MARCH, 1965

NUMBER 37

The NOTEBOOK

HEWLETT PACKARD BOONTON DIVISION



# A Compact, Versatile 10 to 500 MC Oscillator

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The 3200A VHF Oscillator (Figure 1) is a compact, versatile general purpose instrument intended for use in receiver and amplifier testing, driving bridges, slotted lines, antennas and filter networks, and as a local oscillator for heterodyne detector systems in the frequency range from 10 to 500 mc. Completely self-contained, the instrument is packaged in the new Hewlett-Packard modular cabinet, permitting convenient bench use as well as rack mounting for system applications. The oscillator is housed in a rugged aluminum casting for maximum stability and extremely low leakage. Six frequency ranges are provided for adequate band spread on a slide rule dial.


Figure 1. 3200 VHF Oscillator

## CIRCUIT DESIGN

The oscillator circuit, shown in Figure 2, employs push-pull 6DZ4 tubes with capacitive tuning and a turret system which permits switching of the tank circuit inductance on the various frequency ranges. Feedback is accomplished with a capacitive divider from one plate to the opposite grid, using the grid-to-cathode capacitance of the tube, together with a fixed mounted capacitor from the other plate. This two-tube oscillator is particularly well suited to this design because it provides more power than a single 6DZ4 tube and feedback is obtained by fixed capacitance on the top four bands. On the two lower bands, drive is reduced by switching in additional capacitance from the grids to ground. The two-tube oscillator also works well with a split-stator capacitor which requires no wiping contacts, eliminating a potential source of noise and instability.

In this oscillator, the center of the tank is at ground potential and therefore the rotor of the capacitor is also at ground potential for RF frequencies. Since the center of the oscillator coil is also roughly at the neutral or ground plane, plate power can be injected from this point from a common supply ring on the turret. This ring is a slip ring rather than a switchable contact. Actually, the oscillator turret is so constructed that the center of each coil is permanently tied back to this common slip ring to individual resistors. These resistors serve to break up undesirable RF paths, without introducing appreciable plate voltage or RF loss.

## FREQUENCY STABILITY

The oscillator is specified for a ±0.002% stability after a 5-minute warmup. However, *typical* data shown in Figure 3 indicates that, under controlled conditions, 5-minute stabilities of 0.0001%, or 1 part per million, have been measured at some frequencies.

Frequency stability has been achieved through careful design of the circuit components and the use of a substantial aluminum casting which provides a large thermal mass. Particular care has also been given to the mechanical design of the turret assembly. The detent mechanism is positive, assuring accurate and stable positioning of the active oscillator inductor. The turret itself is precision molded from orlon filled diallyl phthalate. Turret contacts are constructed of coin silver and tuning ca-

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pacitor contacts are of coin silver and beryllium copper laminate. Both the detent spring and tuning capacitor contacts have been subjected to long life tests without failure. The circuit is mounted on a silverplated brass chassis in such a way that lead lengths have been minimized and fundamental circuit symmetry has been maintained.

The position of the tuning capacitor is indicated on a large slide rule dial which is simultaneously rotated by the oscillator range switch mechanism to display only the active frequency range. The frequency drive mechanism is backlash-free and employs a cable drive. The cable consists of a glass core, for dimensional stability, enclosed in braided Nylon for long wear and traction. Nonconductive cable is used so that entrance into the RF enclosure can be made through waveguide-below-cutoff tubes, permitting low RF leakage without wiping grounds. The turret drive shaft also utilizes nonconductive Fiberglass Epoxy which passes through a waveguide-below-cutoff tube into the RF enclosure.

## MODULATION

The simplified modulation circuit is shown in Figure 4. AM plate modulation is injected through front panel terminals from an external source of audio power. The modulation signal is impressed across a resistor in series with the plate supply to the oscillator. The oscillator is specified at less than 1% AM distortion at a level of 30% AM. However, modulation up to 50% AM can be obtained with a resulting increase in distortion. Approximately 30 volts RMS into 600 ohms is required from an external source to achieve 30% AM. 60-cycle modulation can be conveniently obtained at almost any amplitude desired. If modulation percentages in excess of 40% are required, they may alternately be obtained by switching to pulse operation and applying a transformer-coupled audio signal in series with an adjustable dc (Figure 5); the resultant RF level, however, may be less than the specified CW signal. For 100% modulation, a dc offset voltage equal to the peak voltage of the audio signal is applied at the modulation terminals. The maximum voltage (dc offset voltage plus RMS audio voltage) should not exceed 135 volts. On the range from 260 mc to 500 mc, it will not be possible to modulate linearly 100% since the oscillator will not start before the plate voltage reaches some appreciable value.

Because of the direct plate modulation, some small amount of frequency modulation will occur. Typical FM deviation for a fixed audio input level is shown graphically in Figure 6.

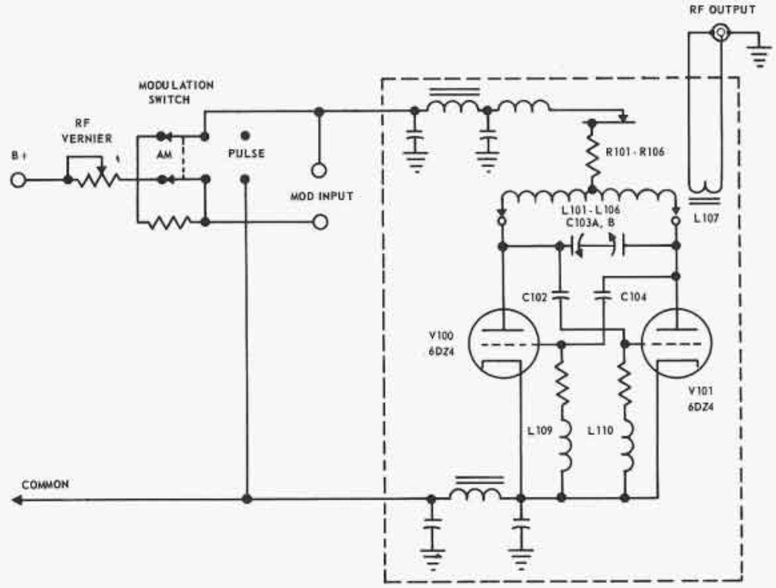



Figure 2. Oscillator Circuit

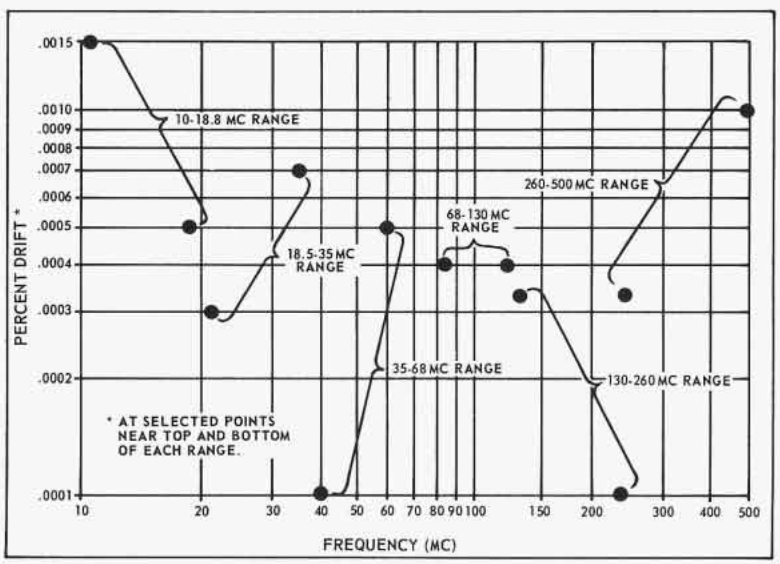



Figure 3. Typical Frequency Drift — For 5 Minutes After 4-hour Warmup

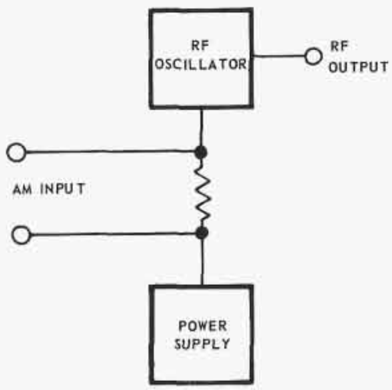



Figure 4. Amplitude Modulation

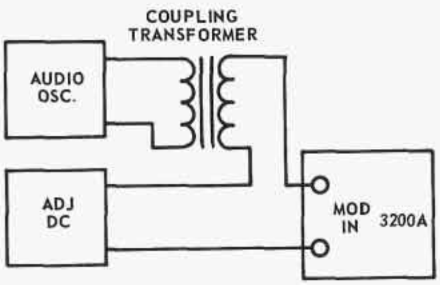



Figure 5. Setup for Obtaining Modulation in Excess of 40%

Provision is also made for external squarewave and pulse modulation through the front panel terminals (Figure 7). With the front panel modulation switch in the "pulse" position, the internal plate voltage supply to the oscillator is disabled and the oscillator plates are fed from an external source. Any varying source of signal, within the ratings of the 6DZ4 oscillator tubes, whose frequency is not limited by the input RF filters, may be applied. The signal source may be squarewave or pulse or remotely programmed dc. Again, some FM will be experienced due to direct plate modulation.

A power capability of 140 volts into 2000 ohms will drive the oscillator to maximum specified output on all ranges. Typically, however, approximately 10 volts peak (except 50 volts on the 260-500 mc range) will produce 1 milliwatt peak power output. For maximum tube life the peak voltage in pulse position should be limited to:

$$V_{peak\ pulse} = 150 - 1.8 \times V_{mod}$$

where $V_{mod}$ = the voltage drop across the modulation terminals in the CW position. Since the modulation input circuit is ungrounded, either positive or negative pulses may be used, provided the more positive terminal from the generator is connected to the left-hand modulation terminals on the 3200A front panel.

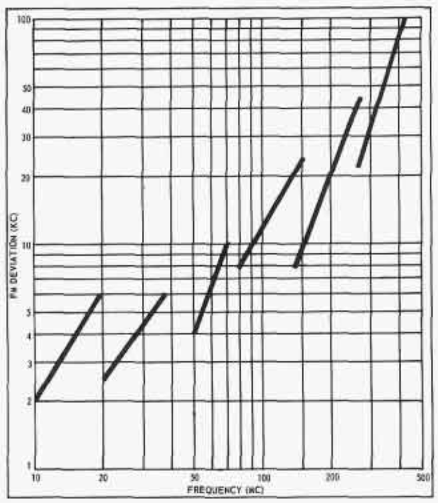



Figure 6. Typical FM Deviation for Fixed Audio Input Level

## RF OUTPUT

The RF output of the oscillator is available through a unique, simplified waveguide-below-cutoff piston attenuator, shown in Figure 13. This attenuator provides a minimum of 120 db attenuation from maximum output and is adjusted by positioning the piston which can be readily locked in place by a rotary clamp. The attenuator piston is marked at intervals of 10 db attenuation. These graduations permit setting the attenuator to precise ratios. The attenuator has a bore diameter of 0.757 inches, providing an attenuation of 42 db per inch for all frequencies in the range of the instrument. The gradua-

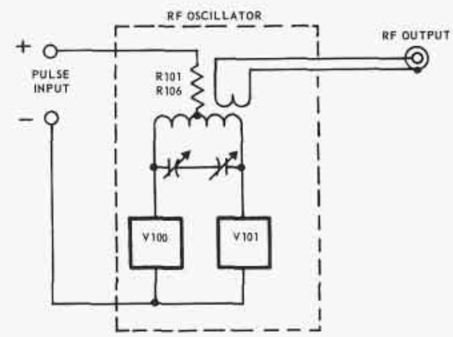



Figure 7. Pulse Modulation

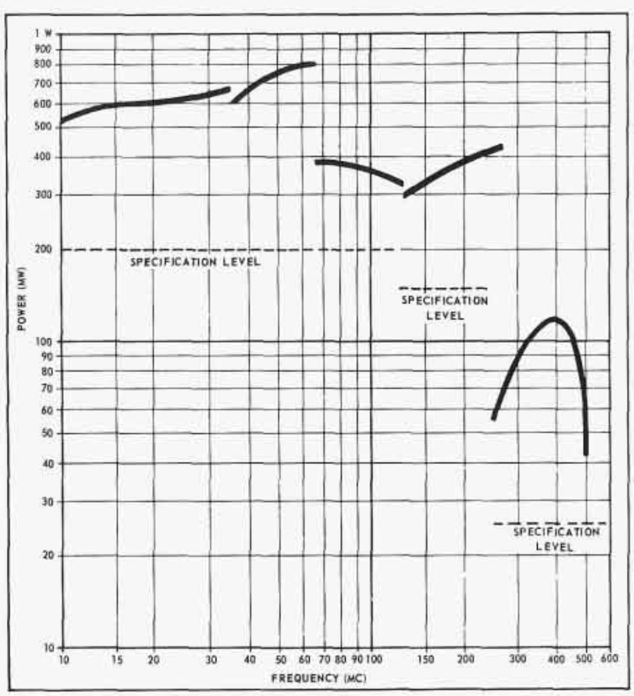



Figure 8. Typical Maximum Power Output

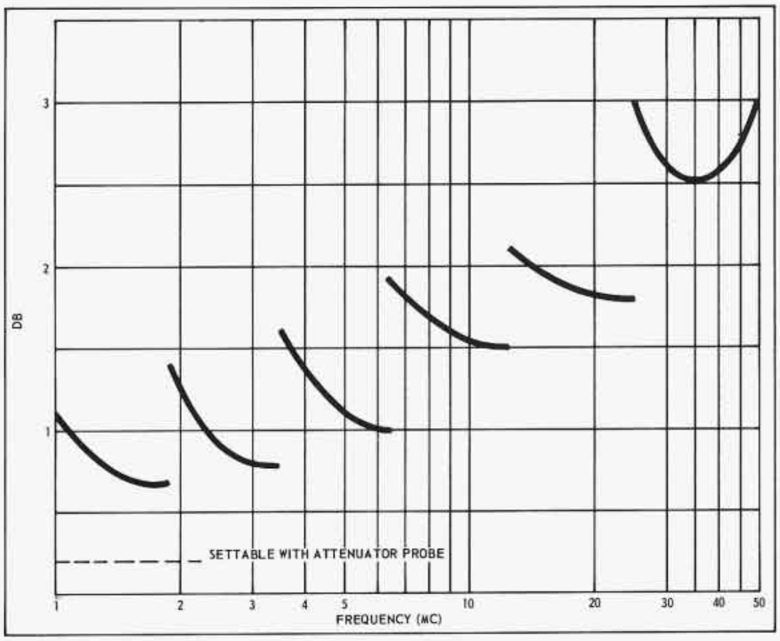



**Figure 9. Typical Settability Using Electrical Vernier**

tions also permit resetting to a particular power level. The first graduation will provide roughly 1 volt into 50 ohms and the last graduation will provide roughly 1 microvolt into 50 ohms.

The attenuator piston is completely removeable, and the pickup loop, employing a ferrite core for maximum low frequency coupling, is completely encapsulated in a low dielectric constant resin for maximum stability and protection. A simplified schematic of the output system is shown in Figure 2. In order to provide maximum available power output, no internal dissipative elements are employed. The output circuit is designed to feed an external 50-ohm load. If critical match or low VSWR is required, a suitable pad may be readily connected in series with the attenuator output.

Maximum RF output power is specified at greater than 200 milliwatts, 10-130 mc; greater than 150 milliwatts, 130-260 mc, and greater than 25 milliwatts, on the highest range, 260-500 mc. Curves of *typical* maximum output power, as a function of frequency, are shown in Figure 8. RF shielding, consisting of aluminum castings and compressed braid, will permit measurements at levels down to 1 microvolt.

In addition to the control of RF output level by positioning the attenuator piston, a front panel electrical vernier control is provided. This control varies the plate voltage on the oscillator and provides precise settability over a typical range as shown in Figure 9.

With the 3200A operating into a 50-ohm load, frequency shift from no load to specified output typically is less than 2%. If the 3200A is operated at maximum specified output into 50 ohms and then mismatched so as to increase VSWR up to 40 db, frequency shift will be less than 2% for typical data. See Figure 10.

## POWER SUPPLY

All necessary operating voltages are provided by an internal solid-state power supply, shown in the simplified schematic, Figure 11. This supply provides regulated dc for the oscillator filaments and plates for minimum hum modulation and maximum tube life. In the circuit, the B supply reference is returned to regulated B— instead of unregulated B—. This reduces the current change through the reference tube

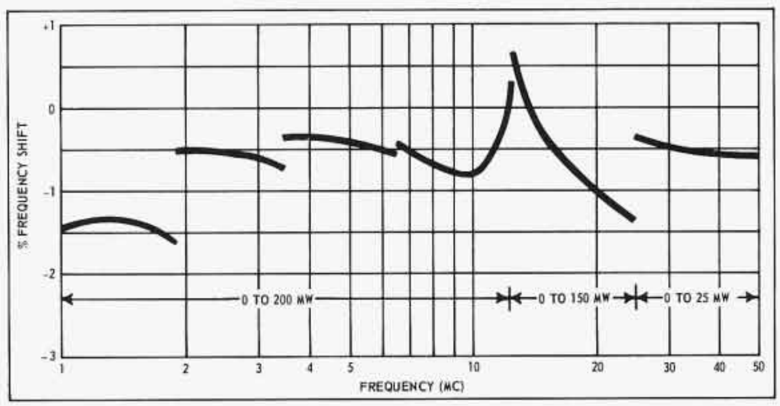



**Figure 10. Typical Frequency Shift — No Load to Specified Output and Worst Mismatch**

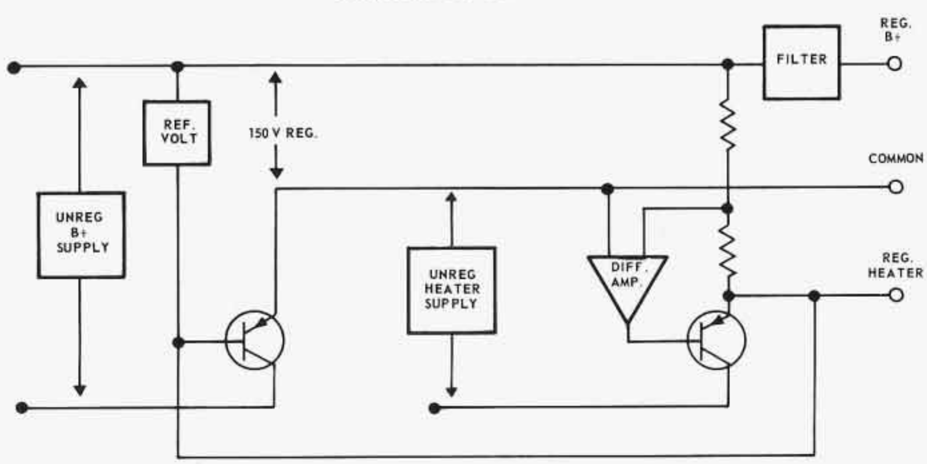



**Figure 11. Power Supply**

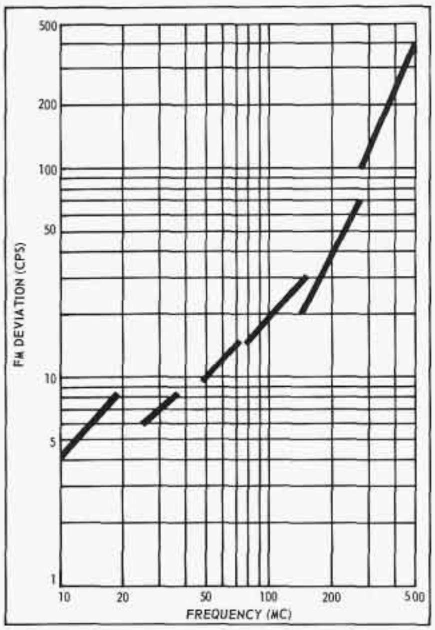



Figure 12. Residual FM Due to Hum and Noise

caused by changes in unregulated B— or line voltage. The heater reference is tapped down from the regulated 150 volt supply, eliminating the need for a second reference. A filter in the B+ supply reduces hum, providing almost constant power operation of the oscillator tubes. Further reduction in the B supply hum is obtained by minimizing the common resistance in the B— and HTR+ return leads, and establishing the common tie point at the RF filter on the instrument baseplate casting. Residual FM, due to hum and noise, for a typical instrument is shown in Figure 12.

Frequency stability of the oscillator, as a function of input line voltage changes, is specified at 0.001% for a 5-volt change. The 3200A oscillator is designed for operation with an input line voltage of 105 to 125 volts and 210 to 225 volts, 50 or 60 cps. The unit has been operated from a 400 and 1000 cps power source, however, and has typically met its specifications at these higher line frequencies. Power consumption is 30 watts.

### MAINTENANCE

As shown in Figure 13, considerable attention has been given to ease of maintenance. All of the power supply circuits are mounted on a stable circuit

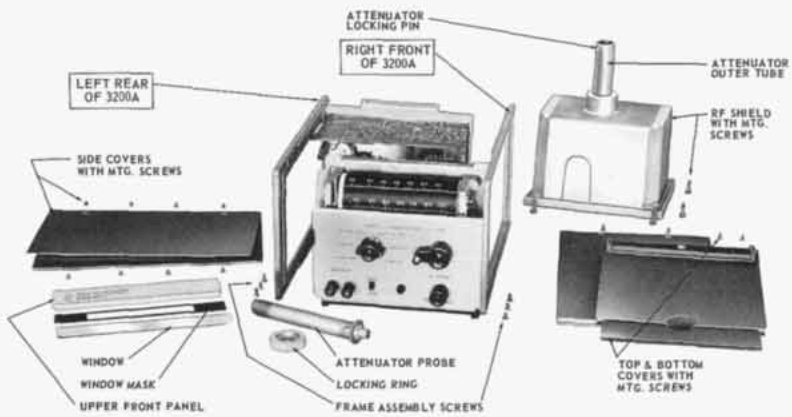



Figure 13. 3200A — Disassembled

board and the power supply may be readily disconnected from the oscillator assembly through a multi-conductor plug. The entire RF casting can be readily removed by loosening just four screws.

# New Transistor Test Jig Provides Y Parameters—500 KC to 250 MC

## CHARLES W. QUINN, *Applications Engineer*

Figure 1. 13510A Transistor Test Jig

### INTRODUCTION

Transistor measurement techniques utilizing the 250A RX Meter and special jigs built in the Boonton laboratory were described in articles published in Notebook Numbers 19, 20, and 26 and drawings showing the construction details of these jigs were made available to customers upon request. Over the past several years, however, Boonton has received numerous requests from customers to build and market these jigs and, as a result, has designed the 13510A Transistor Test Jig (Figure 1), an improvement over the original design. This new jig is designed to provide consistant, convenient, and precise readings over the entire the 500 kc to 250 mc frequency range of the RX Meter.

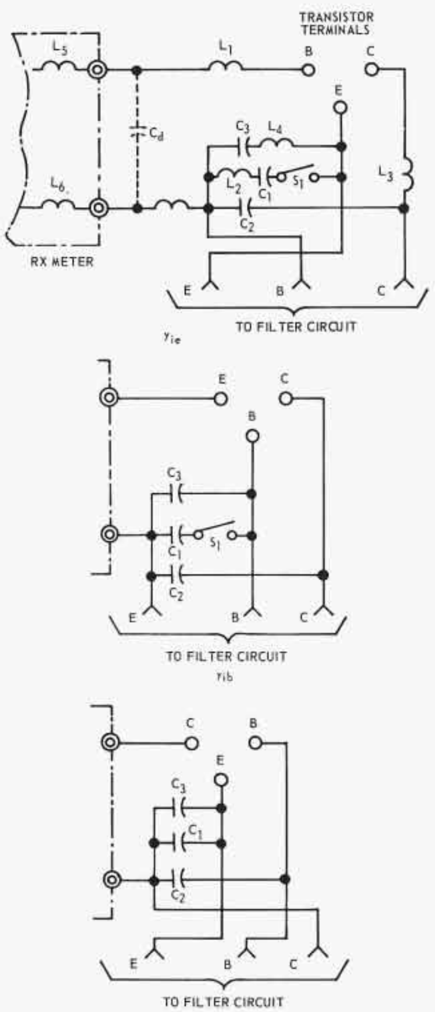
### DESCRIPTION

The 13510A Transistor Test Jig consists of four basic components: a mounting adapter and three separate plug-in test circuits for measuring $y_{ie}$, $y_{ib}$, and $y_{oe}$. Included as part of the jig are bias feed and bypassing for an external power supply. The jig may be readily mounted on the RX Meter using the existing rear set of accessory holes on the ground plate surrounding the terminals. The parameters obtainable from the RX Meter readings are listed and defined below:

$y_{ie}$ = Input admittance, common emitter output circuit short circuited

$$= \frac{1}{h_{ie}} = \frac{1}{R_p} + j\omega C_p = y_{11e}$$

$y_{ib}$ = Input admittance, common base, output circuit short circuited




$L_1 = 3$ nh, $L_2 = 4$ nh, $L_3 = 8.5$ nh, $L_4 = 34$ nh — lead and terminal inductances

$L_5$, $L_6 = 3$ nh (RX Meter terminal inductances)

$C_d$ = distributed capacitance of HIGH terminals

$C_1 = 29\ \mu f$ GE Tantalum, 30 v, bypass, HF

$C_2$, $C_3 = 0.1\ \mu f$ Scionics Pelet, 50 v, bypass, VHF

$S_1$ = RF switch

**Figure 2. Equivalent Test Circuits**

$$= \frac{1}{h_{ib}} = \frac{1}{R_p} + j\omega C_p = y_{11b}$$

$y_{oe}$ = Output admittance, common emitter, input circuit short circuited

$$= \frac{1}{R_p} + j\omega C_p = y_{22e}$$

## DESIGN CONSIDERATIONS

A jig (or fixture) designed to work over the 250 kc to 500 mc frequency range of the RX Meter must, of course, be a broadband or untuned device. This means that the residual inductance must be held to a minimum and made as consistant as possible from one test circuit to another. These requirements have been met through the careful design of the test circuits. The circuits have been designed in printed circuit form for stability and are precision manufactured to insure maximum repeatability. Design of the 13510A jig is such that the RX Meter may be balanced for one test circuit and then used with other test circuits without rebalancing.

The bypassing system (Figure 2) is switchable so that capacitor $C_1$ may be removed from the circuit over a portion of the frequency range, thereby simplifying the corrections which would have to be made in the "crossover region" (1 to 10 mc). This switch is normally closed for measurements above 10 mc.

## TRANSISTOR BIAS

Bias for the transistor under test is provided from an external supply, through the filter circuit on the 13510A jig, when the plug-in test circuit board is connected to terminals $T_1$, $T_2$, and $T_3$ (Figure 2) and the RX Meter terminals. Any dc supply which has less than 1 millivolt ripple (such as the -hp- 721A) may be used to provide transistor bias. Batteries may also be used if desired. The ideal supply for this application is one which provides a combination constant-current, emitter-base supply, and a constant-voltage (with adjustable current limit) for collector-base biasing. Many configurations are usable. Some examples are shown in Figure 4. It should be noted that the

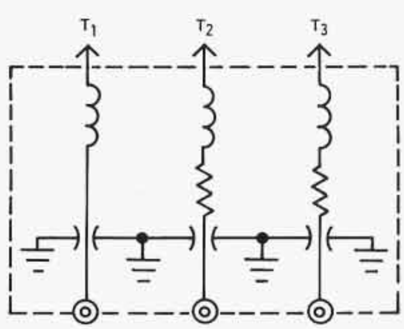



**Figure 3. Equivalent Filter Circuit**

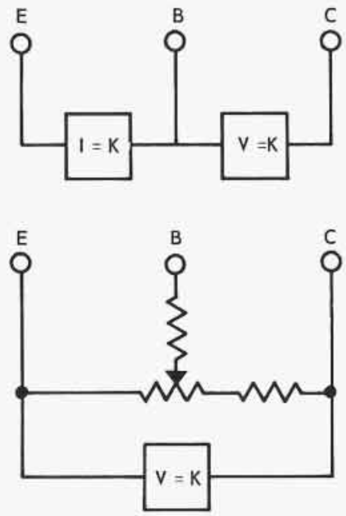



**Figure 4. Recommended Bias Supply Configurations**

limit for current passing through the RX Meter terminals is 50 milliamperes. Collector-to-base voltages should not exceed 30 volts. Levels at the bridge terminals should usually be kept below 20 millivolts.

## CORRECTIONS

For most measurements, direct readings of the $C_p$ and $R_p$ dials on the RX Meter may be used. In cases of extremely low impedance (below 200 ohms) and high frequencies (above approximately 50 mc), however, some correction of these dial readings may be desirable. When measuring $h_{ib}$, for example, correction of the $C_p$ and $R_p$ dial readings would be indicated.

Corrections for series inductance can be made by adding the series inductance of the jig to that of the RX Meter. The equation to be used for these corrections is (Figure 5):

$$(1)\quad y(\ ) = \frac{y(\ )\, y_s}{y_s - y(\ )}$$

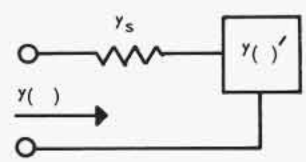



**Figure 5. Correction Equation for Series Inductance**

For frequencies above 10 mc, the value of $y_s$ is nominally 10 nh. Below 10 mc, $y_s$ is nominally 41 nh; most of which is contributed by the jig bypass electro-

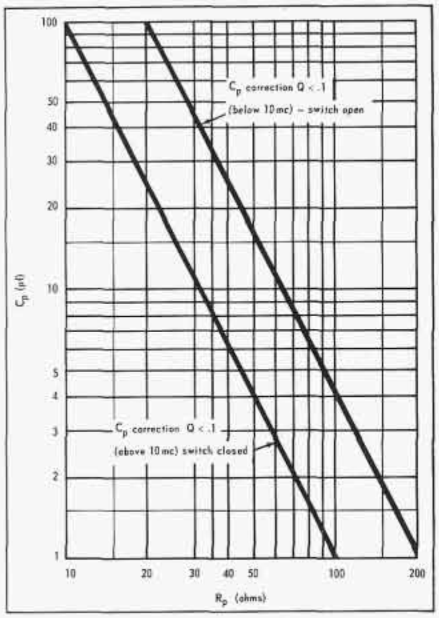



**Figure 6. $y_s$ vs. Frequency Correction — Below 50 mc**

lytic capacitor, $C_3$. These corrections may be obtained more quickly through graphical solution as shown in Figures 6 and 7. For frequencies below 50 mc and impedances below 200 ohms, the correction curves in Figure 6 may be used. No correction is necessary for $R_p$ below 50 mc. Above 50 mc, equation 1 should be used with the value of $y_s$ obtained from Figure 7.

With the corrected values for $y_{ie}$, $y_{ib}$, and $y_{oe}$, known, $y_{fe}$ can be calculated to a good approximation by the equation:

$$(2)\quad y_{fe} = \frac{y_{ib} - y_{ie} - y_{oe}}{y_{ie}}.$$

This equation is a more exact expression than the equation:

$$(3)\quad h_{fe} = \frac{h_{ie} - h_{ib}}{h_{ib}},$$

used in Notebooks Numbers 19 and 26.

## EXAMPLE

The following is an example of the procedure and calculations used to determine the $y_{ie}$, $y_{ib}$, and $y_{oe}$ parameters of an RCA 2N706 transistor utilizing the RX Meter and the 13510A Transistor Test Jig. Measurements were made at 250 mc with a bias supply of 6 volts, 2 milliamperes.

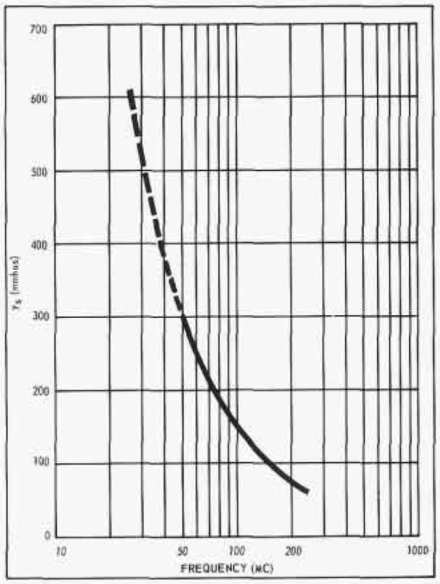



**Figure 7. $y_s$ vs. Frequency Correction — Above 50 mc**

### Determination of $y_{ie}$

*RX Meter Readings:*

| *Rp* | *Cp* |
|---|---|
| 74 ohms | + 3.2 pf |
| 74 ohms | − j 200 ohms |

$$y_{ie} = G + j\beta$$
$$y_{ie} = 13.5 + j\,5.0 \text{ mmhos}$$
$$= 14.4 \angle{+20.6^\circ} \text{ mmhos}$$

*Series Inductance RX Meter and Jig:*

$$L_s = 10 \text{ nh},\ X_s = 15.7 \text{ ohms},$$
$$y_s = -j\,62.8 \text{ mmhos}$$
$$y_s = 62.8 \angle{-90^\circ}$$

*Corrected $y_{ie}$:*

$$y_{ie}' = \frac{y_{ie}\, y_s}{y_s - y_{ie}}$$

$$y_{ie}' = \frac{14.4 \angle{+20.6^\circ} \times 62.8 \angle{-90^\circ}}{-j\,62 - 13.5 - j\,5.0}$$

$$= \frac{900 \angle{-69.4^\circ}}{-13.5 - j\,67.8}$$

$$= \frac{900 \angle{-69.4^\circ}}{68.8 \angle{-101.3^\circ}}$$

$$y_{ie}' = 13.1 \angle{+31.9^\circ}$$
$$= 11.05 + j\,6.9 \text{ mmhos}$$

### Determination of $y_{ib}$

*RX Meter Readings:*

| *Rp* | *Cp* |
|---|---|
| 85 ohms | − 2.55 pf |
| 85 ohms | + 250 ohms |

$$y_{ib} = G + j\beta$$
$$= 11.8 - j\,4.0 \text{ mmhos}$$
$$= 12.5 \angle{-18.7^\circ} \text{ mmhos}$$

*Series Inductance of RX Meter and Jig:*

$$y_s = -62.8 \text{ mmhos}$$
$$= 62.8 \angle{-90^\circ} \text{ mmhos}$$

*Corrected $y_{ib}$:*

$$y_{ib}' = \frac{y_{ib}\, y_s}{y_s - y_{ib}}$$

$$y_{ib}' = \frac{12.5 \angle{-18.7^\circ}\ 62.8 \angle{-90^\circ}}{-j\,62.8 - 118 + j\,4.0}$$

$$= \frac{785 \angle{-108.7^\circ}}{-11.8 - j\,58.8}$$

$$= \frac{785 \angle{-108.7^\circ}}{59.8 \angle{-101.4^\circ}}$$

$$= 13.1 \angle{-7.3^\circ} \text{ mmhos}$$

$$y_{ib}' = 13.0 - j\,1.67 \text{ mmhos}$$

### Determination of $y_{oe}$

*RX Meter Readings:*

| *Rp* | *Cp* |
|---|---|
| 140 ohms | + 5.3 pf |
| 140 ohms | − j 120 ohms |

$$y_{oe} = \frac{G}{7.1}\ \frac{+j\beta}{+j\,8.35} \text{ mmhos}$$

$$= 10.9 \angle{+49.6^\circ}$$

*Series Inductance of RX Meter and Jig:*

$$y_s = -j\,62.8$$
$$= 62.8 \angle{-90^\circ}$$

*Corrected $y_{oe}$:*

$$y_{oe}' = \frac{y_{oe}\, y_s}{y_s - y_{oe}}$$

$$y_{oe}' = \frac{10.9 \angle{+49.6^\circ} \times 62.8 \angle{-90^\circ}}{-j\,62.8 - 7.1 - j\,8.3}$$

$$= \frac{684 \angle{-40.4^\circ}}{-j\,62.8 - j\,71.1}$$

$$= \frac{684 \underline{/-40.4^\circ}}{71.1 \underline{/-95.7^\circ}}$$

$$= 9.63 \underline{/+55.3^\circ} \text{ mmhos}$$

$$y'_{oe} = 5.47 + j\,7.92 \text{ mmhos}$$

### CONCLUSION

The 13510A Transistor Test Jig provides a simple and convenient method for measuring the Y parameters of transistors over the range from 500 kc to 250 mc. Through careful design, residuals have been minimized and, by employing printed circuit techniques, excellent unit-to-unit uniformity has been achieved. By applying the corrections described in this article, absolute measurements to accessories in the order of 10% can be obtained. Measurements, based directly upon RX Meter dial readings, provide a good basis for judging relative characteristics.

## NEW DIRECT READING VECTOR IMPEDANCE METER TO BE SHOWN AT IEEE SHOW

The IEEE Show, March 22-25 in New York City will mark the introduction of our new and unique Vector Impedance Meter, Model 4800A, which provides automatic direct reading impedance measurements continuously from 5 cps to 500 kc. Impedance magnitude from 1 ohm to 10 megohms and phase angle from 0 to 360 degrees is instantaneously displayed on two front panel meters. Analog outputs, directly proportional to impedance magnitude, phase angle, and frequency are also available so that, by simple connection to an X-Y recorder, direct reading plots of impedance as a function of frequency may be conveniently obtained.

The Vector Impedance Meter will also function as a direct reading L-C meter covering ranges of 1 microhenry to 100,000 henries and 0.1 picofarad to 10,000 microfarads. By employing the "Q by delta f" approach, Q measurements can also be made.

See the new Vector Impedance Meter, the new Frequency Doubler Probe, as well as the VHF Oscillator and Transistor Test Jig in Booths Nos. 3501-3503.

## NEW ACCESSORY 500-1000 MC FREQUENCY DOUBLER PROBE

A new Frequency Doubler Probe, Model 13515A, providing additional frequency coverage from 500-1000 mc from the 3200A VHF Oscillator, will be introduced at the IEEE Show, March 22-25. In operation, the Frequency Doubler Probe is merely substituted for the standard 3200A attenuator probe and doubles the output frequency of the oscillator in the 250-500 mc range. The doubler circuit, housed in the probe tip, is all solid-state and requires no tuning. Tentative specifications are given below:

RF RANGE: 500 to 1000 mc*
*With 3200A operating 260-500 mc (Range No. 6), 250-260 mc (Range No. 5)

RF OUTPUT:
Maximum Power: > 4 mw
(Across external 50-ohm load with VSWR < 1.1)

HARMONIC SUPPRESSION:
Fundamental: > 16 db*
Higher Order:
> 16 db* (500-800 mc)
> 14 db* (800-1000 mc)
* below desired signal