Bob’s TechTalk #30
by Bob Eckweiler, AF6C

A Simple Transistor Checker:

Figure 1: The 1980’s Era Prototype Transistor Checker

Introduction:

We’ve gotten into some interesting theory over the past few years. Perhaps it is time to change pace and build something! To be honest, my initial idea was to build a fancy code practice oscillator (CPO) – something every ham should have. The CPO I was planning would have three stages and plenty of audio; and we could discuss each stage and how it worked as we went along. However, much of my free time recently was used taking an ARRL antenna modeling class, and I wanted to breadboard up the circuit before passing it on to others to build. So look for it in a not-to-distant ***Bob’s Tech Talk*** series. I’ve also had a request to talk about inductors, those mysterious components that make radio possible. Look for that in an upcoming series too.

This month I’m going to show you how to build a simple transistor checker. This checker can measure a transistor’s beta (ß) and can check for leakage (we’ll discuss beta later in the article.) It can also tell you if a transistor is NPN or PNP. Figure 1 shows a prototype of the transistor checker that I built some years back. It is powered by four common alkaline AAA batteries and reads beta on a 1 mA meter. The prototype has two scales: 0–500ß and 0–50ß. The latest version has scales of 0–500ß and 0–100ß. The latest version also has a battery test function. While accuracy could be improved by using 1% precision resistors for R1, R2, R4 and R6, standard 5% quarter or half-watt resistors will give adequate precision for most uses.

What is Beta?:

Beta is one of the most important parameters of a transistor. Actually, there are two beta parameters – ß$_{DC}$ and ß$_{AC}$; we’re mostly interested here in ß$_{DC}$. The ARRL handbook has a good chapter on the basics of how transistors work, so I won’t get into the physics of their operation here. Instead, let’s look at figure 2, which is a simple representation of an NPN transistor.

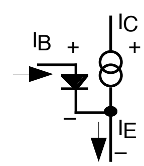

Figure 2: Ckt. equivalent of an NPN transistor

The two overlapping circles is the symbol for a current generator. Looking at the figure, the base circuit is just a simple diode with the anode connected to the base (B) lead and the cathode connected to the emitter lead (E). When a positive voltage is applied across the diode as shown, no current will flow (other than leakage current) thru the base diode until the voltage reaches the about 0.7V for a silicon transistor or 0.3V for a germanium transistor. If a voltage is applied between the collector and emitter as shown, with no current flowing in the base circuit, the current generator will allow no current to flow from the collector to the emitter. (again, other than leakage current). Things get interesting when current begins to flow in the base circuit; then current will also flow between the collector and emitter. The amount of current flowing in the base circuit controls the amount of current flowing between the collector and emitter. Usually the collector current is much greater than the base current and this current gain is called the DC beta of the transistor. Thus beta is the ratio of the collector current vs. the base current when the transistor is properly biased.

$$\beta = \frac{I_C}{I_B}$$

A PNP transistor is similar except the voltages, currents and diode junctions are reversed.

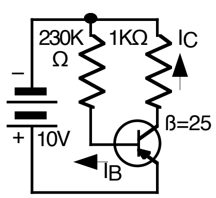

Figure 3: PNP transistor example

If you look at figure 3 (which uses a PNP silicon transistor just to be different), you can determine the base current IB as:

$$I_B = \frac{10V - 0.7V}{230K\Omega} = 0.04mA$$

Now that we know the base current, the collector current is:

$$I_C = \beta I_B = 25 \cdot 0.04mA = 1.00mA$$

Thus, if we know the base current and measure the resulting collector current we can easily calculate the transistor's DC beta. Note that the 1KΩ collector resistor doesn't play a part. However, there are three things you must watch out for; they are: *saturation*, *cutoff* and *drift*.

Saturation:

If you continue to raise the base current the collector current will increase; as it does more of the 10 volts is dropped across the 1K resistor. finally when the collector current reaches 10 mA the collector current cannot increase any more because the current is being limited by the 1KΩ resistor. The voltage across the transistor is nearly zero. This is saturation. The saturation current is set by the resistor in the collector circuit.

Cutoff:

The base current is usually determined by a voltage flowing through a resistor. If the voltage at the base drops below about 0.7V for a silicon transistor or 0.3V for a germanium transistor no collector current will flow. This is cutoff.

Drift:

The beta of a transistor is not very stable in value. It changes from transistor to transistor of the same type and is also very subject to change with temperature. When you learn about biasing transistors you learn about the *K-value* which is the sensitivity of a transistor circuit to changes in beta. Many biasing circuits are designed to make a transistor circuit much less sensitive to changes in beta.

Different transistors have different DC beta values. Numbers from 10 to around 300 are often encountered. *Darlington* transistors, which are two transistors with their collectors wired together and the emitter of the first connected to the collector of the second have values of beta in the tens of thousands! Figure 4 shows the schematic symbol for a Darlington transistor.

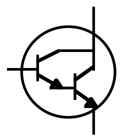

Figure 4: An NPN Darlington transistor symbol.

A Simple Transistor Checker:
Figure 5 is the schematic of the latest version of my transistor checker. The circuit is very simple. Power is supplied by six volts from four AAA batteries. The meter normally reads a full scale of 5 mA, corresponding to a beta of 500, because of the shunt resistor R1. S3, a normally closed pushbutton switch, removes the shunt resistor (R1) from the meter, so the meter reads 0–1 mA full scale, corresponding to a beta of 100, a five fold increase in sensitivity. A **Battery Test** pushbutton, S4 (not on the prototype) checks the condition of the batteries. When pressed it causes the meter to read the battery voltage with 6V being about 4/5s of full scale.

The two transistor sockets are wired identically except for polarity. We'll discuss the NPN socket circuit; the PNP socket circuit works similarly except for polarity. When an NPN transistor is placed in the NPN socket, the only current that will flow is the collector-to-emitter leakage current. This is read directly on the meter and should be almost zero on the most sensitive meter position, though it may be measurable on a germanium transistor. Pushing the NPN TEST pushbutton sends a current of 10 µA into the transistor's base. The resulting collector current is measured on the meter. Meter scales of 0 - 500 and 0 - 100 will read beta directly and read leakage times 10 µA on the normal position and the high sensitivity position (S3 pressed.) Add a green arc on the meter scale between 360 and 420 on the 0 - 500 scale to indicate the condition of the batteries.

There is one very minor fault with this circuit! Actually you're not measuring beta on the meter, instead you're measuring beta + 1. This is because the current measured is the base current plus the collector current. Except for very low gain transistors, this is hidden within the accuracy of the circuit components. However, to be a perfectionist you may want to mark the meter scale as "ß+1"

Selecting R1:
Since the meter is the most expensive part of this circuit, and since numerous 0–1 mA meters are available on the retail and surplus market, I don't want to specify a meter. Any 0–1 mA meter with an internal resistance less that a few hundred ohms will work. I used a surplus 1-1/2" square Simpson voltmeter (Series 1212) that has a 0–1 mA movement and took out the multiplier resistor. Since your meter will be different from mine, you must choose your own R1. The value of R1 is dependent upon the resistance of the meter. Most meters in the 0–1mA range have an internal resistance on the order of 50Ω. YOU CANNOT measure the meter resistance with an ohmmeter without probably damaging the meter. Instead, breadboard the simple circuit shown in Figure 6. Set the potentiometer R102 to maximum and attach the 6V battery (Use the 4 AAAs in the battery holder you've obtained for your project) Leave R103 totally disconnected from the circuit. The meter should be reading somewhere near 3/4 scale. Now slowly increase R102 until the meter reads full scale (the last mark on the scale). Being careful not to change the setting of R102, attach R103 and adjust it until the meter reads 1/2 scale. Next, being careful not to change

the setting of R103, remove it from the circuit and measure its resistance with your ohmmeter. What you read is the same as the resistance of the meter. Divide this value by four to obtain the needed resistance for R1 for that particular meter.

Operation:

Your Transistor Checker is easy to use. If you haven't used it in a while, first check the battery by pushing the BAT. TEST pushbutton and being sure the meter reads

"in the green" (above 380 on the 0 - 500 scale). No transistor should be in a socket nor should S3 be pushed when checking the battery.

Now install the transistor you wish to check. If you know its polarity, install it in the correct socket. If you don't, because it's unmarked, or you can't find any information on it, take your best guess. While this circuit is kind to most transistors even when installed in the wrong socket, certain special transistors can be damaged. However, most general 2N series transistors will not suffer; transistors to avoid are FETs, especially MOSFETS and GaAs FETS; they are expensive (especially the GaAS FETS) and you won't often run into them without knowing. Generally JFETs will not be damaged, but are incompatible with this tester. When you install the transistor, be sure to connect the leads correctly into the socket.

Once you have the transistor in what you believe is the proper socket, check the meter. The meter gives an indication of collector-to-emitter leakage current on the 0 – 500 or 0 – 100 scales at 10 µA per division. Press the **0 – 100 Beta** pushbutton for the more sensitive scale. If the meter move upscale significantly you may have the transistor in the wrong socket. Leakage current should be almost (if not totally) unnoticeable for small silicon transistors and small, but possibly detectable, for germanium transistors.

Now you're ready to measure the transistor's beta. Press the appropriate **TEST** pushbutton for the socket you have your transistor in and read beta directly on the 0 – 500 meter scale. If the reading is less than 100, you can push the **0 - 100 Beta** pushbutton and read beta on the more sensitive scale.

Well, that about does it. You can read more about transistors in the *ARRL Amateur Radio Handbook*. If you'd like to make your instrument more accurate, 1% resistors can be substituted for R1, R2, R4 and R6 (see Parts List), R3 and R5 act only to limit current and are fine at 5%.

Uses:

Besides the obvious use of checking transistors, this device is also handy for matching transistors and selecting transistors to use in circuits where complementary pairs (a matched NPN and PNP transistor is used). It can also help determine many of the characteristics of an unknown transistor and help select a substitute transistor.

Parts:

A list of parts is available on page 5. With the exception of the meter and possibly the transistor sockets, all parts are readily available. If there is enough interest perhaps the club can do a group buy.

Next month, maybe we'll get started on a code practice oscillator.

73, from AF6C

This article is based on the TechTalk article that originally appeared in the June 2004 issue of RF, the newsletter of the Orange County Amateur Radio Club - W6ZE.

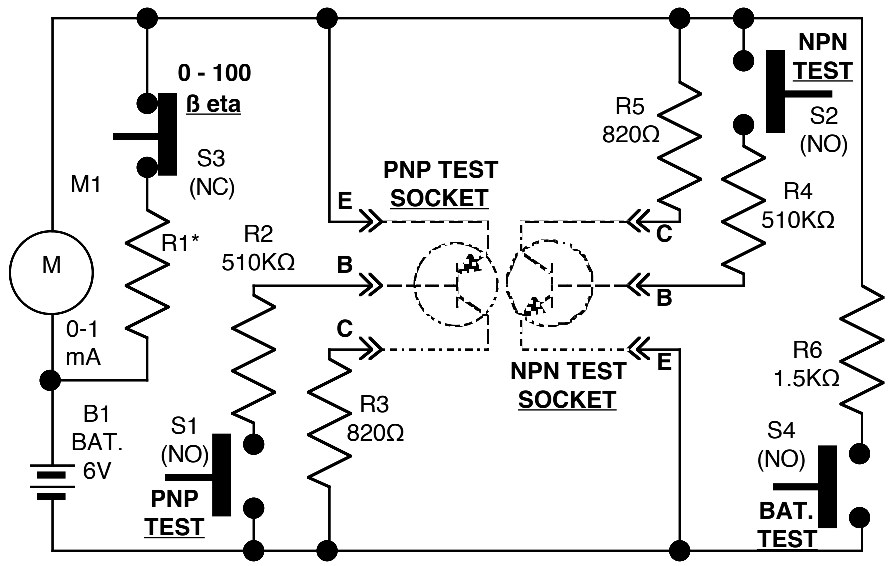

Figure 5 – Schematic of the updated Simple Transistor Checker

Parts List for Transistor Checker

B1	4 ea. AAA alkaline batteries in an MPD battery holder (Digikey BC4AAAW-ND)
M1	0-1 ma ammeter 1–1/2" to 2" face (see text) A Simpson 1212 series voltmeter (*1000Ω/V* marked in the meter corner) may be used by first removing the meter's internal shunt resistor.
R1	Resistor, meter shunt, 1/4 or 1/2 watt carbon film. (See text)
R2, R4	510KΩ 5% 1/4 or 1/2 watt carbon film resistor. [536K 1%]
R3, R5	820Ω 5% 1/4 or 1/2 watt carbon film resistor.
R6	1.5KΩ 5% 1/4 or 1/2 watt carbon film resistor. [1.5K - 4R1, 1%]
S1, S2, S4	SPST normally <u>open</u> miniature momentary pushbutton switch (Radio Shack 275-1547 or Switchcraft 953 [SPDT])
S3	SPST normally <u>closed</u> miniature momentary pushbutton switch (Radio Shack 275-1548 or Switchcraft 953 [SPDT])

Miscellaneous:

1 ea.	Case, molded plastic with aluminum cover. 5–1/16" x 2–5/8" x 1–5/8", (Radio Shack 910-5035)
2 ea.	Transistor Socket, chassis mount, Elco 05-3301 (These may be hard to find, but there are many small PC mount transistor sockets that can be adapted)
1 ea.	Meter face. Use an inkjet printer, glossy paper and your favorite drawing program. Mark two scales 0-100 and 0-500 and put in a a green segment for the battery test indicator. Cement the paper to the back of the existing meter scale plate.

