BJT with Active Loads

Dr. M. Shiple

Advanced Electronic Circuits (EEI 184), 2018

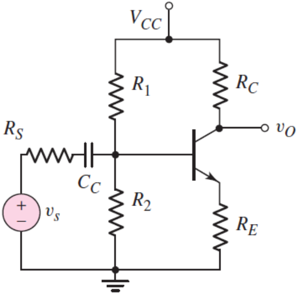
Outline

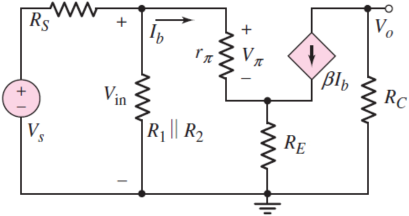
1.Introduction

Problem

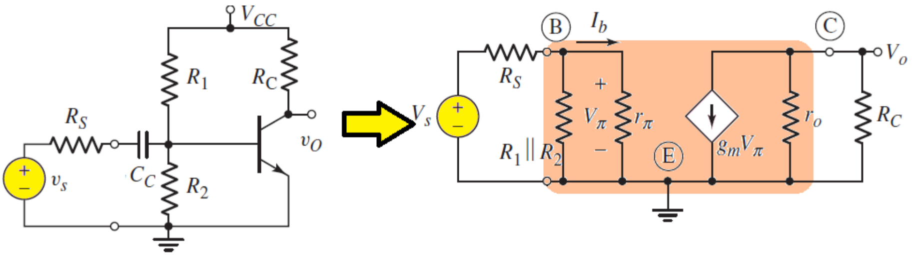
$$\frac{V_o}{V_s} = -\frac{\beta R_C}{r_\pi + (1+\beta) R_E}$$

which resistor should be replaced , R_E , or R_C





Problem

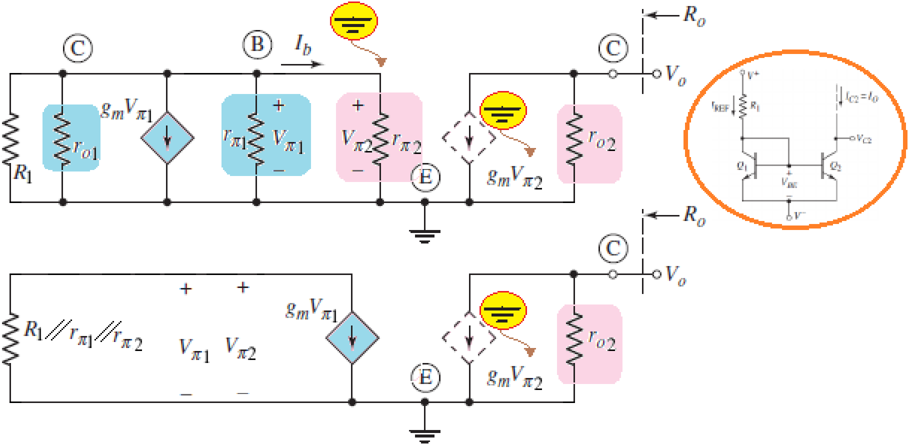


For $R_S = 0$ and $r_o = \infty \because g_m = \frac{I_C}{V_A}$

$$A_v = -g_m R_C \qquad and \qquad g_m = \frac{I_C}{V_A} \qquad and \qquad V_O = V_{CC} - I_C R_C$$

1. To increase gain $\therefore R_C \uparrow$, But on the other hand $V_O \downarrow$.
2. To increase gain $\therefore R_C \uparrow$, BOTOH $I_C \downarrow$ (driving current ☹).
3. To increase gain $\therefore R_C \uparrow$, BOTOH area occupation on die $\uparrow$

R Equivalent model



$$V_{\pi 1} = V_{\pi 2} = -g_m V_{\pi 1}(R_1 || r_{\pi 1} || r_{\pi 2})$$

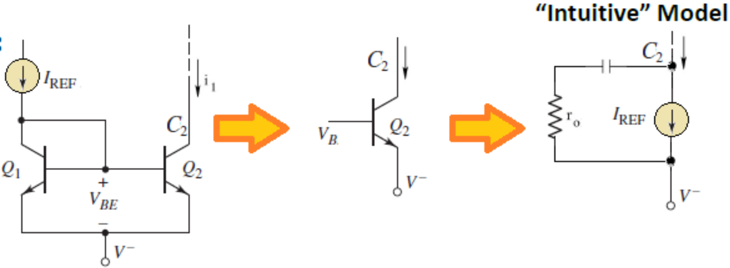
$$0 = V_{\pi 1}(1 + g_m(R_1 || r_{\pi 1} || r_{\pi 2}))$$

$\therefore 0 = V_{\pi 1} = V_{\pi 2} \Rightarrow$ Current sources could be replaced by r_o

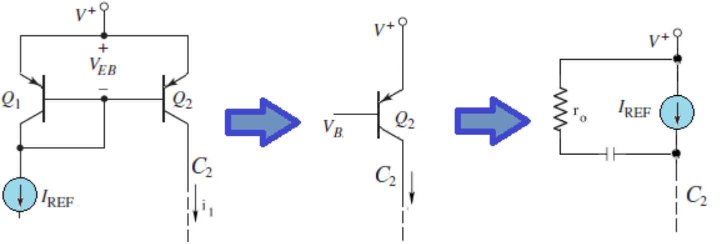
2.BJT Active Load Circuits

R Equivalent model

NMOS Version:

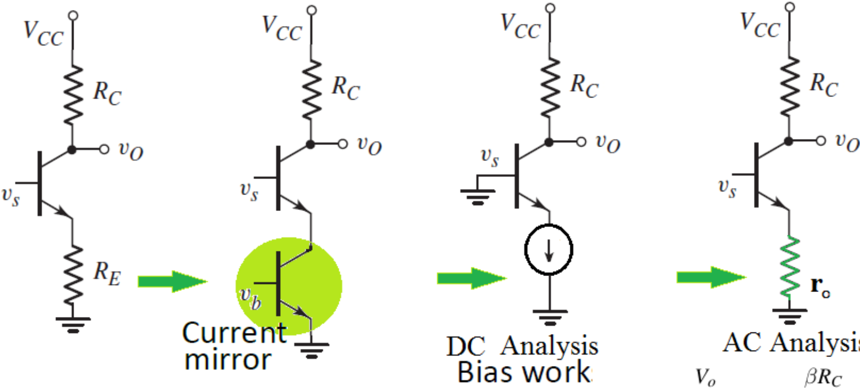


PMOS Version:



Replacing R_E

Biasing Common Emitter Amplifier (R_E)



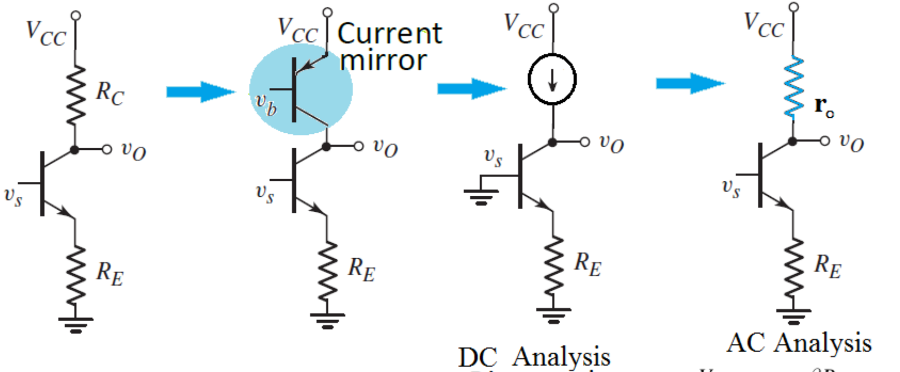
$$\frac{V_o}{V_s} = -\frac{\beta R_C}{r_\pi + (1+\beta)R_E}$$

Its Clear $r_o \uparrow$ therefore, gain will be reduced.

Do Not Place A CURRENT SOURCE at Emitter OF CE AMPLIFER

Replacing R_c

Biasing Common Emitter Amplifier (R_c)

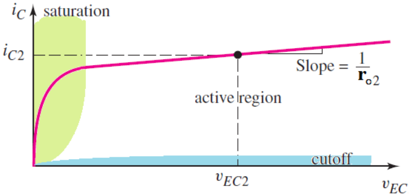


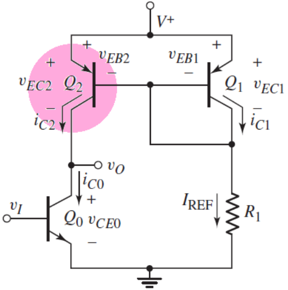
$$\frac{V_o}{V_s} = -\frac{\beta R_C}{r_\pi + (1+\beta)R_E}$$

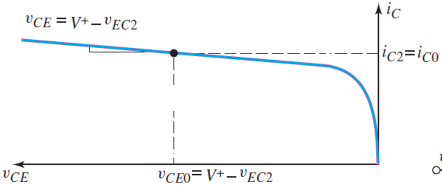
Its Clear $r_o \uparrow$ therefore, gain will be increase.

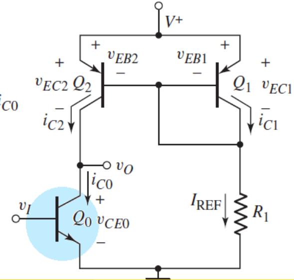
Place A CURRENT SOURCE at Collector OF CE AMPLIFER

Active load circuits

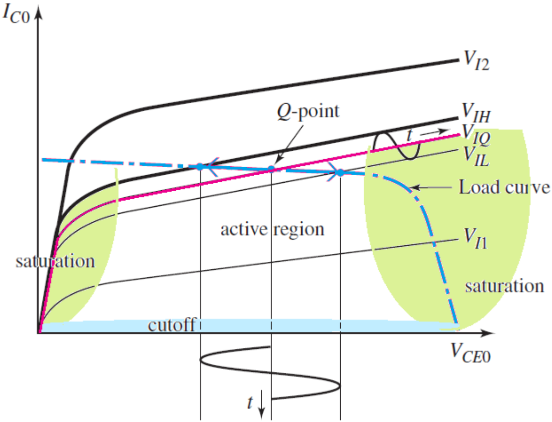


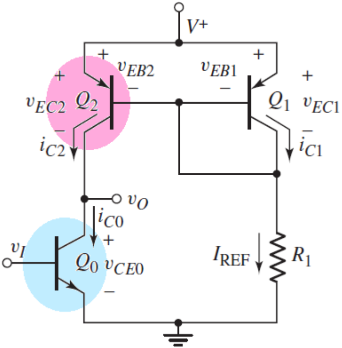




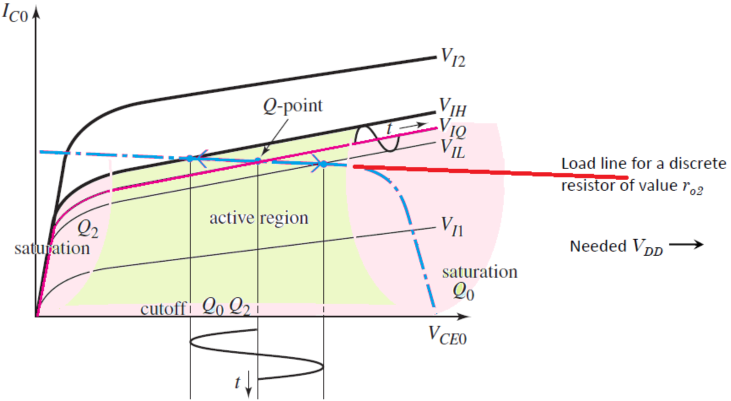


Active load circuits



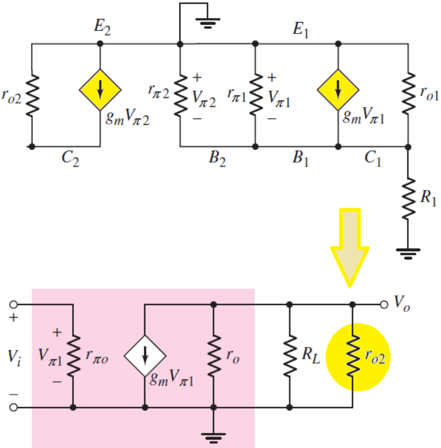


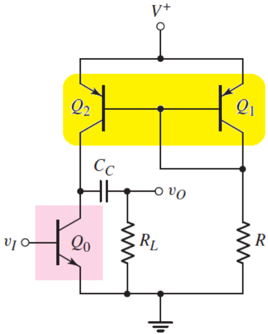
Active load circuits



a very large R_C without increasing V_{DD}

Active load circuits





$$A_v = \frac{V_o}{V_i} = -g_m(r_o \| R_L \| r_{o2}) \qquad g_m = \frac{I_{CQ}}{V_T} = \frac{\beta}{r_\pi}$$

Conclusion

However, it is important to understand how narrow the input transition width is such that the transistors are biased correctly. For this reason, the use of active loads in discrete circuits is almost impossible.

Examples

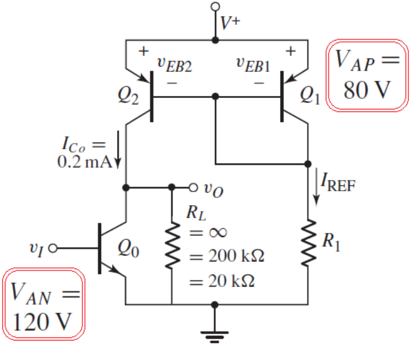
Ex1:

$$g_m = \frac{I_{CQ}}{V_T} = 7.69A/V$$

$$A_v = -g_m(r_o||R_L||r_{o2}) = -1846 \quad R_L = \infty$$

$$A_v = -839 \quad R_L = 200K\Omega$$

$$A_v = -142 \quad R_L = 20K\Omega$$

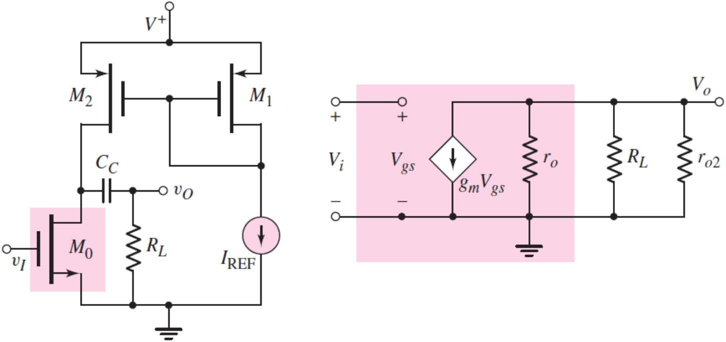


Comment:

The small-signal voltage gain is a strong function of the R_L . Therefore, the R_{in} of the next stage must be large in order to minimize the loading effect.

3.FET Active Load Circuits

Active load circuits



$$A_v = \frac{V_o}{V_i} = -g_m(r_o||R_L||r_{o2}) \qquad g_m = 2\sqrt{K_nI_{REF}} = K_n(V_{ov})$$

Comment:

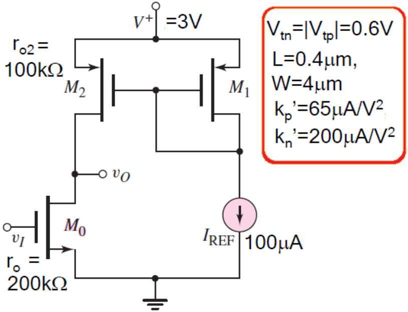
Gain is smaller than equivalent bipolar circuits, because of the smaller (g_m) transconductance for the MOSFET.

Examples

Ex1:

$$g_m = \sqrt{2K_n' I_{REF}\left(\frac{W}{L}\right)} = 0.63mA/V$$

$$A_v = -g_m(r_{on}||r_{op}) = -42$$



Comment:

The small-signal voltage gain is a strong function of the R_L RL. Therefore, the R_{in} of the next stage must be large in order to minimize the loading effect.