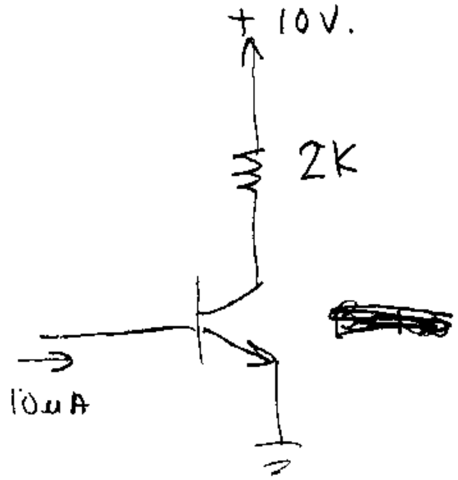
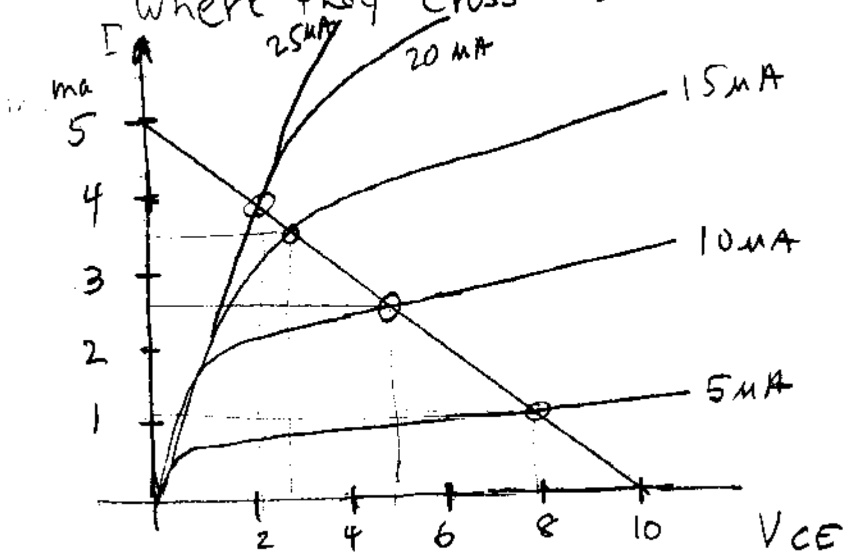
Load line analysis of transistor circuit

Like a diode



Plot transistor curve and load line on same graph.

Where they cross---



Transistor: I_C vs. V_{CE}

Resistor I vs V_{CE} ← $V_{CE} + V_R = 10$

so $V_{CE} = 10 - V_R$

Resistor:

V_R	I	V_{CE}
0	0	10
10	5ma	0

plot this.

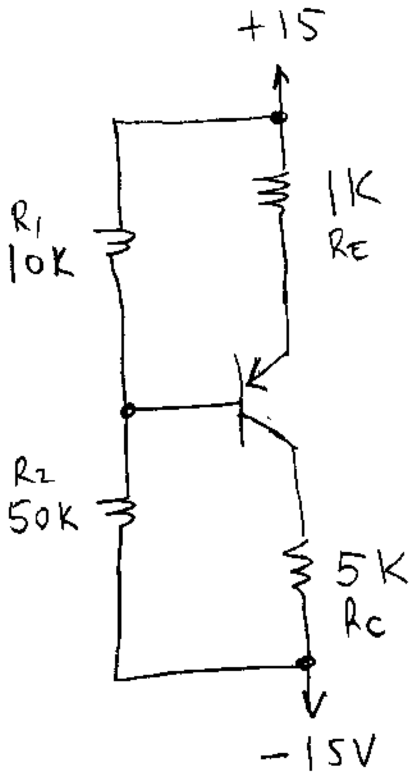
From graph:

I_B	V_{CE}	I_C
10uA	4.9	2.6
5uA	1.1	7.9
15uA	2.8	3.6
20uA	2.1	4.0
25uA	2.1	4.0

(20uA and 25uA rows:) saturation.

Real saturation voltage ≈ .2

Another circuit — Biasing a transistor amplifier



Find operating point.

$\beta = 50 \qquad V_{BE} = .6$

Make Thevenin equivalent of base circuit.

$$\frac{R_1}{R_1+R_2} = \frac{V_{R1}}{V_{TOTAL}}$$

$$\frac{10K}{60K} = \frac{V_{R1}}{30}$$

$$V_{R1} = \frac{10K}{60K} * 30 = \frac{30}{6} = 5$$

$$V_{R2} = 25$$

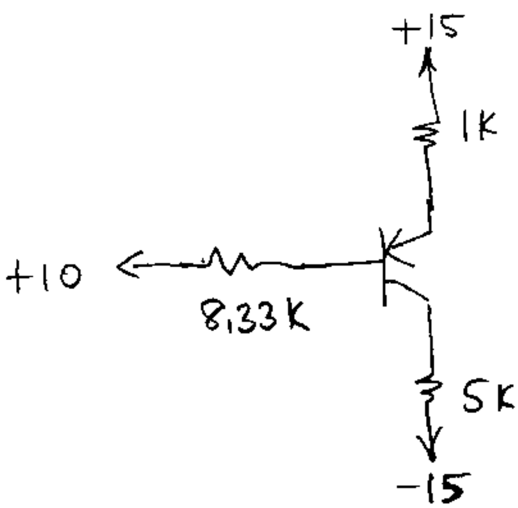
$$V_B = 10$$

$$R = R_1 \| R_2 = \frac{(10K)(50K)}{10K+50K}$$

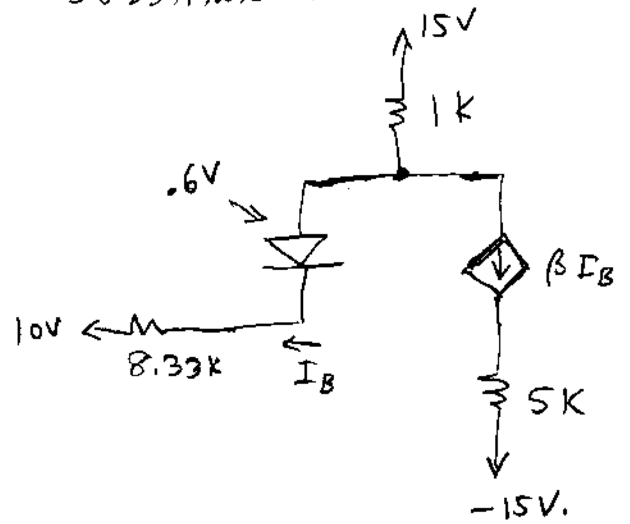
$$= \frac{500 \text{ Meg}}{60K}$$

$$= \frac{50}{6} K$$

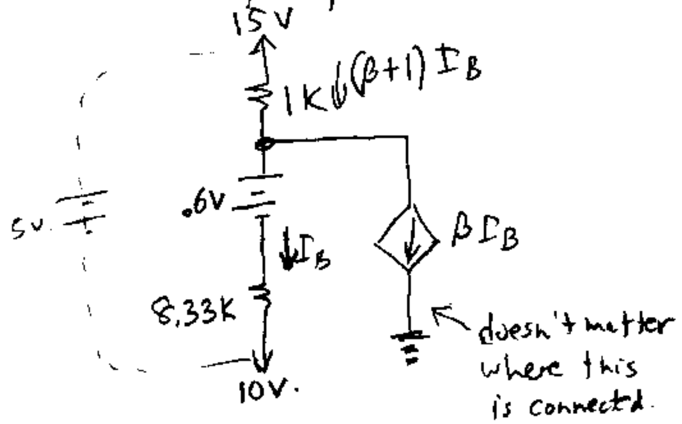
$$= 8.33 K$$

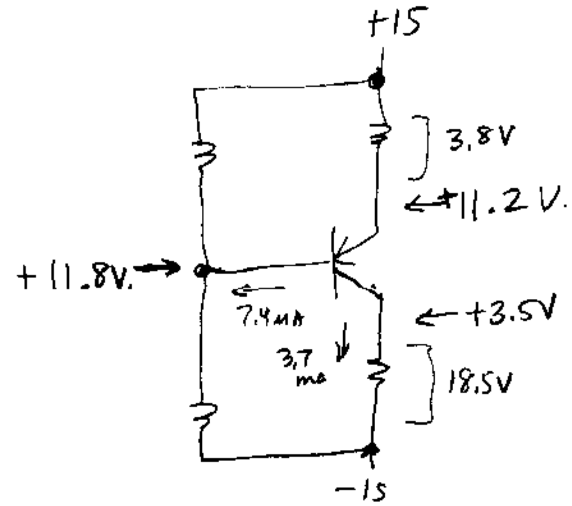


Substitute the model.



Simplify it





Circuit with Q point.

Loop equation.

$$(1K)(\beta+1)(I_B) + .6 + (8.33K)(I_B) = 5$$

$$(51K)(I_B) + .6 + (8.33K) I_B = 5$$

$$(59.33K) I_B = 4.4$$

$$I_B = \frac{4.4}{59.33K} = 7.4 \times 10^{-5}$$

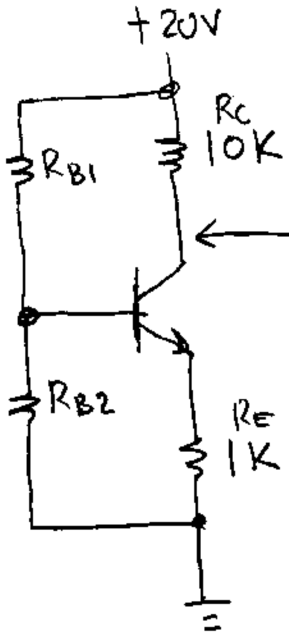
$$= 74 \mu A$$

$$I_C = \beta I_B = .0037 \text{ A}$$

$$V_{RC} = IR = (.0037)(5000) = 18.5$$

$$I_E = (\beta+1) I_B = .0038 \text{ A}$$

$$V_{RE} = (.0038)(1000) = 3.8$$



Choose R_{B1}, R_{B2} to get 10V. here

$\beta = \infty \qquad V_{BE} = .6$

$$I_C = \frac{V_{RC}}{R_C} = 1\,ma$$

$$I_E \approx 1\,ma$$

$$V_E = V_{RE} = (1\,ma)(1k) = 1$$

$$V_B = V_E + V_{BE} = 1 + .6 = 1.6$$

Choose R_{B1}, R_{B2} for 1.6 V at junction.

How about -- $R_{B1} = 16\,K \quad (I = .1\,ma)$

$$R_{B2} = \frac{20-1.6}{.1\,ma} = \frac{18.4}{.1\,ma} = 184K$$

Any resistors in this ratio will work.
The higher the better, but
you need to account for base current.

Same circuit —

$10V < V_C < 11 V.$

$\beta > 50 \qquad V_{BE} = .6$

↑ could be infinite

Observe -- Base current makes V_B go <u>down</u>

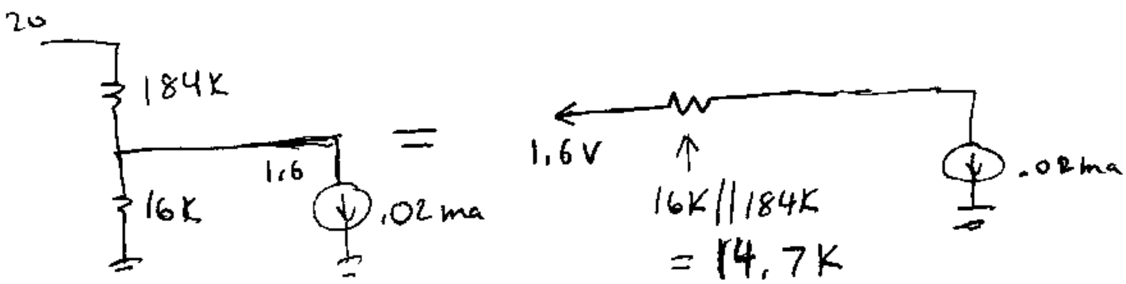
which makes V_E go down

and V_C go up.

Analyze for $\beta = 50$ $\qquad (\alpha = \frac{50}{51} = .98)$

If $I_C = 1ma$, $\quad I_B = .02$ ma

Base resistors equivalent circuit



$V = IR \Rightarrow (.02 ma)(14.7K)$

$= .3 V.$

$V_{RE} = 1.3 - .6 = .7$

$I_E \quad I_{RE} = \frac{V}{R} = \frac{.7}{1K} = .7 ma$

$I_C = \alpha I_E = (.98)(.7 ma) \approx .7 ma$ ← close enough

$V_{RC} = (.7ma)(10K) = 7$ volts.

$V_C = 13 V.$ ← out of spec!

How to figure R_{B1}, R_{B2} correctly

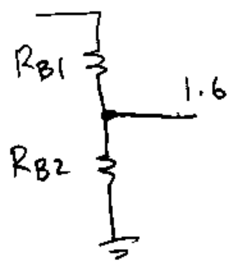
$\beta = \infty \quad V_C = 10, \; V_E = 1$

$\beta = 50 \quad V_C = 11, \; V_E = .9$

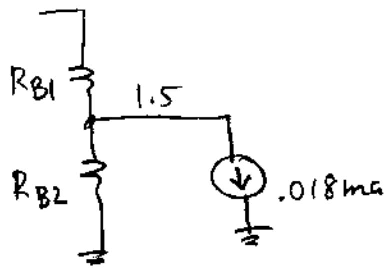
Need base voltage: 1.6 with $\beta = \infty$, $I_B = 0$

1.5 with $\beta = 50$, $I_B = \frac{.9\,ma}{50} = .018\,ma$

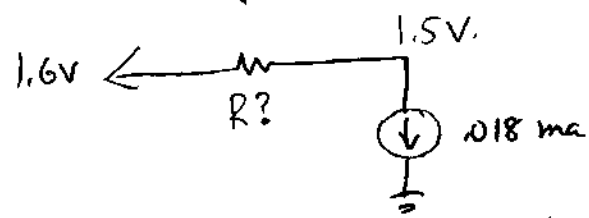
Base resistors equivalent circuit:



or



↓



$$R = \frac{V}{I} = \frac{1.6 - 1.5}{.018\,ma} = \frac{.1}{.018\,ma} = 5.5556\,K$$

↑ Value of R_{B1}, R_{B2} in parallel

To get 1.6V, open circuit the ratio must be $\frac{R_{B1}}{R_{B2}} = \frac{1.6}{18.4} = \frac{V_{R1}}{V_{R2}}$

$\frac{18.4}{1.6} = 11.5$

$R_{B2} = 11.5\,R_{B1}$

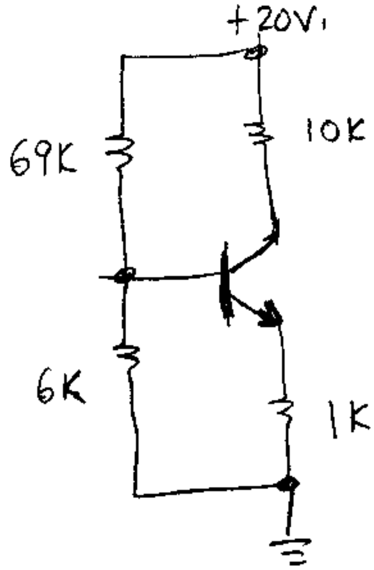
so → $\frac{R_{B1} R_{B2}}{R_{B1} + R_{B2}} = 5.56K = \frac{(R_{B1})(11.5\,R_{B1})}{R_{B1} + 11.5\,R_{B1}} =$

$5.56K = \frac{11.5\,R_{B1}^2}{12.5\,R_{B1}} = \frac{11.5}{12.5} R_{B1}$ → $R_{B1} = (5.56K)\left(\frac{12.5}{11.5}\right) = 6.03K$ (6K)

$R_{B2} = 69\,K$

Here's the answer:

Homework: check it.



Hw:

p.	#
130	14, 15, 16, 17
154	19, 22, 25, 28