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A Transistor Test Set

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The Boonton Radio Corporation Transistor Test Set Type 275-A is an instrument for measuring small signal parameters of a transistor. The common base short circuit current gain Alpha (h_{fb}), the common emitter short circuit current gain, Beta (h_{fe}), and the transistor input impedance common base with the output short circuited (h_{ib}) are measured. The instrument differs from the conventional transistor test set in that the parameters measured are determined by the position of a linear potentiometer required to produce a minimum reading on a sensitive detector. It does not therefore require the calibration of, nor depend upon the constancy of level of the ac signal applied for measurement purposes.

Reference to the photograph (Figure 1) reveals the unit as a self contained, line powered, bench type instrument with well placed, easily operated controls.

The Block Diagram (in Figure 2) shows the basic components of the 275-A. It contains, beside the basic measuring circuit, which is the heart of the instrument, a simple 1-kc oscillator, a sensitive detector of wide dynamic range, and three power supplies.

Theory of the Measurement

The Null techniques used in measuring Alpha and Beta in the 275-A Test Set were devised by D. E. Thomas of the Bell Telephone Laboratories(1). The equivalent circuit of the basic measurement is illustrated in Figure 3. When the potentiometer, which is linear, is moved to a position where the signal voltage between the base of the transistor and ground is a minimum, the small signal Alpha of the transistor is a linear function of the angular position of the potentiometer.

If the circuit of Figure 3 is modified to the circuit of Figure 4 in which R_2 is a fixed resistance and the potentiometer (R_T) is now used as a variable resistance, the small signal β of the transistor is a linear function of the angular position of the potentiometer. Finally, h_{ib} is measured in the variable ratio arm bridge shown schematically in Figure 5. The potentiometer ($R_1 + R_2$) of the measuring circuit provides the two variable ratio arms, and the remaining arms are the standard resistance R_s and the unknown resistance h_{ib}. The potentiometer position required to make V a minimum is then calibrated in terms of the resistance value of h_{ib}.

Figure 1. Transistor Test Set Type 275-A.

Specifications

Now that the basic principle of operation has been explained, let us consider the range of values over which the parameters α, β, and h_{ib} may be measured. Note particularly that these parameters may be measured down to 0.01 ma. emitter current.

(1) These null techniques are incorporated in the Type 275-A Transistor Test Set under Western Electric License.

YOU WILL FIND . . .

ESTIMATE THE Q WIN A Q METER

Yes, that is all that is necessary to win the factory reconditioned Type 160-A Q Meter which will be on display in the BRC exhibit at the IRE show to be held in the New York Coliseum from March 21st through March 24th. The Q Meter will be awarded to the person whose estimate is closest to the actual measured Q of the coil to be displayed with the Q Meter. Complete information will be furnished by engineering personnel on duty in BRC Booths 3101 and 3102.

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Alpha (h_{fb}):
RANGE: 0.001 to 0.990 or 0.9000 to 0.9999
ACCURACY: for $f_\alpha \geq 500$ kc. (*)
Better than ±1% for α from 0.100 to 0.990
Better than ±0.5% for α from 0.9000 to 0.9999
for any α % error $= \pm\left(0.1 + \frac{.09}{\alpha}\right)$

Beta (h_{fe}):
RANGE: 1 to 200
ACCURACY: ±2% from 7 to 200 for $f_\alpha \geq 500$ kc. (*)

h_{ib}:
RANGE: At x0.1; 0.30 to 30 ohms
At x1.0; 3.0 to 300 ohms
At x10.0; 30.0 to 3000 ohms
ACCURACY (stated for linear resistors): ±3%

Internal Power Supply:
EMITTER CURRENT (I_E): 0.01 to 100 ma. in 10 overlapping ranges
COLLECTOR VOLTAGE (V_{CB}): 0 to 100 volts in 6 overlapping ranges

External Power Supply Capability:
$I_E = 5$ amperes max. (for Alpha only)
Note: The base current should not exceed 100 ma. in any case.
V_{CB}: not to exceed 100 volts dc

Meter Accuracy: ±1½% full scale

*$f_\alpha \equiv$ the frequency for which

$$|\alpha| = \frac{1}{\sqrt{2}}\alpha_o$$

where α_o = forward short circuit current gain, grounded base at very low frequency.

It can be seen from this brief outline that the instrument provides maximum accuracy in the range of maximum interest, namely values of α from 0.9 to 0.9999, and sufficient precision (4 significant figures) in Alpha to reliably detect small but important Alpha variations with changes in bias and device characteristics.

Applications

An instrument with the above measuring capabilities will prove equally useful to engineers engaged in circuit design, device development and production, and active network analysis and synthesis.

Fast, simple and accurate measurements of transistor small signal parameters over the operating range required for a particular application are important to the successful design of a large percentage of transistor circuits. Furthermore, these parameter measurements and their relationship to circuit performance are essential in formulating sound device parameter requirements. When device requirements are formulated on a sound basis, the chances of having equipment give satisfactory performance in mass production with transistors produced on the basis of these requirements are greatly improved. Also, in the case of failure to meet prototype design expectations, the search for the cause of the failure is facilitated.

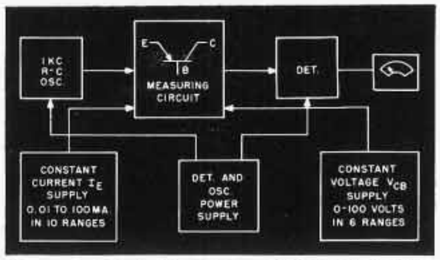
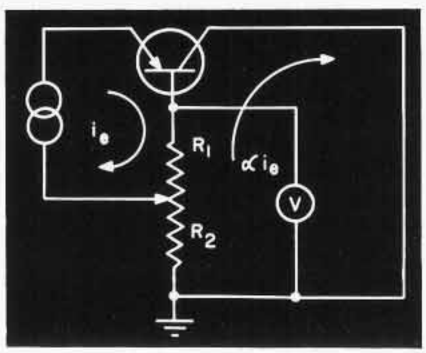


Figure 2. Block Diagram — Transistor Test Set Type 275-A.



When $V = O$, $i_e R_1 = \alpha\, i_e\, (R_1 + R_2)$

$$\text{so } \alpha = \frac{R_1}{R_1 + R_2} = \frac{R_1}{R_T}$$

$$\text{if } R_1 + R_2 = R_T$$

Figure 3. AC Equivalent Circuit — Alpha Measurement.

Current Gain and Amplifier Linearity

One of the simplest examples of the use of the BRC Transistor Test Set Type 275-A is in connection with the design of a fully loaded common emitter transistor audio amplifier stage. Since the small signal common emitter current gain, i_{out}/i_{in} is given by

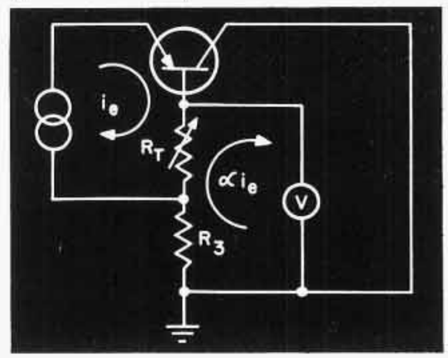
$$\frac{i_{out}}{i_{in}} = \beta = \frac{\alpha}{1-\alpha} \qquad (1)$$

then any change in β over the range of bias covered by the transistor load line will result in nonlinearity of amplification. The magnitude of this nonlinearity will be quantitatively related to the degree of departure of β from constancy. Now if we look at the variation of β as a function of the corresponding variation in α with operating bias, we find that

$$\frac{d\beta}{\beta} = \frac{d\,\frac{i_{out}}{i_{in}}}{\frac{i_{out}}{i_{in}}} = \frac{d\alpha}{\alpha}\left[\frac{1}{1-\alpha}\right]$$

$$\text{or } \frac{d\beta}{\beta} = \beta\,\frac{d\alpha}{\alpha} \qquad (2)$$

Equation (2) shows that the common emitter current gain nonlinearity will be β times the common base current gain nonlinearity.



When $V = O$, $i_e R_T = \alpha\, i_e\, (R_T + R_3)$

$$\text{so } \alpha = R_T/R_T + R_3$$

$$\text{but } \beta = \frac{\alpha}{1-\alpha} = \frac{R_T}{R_3}$$

Figure 4. AC Equivalent Circuit — Beta Measurement.

Figure 6 which shows a comparison of β change as compared to α change in a particular transistor over a wide range of operating bias, graphically illustrates the considerably greater change in β than in α in a high α transistor. By precise measurements of α or β with the 275-A, across the desired operating range of bias, limits on α or β variation can be set to meet the required linearity of the application.

Next consider the case in which we wish to improve the common emitter gain linearity, or increase the common emitter gain-bandwidth, by the use of collector-to-base feedback. The necessary reduction in gain to obtain the desired improvement in linearity or increase in band width and the required collector-to-base feedback resistance can be easily determined if the small signal values of α or β are known (Reference 1).

These values can be rapidly determined on the 275-A Test Set.

Current Gain — Switching Transistors

In switching applications it is desirable that transistors maintain a high value of α as close as possible to cutoff; i.e., low emitter current and maximum collector voltage and also, into the saturation region, i.e., low collector voltage and high collector current. The Transistor Test Set, Type 275-A because of its ability to measure at extremely low emitter currents, (0.01 ma.) can give quick answers to α or β variation in the cutoff region. Likewise the saturation region variation can be studied. In the event of serious falloff in α in the saturation region, the source can be traced to either internal generator current gain magnitude fall off at high current densities, or robbing of collector junction voltage by high internal series collector resistance. Thus many of the uncertainties in tracing switching transistor troubles on a large signal basis only can be eliminated.

Input Resistance

One of the most useful functions of the Transistor Test Set Type275-A is to study the effects of the often neglected parameter h_{ib}. The 275-A measures low frequency (1 kc) h_{ib} since this is effective in locating excessive series emitter resistance, which is frequently the cause of trouble in transistors. h_{ib} (the input impedance of the transistor common base with the collector shorted to the base) is given by

$$h_{ib} = r_e' + r_e + (1-\alpha_o) r_b \quad (3)$$

where r_e is the junction diffusion resistance. At room temperatures this is given approximately by $n26/I_E$, where n is usually unity for germanium, but may be as large as 2 for silicon, and I_E is the dc emitter current in milliamperes.

r_e' is any residual series emitter resistance due to contact or spreading resistance.
r_b is the base resistance.
α_o is the low frequency magnitude of alpha.

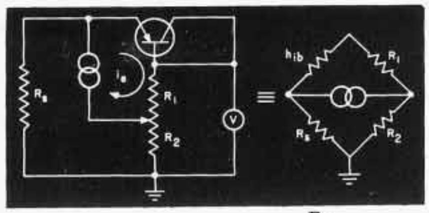
Since the transistor is essentially a power operated device, the power dissipated in r_e' of (3) usually represents a loss in gain.

Now how can the Transistor Test Set 275-A be used to detect this high value of r_e', if it exists? It is reasonable to assume that r_e' and $(1-\alpha_o)$ r_b are constant over the operating range of interest. Then if h_{ib} is measured at two or more values of I_E in the anticipated range of use and these values are linearly plotted as a function of $1/I_E$, a straight line connecting these points will have an intercept on the $1/I_E = 0$ axis equal to $r_e' + (1-\alpha_o)$ r_b. Since $(1-\alpha_o)$ r_b is expected to be very small for high α_o transistors, the major portion of large valued intercepts will in general be due to high r_e'. The fact that all transistors do not have a low value of r_e' is shown in Figure 7, where r_e' has been investigated by the above technique for two different transistors using the 275-A Test Set. Transistor #2 has an intercept of 1.5 ohms which indicates that r_e' is quite low for a transistor of this power level. Transistor #1 on the other hand has an intercept of 20 ohms indicating a high value of r_e'.

In those applications where power gain is not important, this high value of r_e' may be negligible. Let us, however, consider the seriousness of large r_e' in the design of a single mismatched IF amplifier stage using single tuned reactance network coupling (Reference 2). The single tuned interstage coupling network is illustrated in Figure 8. In this circuit, Q is given by $\omega L/R_2$ or $1/\omega CR_2$ at band center frequency. R_2 is the resistance component of h_{ib} (in this example, taken as the measured low frequency value of h_{ib}), and R_1 is the impedance transformed value of R_2 facing the collector of the driving transistor at resonance and given by:

$$R_1 = Q^2 R_2 = (\omega L)^2 / R_2 = (\omega L)^2 / h_{ib}$$

Now suppose that transistor #1 of Figure 7 with an emitter current bias



Where $h_{ib} = R_s \times \frac{R_1}{R_2}$

at null, $V = O$

Figure 5. AC Equivalent Circuit — h_{ib} Measurement.

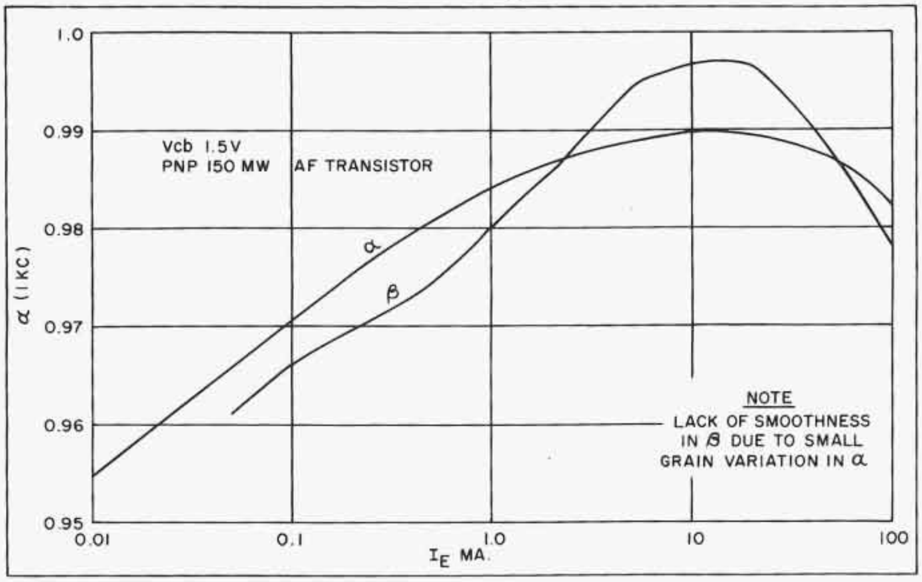


Figure 6. Beta and Delta Versus I_E

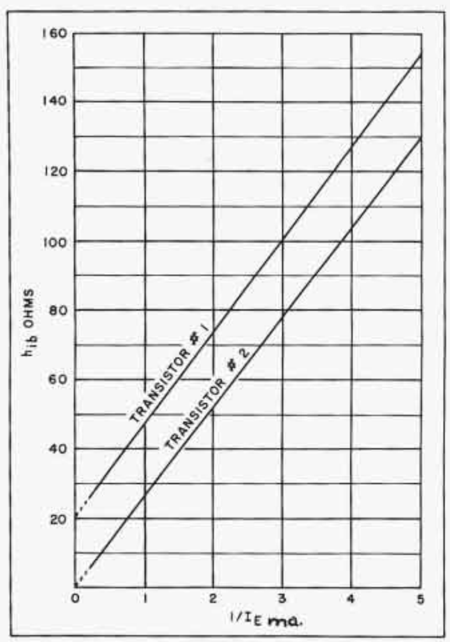


Figure 7. h_{ib} Versus $1/I_E$ For Typical Transistors.

of 2 ma. were used in the common base connection with this circuit. R_2 (h_{ib}) would be 34 ohms whereas if it were not for the high values of r_e' it would be of the order of 14Ω or approximately one-half. Therefore half the power into the transistor is lost by dissipation in a passive resistor. Furthermore, if we had a fixed production circuit and the h_{ib} of the transistor varied from 15Ω to 30Ω we would have a four-to-one variation in power gain and a two-to-one variation in band width.

Nothing has been said about h_{ie}, the common emitter input impedance. This is given by

$$h_{ie} = r_b + \frac{r_e + r_e'}{1-\alpha} \qquad (6)$$

For high α transistors at frequencies below β cutoff the second term of (6) is usually the larger term. Therefore r_e' is often as important in the common emitter connection as it is in the common base connection.

Many transistor circuits will require at least a reasonably good control of h_{ib}, if not an approach to the minimum value obtainable when r_e' vanishes. It is apparent from the above discussion that some of the frustration and failure which might be experienced in designing transistor circuits can be avoided by a study of the effect of h_{ib} on circuit performance, followed by suitable measurements of h_{ib} on the Transistor Test Set Type 275-A.

Description

There are several circuit features in the 275-A, worthy of note, that have not yet been described.

Expanded Alpha Range

In the specification it was seen that an expanded Alpha range giving four significant figures is provided. This is achieved, simply and stably, as shown in Figure 9. The adjustment R_v is required to correct for unit-to-unit variations in the total resistance of the linear measuring circuit potentiometer, R_T.

Transistor Protection

An important item to the user of the 275-A is the protection provided against accidental burnout of the device under test. First, each current and voltage range is limited to a maximum output value less than twice the full scale value of that range. Secondly, a means is provided to check the polarity of the transistor being tested in a safe manner. This operates as follows: The switch labeled SET-CHECK-MIN (lower left of main dial in Figure 1) is moved to SET, disconnecting the transistor socket, shorting the I_E supply, and open circuiting the V_{CB} supply. The desired I_E and V_{CB} are set by manipulation of the proper range switches and coarse and fine controls. The SET-CHECK-MIN switch is moved to CHECK and the METER switch is set at I_E. If the emitter current does not drop below ½ of the value set, the device is correctly poled. If polarity is not correct, the current will drop nearly to zero. If polarity is correct, moving both switches to MIN connects the transistor and permits a minimum to be achieved by rotating the main dial.

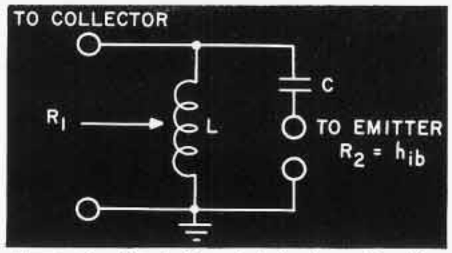
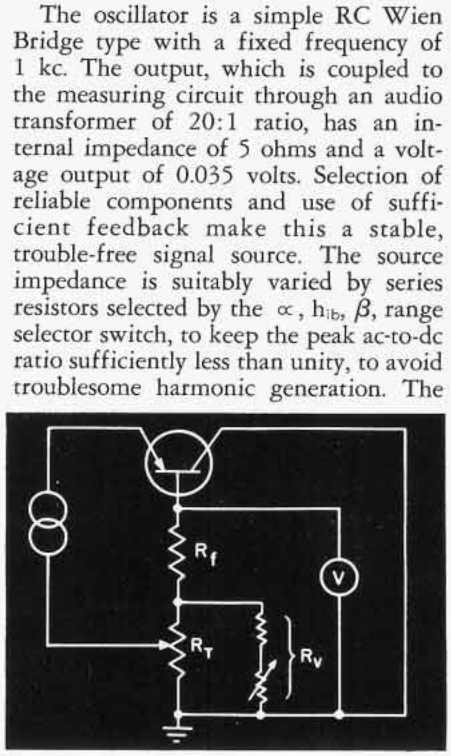


Figure 8. Single Tuned Interstage Coupling Transistor. IF Amplifier.

Oscillator

The oscillator is a simple RC Wien Bridge type with a fixed frequency of 1 kc. The output, which is coupled to the measuring circuit through an audio transformer of 20:1 ratio, has an internal impedance of 5 ohms and a voltage output of 0.035 volts. Selection of reliable components and use of sufficient feedback make this a stable, trouble-free signal source. The source impedance is suitably varied by series resistors selected by the α, h_{ib}, β, range selector switch, to keep the peak ac-to-dc ratio sufficiently less than unity, to avoid troublesome harmonic generation. The harmonic generation obscures the minimum at balance and excess even order harmonics will cause a bias shift.



$$R_T' = \frac{R_V R_T}{R_V + R_T}$$

$$R_f = 9 R_T'$$

Figure 9. AC Equivalent Circuit-Expanded Alpha Scale.

Detector

This circuit consists of two amplifiers, a cathode follower, and averaging rectifier. The resulting dc output is applied to the meter and a dc voltage is fed back to the grids of each stage as in automatic gain control, to extend the dynamic range of the indicator and permit a highly sensitive indication of the minimum, without the need for auxiliary level controls. Feed back of dc also prevents any possible damage to the meter by the large signal at the input of the detector when the potentiometer arm is far off the balance point.

Power Supplies

There are three power supplies: two are used for the transistor emitter and collector biasing, and the third is used to supply the internal oscillator and the detector.

The emitter power supply has a very high output impedance and the following ranges: 0-0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50, and 100 ma., covering most of the low and medium power transistors. The control that varies the emitter current over the entire range has both coarse and fine sections, permitting the user to set the desired emitter bias very precisely. Because of the high internal resistance, the bias magnitude, which is set by shorting the emitter and base terminal for transistor protection, is not affected when the transistor is placed in the circuit Also, inserting different transistors has no effect on the I_E selected. Since the ac output impedance is many times the dc resistance, the shunting effect on the measuring circuit is negligible. Figure 10 gives a better understanding of the I_E power supply. Current through the tube is adjusted from 0.01 ma. to 100 ma. by the variable cathode resistor, R_C. The emitter current ranges below 5.0 ma. are obtained by a current divider in the plate circuit, since the resulting power dissipation is very low. The breakdown diode (Z in Figure 8) protects the emitter-base junction of the transistor by limiting the high open-circuit voltage that develops because of the large impedance of the I_E supply.

The collector power supply is an electronically regulated constant voltage source with ranges of 0-2, 5, 10, 20, 50, and 100 volts. Like the emitter power supply this also allows easy, accurate selection of the desired V_{CB}. A current regulating tube improves the stability of the reference tube voltage vs. power line fluctuations. This is especially important at low V_{CB} values. The internal ac and dc impedances are so low that neither switching in the transistor nor I_c variation has significant effect on the value of the voltage set. Of course, the ac output resistance, which is less than 15 ohms, acts as an ac short to the several megohm output resistance of the transistor under test.

In addition to the above mentioned circuit features of the instrument, certain additional features are provided. For example, a socket is provided for connection of external power supplies providing up to 5 amperes of emitter current and 100 volts of collector-to-base biasing for Alpha and Beta measurements. (The base current should never exceed 100 ma.) Also, a jack is provided at the rear of the instrument so that a milliammeter can be inserted to measure the dc base current.

Another jack at the rear of the instrument permits the use of a sensitive narrow-band external detector, such as the Hewlett-Packard 302A Wave Analyzer, for measurements at very low signal level and I_E values below 10

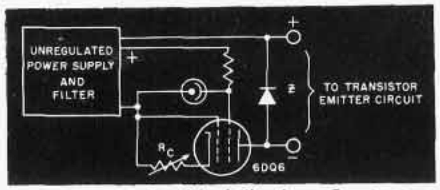


Figure 10. Simplified Circuit — Constant Current I_E Supply.

micro-amperes. The internal power supplies I_E and V_{CB}, which are metered to $\pm 1\frac{1}{2}\%$ of full scale, can be used to energize external circuits when not in use measuring transistors.

A jig, Type 575-A, with different types of transistor sockets, is supplied with the instrument for the customers' convenience, permitting a variety of transistors to be tested with little trouble. A feature of the Type 575-A jig is that the socket mounting plate may be readily removed and duplicated to facilitate mounting of special sockets, heat sinks, or other devices.

Summary

This unique instrument which enables the user to measure, with a new technique, the important dynamic parameters (α, β, h_{ib}) of a transistor is very simple to operate and stable of calibration. It is also evident that dc transistor characteristics such as dc Alpha, dc Beta, I_{CO}, I_{CBO}, I_{EO}, I_{CEO}, I_{CES}, etc., can be measured.

Because of its versatility the limit to the usefulness of the 275-A will be the ingenuity of the user.

Acknowledgment

The authors take this opportunity to express their thanks to Mr. D. E. Thomas of the Bell Telephone Laboratories for his ideas and constructive help while developing the instrument and writing this article. We also wish to thank Mr. J. E. Wachter and co-workers of Boonton Radio Corporation who contributed to the work.

References

(1) Thomas, D. E., "Some Design Considerations for High Frequency Transistor Amplifiers", Bell System Technical Journal, Vol. 38, No. 6, Nov. 1959, pp. 1571-1577.

(2) Thomas, D. E., "Some Design Considerations for High Frequency Transistor Amplifiers", Bell System Technical Journal, Vol. 38, No. 6, Nov. 1959, pp. 1560-61.

New Navigation Aid Test Set

ROBERT POIRIER, *Development Engineer*

Boonton Radio Corporation will soon introduce the Navigation Aid Test Set Type 235-A which provides all of the rf circuitry required for bench testing the ATC (Air Traffic Control) Transponders and airborne DMET (Distance Measuring Equipment — Tacan) sections of the VORTAC navigation system.

At the outset of the development of this instrument, it was proposed that all of the rf circuitry for testing ATC Transponders and airborne DMET be contained in a single package. Although the test procedures of the two devices are different, the Transponder being fundamentally a replying device and the DMET Radio Set an interrogation device, the one package concept is facilitated by the close interlacing of the receiver operating frequencies of the two devices.

The BRC Navigation Aid Test Set Type 235-A contains three basic interconnected units: viz, a crystal-controlled RF Signal Generator, a peak pulse power comparator, and a wavemeter. Used in conjunction with either the Collins Radio Company's 578X-1 Transponder Bench Test Set or the 578D-1 DMET Bench Test Set and a suitable oscilloscope (Hewlett-Packard Type 150A with 152B Dual Channel Ampli-

Figure 1. Navigation Aid Test Set Type 235-A.

fier) the BRC Navigation Aid Test Set Type 235-A is capable of performing the tests shown in the table in Figure 2.

Crystal-Controlled RF Signal Generator

Referring to the functional block diagram (Figure 3), the receiver test frequencies are generated in three crystal oscillators, heterodyned twice, and doubled in the final modulator stage. The coarse frequency oscillator generates eight 5-mc intervals of frequencies from 25 mc to 65 mc inclusive, and the fine frequency oscillator generates nine 0.5-mc intervals of frequencies from 6.1 mc to 10.6 mc inclusive. After mixing, the sum of the inputs is extracted, providing a frequency spectrum of 31.1 mc to 75.6 mc inclusive in 0.5-mc steps. A tuned amplifier suppresses the spurious products. The bandswitching oscillator and multiplier generate one frequency for each of the two bands; viz., 448.9 mc for the low band and 533.9 mc for the high band. The sum of the outputs of the first mixer and either of the two output frequencies from the bandswitching oscillator is generated in the second mixer, and after filtering and doubling, results in two bands of output frequencies from 960 mc to 1049 mc inclusive and 1130 mc to 1219 mc inclusive in 1-mc steps. Digital readout of the output frequencies, together with a printed dial readout of DMET channel numbers 1 through 63 for the frequencies 962 mc to 1024 mc inclusive and 64 through 126 for the frequencies 1151 mc to 1213 mc inclusive, are provided on the front panel of the instrument.

A total of 180 discrete crystal-controlled output frequencies are generated from 21 crystals, the frequency accuracy of which depends primarily on the two crystals in the bandswitching oscillator. The bandswitching oscillator crystals are specified to $\pm 0.0025\%$, the coarse frequency oscillator crystals to $\pm 0.005\%$, and the fine frequency oscillator crystals to $\pm 0.01\%$. The output frequency accuracy is specified to $\pm 0.005\%$ at room temperature. No crystal ovens are used, since the instrument is intended for use in laboratory ambient conditions.

A similar frequency generator could have been built with 20 crystals, with the frequency accuracy depending primarily on only one crystal, by choosing either the sum or difference products of the second mixer for the high and low bands respectively. The disadvantages of the sum or difference mixing; viz., reduced frequency accuracy of the low

578X-1 Transponder Bench Test Set	578D-1 DMET Bench Test Set
1. Receiver Sensitivity	1. Receiver Sensitivity
2. Receiver Bandwidth	2. Transmitter Power
3. Transmitter Frequency	3. Search Speed
4. Transmitter Power	4. Search Range Limit
5. Side-lobe Suppression	5. Decoder Selectivity
6. Echo Rejection	6. Identification
7. Decoder Tolerance	7. Flag Operation
8. Receiver Dead Time	8. Distance Accuracy
9. Reply Pulse Position	9. Tracking Rate
10. PAR Response	10. Transmitter Pulse Characteristics
11. AOC and Count Down	11. A.G.C. Performance
12. Identification Pulse Delay	12. Distance Indication
13. Transmitter Pulse Characteristics	
14. Image Response	
15. Random Trigger Rate	
16. Transponder Delay Time	
17. Suppressor Output	

Figure 2. Tests Available With The BRC 235-A When Used With A Synchroscope and the Collins 578X-1 or 578D-1 Test Sets.

(difference) band and the reversal in direction of the digital readout between the two bands, justify the use of 21 crystals and frequency switching of the X12 multiplier.

Both grid and cathode modulation are employed in the Navigation Aid Test Set. When the CW output level has been set to the calibration mark of the thermistor bridge meter, the positive pulse modulation signal is applied to the cathode of the final doubler to completely interrupt the CW output for the duration of each pulse. The demodulated interrupted CW may be observed as a relative amplitude either on an integral peak voltmeter or an external synchroscope for a peak pulse calibration of the calibrated CW output level. Subsequently, the doubler stage is biased to cut-off and the positive pulse modulation signal is applied to the grid through a variable modulation level control which is adjusted so that the detected peak pulse amplitude is the same as that for the interrupted CW signal. The peak pulse output level, thus obtained, is referenced to the thermistor bridge calibration of the CW output level. Frequency multiplication is employed in the output stage in order to obtain a high ratio between the peak pulse output level and the CW output, between pulses, in a single stage modulator. The peak pulse to CW ratio is directly related to the purity of the

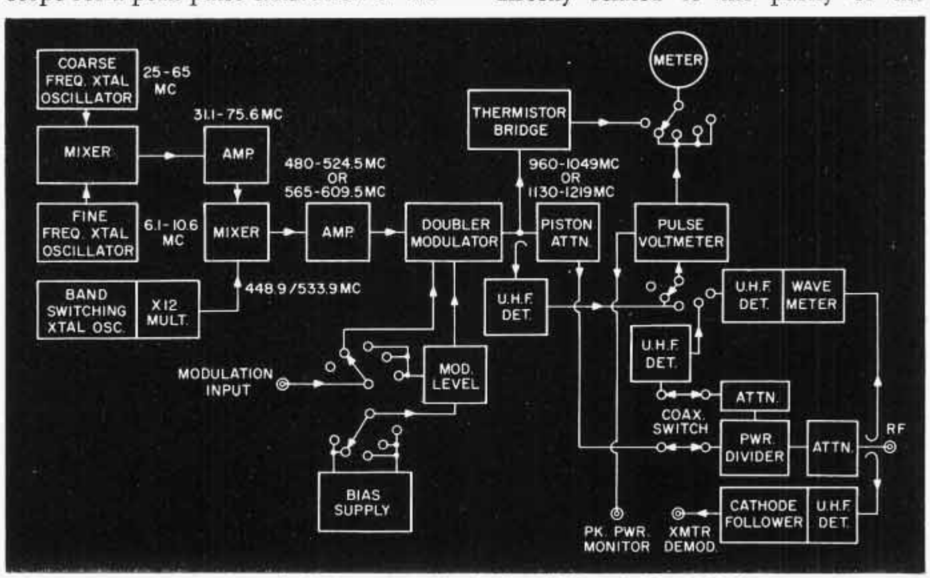


Figure 3 Block Diagram — Navigation Aid Test Set Type 235-A.

driving frequency and, in the 235-A, can be 60 db or better. Spurious outputs are at least 30 db down.

Peak Pulse Power Comparator

Incorporated in the Navigation Aid Test Set is a circuit for measuring the peak pulse output of the transmitters in the ATC Transponders and DMET Radio Sets. In principle, this measurement is made by comparing the relative amplitude of the detected transmitter output pulse after a precisely known suitable amount of fixed attenuation with the variable calibrated output of the RF Signal Generator observed through the same detector. The measurement is made by adjusting the output of the RF Signal Generator, by means of the piston attenuator, for the same detected peak amplitude as was observed for the transmitter output, and reading the piston attenuator dial which is also calibrated in terms of transmitter peak output power over the range of 23 to 33 dbw. The peak power output of the RF Signal Generator is compared with the accurately attenuated transmitter output pulse in the same detector, at the same level but not normally at the same frequency. There is a difference of 60 mc between the transmitter and receiver frequencies of the ATC Transponder, and a difference of 63 mc between these frequencies in the DMET Radio Set. The RF Signal Generator portion of the 235-A is designed for receiver frequencies and does not produce the Transponder transmitter frequency. Some of the DMET transmitter frequencies are incidentally available. The peak power measuring detector is sufficiently flat over 63-mc increments of frequency for an overall accuracy of ±1.5 db for the peak power measurement.

Wavemeter

The wavemeter incorporated in the Navigation Aid Test Set is for the purpose of measuring the transmitter output frequency of the ATC Transponder which obtains from a free-running tunable cavity oscillator. The frequency range of the wavemeter is 1070 mc to 1110 mc in order to accommodate the Transponder operating frequency which consists of a pulse spectrum centered on 1090 mc. Frequency accuracy of the wavemeter is ±0.5 mc over the range of 1070 mc to 1110 mc.

The VSWR of the rf connection on the front panel of the 235-A will be 1.2 or less, and will not be observably dependent on the tuning of the wavemeter. The path between the rf panel connector and the wavemeter includes about 50 db of attenuation. Referring again to the block diagram, the wavemeter indicator is the integral peak voltmeter which provides that the wavemeter indication is dependent only on the transmitter power and spectrum, and is negligibly affected by the reply repetition rate and the number of pulses in the reply code.

Conclusion

The Navigation Aid Test Set provides complete facilities for the accurate testing and calibration of airborne DMET and ATC Transponder Systems and has been specifically developed to serve the needs of BRC customers engaged in the design and operation of this type equipment.

SPECIFICATIONS(1)

Signal Generator Section

OUTPUT FREQUENCY RANGE: Channels spaced 1 mc in the range 960 mc to 1049 mc inclusive and 1130 mc to 1219 mc inclusive.
OUTPUT FREQUENCY ACCURACY: ±0.005% from 60°F to 100°F.
RF OUTPUT LEVEL: —10 to —100 dbm.
RF OUTPUT ACCURACY: ±1 db.
LEAKAGE: Less than —112 dbm.
MODULATION CAPABILITY: Designed for pulse modulation.
Input impedance: 150 ohms.
Input level: +7.5 v peak or more.
Time response: Risetime = 0.14 μsec or less; overshoot 5% or less.
RF Output Impedance: 50 ohms with VSWR of 1.2 or less.

External Power Measurement
FREQUENCY RANGE: 960 to 1215 mc.
INPUT IMPEDANCE: 50 ohms VSWR 1.2 or less.
POWER LEVEL RANGE: 23 to 33 dbw.
200 to 2000 watts
ACCURACY: ±1.5 db.

External Frequency Measurement (ATC Transponder only)
FREQUENCY RANGE: 1070 to 1110 mc.
ACCURACY: ±0.5 mc.

RF Envelope Pulse Detector
FREQUENCY RANGE: 960 to 1215 mc.
SENSITIVITY: External signals; will produce +0.5 volts peak open circuit from a 150-ohm source with 30 dbw input.
Internal signals; will produce +0.5 volts peak open circuit from a 150-ohm source with a level of —13 dbm from the internal generator.
BANDWIDTH: Flat within 3 db to 7 mc.
TIME RESPONSE: Response to Heaviside unit step 0.057 μsec. Risetime, less than 2% overshoot.

Power Requirements: 115/230 volts ac ±10%, 50 to 420 cps.

(1) Based on: Report of Special Committee 58 of the RTCA, "Minimum Performance Standards Airborne Tacan Distance Measuring Equipment Operating Within the Radio Frequency Band 960-1215 Megacycles", dated December 18, 1958.
AEEC Letter No. 57-3-27, entitled, "Status Report of ATC Radar Beacon System Project and Draft Revision of Characteristic No. 532A", dated October 21, 1957.

A NEW UHF Q METER

From the beginning of the Company's history, Boonton Radio Corporation has been active in the development and manufacture of impedance measuring instruments. The first instrument produced by the Company was the Q Meter in the frequency range of 50 Kc to 75 Mc. Later development resulted in a Q Meter making measurements up into the 200-Mc range. Other developments have produced the RX Meter, an RF Bridge operating between the frequencies of 500 Kc and 200 Mc, the QX Checker and subsequently the Q Comparator which offer methods of measuring the deviation of a test sample in Q, L, or C from a standard.

The Q Meters developed in the past have made use of the resonance rise method of measurement. This well known method inserts a known voltage across a very low resistance in series with a resonance circuit. A vacuum tube voltmeter measures the voltage across the capacitor in the resonant circuit while the inductance in this circuit is ordinarily the device of which the Q is to be measured. If the insertion resistor is very low in value and the capacitor has very high Q, the vacuum tube voltmeter across the capacitor can be made to read directly in Q of the test coil. This method has the advantage of being very simple, capable of good accuracy, and entirely direct reading on a precision meter. Beside Q, the Q Meter can also be used to measure capacitance, inductance and resistance over the frequency range of the instrument.

The need for a Q Meter at frequencies above 200 Mc has long existed, but the difficulty in designing a very low and constant value pure resistance insertion impedance and the problems associated with designing a high Q, low inductance variable capacitance over this range have made such an instrument impracticable. It has been known for several years that Q could also be deduced by varying the frequency applied to a resonance circuit so as to obtain a voltage across the capacitance 3 db down from the resonant peak on each side of that resonance. The frequency bandwidth between the 3 db points divided by the resonant frequency yields the Q. Such a method in the low frequency Q Meter, however, does not yield a simple direct reading instrument.

The Boonton Radio Corporation now has a Q Meter, in advanced stages of preparation for manufacture, covering the frequency range of 200 to 600 Mc. making use of the frequency variation method of Q measurement. This instrument consists of a specially designed oscillator, Q capacitor and sensitive detector. The Q capacitor is designed so that inductive effects are automatically removed from the measurement thus yielding a device which exhibits pure capacitance over the frequency range.

The oscillator frequency varies logarithmically with the dial shaft position and the Q of the test sample is indicated directly on a calibrated dial. A dial which reads directly in inductance is also supplied. When using the internal Q capacitor, the instrument will read Q, L, C, and R over a frequency range of 200 to 600 Mc. The Q range is 20 to 2,000. The range of inductance measurements is 3 to 200 milli-microhenries and the capacitance range is 4 to 25 micromicrofarads. A special coupling means is provided so that the resonant frequency and the Q of external cavities located at a distance from the instrument may be measured. The Q range in this application extends upward to 25,000.

A model of the new UHF Q Meter Type 280-A will be exhibited in Booth No. 3101-3102 at the IRE Convention in March of this year.

BOONTON RADIO PLANS EXPANSION

Plans are well under way for the expansion of Boonton Radio's product line and of its facilities. Our Engineering Manager, John P. Van Duyne has been undertaking a broad program of expansion of our engineering personnel to increase the number of precision electronic instruments introduced in the field.

A new site, comprising 70 acres, has been purchased in Rockaway Township four miles west of the Company's present Plant. This site is approximately 36 miles west of New York City and is reached directly by Route 46 from the George Washington Bridge to the newly completed Route 80 which passes within one mile of the new site.

A new building is planned for completion in 1960 which will contain approximately 60,000 square feet. This building will be two and one-half times larger than the Company's present quarters.

The new building will be equipped with modern machinery and new methods which will lead to better control and more precise manufacturing procedures for our present instruments. New techniques and new operations are being included to take care of specialized and more precise manufacturing methods needed for new instruments which are being introduced at the IRE in New York in March as well as new instruments which are planned for the future.

The initial building is part of a master plan which is being completed for the new site. This master plan includes a much larger program of building and expansion which it is expected will be carried out during the next five years.

This planned expansion of our staff and our facilities will place the Company in a position to produce a larger line of precision electronic instruments and to manufacture equipment for which techniques have not been available in our currently used facilities.

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