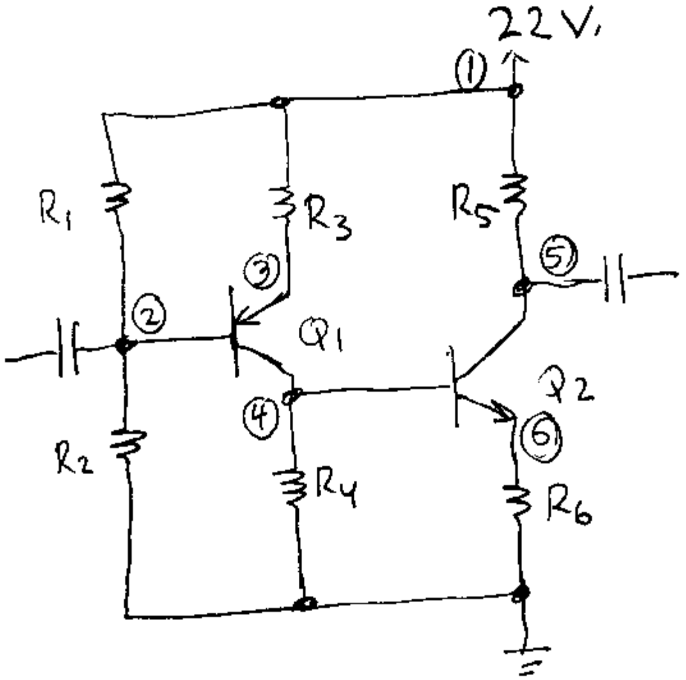
Biasing - (finish it).

Multi-stage amplifier design example



Specs:

Gain = 100
(10 each stage)

Rout = 10K

Choose resistors to maximize output capability.

$\beta = 100$ $V_{BE} = .6$

Procedure:

Choose $R_5 = 10\text{ K}$ (for Rout)

then $R_6 = 1\text{K}$ (for gain in 2nd stage)

For maximum output capability –
want half of the voltage across the transistor

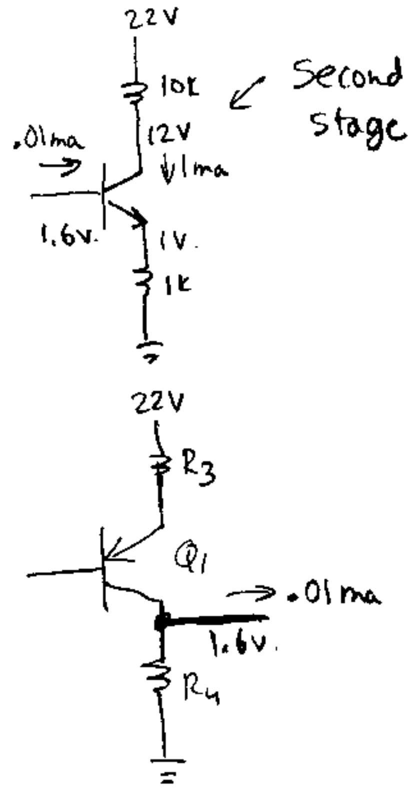
$\Rightarrow V_{CE_{Q2}} = 11$ (this works if there is no external load – more next week).

This means the other 11V is in the resistors.

Assume $I_C \approx I_E$ -- then $V_{R5} = 10\text{V}.$ $I_C = 1\text{ ma}$

$V_{R6} = 1\text{V}$

$$I_B = \frac{I_C}{\beta} = .01\text{ ma}$$



Now, design the first stage.

It must have 1.6 V on the collector with .01 ma to the base of the second stage.

Choose current = 10 × base current of next stage = .1 ma

$\Rightarrow R_4 = 16K$

$I_{R4} = .1$ ma

$I_{CQ1} = .11$ ma

$I_E \approx .11$ ma

For gain of 10, $R_3 = 1.6K$

$V_{R3} = IR = (.11\text{ ma})(1.6K)$

$= .17$ V.

So.. $V_3 = 22 - .17 = 21.83$

$V_2 = 21.83 - .6 = 21.23$

$I_B = .001$ ma

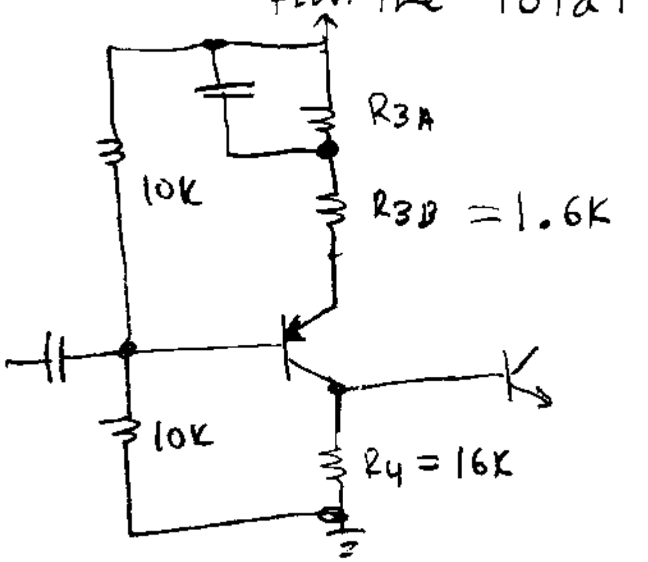
This is a bad design.
The voltage across R3 is too small.
Small variations are amplified.
It will be difficult to get a consistent operating point.

Idea: Split R_3 into 2 parts.

Put a big capacitor across one of them.

The unbypassed one determines the gain.

The total determines the DC bias.



Since not much voltage swing is needed, make R_{3A} fairly large.

Choose to get a good DC voltage.

How about --- make V_B ½ supply = 11V,

Then $R_1 = R_2$

Arbitrarily choose 10K

Then $V_E = 11 + .6 = 11.6$

$V_{jct} = 11.6 + .2 = 11.8$

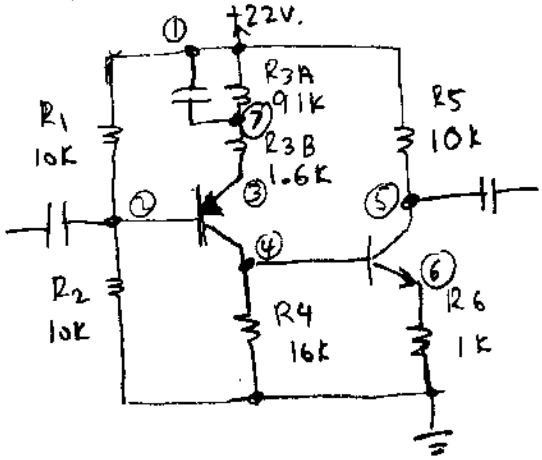
$V_{R3A} = 22 - 11.8 = 10.2$

$$R = \frac{V}{I} = \frac{10.2}{.11\,ma} = 92\,K$$

use 91K

(how much will this change the result?)

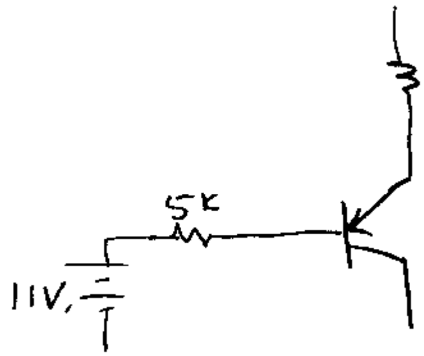
Here's the circuit:



Verify it. (in to out)

V_2 ignoring load: $\left(\frac{10k}{20k}\right)(22V) = 11V.$

$R_{EQ} = 10k \| 10k = 5K$



If $V_2 = 11V$, then V_3 must be 11.6V.

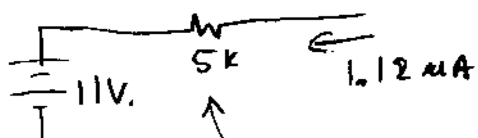
$V_{R3} = 22 - 11.6 = 10.4$

$R_3 = R_{3A} + R_{3B} = 92.6K$

$I_{R3} = \frac{V}{R} = \frac{10.4}{92.6k} = .112$ ma

If $\beta = 100$, $I_B = .00112$ ma $= 1.12\ \mu A$

Correct base voltage --



$V = IR$

$= (1.12\mu A)(5K)$

$= .0056$ V.

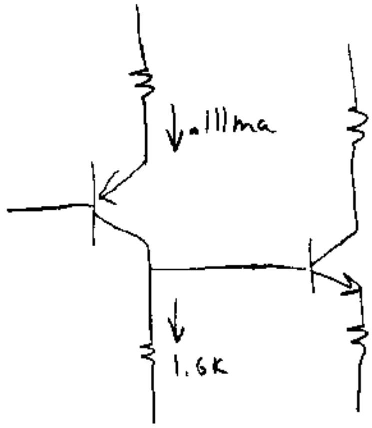
Ignore it.

We could have made R_1, R_2 higher.

Should have.

$I_{R4} = I_{R3} - I_B = .112\,ma - .001\,ma = .111\,ma$

$V_{R4} = IR = (.111\,ma)(16\,K) = 1.78$ (assuming next stage base current = 0)



Q_2 $V_{BE} = .6$ (assume)

so $V_{Q2E} = 1.78 - .6$

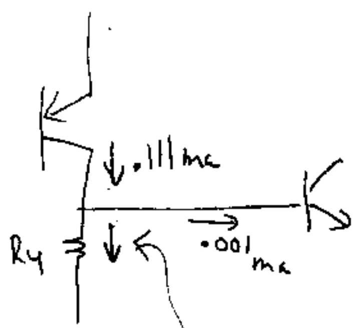
$= 1.18$

$I = 1.18\,ma$

If $\beta = 100$, $I_B = .0118\,ma$

$\approx .012$

Go back to V_{R4} - Calculate again with this assumed base current



$.111 - .012 = .099\,ma$

$V_{R4} = IR = (.099)(16\,K)$

$= 1.58\,V. \approx 1.6$

(confirms 1.6 design value)

$V_{EQ2} = 1.6 - .6 = 1.0$ $I_E = 1\,ma$

Since $I_C = 1\,ma$, $V_{R5} = 10$, so $V_5 = 22 - 10 = 12$

Design:

Start at the <u>output</u>.

Choose voltages, currents and work back toward the input.

Analysis:

Start at the <u>input</u>.

Use thevenin, Norton equivalent circuits

If you don't know something, like base current,

Assume a value that seems good.

Calculate the voltage you are looking for.

Then calculate the real value for what you assumed.

Re-calculate the voltage you are looking for.

Usually, this is close enough.

HW: sec 3.5

P	#	
150	3.32, 3.33	Not to hand in
160	3.55	

p. 161 D 3.67 To hand in

Design

Verify with simulation

Due next Monday