Transistor Beta Tester With Linear Scale

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Tube testers are accepted as necessary units of test equipment. Increased use of transistors makes some means for testing them almost imperative, and this design gives a direct reading with a minimum of manipulation.

This simple and low-cost instrument has a linear, direct-reading dial and two "beta" ranges. The accuracy can be made as high as one per cent depending on the components used, while the cost of the instrument is relatively low.

Basically, the circuit[1] is that of an oscillator. The point at which oscillation starts is determined by the β of the transistor and by a potentiometer R_1 in *Fig.* 1. The frequency of oscillation which lies in the audio range, depends mostly on the transformer characteristics.

Theory

To understand the operation of the circuit, let us examine the conditions which prevail when the circuit just begins to oscillate: (see *Fig. 1*)

let N = Transformer turns ratio
I_c = a.c. collector current
I_b = a.c. base current
β = the base-to-collector current gain

We have:

$$I_1 + I_2 = I_c; \text{ and } I_b = \frac{I}{N}(I_1)$$

Also:

$$I_2 = \frac{R_1}{R_o}(I_1)$$

Then:

$$I_c = I_1\left(1 + \frac{R_1}{R_o}\right);\ I_1 = \frac{I_c}{1 + \frac{R_1}{R_o}}$$

Therefore:

$$I_b = -\frac{I_c}{N}\left(\frac{1}{1 + \frac{R_1}{R_o}}\right)$$

since

$$\beta = -\frac{I_c}{I_b}$$

we see that

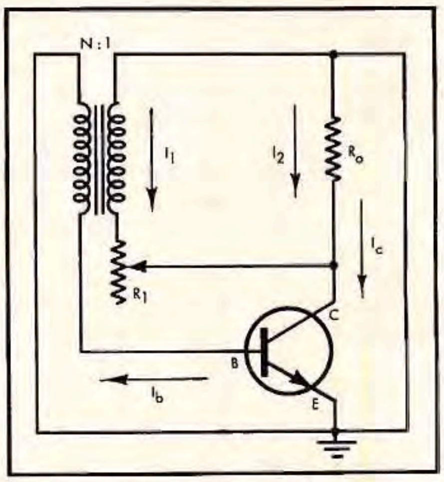

Fig. 1. Simplied schematic of basic arrangement for testing transistors.

$$\beta = N\left(1 + \frac{R_1}{R_o}\right) \qquad (1)$$

Therefore, for a given transformer ratio and a given transistor β, the circuit will start oscillating only when R_1 is *above* a certain critical value, given by the relationship of Eq. (*1*). Thus the potentiometer R_1 can be calibrated to read β directly.

Let us investigate the circuit further to see what other useful relationships we can determine, and how we can make a *linear*, direct-reading, dial scale. Suppose we make the resistor R_1 a 10-turn potentiometer, and we use a 15-turn dial such as a Beckman type "RB" (or other similar device) to read out our β values directly. This dial has 100 major divisions per turn, and a total of 15 turns or 1500 divisions. If we determine the *minimum* β value we wish to read, we automatically set the *maximum* value of β we can read on one range. This is true since our resistor R_1 in *Fig.* 1 goes from a minimum value of zero ohms to its maximum value when rotated the full 10-turns, and β varies with R_1 according to Eq. (*1*).

Let us call our minimum value of β by the term β_{min}. Then our maximum value, β_{max}, will be $\beta_{min} + 100.0$ since, after 10 turns, the dial will read 100.0 divisions *more* than at its initial position.

Let us call R_{min} the total circuit resistance, including the transformer primary resistance, when R_1 equals zero. Let us call R_p the total resistance of the potentiometer.

Then using Eq. (*1*) we can write the following:

$$\beta_{min} = N\left(1 + \frac{R_{min}}{R_o}\right) \qquad (2)$$

$$\beta_{max} = 100.0 + \beta_{min} = N\left(1 + \frac{R_{min} + R_p}{R_o}\right) \quad (3)$$

Combining (*2*) and (*3*):

$$100.0 + (N)\left(1 + \frac{R_{min}}{R_o}\right) = N\left(1 + \frac{R_{min}}{R_o} + \frac{R_p}{R_o}\right)$$

Therefore:

$$100.0 = N\left(\frac{R_p}{R_o}\right)$$

and

$$\frac{R_o}{N} = \frac{R_p}{100} \qquad (4)$$

This equation gives the relationship necessary to get the correct dial reading for β_{min} and β_{max} for a given N, R_o, and R_p. Note that this relationship is independent of R_{min}.

If we substitute Eq. (*4*) back into Eq. (*2*) we get:

$$\beta_{min} = N + \frac{R_{min} \times 100}{R_p} \qquad (5)$$

This equation tells us what the minimum value of β is we can read, with a given turns ratio N, R_{min}, and R_p.

From Eqs. (*2*) and (*3*) we note an important property of this circuit, namely: we can change the range of β readings

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[1] G. F. Montgomery, "Transistor beta tester." *Electronics*, May, 1957, pg. 198.

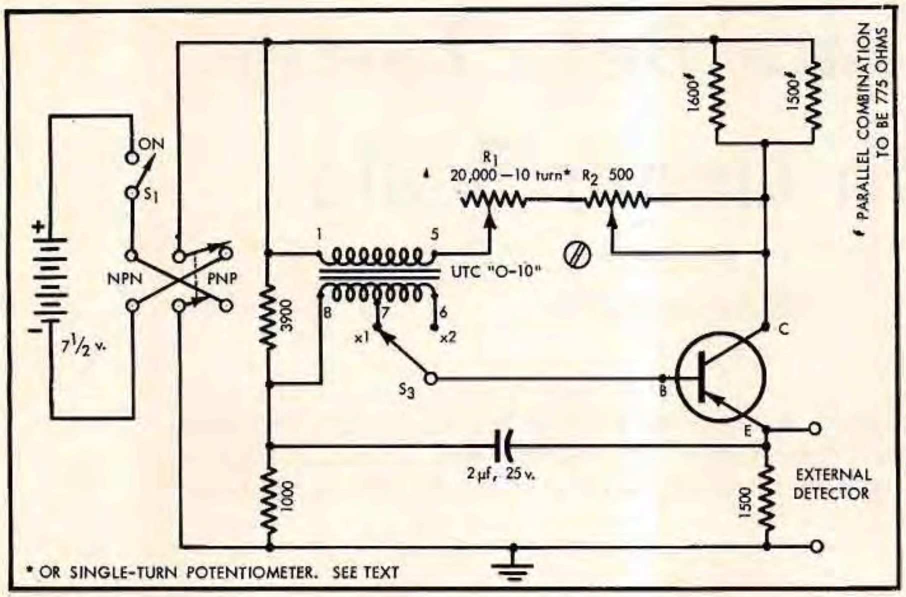

Fig. 2. Complete schematic of transistor tester. R_1 may be a special 10-turn potentiometer, used with a 15-turn dial, although a single-turn four-watt type of pot may be used instead.

directly by changing only the transformer ratio N. Thus, if we use a multitap winding in the base circuit, having transformation ratios of N and KN, we can have two ranges of β namely: from β_{min} to $(100 + \beta_{min})$ and from $K \times (\beta_{min})$ and from $K \times (\beta_{min})$ to $K \times (100.0 + \beta_{min})$. All we have to do is multiply our dial reading by the factor K.

Having established the relationships which govern the operation of this circuit, a practical form of it can be designed as in *Fig.* 2.

To keep the cost at a minimum, the surplus market was scanned, and it was found that 10-turn, 20,000-ohm, potentiometers were available. R_p then is 20,000 ohms.

Next T_1 was chosen so as to get two β ranges. A UTC type 0–10 was selected. For this transformer, $N = 3.875$ using ½ primary to full secondary, or $N = 7.75$, using full primary to full secondary.

Using $N = 3.875$ we find R_o from Eq.

$$(4): R_o = N \times \frac{20{,}000}{100} = 775 \text{ ohms.}$$

R_o should be measured accurately on a bridge. This will eliminate the necessity of using a variable adjustment for R_o.

β_{min} can now be chosen. A value of $\beta_{min} = 5.0$ seemed reasonable after looking over the characteristics of transistors presently available. Then:

$$5.0 = \beta_{min} = N\left(1 + \frac{R_{min}}{R_o}\right) = (3.875) \times \left(1 + \frac{R_{min}}{775}\right)$$

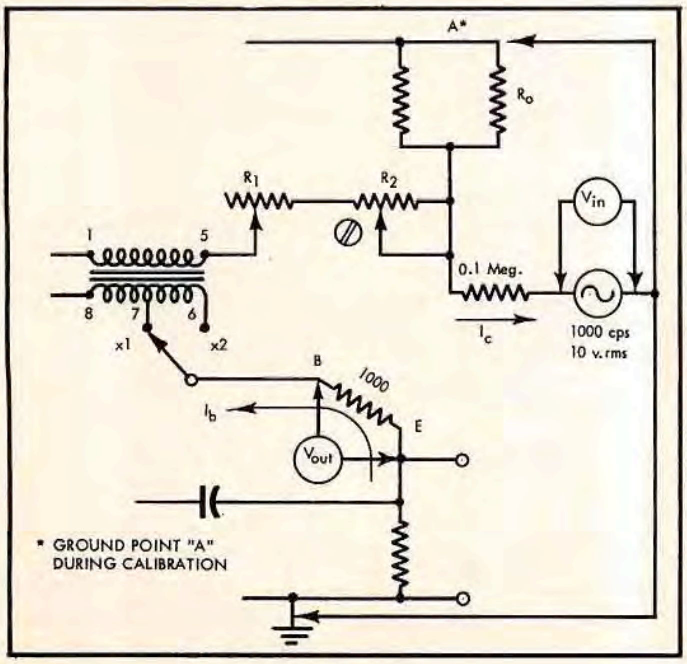

Fig. 3. Circuit used for calibration of the transistor tester.

Thus, $R_{min} = 225$ ohms.

A 500-ohm potentiometer (R_2 in *Fig.* 2), is used to adjust R_{min} to its exact value.

The rest of the circuit is designed so that any transistor inserted in the test instrument will operate at approximately 6 volts collector voltage and approximately 1 ma emitter current. Switch S_2 is included so that either PNP or NPN units can be tested, and switch S_3 changes the dial reading from "times 1" to "times 2." One word of caution: check to see that the transformer is wired with the same phasing shown in *Fig.* 2—otherwise the circuit will not oscillate. To keep the instrument as simple and inexpensive as possible, no detector or meter was incorporated in the circuit. Any detector, such as earphones, VTVM, or oscilloscope can be used to detect when oscillation just starts.

When taking a reading, start from a high dial setting towards the low one. A reading should be taken when the oscillations just start, *not* when they stop, as indicated when going from a low reading to a high one.

Calibration

To calibrate the β tester, an oscillator, a VTVM (such as a Ballatine Model 300) and two precision resistors are required, one of 0.1 megohms and one of 1000 ohms, as in *Fig.* 3. The audio oscillator is set for 1000 cps, and its output at about 10 volts. The battery leads are shorted and are the "ground point." The 0.1-meg. resistor is wired between the collector terminal and the oscillator. The 1000-ohm resistor is wired between the base and emitter terminals. S_3 should be in the "X1" position.

By comparing *Fig.* 3 to *Fig.* 1 it will be noted that:

$$\beta = \frac{I_c}{I_b} = \frac{V_{in}}{100{,}000} \div \frac{V_{out}}{1000} = \frac{V_{in}}{V_{out} \times 100}$$

The dial should now be set so that when the 10-turn potentiometer is at zero resistance, it reads β_{min}, i.e. 5.0. Rotate the dial ten full turns to check if it reads 105.0 i.e.: $\beta_{min} + 100.0$. (To avoid turning the potentiometer ten turns every time, leave it at its maximum resistance setting and use a short clip lead to short it out when zero resistance is required during calibration measurements). With R_1 at zero ohms (using clip lead) adjust R_2 to get:

$$\frac{V_{in}}{100 \times V_{out}} = \beta_{min}.$$

With R_1 at maximum resistance see if:

$$\frac{V_{in}}{100 \times V_{out}} = 100 + \beta_{min}$$

If R_o is the proper value then the measurements should check. If not, R_o has to be trimmed slightly, leaving R_2 set, until

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the values of β_{min} and $100+\beta_{min}$ coincide with the meter indications.

It should be emphasized that the meter should be calibrated first to make sure an accurate calibration is obtained for the β tester.

When R_0 and R_2 are adjusted to give the proper values of β at both ends of the scale, all other points in between are automatically calibrated to an accuracy equal to the linearity of the potentiometer used. The points can be checked as a matter of routine, and will be found to coincide exactly with the dial readings. Readings with switch S_3 in the "X2" position will be exactly one-half those taken with S_3 in the "X" position.

Single-turn Potentiometer

If a more common type, single-turn, wire-wound linear potentiometer is used with a dial marked from "0" to "100," the method of calibration is the same, with the following exception. Since the β_{min} reading should be "5.0", and the dial reads "0", and the β_{max} reading should be "105", and the dial reads "100", the user should always make a note to *add* the quantity "5.0" to every reading he makes with the instrument. Thus, a reading of $\beta=42.0$ on the dial, really indicates a true β value of 47.0 and so on. This constant offset between true β and dial reading does not diminish the usefulness of the instrument and enables the builder to save the cost of a more expensive potentiometer. A dial can be especially made to suit the requirements, or *Fig.* 4 can be cut out and glued to the cabinet to serve as the dial, preferably under a thin piece of transparent plastic for protection.

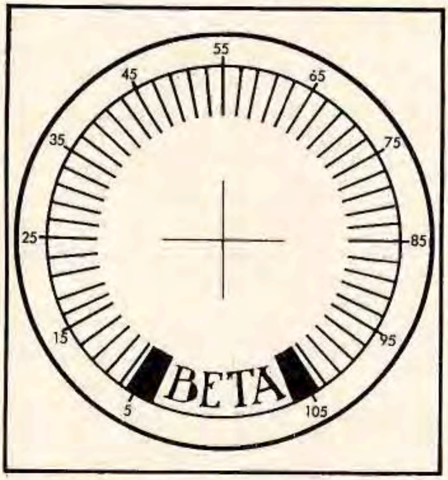

Fig. 4. Dial scale may be cut out and used with the single-turn potentiometer.

Construction

All the components can be placed inside a $3'' \times 4'' \times 5''$ aluminum box. The placement of the parts can be seen from the photographs. All resistors and capacitors can be mounted on a small terminal board, and wires run to the battery, switches, and potentiometers as required. An "L" or "U" shaped bracket is used to secure the battery, or it can be mounted on the bottom cover plate.

Three type X-2146 spring loaded diode clips (manufactured by Cambridge Thermonic Corp.) are used to clip the transistor leads during the measurement other types may be found equally suitable.