ECE321 ELECTRONICS I
FALL 2006

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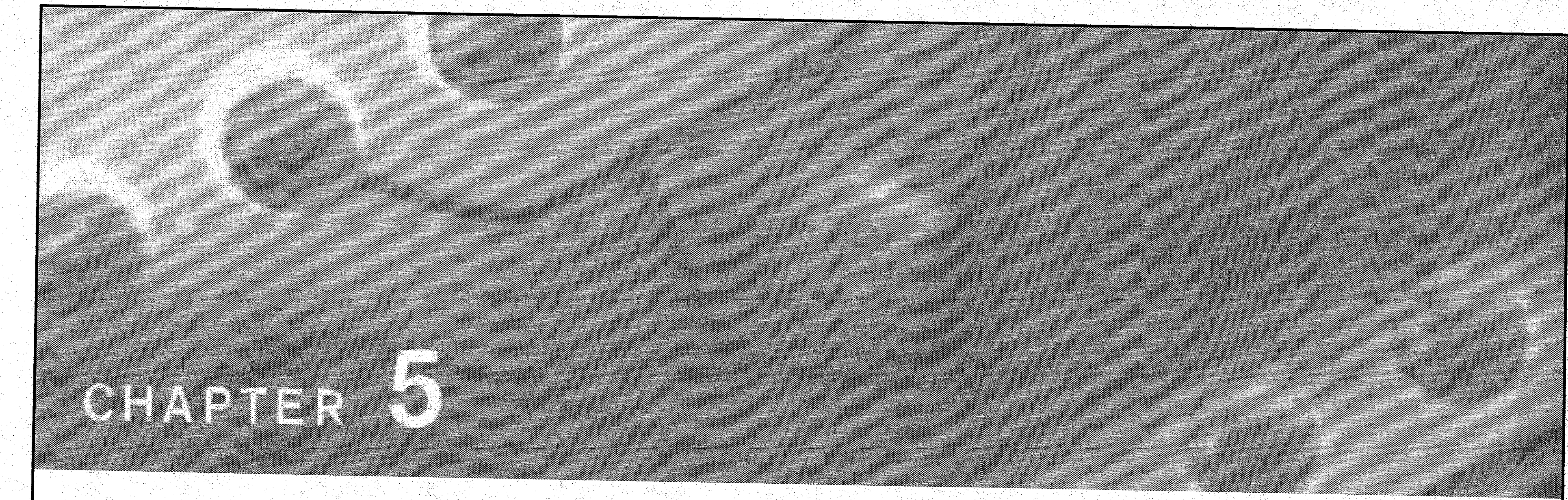
Lecture 18

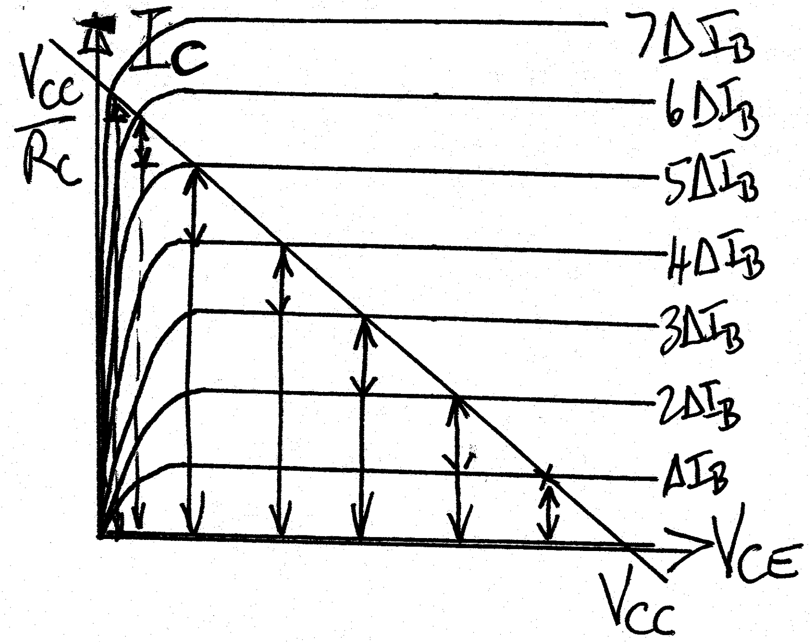
30th November, 2006



Bipolar Junction Transistors (BJTs)

5.10 BJT Inverter
5.11 SPICE

BJT INVERTER



$\Delta I_C = \beta \Delta I_B$

until 5→6 ΔI_B

& I_C characteristics enter non-linear region, i.e. saturation.

As I_B, I_C increase V_{CE} decreases towards zero as V_{BE} increases and NEGATIVE V_{CB} decreases.

I_C never reaches V_{CC}/R_C due to transistor saturation.

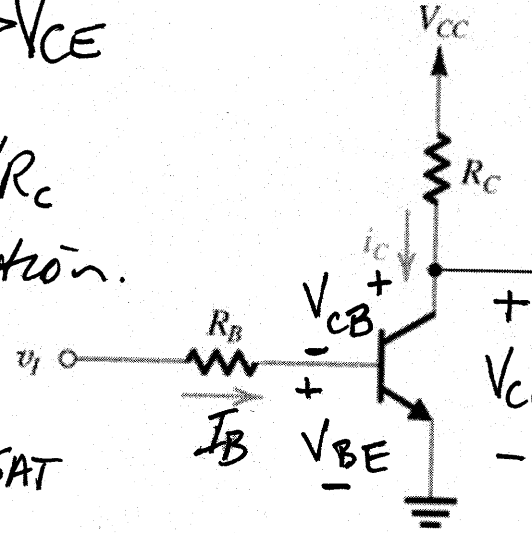


Figure 5.74 Basic BJT digital logic inverter.

$V_{CE} = V_{BE} + V_{CB}$

$$\text{Max } I_C = \frac{(V_{CC} - V_{CE})_{SAT}}{R_C}$$

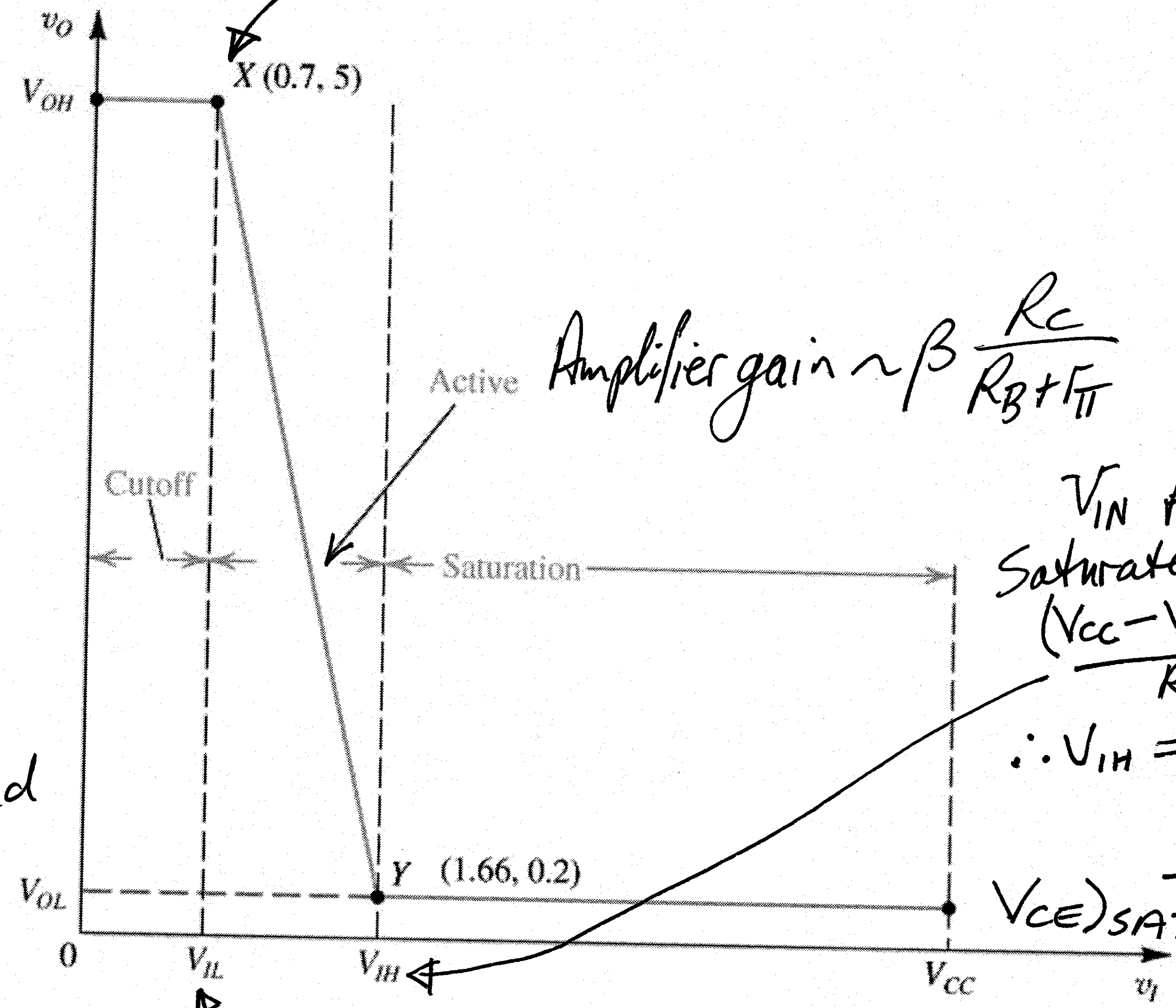
↑ slowly decreases as I_B increases.

At onset of saturation
- $V_{CE} \sim 0.3V$
- $V_{CB} \sim -0.4V$
- $V_{BE} \sim .7V$

In saturation (for example)
- $V_{CE} \sim 0.25V$
- $V_{CB} \sim -0.5V$
- $V_{BE} \sim 0.75V$

BJT off "1" state →

BJT saturated "0" state →



Amplifier gain $\sim \beta \frac{R_C}{R_B + r_\pi}$

V_{IN} for saturation

Saturates when $\frac{(V_{CC} - V_{CE})_{SAT}}{R_C} < \beta \frac{(v_I - v_{BE})}{R_B}$

$\therefore V_{IH} = \frac{R_B}{\beta R_C}\left[(V_{CC} - V_{CE})_{SAT}\right] + v_{BE} \xrightarrow[R_C = 1K\ R_B = 10K]{V_{CC} = 5V\ \beta = 50} 1.66V$

$V_{CE})_{SAT}$

$v_I \doteq 0.7$, BJT starts to turn on.

$\therefore$ "Hi" noise margin $\doteq NM_H = V_{OH} - V_{IH} = 5 - 1.66 = 3.34V$

& $NML = V_{IL} - V_{OL} = 0.7 - 0.2 = 0.5V$

Figure 5.75 Sketch of the voltage transfer characteristic of the inverter circuit of Fig. 5.74 for the case R_B 5 10 kΩ, R_C 5 1 kΩ, β 5 50, and V_{CC} 5 5 V. For the calculation of the coordinates of X and Y, refer to the text.

Stored base charge

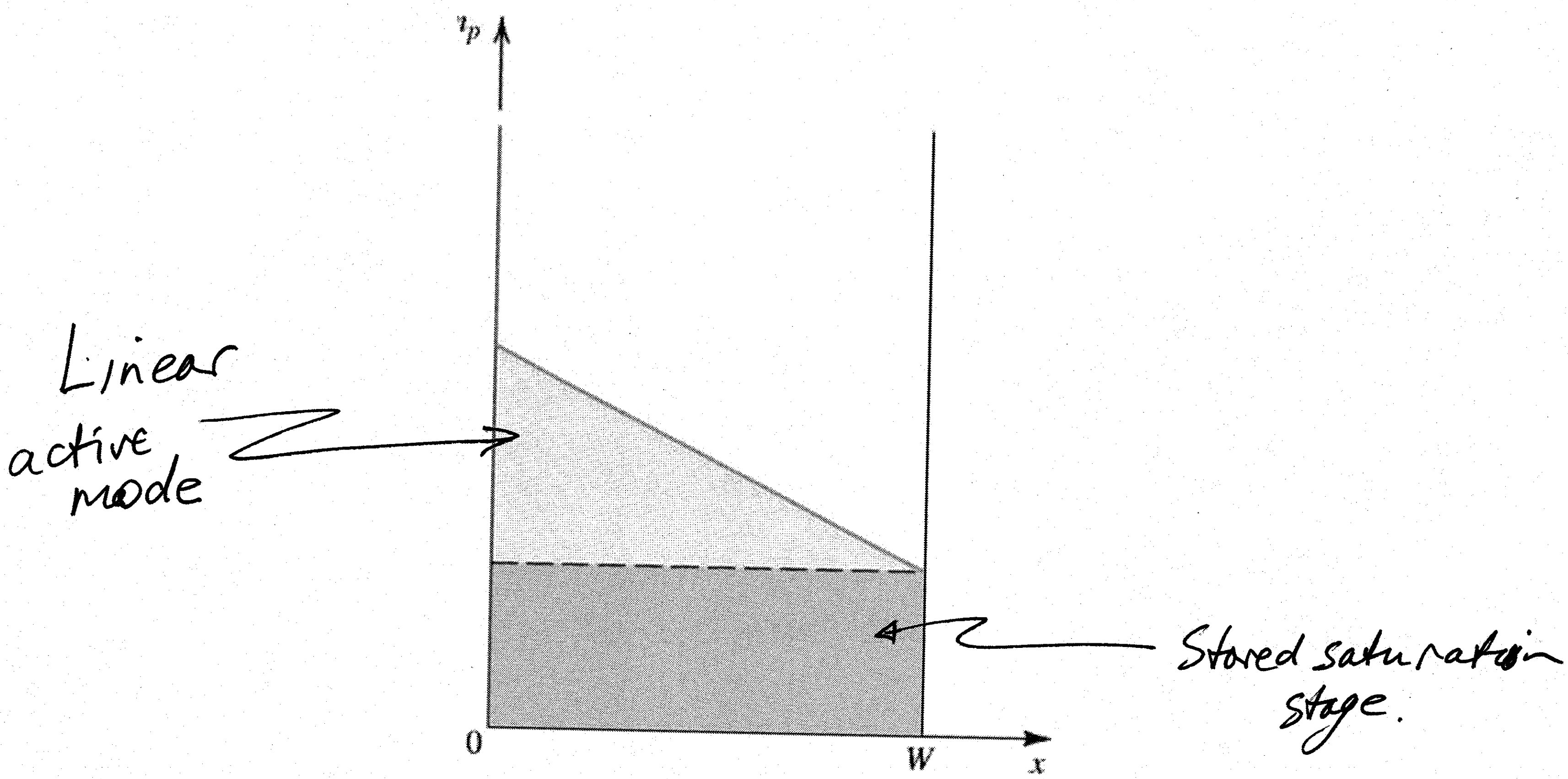


Figure 5.76 The minority-carrier charge stored in the base of a saturated transistor can be divided into two components: That in blue produces the gradient that gives rise to the diffusion current across the base, and that in gray results from driving the transistor deeper into saturation.

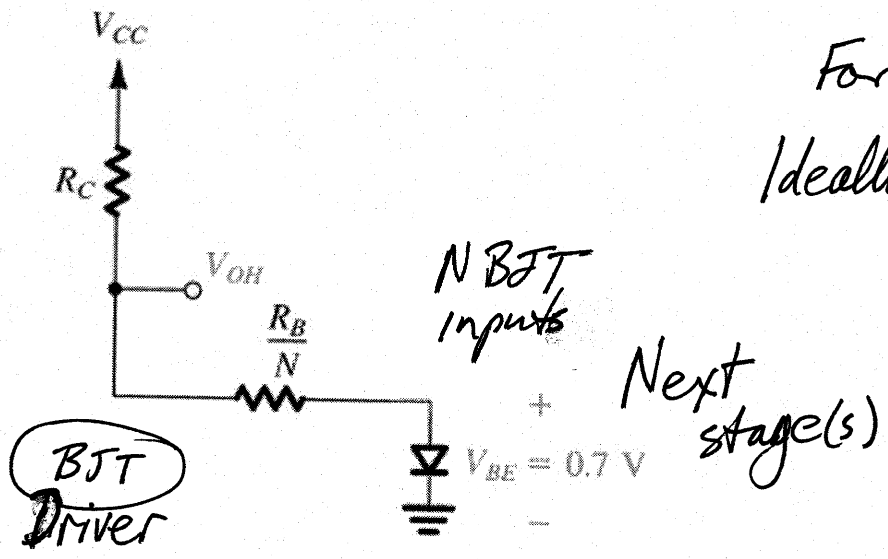
For loading by N (multiple) gates

$R_B = 10K\Omega$ $R_C = 1K\Omega$ $V_{CC} = 5_V$ $N = 5$

For

For BJT "off"

Ideally $V_{OH} \sim 5_V$



$$V_{OH} = 0.7 + \frac{R_B}{N} \cdot \frac{V_{CC} - 0.7_V}{\frac{R_B}{N} + R_C}$$

$$\simeq 3.6_V$$

Figure E5.53

Transport Ebers Moll model

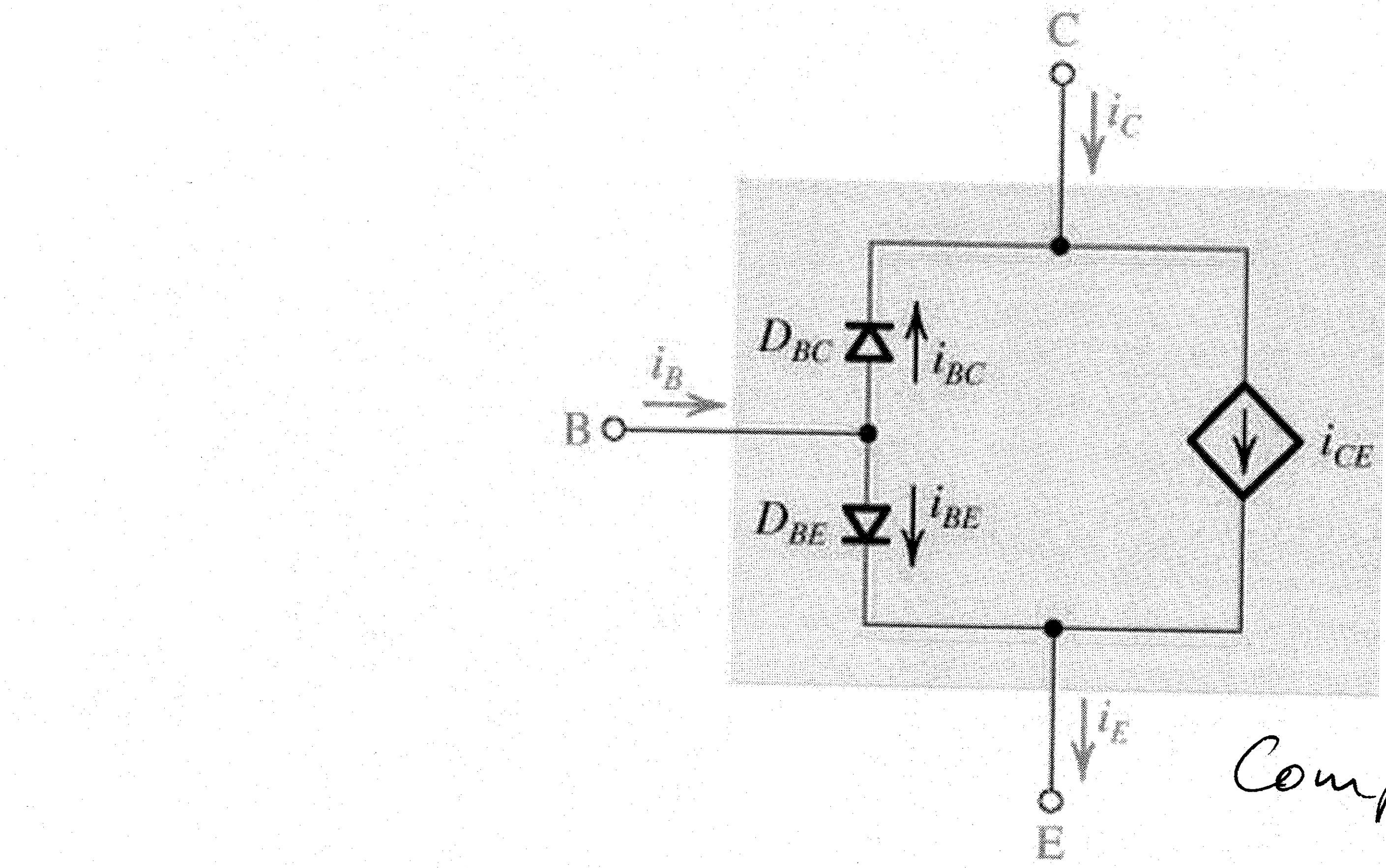
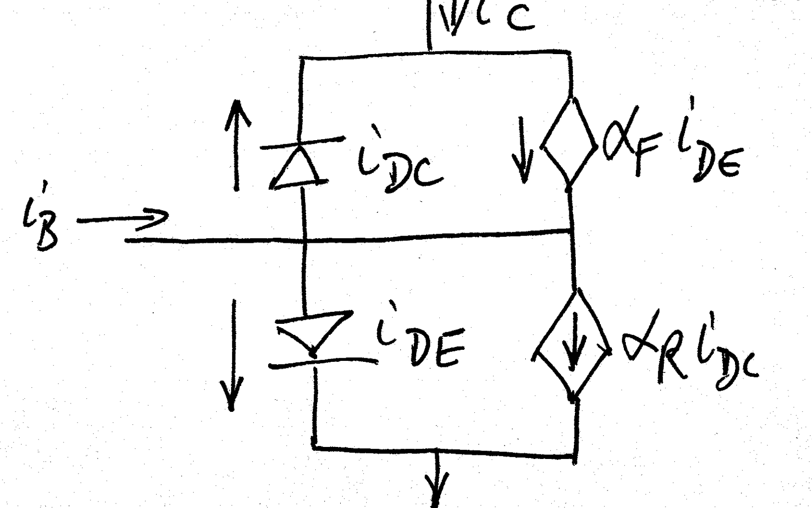
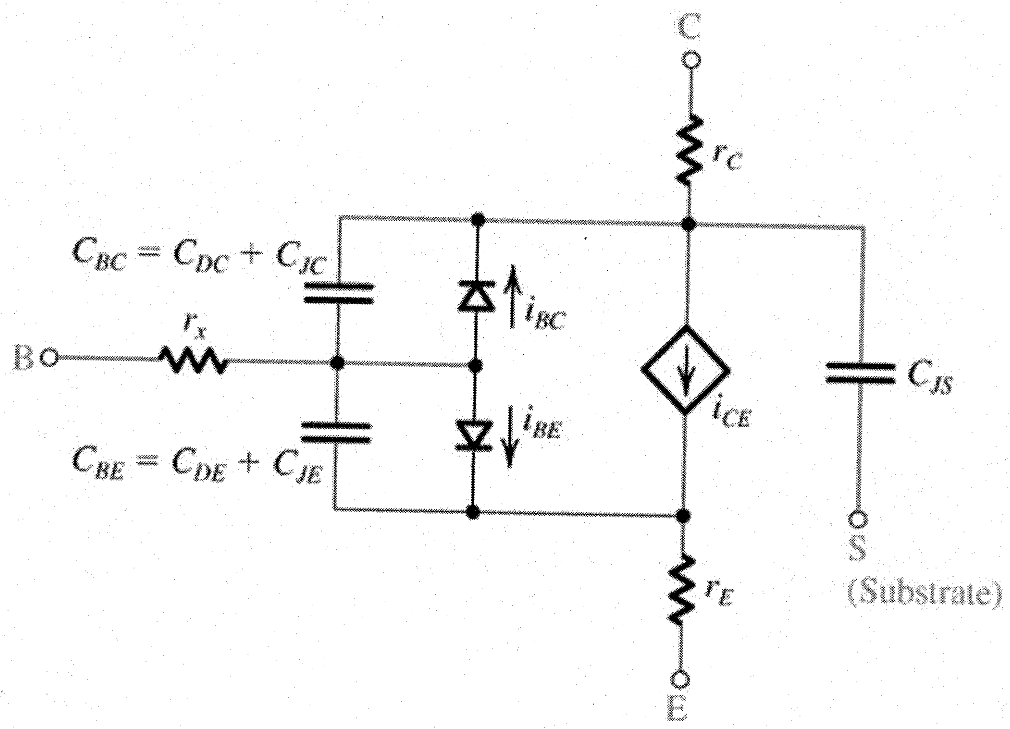


Figure 5.77 The transport form of the Ebers-Moll model for an *npn* BJT.

Compare Injection Ebers-Moll.



HF Model



Ebers-Moll ⟶ Gummel-Poon circuit — SPICE

$I \propto Q_n$ Base charge

$\propto Q_B$

Figure 5.78 The SPICE large-signal Ebers-Moll model for an *npn* BJT.

Switching base charge

$I \propto Q_B$) while base charge exists ⟶ turn-off Gummel Poon

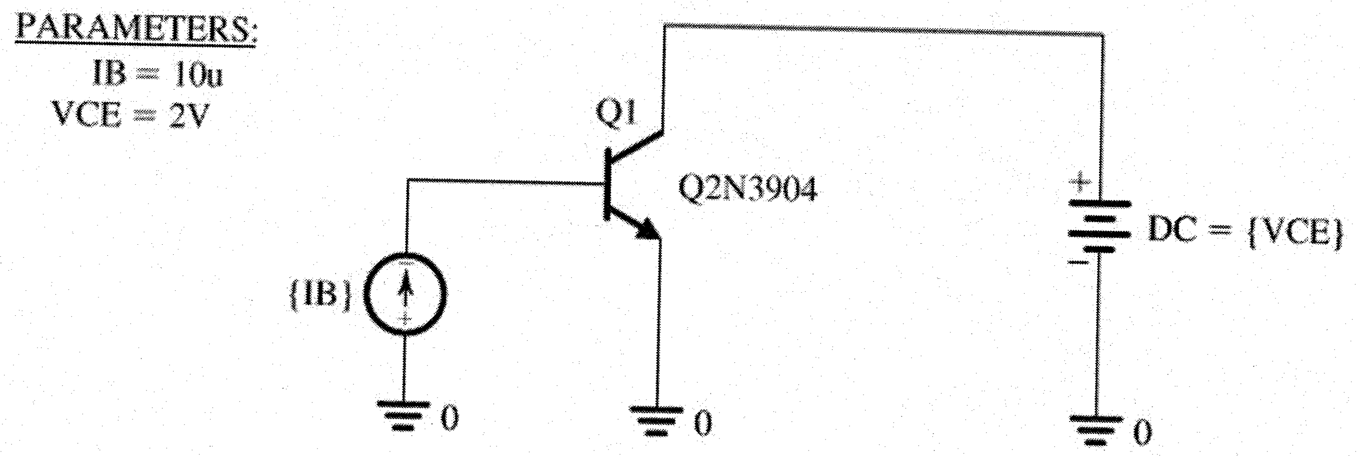


Figure 5.79 The PSpice testbench used to demonstrate the dependence of β_{dc} on the collector bias current I_C for the Q2N3904 discrete BJT (Example 5.20).

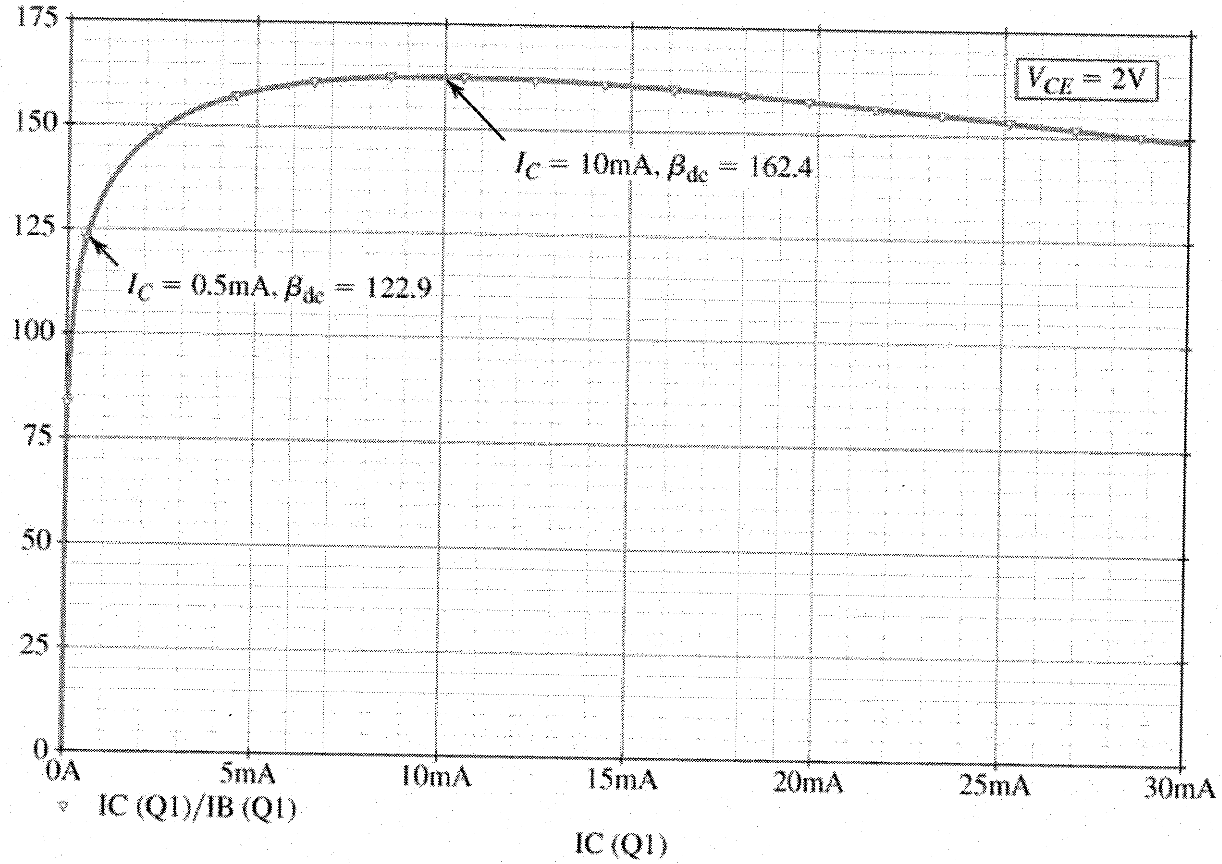


Figure 5.80 Dependence of β_{dc} on I_C (at V_{CE} 5 2 V) in the Q2N3904 discrete BJT (Example 5.20).

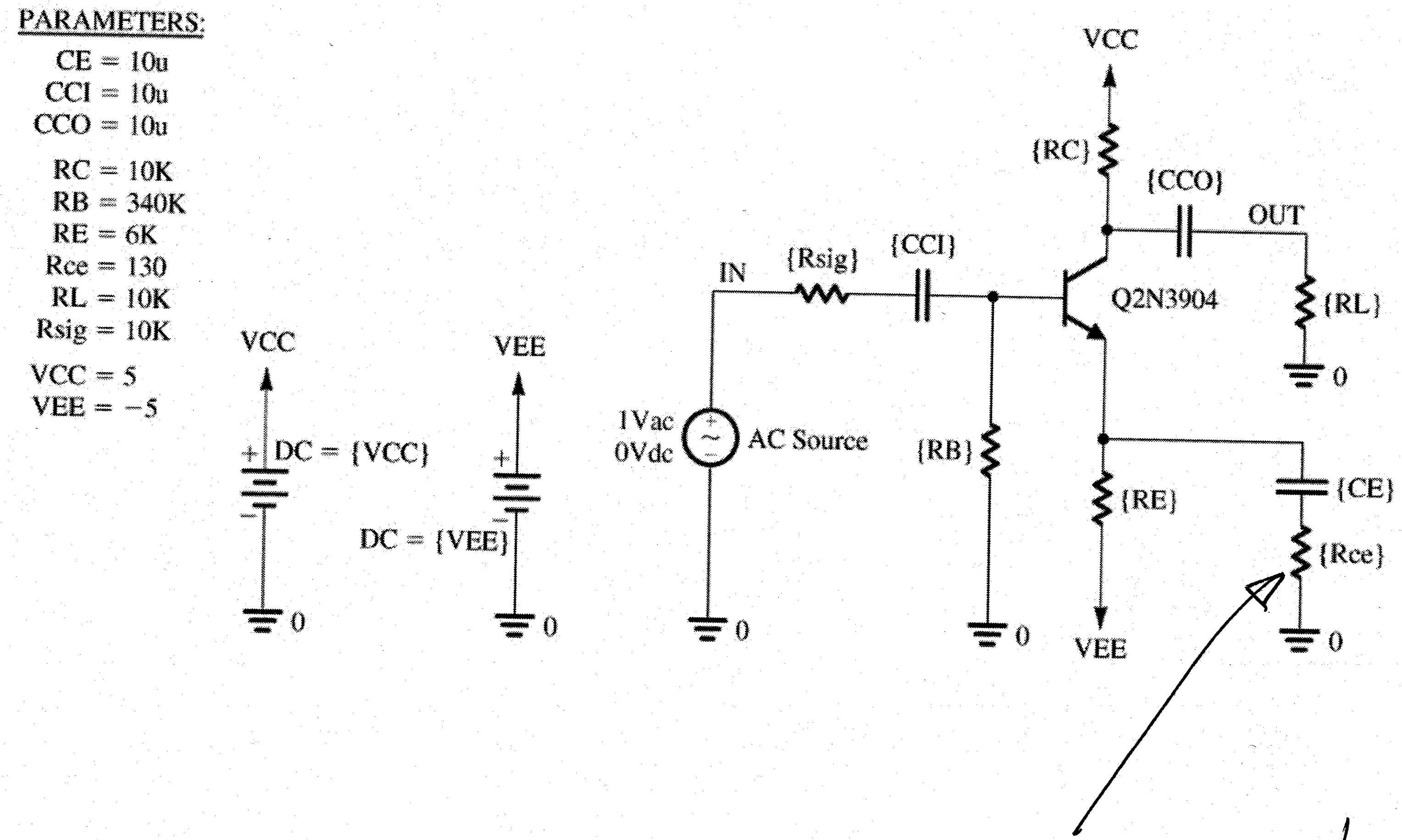


Figure 5.81 Capture schematic of the CE amplifier in Example 5.21.

Use resistor to control f.b.

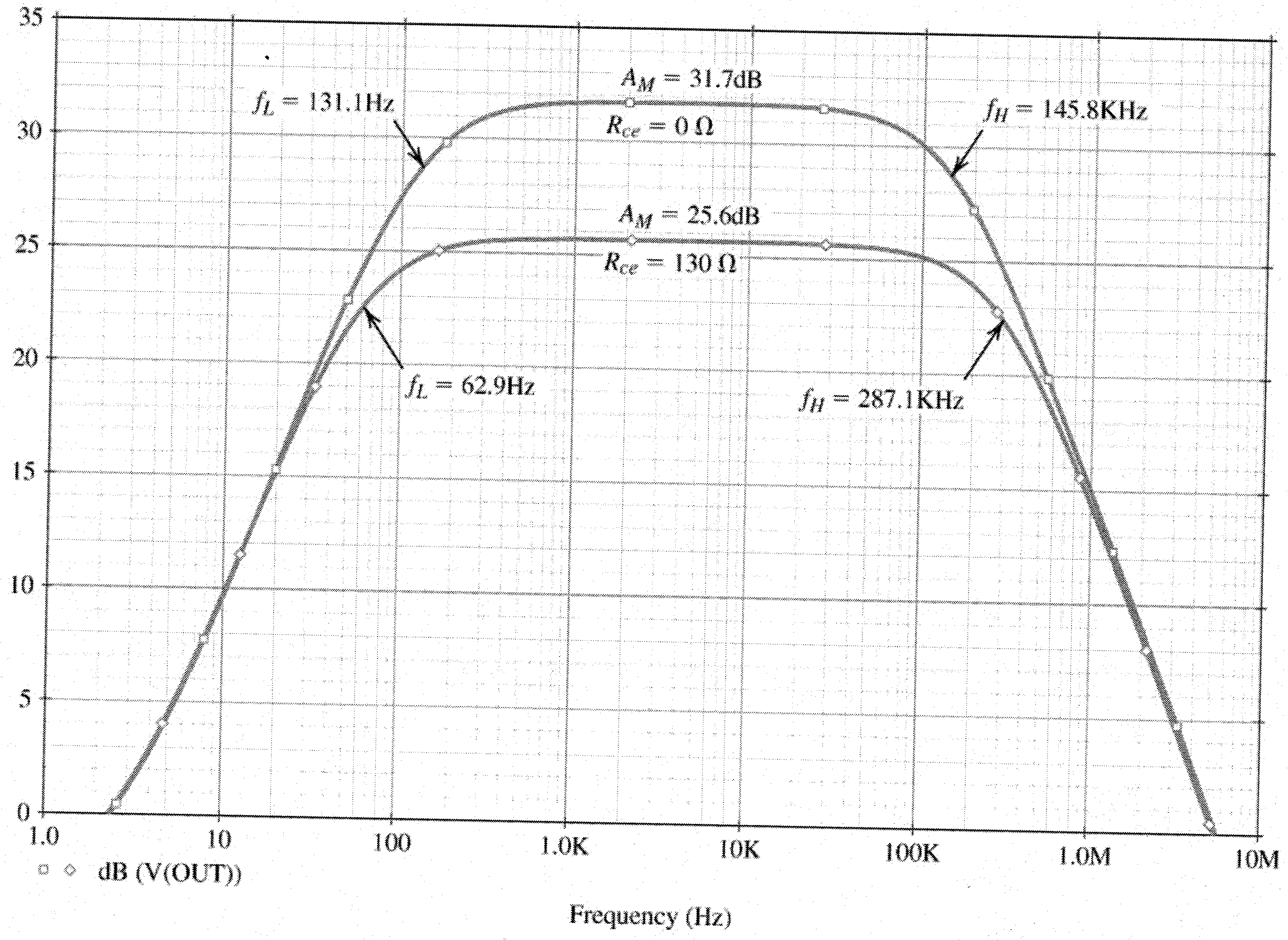


Figure 5.82 Frequency response of the CE amplifier in Example 5.21 with $R_{ce} = 0$ and $R_{ce} = 130\ \Omega$.