Transistor Parameters

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Contents

1 Measuring Transistor Parameters

Consider the circuit

```
c:\sbnotes\transistor.pdf
http://www.stem2.org/je/transistor.pdf
```

which uses the 2N3904 NPN transistor. Looking at the flat side of the transister the pins from left to right are E (emitter), B (base), and C (collector). The transistor is powered by about -15 volts. Resister R_C connects the collector to the positive side of the power supply, which is called v_+. Resistor R_E connects the negative side of the power supply, which is called v_-, to the emitter. A pair of resistors in series, R_{B2} and R_{B1}, connect v_+ to v_-. The center point of the pair is connected to the base of the 2N3904. These resistors form a voltage divider.

Measured resistances for a specific circuit are

$$R_{B2} = 19.95K, R_{B1} = 9.88K$$

$$R_E = 9.92K, R_C = 9.90K.$$

Measured voltages are

$$\Delta v = v_+ - v_- = 15.11, v_{R_{B2}} = 10.06, v_{R_{B1}} = 4.95$$

$$v_{R_C} = 4.22, v_{R_E} = 4.30,$$
$$v_{BE} = 0.68$$

We calculate a positive voltage that we call

$$v_B = (v_+ - v_-) - v_{R_{B2}} = 5.05$$
$$I_C = \frac{v_{R_C}}{R_C} = 4.262626262626262 \times 10^{-4}$$
$$I_E = \frac{V_{R_E}}{R_E} = 4.334677419354839 \times 10^{-4}$$
$$I_B = I_E - I_C = 7.205115672857614 \times 10^{-6}.$$
$$\beta = \frac{I_C}{I_B} = 59.16110797060481$$

Matlab program transistor.m

```
% Transistor measurements
format long
rb2 = 19.95e3
rb1 = 9.88e3
re = 9.92e3
rc = 9.90e3
%\[v_+ - v_- = 15.11 ,
dv=15.11
vrb2 = 10.06
vrb1= 4.95
vrc= 4.22
vre= 4.30
vec=6.74
vbe=.68
%We calculate
vrb1= dv - vrb2
ic=  vrc/rc
ie= vre/re
ib=ie-ic
beta=ic/ib
%Thevinin method
rt=(rb1*rb2)/(rb1+rb2)
vt=dv*rb1/(rb1+rb2)
ib=abs(vt-vb)/rt
beta=ic/ib
```

Output of Matlab:

```
14-Jan-2011
>> transistor
rb2 = 19950
rb1 =  9880
re =9920
```

```
rc =9900
dv =15.11000000000000
vrb2 =10.06000000000000
vrb1 =4.95000000000000
vrc =4.22000000000000
vre =4.30000000000000
vec =6.74000000000000
vbe =0.68000000000000
vrb1 =5.05000000000000
ic =4.262626262626262e-004
ie =4.334677419354839e-004
ib =7.205115672857614e-006
beta =59.16110797060481
rt =6.607643312101911e+003
vt =5.00458598726115
ib =6.872951609793594e-006
beta =62.02031535551981
```

If we break the circuit at the connection to the base and at the supply voltage v_-, the circuit to the left consists of a power supply voltage source of $\Delta v = 15.11$ volts, and the two resistors R_{B1} and R_{B2} in series. Shorting the voltage source, we find a Thevenin equivalent resistence of the two resistors in parallel

$$R_T = \frac{R_{B1}R_{B2}}{R_{B1}+R_{B2}}$$

and an equivalent voltage source v_T consisting of the open circuit voltage seen at the two terminals. This is the voltage divider voltage

$$v_T = \Delta v \frac{R_{B1}}{R_{B1}+R_{B2}}.$$

Then the positive current flow I_B into the transistor is

$$I_B = \frac{|v_T - v_B|}{R_T}.$$

We have taken the absolute value because we know that the current flow into the base is positive, and we have taken all of our voltages as absolute values, and possibly disregarded some signs. Notice that this Thevinin method of computing I_B does not require I_C or I_E and its difference, which is good because these two numbers are nearly equal and computing this difference could lead to roundoff error. However v_T and v_B are also nearly equal, but probably not so nearly equal. So this method is probably better provided that the resistance and voltage values are measured quite acurately.