ECE 2100 Lecture Notes 3/12/03

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3/11/03

HW #15, due: W, 3/12 prob. 4.2 (ans: β = 368,122,24.2), Ex. 4.1 - 4.7 or see hw 15-16 handout Assume $V_T = 25mV$

HW #16, due: F, 3/14 Hw 15-16 handout

HW #17, due: W, 3/26 Hw 17 handout

Stuff

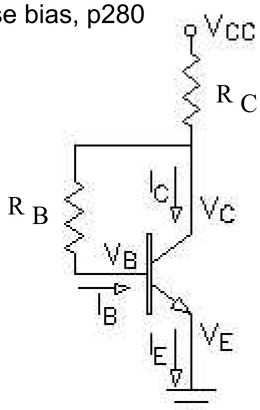
Interested in research at the "U"? Check out a series of talks in EMCB 112, Thursdays 2-3pm. These talks are geared for undergraduates.

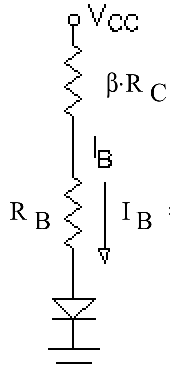
Friday Reed Harrison will be here for a few minutes to talk about ECE 3110 and IC design classes.

Finish up BJT Bias Design

A couple of other bias schemes

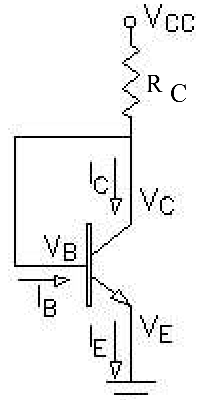
Base bias, p280





$$I_B = \frac{V_{CC} - 0.7 \cdot V}{R_B + \beta \cdot R_C}$$

The bigger R_C is with respect to R_B, the more stable I_C is



Taken to extremes, IC is now very stable at:

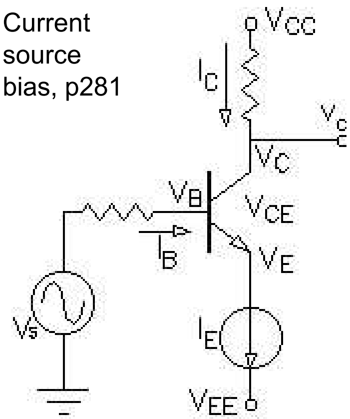
$$I_C = \frac{V_{CC} - 0.7 \cdot V}{R_C}$$

Seems like a useless circuit, but...

Current source bias: We could make the bias current very stable if we had a current source

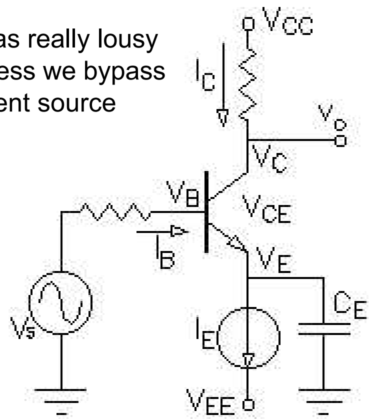
If we can make current sources (drains), then...

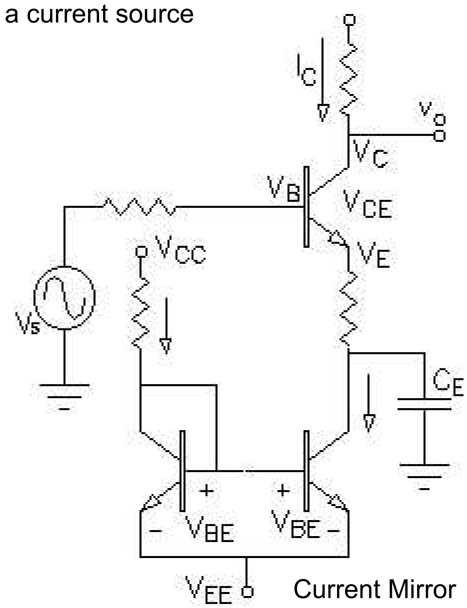
Current source bias, p281



For a perfect current source, $R_E = \infty$

which has really lousy gain unless we bypass the current source





Current Mirror

Current mirrors A way to make a current source (drain)

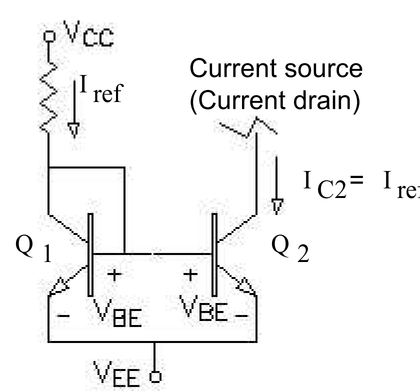
$$I_{C1} = \frac{V_{CC} - V_{EE} - 0.7 \cdot V}{R_C} = I_{ref}$$

Recall that v_{BE} is really not exactly 0.7V, from Ebers-Moll eq.: $I_C = I_S \cdot e^{\frac{v_{BE}}{V_T}}$

Because $V_{BE1} = V_{BE2}$, $I_{C1} = I_{C2}$

We can get a current source (usually called a current drain in this type of configuration). I could make a positive source if I used PNP transistors.

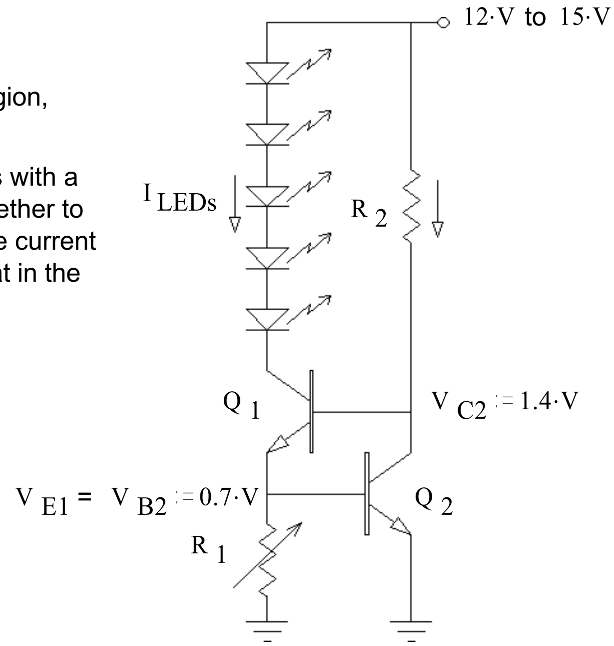
But, the transistors must be identical, and at the same temperature, like in an IC.



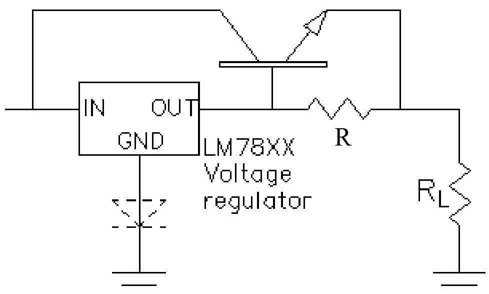
DC in the active region (not bias)

I said early on that few DC circuits use the transistor in its active region, but there are some...

How about an adjustable current source to power multiple LEDs with a non-stable voltage source (like car power). Q_1 and Q_2 work together to maintain the voltages shown (This is negative feedback). So the current through the LEDs can be set by R_1 as $0.7V/R_1$. Select R_2 so that in the worst case the current through it is more than $I_{LED}/100$.



Or perhaps a way to make a 1A voltage regulator handle more current.

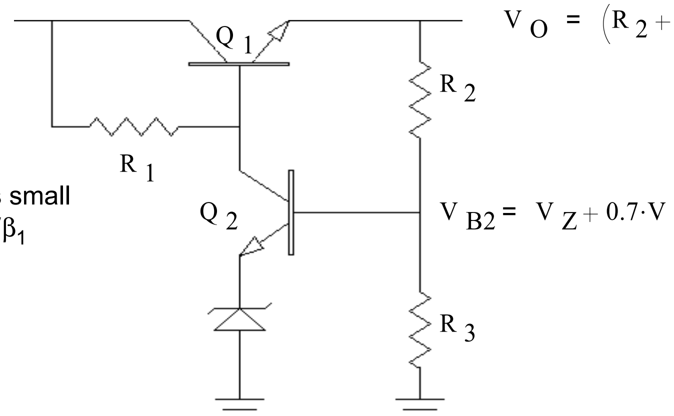


When enough current flows through R to get 0.7V across it, then the transistor will start to turn on to supply more current to the load. You could put a diode in the ground connection of the regulator to make up for the lost 0.7V across R.

Or, you could make the whole regulator from scratch.

$$V_O = (R_2 + R_3)\cdot\frac{V_{B2}}{R_3}$$

Make sure that R_1 is small enough to handle I_L/β_1



Adding Signals to the analysis

DC Bias or Quiescent-point (Q-point) Analysis

Variation of superposition for circuits with DC power supply(s) and AC signals.

1) Zero all signal sources.
2) Consider all coupling and bypass capacitors as open.
3) Use special DC models for non-linear parts and/or active elements (0.7V drop for base-emitter diode).
4) Compute the DC voltages or currents.
5) Check your assumptions and models.

AC Small-Signal Analysis

Variation of superposition for circuits with DC power supply(s) and AC signals.

1) Zero all DC sources. (To zero a voltage source, replace it with a short. To zero a current source, replace it with an open.)
2) Consider all coupling and bypass capacitors as shorts.
3) Use special small-signal models for non-linear parts and/or active elements. Some may depend on Q-point values.

   small-signal emitter resistance: $r_e = \frac{V_T}{I_C}$ $V_T \simeq 25\cdot mV$

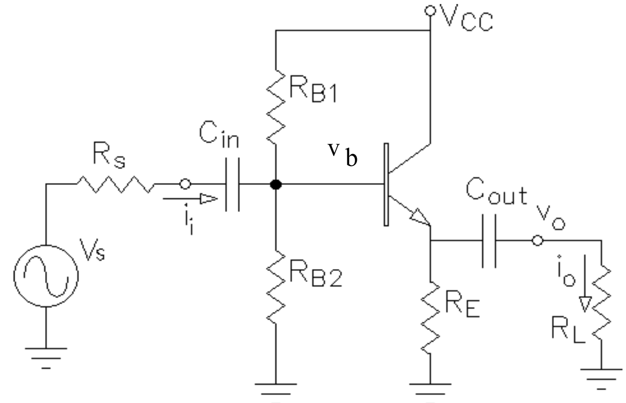
4) Compute the signal voltages or currents of interest.
5) Check your assumptions and models.

Common collector (CC)

The circuits shown are typical arrangements. Note that V_{EE} is often 0 V (ground). The equations below are for these circuits, adapt them as necessary to fit your actual circuit.

Voltage gain about 1. Good for current gain, or to match a high impedance source to a low impedance load.

The small-signal emitter resistance is right in the emitter of the transistor (where the arrow is).



Recall that the emitter resistor looks β times as big from the base's point-of-view. That's also true for signals

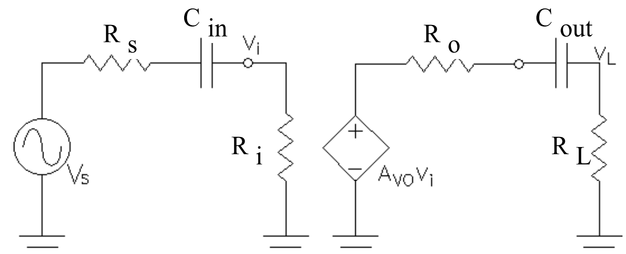
Input impedance: $R_i = R_{B1} \| R_{B2} \| \beta \cdot (r_e + R_E \| R_L)$

The opposite effect also works, resistors at the base look β times smaller from the emitter's point-of-view.

Output impedance: $R_o = R_E \| \dfrac{r_e + R_{B1} \| R_{B2} \| R_S}{\beta}$

Low frequency corner frequencies

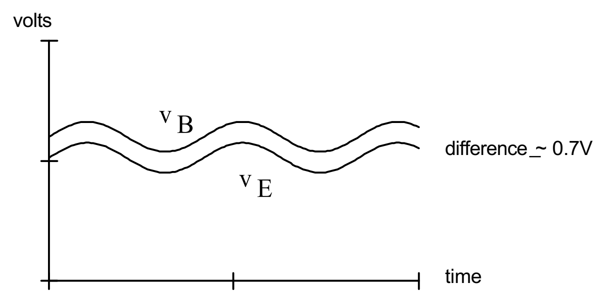
$$f_{CL1} = \frac{1}{2 \cdot \pi \cdot (R_S + R_i) \cdot C_{in}} \qquad f_{CL2} = \frac{1}{2 \cdot \pi \cdot (R_L + R_o) \cdot C_{out}}$$



From the signal analysis, the only thing between the base signal and the output signal is r_e. To find the output, just use the voltage divider equation.

Voltage gain: $A_v = \dfrac{v_o}{v_b} = \dfrac{R_E \| R_L}{r_e + R_E \| R_L} \simeq 1$

OR: $\dfrac{v_o}{v_s} = \dfrac{R_i}{R_S + R_i} \cdot \dfrac{R_E \| R_L}{r_e + R_E \| R_L}$

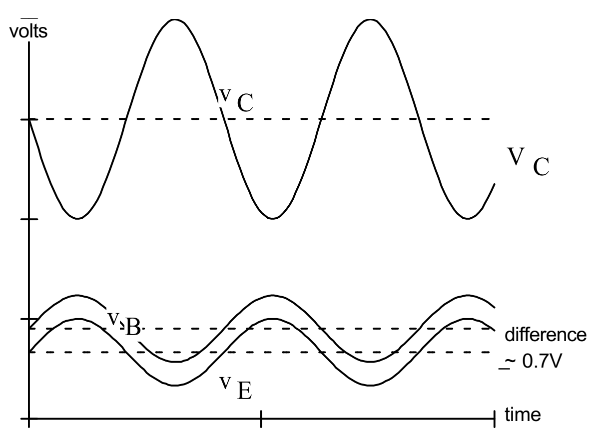


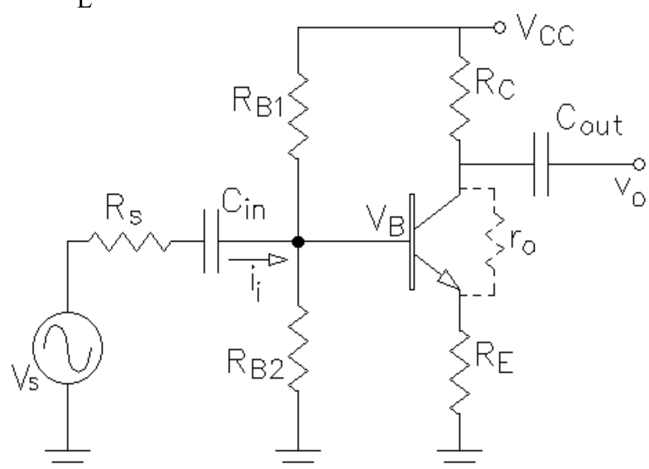
You could think of the ouput as simply 0.7V DC less than the input, which doesn't make the AC signal any less. Of course this doesn't account for the r_e effects.

Current gain: $A_i = \dfrac{i_o}{i_i} = \dfrac{R_E \| R_L}{r_e + R_E \| R_L} \cdot \dfrac{R_i}{R_L} = A_v \cdot \dfrac{R_i}{R_L} \simeq \dfrac{R_i}{R_L}$

Common emitter (CE)

Now let's add a resistor in the collector (R_C). Nearly the same current that flows through R_E flows through R_C.





$v_c = -i_c \cdot R_C$ $\qquad v_e = i_e \cdot R_E \simeq v_b$

$i_c \simeq i_e$ $\qquad$ so: $\dfrac{v_c}{v_b} \simeq -\dfrac{R_C}{R_E}$ $\qquad$ gain