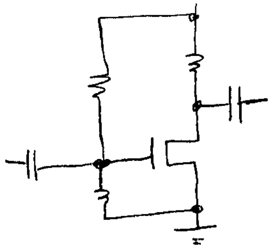
Biasing

Simple V_{GS}:



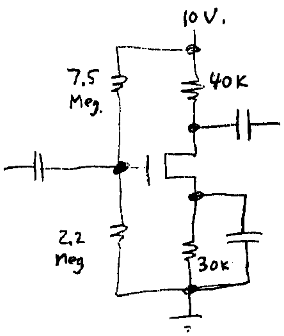
Very sensitive to process variations

HW
43 all exercises
p.363: 36, 37, 38
p.364: 42, 43
p.365: 46, 47, 48
Look for shortcuts

4.4

4.5 all exercises

"4- resistor"



To design:

$K' = 2\times10^{-4}$

$V_{TH} = 2$

$\frac{W}{L} = 10$

Pick voltage and current:

$V_{DD} = 10$

$V_D = 6 \quad V_S = 3 \quad V_{DS} = 3$

$I_D = .1$ ma

$\Rightarrow R_D = \frac{10-6}{10^{-4}} = 40K$

$R_S = \frac{3}{10^{-4}} = 30K$

$I_D = \frac{1}{2}K'\frac{W}{L}(V_{GS} - V_{TH})^2$

$10^{-4} = \frac{1}{2}(2\times10^{-4})(10)(V_{GS} - V_{TH})^2$

$(V_{GS} - V_{TH})^2 = \frac{10^{-4}}{10\times10^{-4}} = \frac{1}{10}$

$V_{GS} - V_{TH} = .316$

$V_{GS} = 2.316$ — use voltage divider

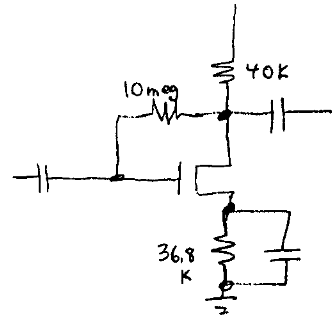
To analyze

Find gate voltage:

$V_G = 2.27$

Loop analysis

Drain-Gate Feedback



Low input resistance

To analyze:

To design:

$V_{GS} = V_{DS}$

Pick voltage and current;

$V_{DD} = 10$

$V_D = 6$

$I_D = .1$ ma

$R_D = 40K$

$K' = 2\times10^{-4}$

$V_{TH} = 2$

$\frac{W}{L} = 10$

$I_D = \frac{1}{2}K'\frac{W}{L}(V_{GS} - V_{TH})^2$

$10^{-4} = \frac{1}{2}(2\times10^{-4})(10)(V_{GS} - V_{TH})^2$

$\frac{1}{10} = (V_{GS} - V_{TH})^2$

$V_{GS} = 2.316$

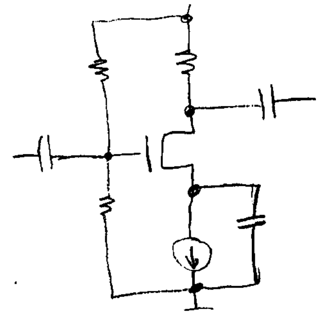
$\Rightarrow V_{DS} = 2.316 \quad V_S = V_D - V_{DS}$

$= 6 - 2.316$

$= 3.68$

$R_S = \frac{V_S}{I} = \frac{3.68}{.1mA} = 36.8K$

Current source



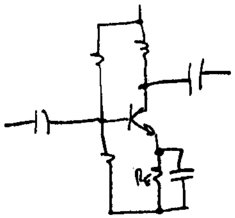
For current source — use current mirror

Easy design — Very consistent.

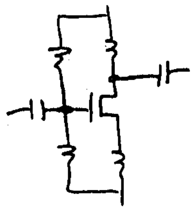
Getting rid of those resistors and capacitors

or... current mirrors
differential amps
etc.

Remember this?



or

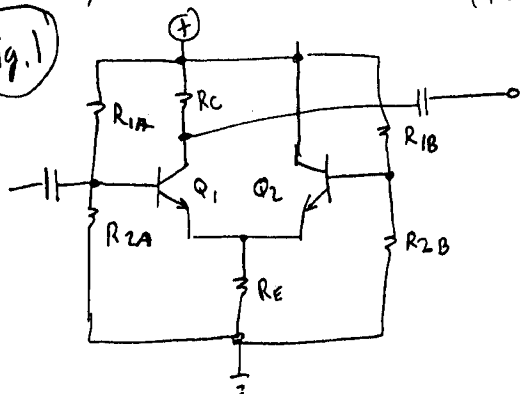


How to eliminate the emitter resistor and capacitor?

Answer: use more transistors.

Try this: (inverting amp.)

Fig. 1



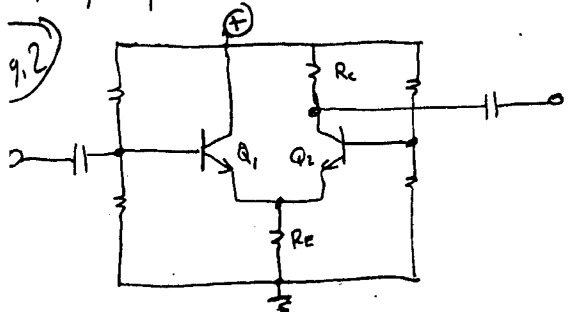
$R_{1A} = R_{1B}$
$R_{2A} = R_{2B}$
so Q_1, Q_2 have identical bias.

Q_2 is an emitter follower on the DC bias, so it eliminates the need for the capacitor.

Q_1 and Q_2 are identical transistors.
(same V_{BE}, β, etc.)

Now, try this one:

g, 2



This is the same except that the output is taken off Q_2 instead of Q_1.

Q_1 is an emitter follower.

Q_2 is a common base amplifier.

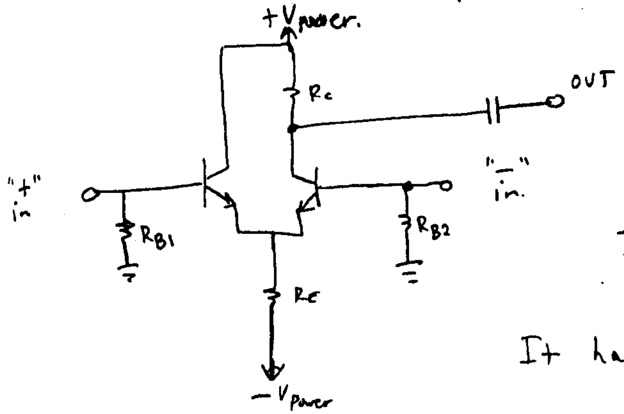
- Low input impedance
- High output impedance
- Current gain = 1
- Voltage gain = high.

This (Fig 2) has characteristics the same as Fig. 1, except that it is non-inverting.

Effective load.

Fig 2 Gain = $\frac{R_C'}{(2r_E/\beta)}$ → Fig 1 Gain = $\frac{-R_C'}{(2r_E/\beta)}$

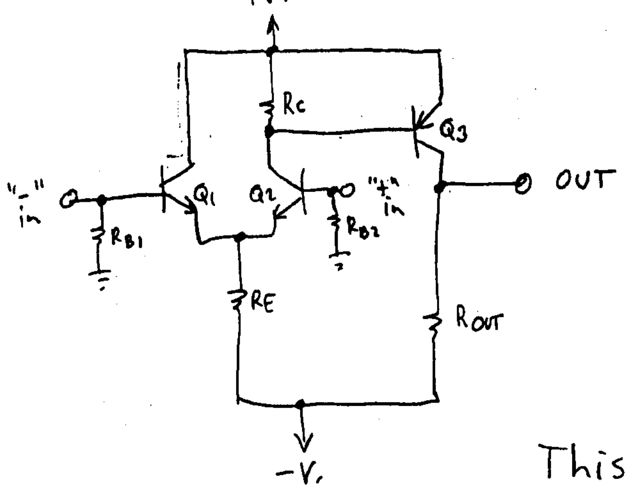
Usual application --
use + and − supply, so $V_B = 0$:



This is a "differential" amplifier.

It has 2 inputs, 1 output.

Now, add another stage



This additional stage inverts phase, so switch + and − inputs.

It also restores the DC level, Proper bias puts OUT at 0 V. DC.

This is a simple op-amp.

High gain! No capacitors!

Other nice properties --

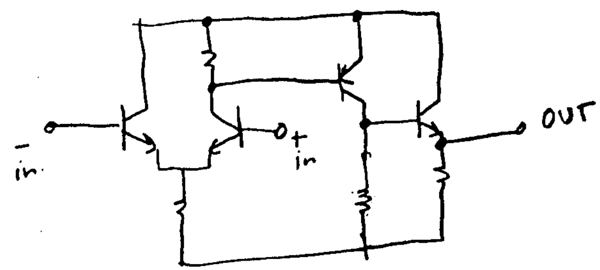
- Q_1 and Q_2 track each other in V_{BE} with temperature.
  - → easy to bias
  - not temperature sensitive.

For best balance, Q_1 and Q_2 should match. —
Exact V_{BE}, β is not critical
but matching affects output offset.

For best results, use adjacent transistors from the same wafer.
- → Easy on an IC.
- → Can buy matched pairs.

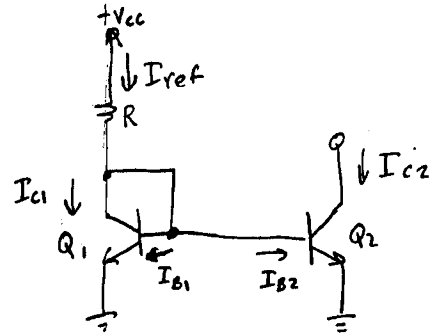
Gain is very high.
(So is distortion.)
Use negative feed back to lower gain and distortion.

Better op-amp with emitter follower:



Improving the op-amp

Current mirrors.



Q_1 and Q_2 are the same.

$I_{c2} \approx I_{ref}$.

Use R to set current.

Suppose -- $V_{cc} = 10$

$R = 10K$

Since $V_{BE} = .6$,

$V_R = 9.4$

so $I_{ref} = .94$ ma.

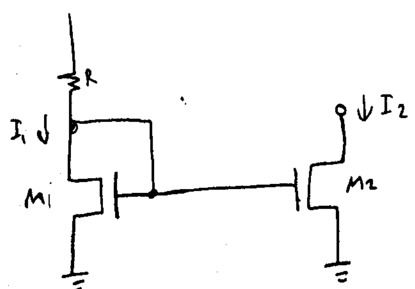
$V_{BEQ1} = V_{BEQ2}$ ⟶ Implies $I_{c2} = .94$ ma also.

Can get other currents by making Q_1, Q_2 different.

Let Q_2 be like Q_1 except 10 times the area --- equivalent to 10 of them in parrell.

Now, $I_{c2} = 9.4$ ma.

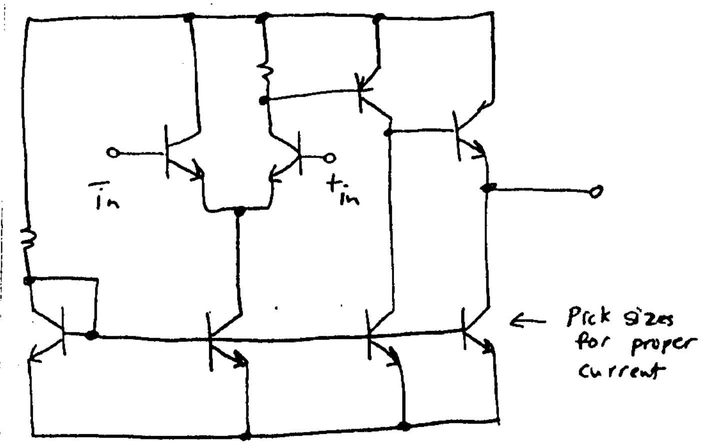
Also:



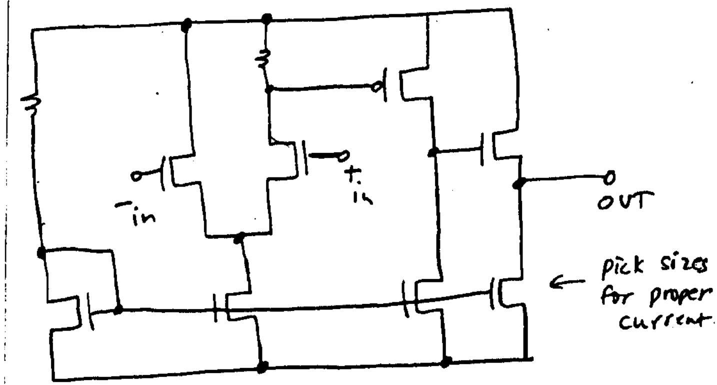
if M_1 and M_2 are identical, $I_1 = I_2$

I_2 Can be scaled by adjusting size.

Op amp with current mirrors:



Similar with FET's



Getting rid of the collector resistor —
Use a current mirror there, too.