appendix C, Manual Backdating Changes,
adapts this manual to the following instruments:
Serial No. 647-02850 and below.

P. O. Box 301, Loveland, Colorado, 80537 U.S.A.

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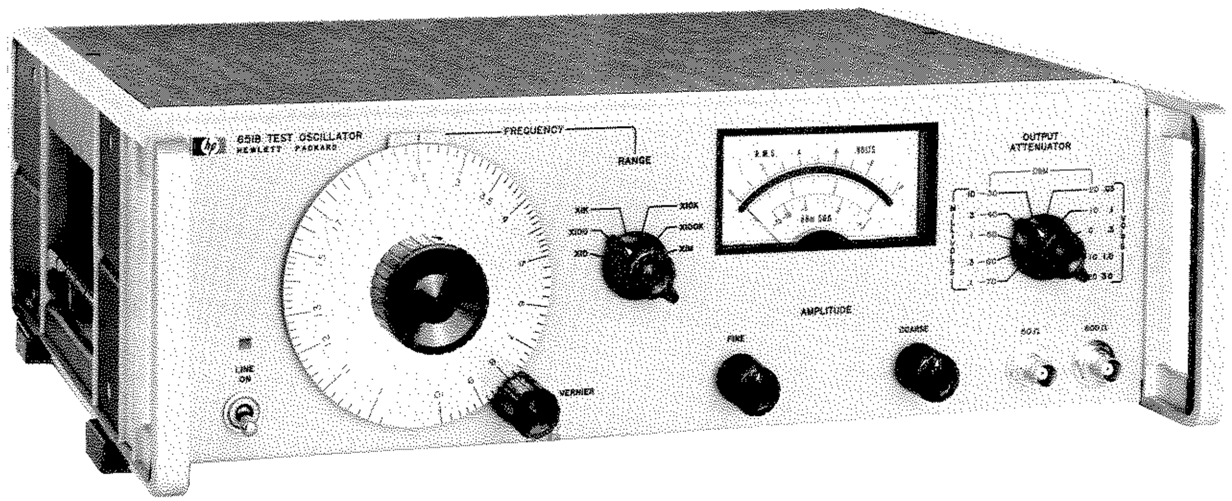


Figure 1-1. Model 651B Test Oscillator

Table 1-1. Specifications

Frequency Range: 10 Hz to 10 MHz, 6 bands, dial calibrations: 1 to 10.

Dial Accuracy: (including warm-up drift and ±10% line voltage variation).
±2%, 100 Hz to 1 MHz.
±3%, 10 Hz to 100 Hz and 1 MHz to 10 MHz.

Output:
Maximum: 3.16 V into 50 Ω or 600 Ω
6.32 V open circuit
+23 dBm into 50 Ω
Ranges: 0.1 mV to 3.16 V full scale, 10 steps in 1, 3, 10 sequence, coarse and fine adjustable. -70 dBm to +23 dBm (50 Ω output) full scale, 10 dBm per step, coarse and fine adjustable.
Flatness: (Amplitude not readjusted to a reference on the output monitor.)
±2% 100 Hz - 1 MHz
±3% 10 Hz - 1 MHz
±4% 10 Hz - 10 MHz*

* This specification applies only at 50 Ω or 75 Ω output. The response above 1 MHz at the 600 Ω output is affected by capacitive loads.

(Amplitude readjusted to a reference on the output monitor.)

Range	Frequency 10 Hz 20 Hz 4 MHz 10 MHz		
3 V and 1 V	2%	1%	2%
0.3 V to 0.3 mV	2.5%	1.5%	2.5%
0.1 mV	3%	2%	3%

Distortion: less than: 1% 10 Hz to 2 MHz, 2% at 2 MHz to 5 MHz, 4% 5 MHz to 10 MHz.
Hum and noise: less than 0.05% of maximum rated output.

Output Monitor: voltmeter monitors level at input of attenuator in volts or dB. Top scale calibrated in volts. Bottom scale in dB.
Accuracy: ±2% of full scale.

Attenuator:
Range: 90 dB in 10 dB steps.
Overall accuracy: ±0.075 dB, -60 dBm to +20 dBm.
±0.2 dB, -70 dBm to -60 dBm.

Amplitude Control: 20 dB range: coarse and fine.

Amplitude Stability: ±2% per mo., 20°C - 30°C.

Temperature range: 0°C to +50°C.

Power: 115 V or 230 V ±10%, 30 W, 50 to 1000 Hz.

SECTION I
GENERAL INFORMATION

1-1. DESCRIPTION.

1-2. The Hewlett-Packard Model 651B Test Oscillator is a wide range capacitance-tuned oscillator covering a frequency range from 10 Hz to 10 MHz. The oscillator has a stable sine-wave output signal that is adjustable from 10 microvolts to 3.16 volts into 50 or 600 ohms. The Model 651B Test Oscillator is shown in Figure 1-1 and the specifications are given in Table 1-1. This manual is written for the standard Model 651B Test Oscillator; refer to paragraph 1-7 for differences between the standard instrument and Options 01 and 02.

1-3. Two output impedances are provided at front panel output connectors. The 600 ohm connector provides an output with an impedance that is compatible with transmission lines and many distribution systems. The 50 ohm connector provides an output where a low-source impedance is desired.

1-4. The Model 651B Test Oscillator output voltage is constantly monitored at the input of the attenuator by an internal voltmeter. The voltmeter has two scales for RMS voltage readings and a dBm scale referenced to 1 milliwatt into 50 ohms. The OUTPUT ATTENUATOR, in conjunction with the AMPLITUDE control, provides a monitored output of desired level when matched into a 50 or 600 ohm load.

1-5. AVAILABLE ACCESSORIES.

1-6. Table 1-2 contains a list of the accessories which will increase the usefulness of the Model 651B.

1-7. OPTIONS.

1-8. OPTION 01.

1-9. Option 01 is a standard -hp- Model 651B Test Oscillator that has the dBm scale of the output monitor referenced to 1 milliwatt into 600 ohms. The front panel OUTPUT ATTENUATOR dBm markings have been changed to correspond with the signal level at the 600Ω output connector (-80 to +10 DBM).

1-10. OPTION 02.

1-11. Option 02 is a standard -hp- Model 651B Test Oscillator that has output impedances of 75 ohms and 600 ohms. Also, the output monitor has the dBm scale referenced to 1 milliwatt into 75 ohms.

1-12. INSTRUMENT IDENTIFICATION.

1-13. Hewlett-Packard uses a two-section eight-digit serial number (000-00000). If the first three digits of the serial number on your instrument do not agree with those on the title page of this manual, change sheets supplied with the manual will define differences between your instrument and the Model 651B described in this manual.

1-14. If a letter prefixes the serial number, the instrument was manufactured outside the United States.

Table 1-2. Available Accessories

-hp- Model 10110A, BNC to Binding Post Adapter: Converts a BNC connector to binding post connectors.	-hp- Model 11048B Feed-thru Termination: Precision 50 Ω feed-thru termination with male and female BNC connectors.
-hp- Model 11004A Line Matching Transformer: Provides fully balanced 135 Ω or 600 Ω output from single-ended input.	-hp- Model 11095A Feed-Thru Termination: Precision 600 Ω feed-thru termination with male and female BNC connectors.
-hp- Model 11005A Line Matching Transformer: Provides fully balanced 600 Ω output from single-ended input.	-hp- Model 11094A Feed-Thru Termination: Precision 75 Ω feed-thru termination with male and female BNC connectors. (Use with Option 02.)

SECTION II
INSTALLATION

2-1. INSPECTION.

2-2. This instrument was carefully inspected both mechanically and electrically before shipment. It should be physically free of mars or scratches and in perfect electrical order upon receipt. To confirm this, the instrument should be inspected for physical damage in transit. Also, check for supplied accessories, and test the electrical performance of the instrument using the procedure outlined in Paragraph 5-5. If there is damage or deficiency, see the warranty on the inside front cover of this manual.

2-3. POWER REQUIREMENTS.

2-4. The Model 651B will operate from either 115 or 230 Vac, 50 to 1000 Hz. The instrument can be easily converted from 115 to 230 volt operation by changing the position of the slide switch located on the rear panel, so that the designation appearing on the switch matches the nominal voltage of the power source. A 0.4 ampere, slow-blow fuse is used for both 115 and 230 volt operation.

2-5. THREE-CONDUCTOR POWER CABLE.

2-6. To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends that the instrument panel and cabinet be grounded. All Hewlett-Packard instruments are equipped with a three-conductor power cable, which, when plugged into an appropriate receptacle, grounds the instrument. The offset pin on the power cable three-prong connector is the ground wire.

2-7. To preserve the protection feature when operating the instrument from a two-contact outlet, use a three-prong to two-prong adapter and connect the green pigtail on the adapter to ground.

2-8. INSTALLATION.

2-9. The Model 651B is fully transistorized; therefore no special cooling is required. However, the instrument should not be operated where the ambient temperature exceeds 50° C.

2-10. RACK/BENCH INSTALLATION.

2-11. The Model 651B is initially shipped as a bench-type instrument (unless ordered specifically as a rack type) with plastic feet and a tilt stand in place. Conversion to a rack-mounted instrument can be accomplished by using the rack mounting kit and instructions furnished with your instrument.

2-12. REPACKAGING FOR SHIPMENT.

2-13. The following is a general guide for repackaging for shipment. If you have any questions, contact your local -hp- Sales and Service Office. (See Appendix B for office locations.)

NOTE

If the instrument is to be shipped to Hewlett-Packard for service or repair, attach a tag to the instrument, identifying the owner and indicating the service or repair to be accomplished; include the model number and full serial number of the instrument. In any correspondence, identify the instrument by model number, serial number and serial number prefix.

a. Place instrument in original container if available. If original container is not available, a suitable one can be purchased from your nearest -hp- Sales and Service Office.

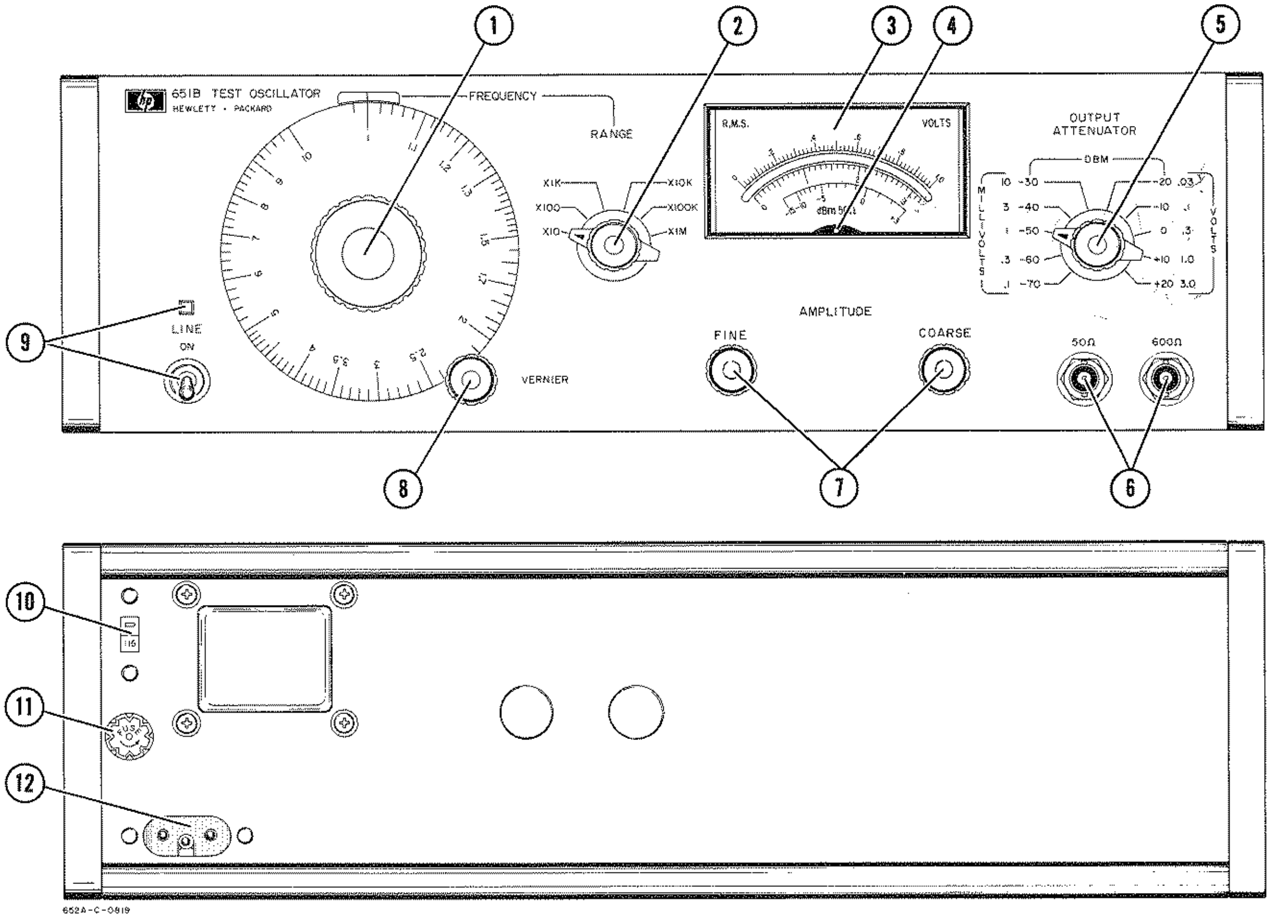
If original container is not used,

b. Wrap instrument in heavy paper or plastic before placing in an inner container.

c. Use plenty of packing material around all sides of instrument and protect panel faces with cardboard strips.

d. Place instrument and inner container in a heavy carton or wooden box and seal with strong tape or metal bands.

e. Mark shipping container with "Delicate Instrument," "Fragile" etc.



(1) FREQUENCY Dial: Varies output frequency within each frequency range. Dial reading multiplied by range setting is the output frequency of the instrument.

(2) FREQUENCY RANGE Switch (S1): Selects one of six frequency ranges, from 10 Hz to 1 MHz.

(3) Output Monitor (M1): Monitors the amplitude of the test oscillator output.

(4) Mechanical Zero Adjust: Allows output monitor to be mechanically zeroed, when instrument is off.

(5) OUTPUT ATTENUATOR: Attenuates test oscillator output in nine steps of 10 dB each.

(6) Output Connectors (J2 and J3): Provides the output signal, at impedance levels of 50Ω and 600Ω. (75Ω and 600Ω on Opt. 02).

(7) AMPLITUDE COARSE and FINE Controls: Controls amplitude of signal applied to OUTPUT ATTENUATOR.

(8) FREQUENCY VERNIER: Provides a fine frequency adjustment for FREQUENCY dial.

(9) LINE ON Switch (S3) and Pilot Lamp: Switch applies primary power to instrument; pilot lamp glows to indicate application of primary power.

(10) 115/230 V Slide Switch (S4): Sets instrument to operate from a primary power source of either 115 Vac or 230 Vac.

(11) FUSE (F1): 0.4 amp fuse protects instrument from overloads.

(12) Primary Power Connector (J1): Connects primary power to test oscillator.

Figure 3-1. Location of Controls and Indicators

SECTION III
OPERATING INSTRUCTIONS

3-1. INTRODUCTION.

3-2. The Model 651B Test Oscillator generates a stable sine wave output that is available at output impedance levels of 600 ohms and 50 ohms. The frequency of the output is variable from 10 Hz to 10 MHz, and the output power level can be varied from 10 microvolts to 3.16 volts into 600 or 50 ohm loads. The amplitude of the output will be indicated on the output monitor, M1.

3-3. CONTROLS AND INDICATORS.

3-4. Figure 3-1 identifies and describes the function of all the front and rear panel controls, connectors, and indicators on the Model 651B.

3-5. ADJUSTMENT OF MECHANICAL ZERO.

3-6. The output monitor is properly zero-set when the meter pointer rests over the zero mark, and the 651B is in normal operating position at normal operating temperature, and is turned off. Zero-set the output monitor as follows to obtain maximum accuracy and mechanical stability.

a. Turn 651B on and allow it to operate for at least 20 minutes, to let the meter movement reach normal operating temperature.

b. Turn 651B off, and allow 30 seconds for all capacitors to discharge.

c. Insert pointed object (such as tip of ballpoint pen) into recess on adjustment wheel, and rotate wheel until meter pointer is exactly over zero.

3-7. OPERATION.

3-8. To operate the 651B Test Oscillator, proceed as follows:

a. Connect primary ac power to 651B (115 or 230 V, 50 Hz to 1000 Hz), and set slide switch S4 to proper position.

b. Turn LINE ON switch to ON position. Indicator lamp will glow, verifying application of primary power.

c. Set FREQUENCY RANGE switch and FREQUENCY dial to desired output frequency.

d. Set OUTPUT ATTENUATOR switch to desired voltage range.

e. Connect load to output connector having an impedance which matches impedance of load.

f. Adjust AMPLITUDE controls for desired output voltage, as indicated on output monitor.

g. The output monitor, M1, indicates the rms value of the output voltage, and the power level in dBm for resistive loads of 50 ohms. The output voltage level is obtained by multiplying the monitor scale readings by the monitor scale multiplier which appears on the OUTPUT ATTENUATOR switch. Use the following equation and the impedance correction graph of Figure 3-2 to obtain the Model 651B output power level in dBm, for loads other than those marked on the output connectors.

$$\text{Output Voltage} = \frac{R_L}{R_L + R_S} \times 2\,V_m$$

Where,

R_L = Load Resistance (Terminating Resistance)

R_S = Source Resistance (Output Impedance of Oscillator)

V_m = Model 651B Output Monitor Reading

Problem: A 600 ohm load is placed on the 50 ohm output connector. The Model 651B output monitor indicates an output of 0.9 volts, with the OUTPUT ATTENUATOR set on the 1.0 volt (+10 dBm) range. Find the actual output voltage and power level (in dBm) of the Model 651B.

Solution: The actual output voltage is calculated as follows:

$$\text{Output Voltage} = \frac{600}{600 + 50} \times 2\,(0.9) = 1.66\text{ V}$$

The indicated power level for an actual output voltage of 1.66 volts would be +17.3 dBm on the 3.0 V (+20 dBm) range. The actual power level (with the 600 Ω load) is the algebraic sum of the theoretically indicated power level (+17.3 dBm) and a correction factor obtained from the impedance graph of Figure 3-2. For this example, a correction factor of -10.8 dBm is obtained from the 50 Ω output impedance line of the graph with a 600 Ω load. The actual power level then is +6.5 dBm [+17.3 dBm + (-10.8 dBm)].

For Option 01-651B which has the dBm scale of the output monitor referenced to 1 milliwatt into 600 Ω use the 600 Ω output impedance line of graph of Figure 3-2.

For Option 02-651B which has the dBm scale of the output monitor referenced to 1 milliwatt into 75 Ω use the 75 Ω output impedance line of graph of Figure 3-2.

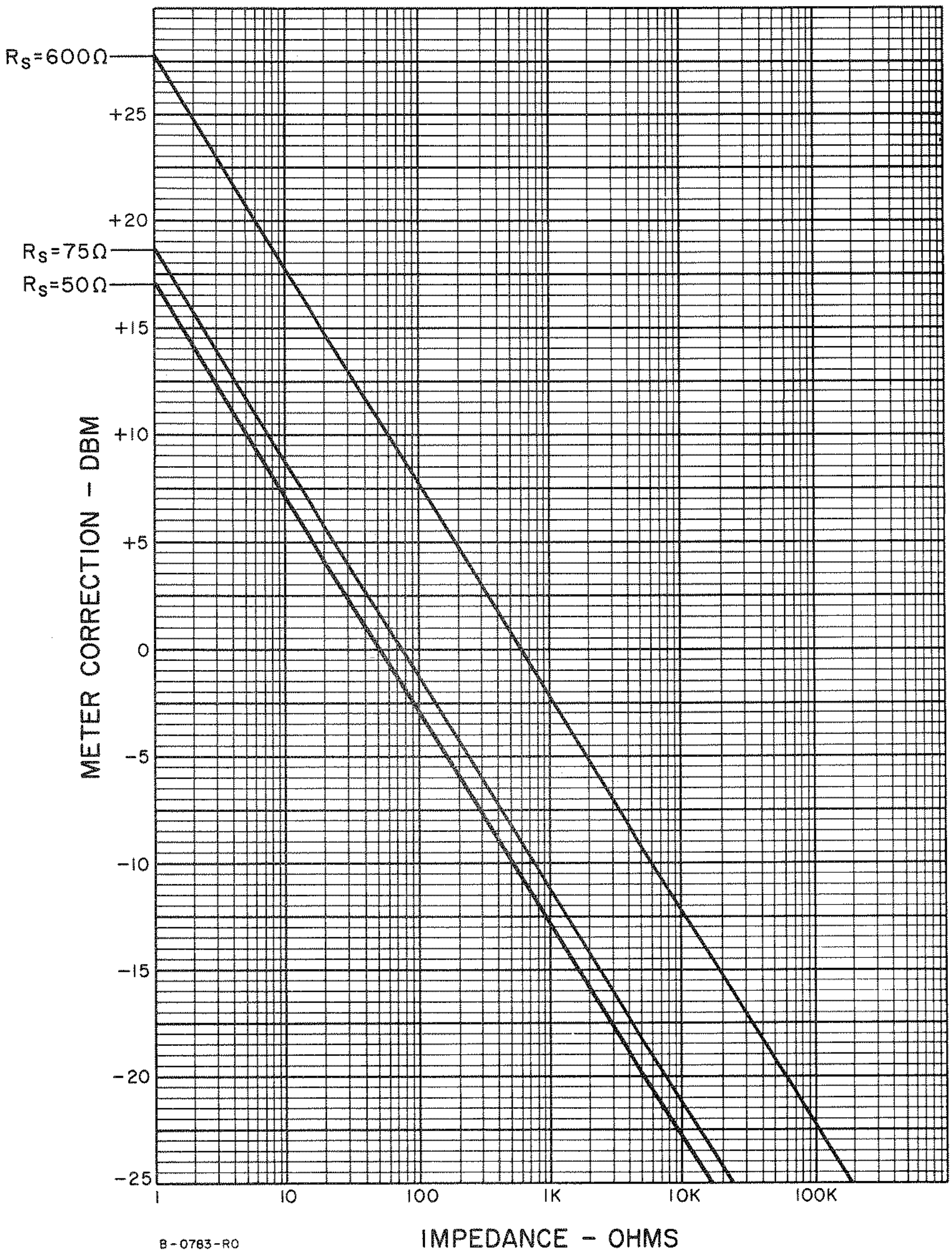


Figure 3-2. Impedance Correction Graph

SECTION IV
THEORY OF OPERATION

4-1. GENERAL DESCRIPTION.

4-2. The Model 651B Test Oscillator includes an oscillator, power amplifier, peak detector, attenuator, and monitor circuit. A block diagram of the instrument is shown in Figure 6-1. The oscillator circuit uses a modified Wein bridge network to generate a stable, distortionless sine wave signal which is applied to the power amplifier circuit. The peak detector circuit provides a degenerative feedback voltage to the oscillator circuit to stabilize the signal applied to the power amplifier. The power amplifier circuit is used to increase the output power available at the 50 ohm and 600 ohm output connectors and to improve the frequency stability of the output signal with changing output loads. The output attenuator provides a means of attenuating the signal at the output connectors in nine steps of 10 dB each. The monitor circuit continuously monitors the signal level at the input to the attenuator. The regulated power supply provides all voltages required by the 651B circuits.

4-3. CIRCUIT DESCRIPTION.

4-4. Refer to Figures 6-2 and 6-3 for the following discussion.

4-5. OSCILLATOR CIRCUIT.

4-6. The oscillator circuit generates a sinusoidal signal at the frequency selected by the RANGE switch and FREQUENCY Dial located on the front panel. The RC bridge network is a modified Wein bridge circuit, consisting of an RC frequency selective network and a resistive voltage divider network. The Wein bridge in the Model 651B Test Oscillator differs from the conventional Wein bridge circuit in the design of the resistive voltage divider network. The resistor in the conventional Wein bridge is replaced with impedance Z1, which consists of A2CR6 and A2CR7.

4-7. Oscillation at the selected frequency is made possible by the use of both positive and negative feedback. Positive feedback is provided through a frequency sensitive RC network to the differential amplifier A2Q2 and A2Q3; negative feedback is provided to the differential amplifier through a network insensitive to frequency. Only at the selected frequency will the positive feedback exceed the negative feedback voltage to sustain oscillation.

4-8. The RANGE switch, S1, selects combinations of resistors and capacitors (S1R1 through S1R24, and S1C1 through S1C14) to establish the frequency sensitive RC networks for the six frequency ranges of the instrument. The FREQUENCY Dial varies the main frequency tuning elements C1A, C1B, and C1C. The RC components maintain the proper phase relationship of the positive feedback voltage. At frequencies where $X_C = R$, the positive feedback voltage is in phase with the oscillator output voltage (refer to Figure 4-1) and exceeds the negative feedback voltage. At frequencies other than where $X_C = R$, the positive feedback voltage is neither of the right phase nor of sufficient amplitude to maintain oscillations.

4-9. A field effect transistor, A2Q1, is used as the impedance converter because of its extremely high input impedance and low noise characteristics. It provides a high impedance in series with the input impedance of the differential amplifier on the lower four frequency ranges (X10 - X10K). The high impedance added prevents the RC bridge circuit from being loaded by the low input impedance of the differential amplifier, A2Q2 and A2Q3, on the lower frequency ranges. The impedance converter is bypassed on the X100K and X1M ranges due to lower resistor values in the RC bridge.

4-10. The difference between the feedback voltages from the bridge circuit is amplified by differential amplifier A2Q2 and A2Q3, and is applied to the complementary symmetry circuit A2Q5 and A2Q6, through emitter follower A2Q4. A positive feedback voltage from the output of the complementary symmetry circuit is applied between resistors A2R8 and A2R9, in the collector circuit of A2Q2, on the first four frequency ranges. The application of the feedback voltage at this point is used to make the effective resistance of the collector load higher than the input impedance of the emitter follower A2Q4, forcing the collector current into the base of the emitter follower. The increase in the base current results in an increase in the loop gain of the oscillator circuit. The feedback voltage is removed on the X100K and X1M frequency ranges due to the value of resistors A2R8 and A2R9 exceeding the input impedance of the emitter follower at the higher frequencies.

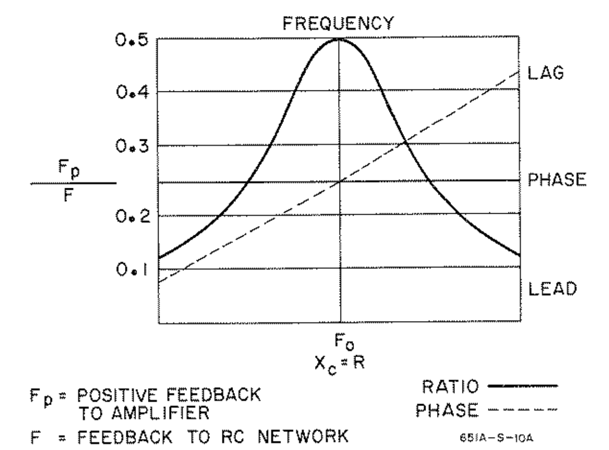


Figure 4-1. RC Network Characteristics

4-11. The complementary symmetry circuit is used to provide power gain and to increase the dynamic voltage range of the oscillator; also, the low output impedance of the complementary symmetry circuit prevents the oscillator output circuit from being loaded by the RC bridge. The complementary symmetry circuit transistors are forward-biased by diodes A2CR2, A2CR3, and A2CR4, and with no signal applied, are conducting slightly to reduce cross-over distortion in the output signal.

4-12. The output of the oscillator circuit drives the power amplifier with a constant voltage set by the AMPLITUDE COARSE and FINE controls, R2 and R3. The voltage level applied to the power amplifier is held constant by the action of the peak detector circuit.

4-13. AUTOMATIC GAIN CONTROL.

4-14. The output of the oscillator circuit is superimposed on a negative reference bias at the base of A2Q7. This bias voltage is determined by the setting of the amplitude controls. The peak detector, A2Q7, will conduct only on the positive peaks when the negative bias is overcome. The average dc voltage across A2C7, A2C8 or A2C9 biases the two diodes A2CR6, A2CR7 so it determines the impedance of the negative feedback side of the Wein bridge. Thus the amplitude of the oscillations is automatically controlled. A2CR5 and A2CR9 provide temperature compensation for the bias voltage on A2Q7, and A2CR8 prevents the reverse breakdown of A2Q7. A2R17 is adjustable to compensate for differences in the operating characteristics of diodes A2CR6 and A2CR7, minimizing distortion in the negative feedback and subsequently in the oscillator output.

4-15. POWER AMPLIFIER.

4-16. The power amplifier circuit increases the power gain of the signal received from the oscillator circuit. The operation of the differential amplifier A2Q8 and A2Q9, emitter follower A2Q10, and complementary symmetry circuit A2Q11 and A2Q12 is similar to the corresponding stages in the oscillator circuit. The negative feedback voltage from the output of the complementary symmetry circuit is applied to the differential amplifier at a fixed level to stabilize the power amplifier output signal. The power amplifier output is continuously monitored by the monitor circuit before the signal is applied to the output attenuator circuit.

4-17. MONITOR CIRCUIT.

4-18. The monitor circuit monitors the signal level applied to the output attenuator circuit and provides a signal to the output monitor M1, which indicates the amplitude of the output in RMS volts and dBm. The amplifier A1Q9 serves both as an impedance converter between the monitor circuit and the power amplifier output circuit, and as a current source to provide full-scale monitor indications. The high input impedance of A1Q9 prevents the power amplifier from being loaded with the low impedance of the output monitor, M1. The emitter follower, A1Q8, provides a positive feedback voltage which is applied between resistors A1R18 and A1R19, in the collector lead of amplifier A1Q9. The application of the feedback voltage at this point is used to increase the effective resistance of the collector circuit, which results in the amplifier A1Q9 appearing as a high impedance current source to the monitor. Diode A1CR10 provides a small amount of forward bias to rectifier diodes A1CR8 and A1CR9, which keeps the diodes out of the non-linear region, thus increasing monitor accuracy at one-tenth full-scale readings. The 10 MHz adjustment, A1C15, compensates for small variations in circuit capacitance so the monitor will have a flat frequency response. The monitor calibration resistor, A1R23, provides an additional calibration adjustment which is made at 400 Hz.

4-19. OUTPUT ATTENUATOR.

4-20. The output attenuator provides a means of attenuating the signal level applied to the 50 ohm and 600 ohm output connectors. The OUTPUT ATTENUATOR switch, S2, selects a combination of four resistor networks to produce the desired level of signal attenuation. Each step provides an attenuation of 10 dB. The AMPLITUDE controls, R2 and R3, vary the level of attenuation in increments between each 10 dB step selected by the OUTPUT ATTENUATOR switch.

4-21. Output impedances other than the standard 50 and 600 ohms can be obtained by changing the value of resistors S2R14 or S2R13. The value of the replacement resistor is added to the 50 ohm oscillator output to give the required output impedance.

4-22. REGULATED POWER SUPPLY.

4-23. The regulated power supply provides all voltages required by the test oscillator circuits. The power supply consists of a +30 volt series regulated supply and a -25 volt series regulated supply which is referenced to the +30 volt circuit.

4-24. The +30 volt regulated supply is of the conventional series regulator type. The emitter follower A1Q2 is used to increase the loop gain of the circuit, thus improving voltage regulation. The +30 volt adjustment, A1R4, sets the +30 volt and -25 volt supply output level.

4-25. The -25 volt regulated supply is of the conventional series regulator type and operates the same as the +30 volt supply. A current limiter, A1Q7, has been added to limit the load current to a set value. When the load current exceeds the set value, the current limiter conducts, causing the series regulator Q2 to reduce the output voltage level until the load causing an excessive current is removed. Diodes A1CR6 and A1CR7 protect the control transistor A1Q6, against short circuits between the two voltage supplies, or short circuits in the output of the -25 volt supply.

Table 5-1. Required Test Equipment

INSTRUMENT TYPE	REQUIRED CHARACTERISTICS	RECOMMENDED MODEL
Oscilloscope	Passband: 10 Hz to 10 MHz Sensitivity: 50 mV/cm Input Impedance: 1 megohm	-hp- Model 180A Oscilloscope
Electronic Counter	Range: 10 Hz to 10 MHz Accuracy: ±5 counts	-hp- Model 5245L Electronic Counter
RMS Voltmeter	Frequency Range: 10 Hz to 10 MHz Voltage Range: 1 mV to 10 V Accuracy: ±1%	-hp- Model 3400A RMS Voltmeter (with known error)
Distortion Analyzer	Distortion Sensitivity: >42 dB	-hp- Model 331A
Wave Analyzer	Frequency Range: 600 kHz to 22 MHz	-hp- Model H05-312A
DC Null Voltmeter	Range: 10 μV to 30 V Accuracy: ±2% of full scale	-hp- Model 419A
† AC Differential Voltmeter	Range: 1 V to 10 V Accuracy: ±0.1% Stability: ±0.1% Per Mo.	-hp- Model 741B AC-DC Differential Voltmeter/DC Standard
Attenuator	Attenuation Range: 90 dB in 10 dB steps Frequency Range: 10 Hz to 10 MHz	-hp- Model 355D VHF Attenuator (with known error)
Amplifier	Gain: 40 dB Frequency Range: 10 Hz to 10 MHz	-hp- Model 461A Amplifier
Thermal Converter	Input: 3 V RMS Output: 7 mV dc Accuracy: ±0.2% Frequency Range: 10 Hz to 10 MHz Input Impedance: a. 50 Ω b. 75 Ω (Use with Option 02-651B only)	Thermal Converter a. -hp- Model 11049A b. -hp- Model H01-11049A
0 to 10 mV Reference Supply	See Figure 5-3 for schematic a. Resistor: fxd, 6500 Ω ±1% b. Resistor: var, 500 Ω ±5% c. Resistor: var, 50 Ω ±5% d. Battery: 1.34 V	a. -hp- Part No. 0811-0392 b. -hp- Part No. 2100-0324 c. -hp- Part No. 2100-1481 d. Mallory RM-42R
Terminating Resistance	a. Feed-thru, 50 Ω b. Feed-thru, 600 Ω c. Feed-thru, 75 Ω (with Option 02-651B only)	a. -hp- Model 11048B b. -hp- Model 11095A c. -hp- Model 11094A
Adapter	BNC to Binding Post	-hp- Model 10111A Adapter
† Recorder	Chart Speed: 1"/hr or less	-hp- Model 680 6" Strip Chart Recorder
DC Voltmeter	Range: 0.1 V to 30 V Accuracy: ±1% of Full Scale	-hp- Model 412A DC VTVM
Impedance Converter (Use with Option 02-651B only)	75 Ω to 50 Ω	See Figure 5-4b for parts list.

† These instruments required only if Amplitude Stability Check (Paragraph 5-18) is performed.