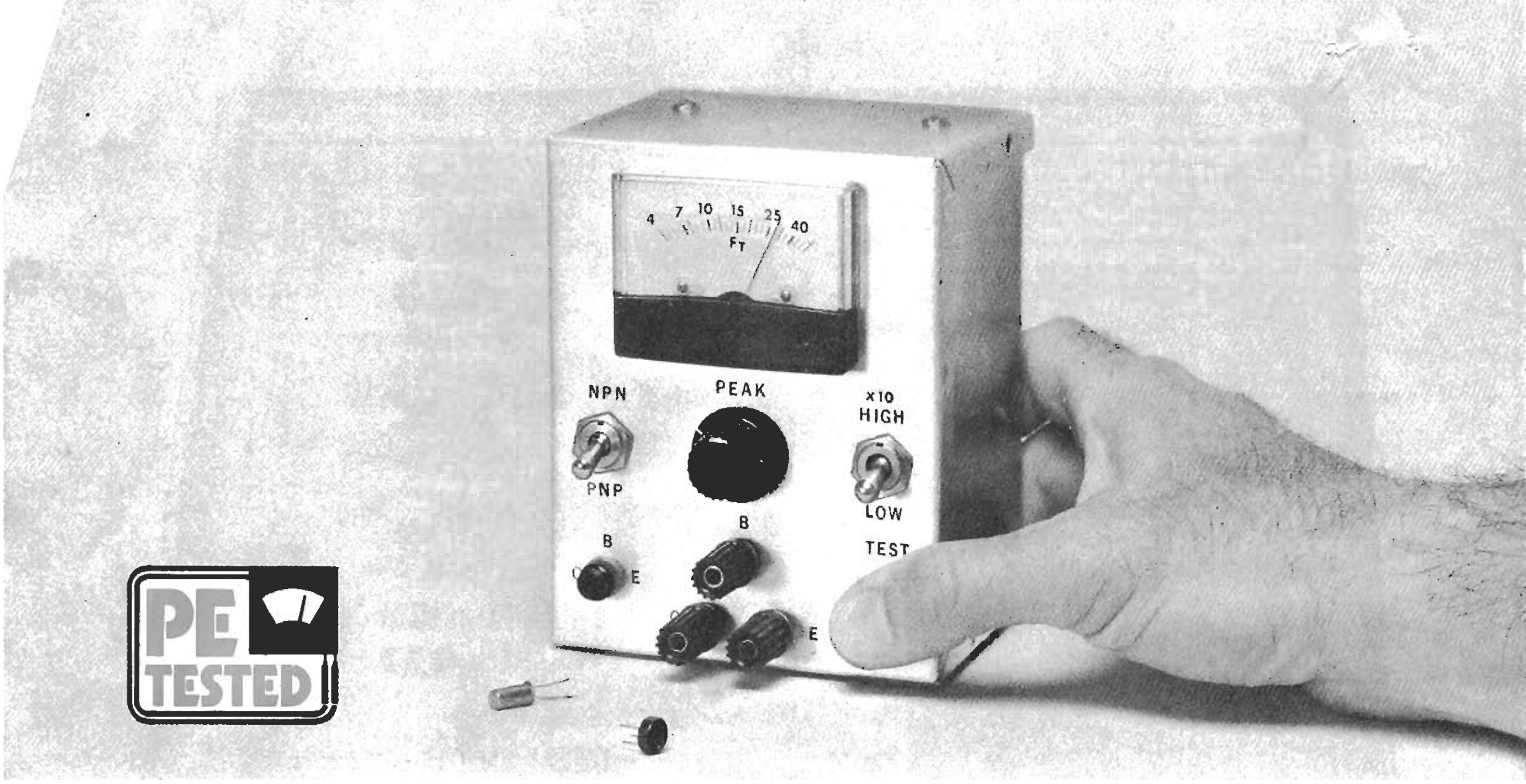


R-F TRANSISTOR TESTER

Checks upper frequency limit of bipolar transistors

BY DANIEL METZGER

CHECKING out an r-f transistor on a "standard" tester is as tricky as testing a high-voltage TV tube on the corner-drugstore machine. When the indicator reads "good," the device can still be bad.

Unfortunately, most transistor testers perform dc checks only. They indicate the device's beta (amplification) and, in some cases, leakage current. Few check performance at radio frequencies, however, which is an essential parameter if you're troubleshooting a transistorized front end.

The important characteristic here is the transistor's cutoff frequency, f_T. As the frequency increases, a transistor's amplifying capability drops rapidly. Above f_T, there is no gain at all, and the transistor just doesn't work. You can check your transistors' f_T to determine if they will operate satisfactorily at r-f by building the circuit shown in Fig. 1. (For more about the importance of f_T, see the box on page 59.)

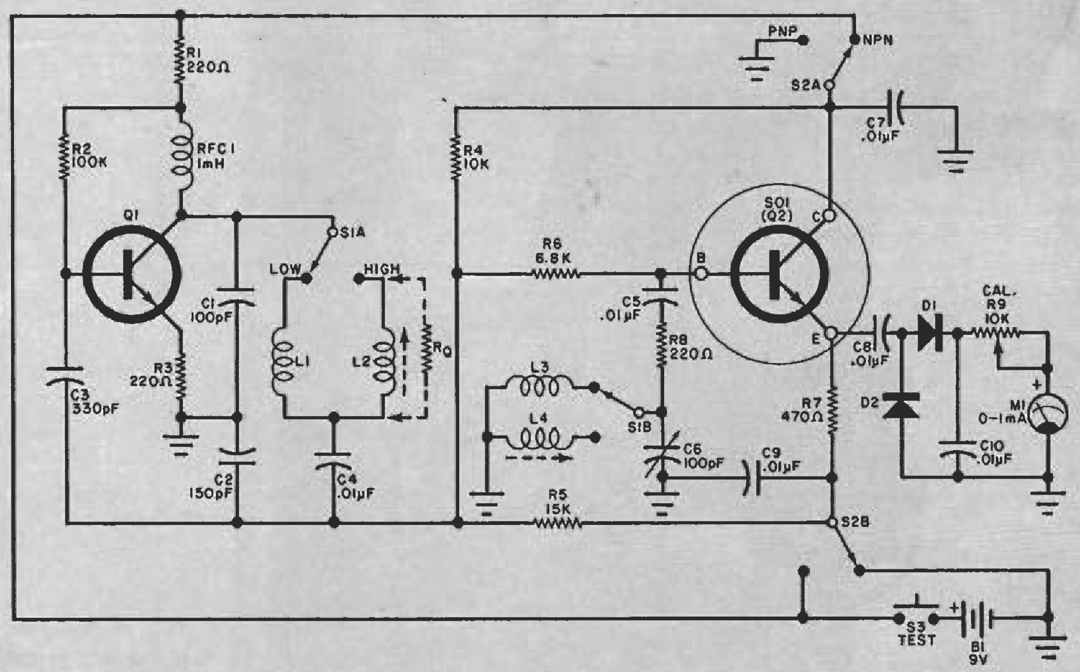
How It Works. The circuit is essentially an emitter-follower amplifier whose input impedance varies with the f_T of the transistor. The input impedance is then used as one leg of a voltage divider, and the output voltage, as indicated on the meter, is a function of f_T.

The *Q1* circuit is a conventional Colpitts oscillator running at 1 MHz on the LOW range and 10 MHz on the HIGH range of *S1*. A signal of approximately 6 volts p-p is applied to the left end of resistor *R6*. Resistors *R4* and *R5* provide base bias for *Q2*, the transistor being tested. Either *L3* or *L4* forms a tuned circuit with *C6* and the input capacitance of the transistor being tested. With *C6* tuned to resonance, the reactance of the transistor's C_{in}, which would otherwise load the signal, is cancelled.

The input impedance of the base of *Q2* is essentially beta times the emitter resistance. This emitter resistance is *R7* in parallel with the effective resistance of the metering circuit. Emitter resistance varies with the setting of the calibrate control, but should be near 400 ohms. If a transistor having an f_T of 17 MHz is checked on the 1-MHz range, it will have a beta of $f_T/f = 17/1 = 17$. The base input resistance of the transistor will then be:

$$r_b = \beta\ r_e = 17(400) = 6800 \text{ ohms}$$

The 6-volt p-p input signal is the voltage divided by *R6* and r_b to produce a 3-volt p-p signal at the base (and also at the emitter) of *Q2*. Diodes *D1* and *D2* rectify this signal, but since each diode requires about 0.6 volt before it begins to conduct, only about 1.8 volts dc appears across *C10*.



PARTS LIST

B1—9-volt battery
C1—100-pF disc capacitor
C2—150-pF disc capacitor
C3—330-pF disc capacitor
C4,C5,C7-C10—0.01-μF disc capacitor
C6—100-pF variable capacitor
D1,D2—Silicon signal diode (1N914 or similar)
L1,L3—400-μH inductor
L2,L4—25 turns No. 26 enamel wire, close-wound on ¼-in. slug-tuned form
M1—0-1-mA dc meter movement
Q1—Transistor (2N4124 or similar)
Q2—Transistor under test
R1,R3,R8—220-ohm, ½-watt resistor
R2—100,000-ohm, ½-watt resistor
R4—10,000-ohm, ½-watt resistor
R5—15,000-ohm, ½-watt resistor
R6—6800-ohm, ½-watt resistor
R7—470-ohm, ½-watt resistor
R9—10,000-ohm trimmer potentiometer
RQ—3300-to-33,000-ohm resistor (see text)
SO1—Transistor socket
S1,S2—Dpdt toggle switch
S3—Spst normally open pushbutton switch

Fig. 1. The transistor being tested (Q2) is connected to socket SO1. Transistor Q1 is an r-f oscillator which supplies a signal to Q2. Frequency is changed by switching reactances.

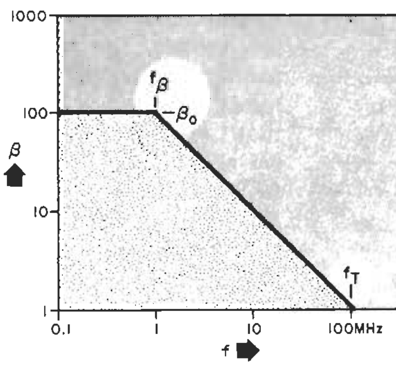
Construction. Almost any type of construction can be used. The prototype was built up on a small piece of perforated board. However, keep in mind that the tester operates in the r-f range, so all leads must be as short as possible.

The test socket (*SO1*) and all controls and switches (except for *R9*) are mounted on the front panel. The battery is supported by a mounting clip. Coils *L2* and *L4* are mounted on a small metal bracket so that their screwdriver adjustments can be easily reached.

On the prototype, three five-way binding posts were connected to *SO1* and mounted on the front panel to facilitate testing using clip leads to connect to the transistor.

Calibration. Calculations such as those given above and in the box can be extended to apply to a range of f_T values and a calibration chart for the low range of the meter can be constructed as shown in Fig. 2. Other values of *R6*, *R7*, and signal frequency can be used to alter the range of the instrument, but care should be taken to ensure that betas higher than 50 will

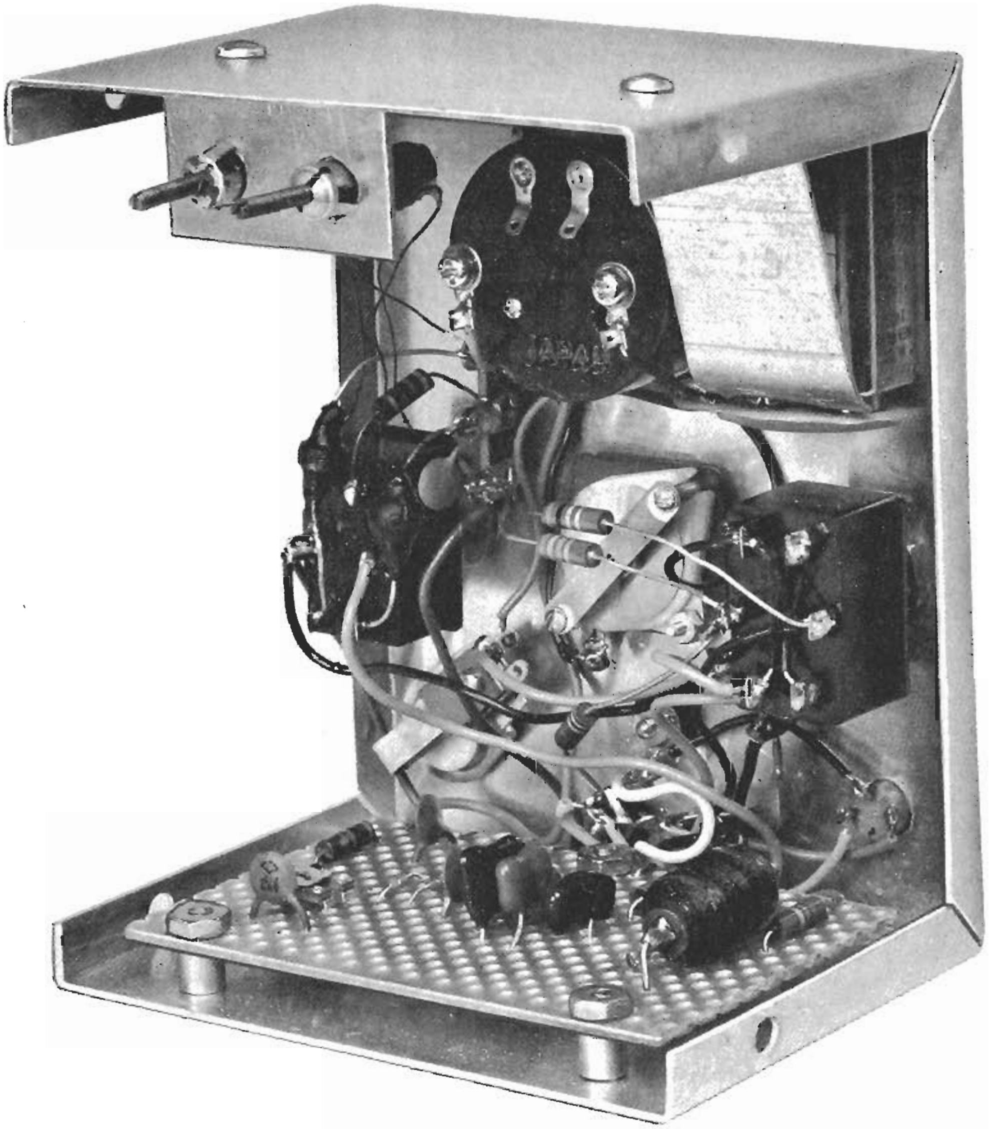
WHAT IS f_T?



The cutoff frequency (sometimes also called gain-bandwidth product) is the frequency at which the current gain (h_{fe}) drops to unity. For frequencies lower than f_T, h_{fe} increases linearly at a rate of 6 dB per octave. (The beta doubles as the frequency is halved.) The rise in beta continues until the low-frequency beta (β_0) is reached at the beta cutoff frequency (f_β) as shown in the diagram. Notice that, for any frequency above f_β, the product of current gain and operating frequency is constant and equal to f_T. Hence, the name gain-bandwidth product for f_T.

Calculating h_{fe} at any frequency when f_T is known is a simple matter if this relationship is kept in mind. For example, if a transistor having an f_T of 200 MHz is to be used in a 27-MHz amplifier, its effective beta is f_T divided by f or 200/27 = 7.4.

To find the frequency at which beta will begin to drop below its full low-frequency value, the procedure is reversed. Thus, in the example above, if the transistor has a low-frequency beta of 150, it will begin to drop at 200/150 = 1.33 MHz.



This photograph shows how prototype was assembled. Be sure to use short lead lengths to avoid r-f interference.

always drive the meter above full scale. This is because many transistors have a low-frequency beta not much higher than 50 and they would otherwise read low on the f_T scale.

To calibrate the instrument, a high-beta transistor with an f_T specification above 250 MHz is inserted in test socket *SO1* with range switch *S1* on LOW. The author used a 2N4124 with a measured low-frequency beta of 200. The beta of the transistor is known to be 200 at 1 MHz, giving an I_m of 1.3 mA as shown in the last line of Fig. 2. A 3-mA meter is then inserted in series with the instrument's meter, and *R9* is adjusted for 1.3 mA. The low range of *S1* is now calibrated. Use *C6* to set the meter pointer at maximum.

To calibrate the high range, it is necessary to insure that *Q1* is really oscillating at 10 times the low frequency (10 MHz in this case). This can be determined by using a grid-dip meter, a high-frequency oscilloscope, or a frequency counter.

Finally, the output of the oscillator (junction of *R4* and *R6*) must be checked with an r-f voltmeter and trimmed if necessary to keep the r-f output constant in both the high and low ranges. The trimming is accomplished by placing a resistor (*RQ*) across *L1* or *L2* and choosing its value so that the r-f voltmeter reads the same on both ranges. The resistor effectively lowers the Q of the coil and reduces the oscillator output on the range for which it is inserted. The value of *RQ* may be from 3300 to 33,000 ohms, depending on the difference in Q between the two coils. The calibration for the high range is simply 10 times the low range. ◈

FIG. 2. SAMPLE CALIBRATION CHART

f_T MHz	β	r_b Ohms	v_e Volts (p-p)	V_{C10} Volts	I_m mA
4.2	4.2	1.67 K	1.2	0	0
7.0	7	2.8 K	1.7	0.5	0.15
10	10	4.0 K	2.2	1.0	0.30
17	17	6.8 K	3.0	1.8	0.55
30	30	12 K	3.8	2.6	0.79
50	50	20 K	4.5	3.3	1.00
>250	200	80 K	5.5	4.3	1.30