AC128 Ge PNP Transistor SPICE Model

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Developing accurate SPICE models is no easy task, but possible by working backwards from the Ebers-Moll equations used in simulation. This paper calculates a working model of a vintage AC128 transistor.

Calculations

Straight from data sheet we can read typical forward gain:

$$B_f = h_{fe} = 90$$

For saturation current we take Vbe and Ic values at low current. From the graph we get 150mV and 6mA:

$$I_s = I_c \cdot e^{(-39 \cdot V_{be})} = 17\mu$$

Now we take values at high current, 400mV and 600mA:

$$R_e = \frac{\left[V_{be} - \frac{ln\left(\frac{I_c}{I_s}\right)}{39}\right]}{I_c} = 0.22$$

Using Ic versus Vce graph at fixed Ib, follow the slope of output conductance back to where it would theoretically intercept zero. This is estimated at about 30 volts:

$$V_{af} = 30$$

Leakage current is approximated by:

$$I_{se} = \frac{I_s}{B_f} = 190n$$

Forward transit time is the period of maximum operating frequency (-3dB point). From data sheet it is 1.5MHz:

$$T_f = \frac{1}{2 \cdot \pi \cdot f} = 106n$$

Taking a wild guess at storage time here with 5us, used for reverse transit time:

$$T_r = 2 \cdot t_s = 10\mu$$

Collector-base capacitance can also be read directly from data sheet:

$$C_{jc} = C_{cb} = 100p$$

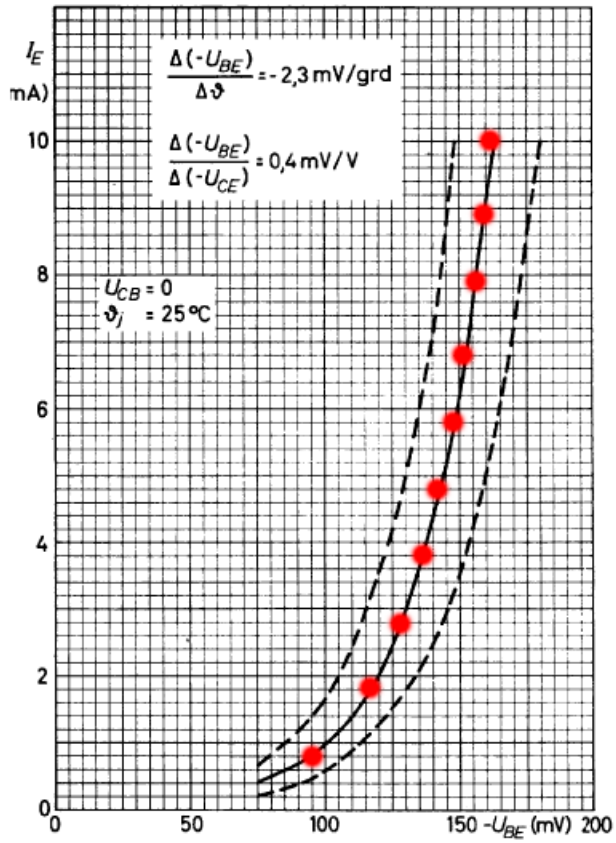
Finally, BR can only be calculated directly (as far as I know) if both junctions are forward biased, such as in saturation. This parameter was fine-tuned by hand observing Ic versus Vce characteristics at fixed Ib.

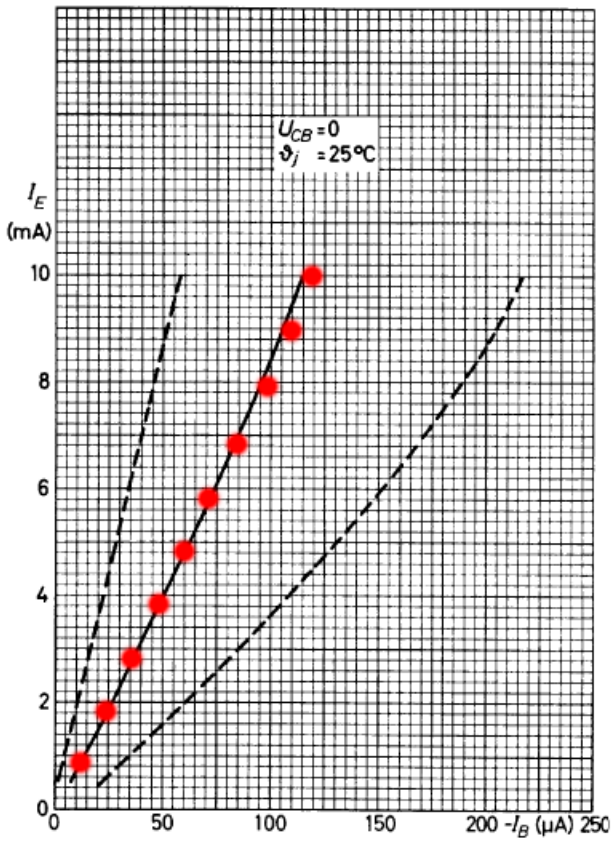
The resulting model is summarized in a single SPICE statement:

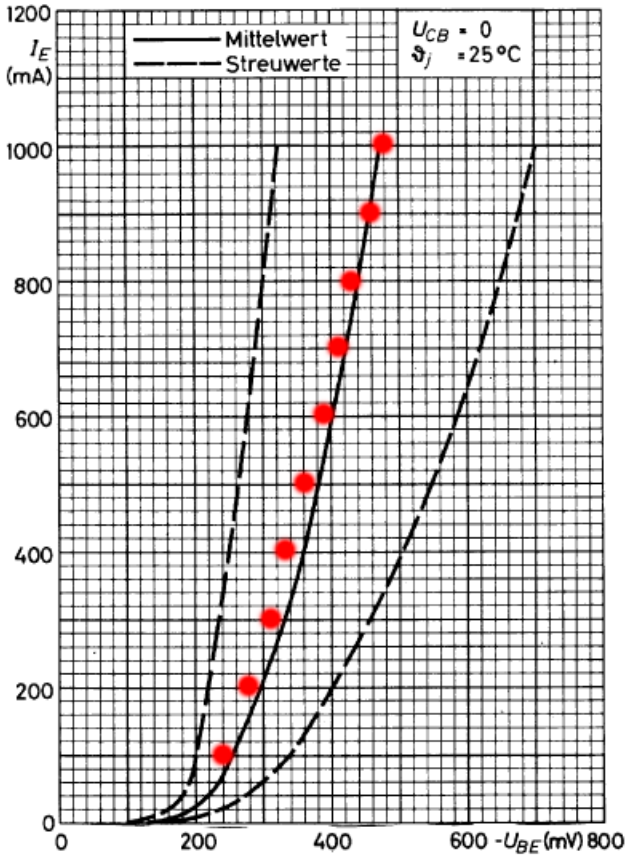
```
.MODEL AC128 PNP
+(
+ BF  = 90
+ IS  = 17u
+ RE  = 220m
+ BR  = 100m
+ VAF = 30
+ ISE = 190n
+ TF  = 106n
+ TR  = 10u
+ CJC = 100p
+)
```

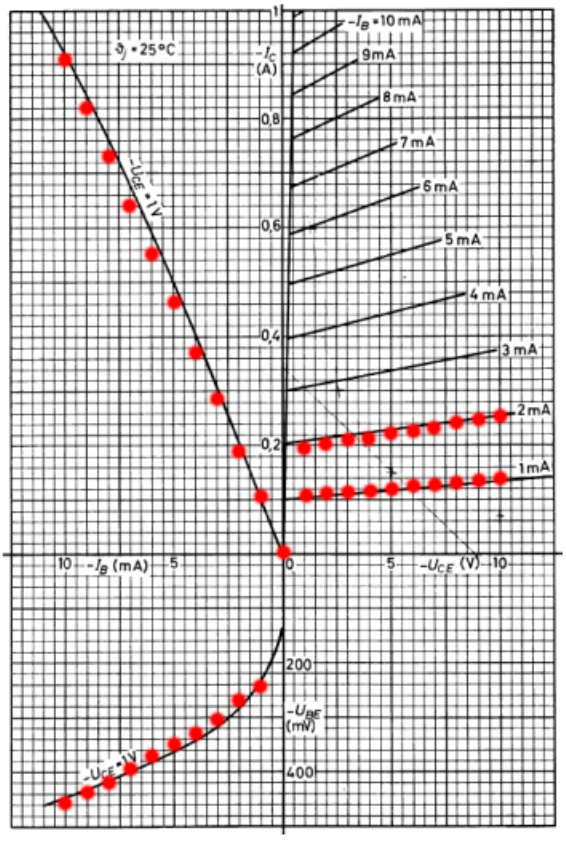
Data Sheet Tests

Multiple simulations were run per datasheet settings and plotted. Results show very good correlation with typical and expected values, demonstrating validity.


I_E (mA)
$\frac{\Delta(-U_{BE})}{\Delta\vartheta}$ = - 2,3 mV/grd
$\frac{\Delta(-U_{BE})}{\Delta(-U_{CE})}$ = 0,4 mV/V
U_{CB} = 0
ϑ_j = 25 °C
0
2
4
6
8
10
0
50
100
150 $-U_{BE}$ (mV) 200


U_{CB} = 0
ϑ_j = 25 °C
I_E (mA)
0
2
4
6
8
10
0
50
100
150
200 $-I_B$ (µA) 250


Mittelwert
Streuwerte
U_{CB} = 0
ϑ_j = 25 °C
I_E (mA)
0
200
400
600
800
1000
1200
0
200
400
600 $-U_{BE}$ (mV) 800


ϑ_j = 25 °C
$-U_{CE}$ = 1V
$-I_B$ = 10 mA
9 mA
8 mA
7 mA
6 mA
5 mA
4 mA
3 mA
2 mA
1 mA
$-I_C$ (A)
0,2
0,4
0,6
0,8
1
10 $-I_B$ (mA) 5
0
5 $-U_{CE}$ (V) 10
200
$-U_{BE}$ (mV)
400
$-U_{CE}$ = 1V

Fuzz-Face Simulation

The acid test for this model is how it simulates a classic Fuzz-Face circuit. Care must be taken with input source, as the circuit is driven by current, not voltage. Results below show the various modes of fuzz as input goes from low to high amplitude.