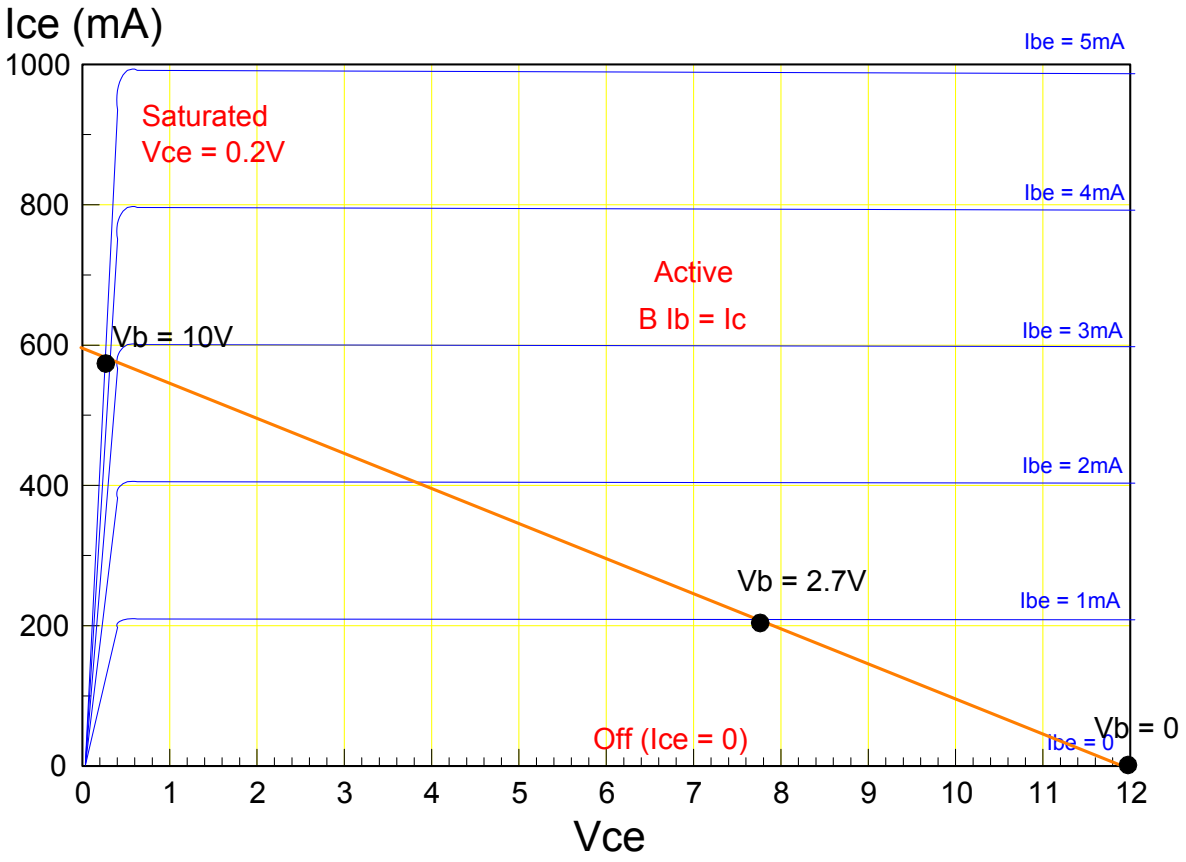
ECE 320 - Solution to Homework #4

Transistor Theory - Transistor Switch Due Wednesday, February 18th

Transistor Theory

1) Assume a transistor has the following V/I characteristics

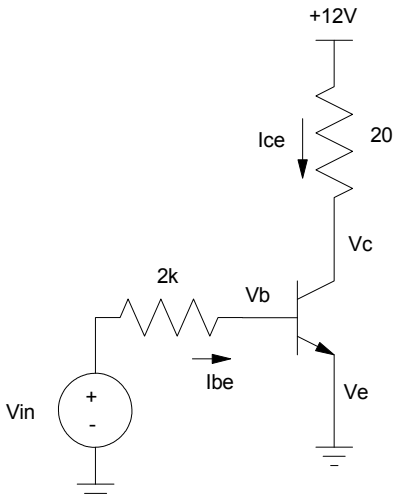
- 1a) Label the regions corresponding to off / active / saturated
- 1b) Determine the gain of the transistor, beta



Problem 1 & 2

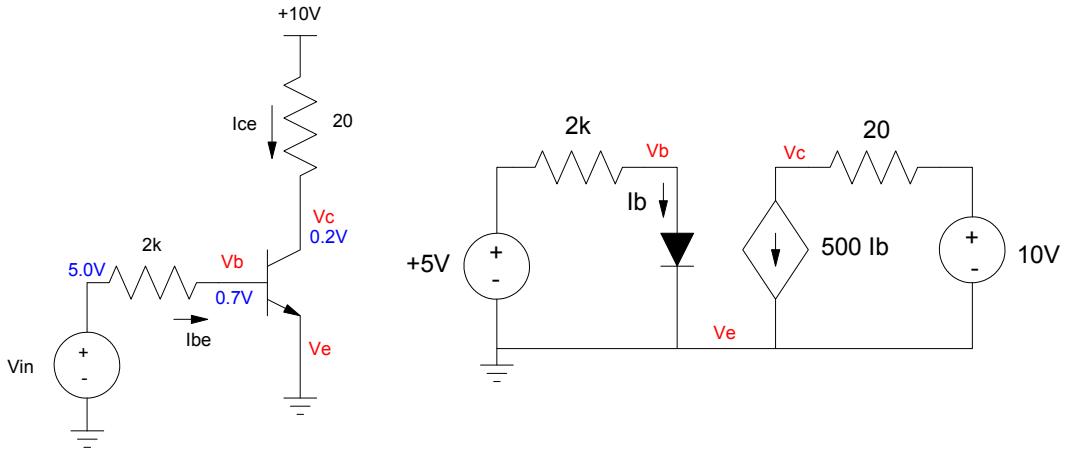
2) Assume this transistor is used in the circuit to the right.

- 2a) Show the load line for this circuit on the above graph
- 2b) Show the operating point for Vin = 0V
- 2c) Show the operating point for Vin = +2.7 V
- 2d) Show the operating point for Vin = +10V



Problem 3) Assume β=500. Determine Vb, Vc, Ve, and Ice for

- Vin = 0V
- Vin = +5V



Problem 3

First, redraw the circuit assuming active mode (shown to the right)

Vin = 0V: You need at least 0.7V to turn on the diode. At 0V, Ib = 0.

Ib = Ic = 0mA

Vc = 10V

Vin = 5V:

$$I_{be} = \frac{5-0.7}{2k} = 2.15mA$$

$$\beta I_b = 1.075A$$

But, the maximum current possible is:

$$I_{c:\max} = \frac{10V-0.2V}{20\Omega} = 490mA$$

βI_b is too large, meaning the transistor is saturated.

$$I_c = \min(1.075A, 490mA)$$

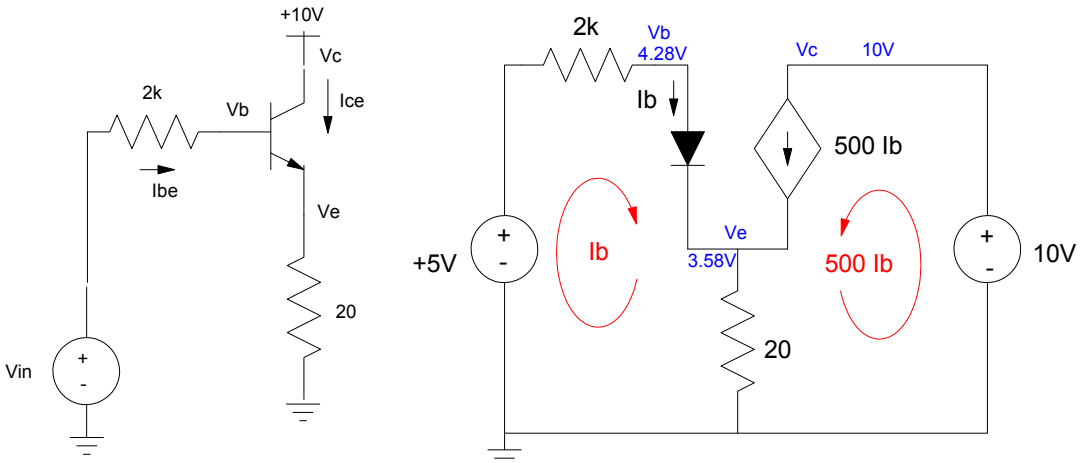
$$I_c = 490mA \quad \text{(saturated)}$$

Vc = 0.2V

Problem 4) Assume gain=500, Determine Vb, Vc, Ve, and Ice for

- Vin = 0V
- Vin = +5V

It helps to redraw the circuit:



a) Vin = 0V

You don't have enough voltage to turn on the diode.

Ib = Ic = 0 (off state)

b) Vin = +5V

Assume you are in the active mode. Taking the current loop around Ib

$$-5 + 2000I_b + 0.7 + 20(I_b + 500I_b) = 0$$

$$I_b = \frac{5-0.7}{2000+(501)20}$$

$$I_b = 357\mu A$$

$$I_c = \beta I_b = 179.9mA$$

This is less than the maximum current (10V/20 Ohms = 500mA), so it really is in the active mode

The voltages are then

$$V_e = 20\Omega \cdot (I_b + 500I_b) = 3.58V$$

$$V_b = V_e + 0.7V = 4.28V$$

$$V_c = 10V$$

Note that Vce = 6.42V. This is more than 0.2V, so it's in the active mode.

Note that with the NPN transistor on the high side, you cannot satuate the transistor with a 5V input.

$\Rightarrow$ The emitter needs to be tied to ground

Transistor Switches Assume a Zetex NPN transistor with a gain of 500 (Zetex 1051A)

5) Design a circuit so that a function generator can drive an 8-Ohm speaker:

- Input: 0V / 5V TTL square wave, 100Hz, < 20mA
- Output: 8 Ohm speaker
- Relationship:
  - When the input is 0V, 0mA flows through the speaker
  - When the input is +5V, 625mA flows through the speaker (tol 10%)

First, design a circuit to turn on the speaker. Simply tie it from 5V to ground.

Next, break the path to ground with a transistor used as an electronic switch.

To find Rb

$$\beta I_b = I_c$$

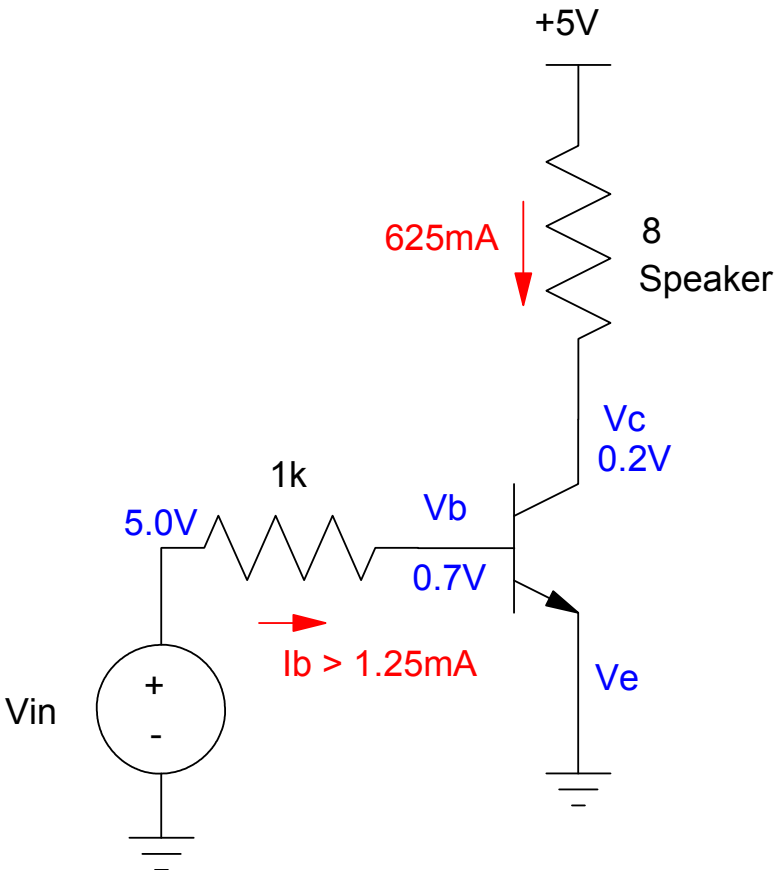
$$I_b = \frac{625mA}{500} = 1.25mA$$

To put you on th eedge of saturation

$$R_b = \frac{5V-0.7V}{1.25mA} = 3440\Omega$$

To make sure you're saturated, pick something smaller, say

Rb = 1k



6) Design a circuit so that a function generator can drive a 1W LED

- Input: 0V / 5V TTL square wave, 1Hz, < 20mA
- Output: 1W LED (Vf = 3V @ 350mA, 100 Lumens @ 350mA)
- Relationship:
  - When the input is 0V, 0mA flows through the LED
  - When the input is +5V, 350mA flows through the speaker (tol 10%)

First, design a circuit to turn on the LED. Connect it to +5V through a 5.14 Ohm resistor:

$$R_c = \frac{5V-3.0V-0.2V}{350mA} = 5.14\Omega$$

Next, break the path to ground with a transistor (the 0.2V above) used as an electronic switch.

To find Rb

$$\beta I_b = I_c$$

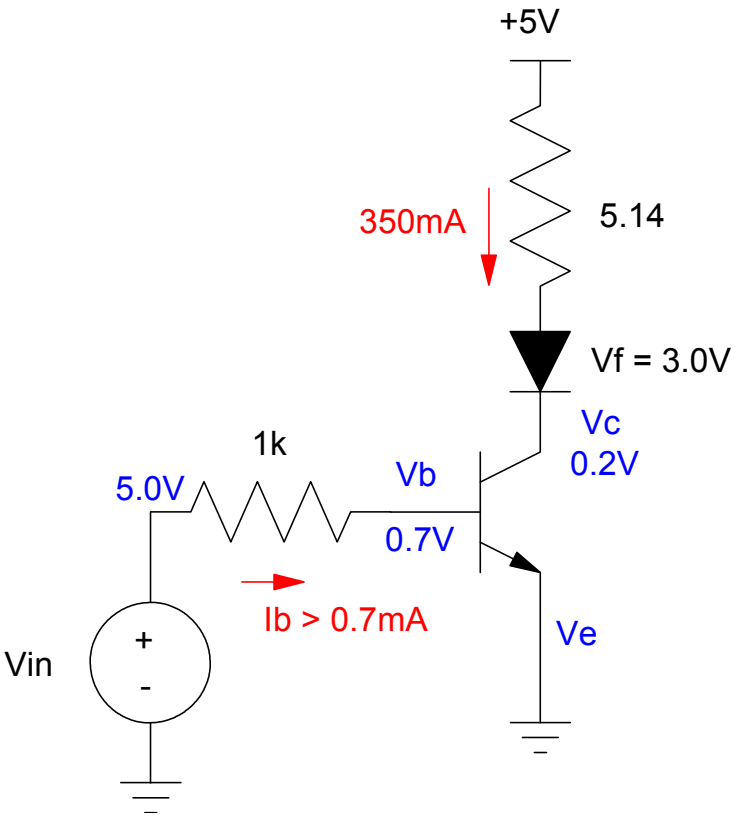
$$I_b = \frac{350mA}{500} = 0.7mA$$

To put you on th eedge of saturation

$$R_b = \frac{5V-0.7V}{0.7mA} = 6142\Omega$$

To make sure you're saturated, pick something smaller, say

Rb = 1k



7) Design a circuit so that a function generator can drive a 1/10th hp DC motor

- Input: 0V / 5V TTL square wave, 0.2Hz, < 20mA
- Output: DC Motor (Ra = 12 Ohms, Current < 1A)
- Relationship:
  - When the input is 0V, 0V is applied to the motor
  - When the input is +5V, +12V is applied to the motor (+/- 1V)

First, design a circuit to turn on the motor. Simply tie it to +12V DC.

Next, break the path to ground with a transistor used as an electronic switch.

To find Rb

$$\beta I_b = I_c$$

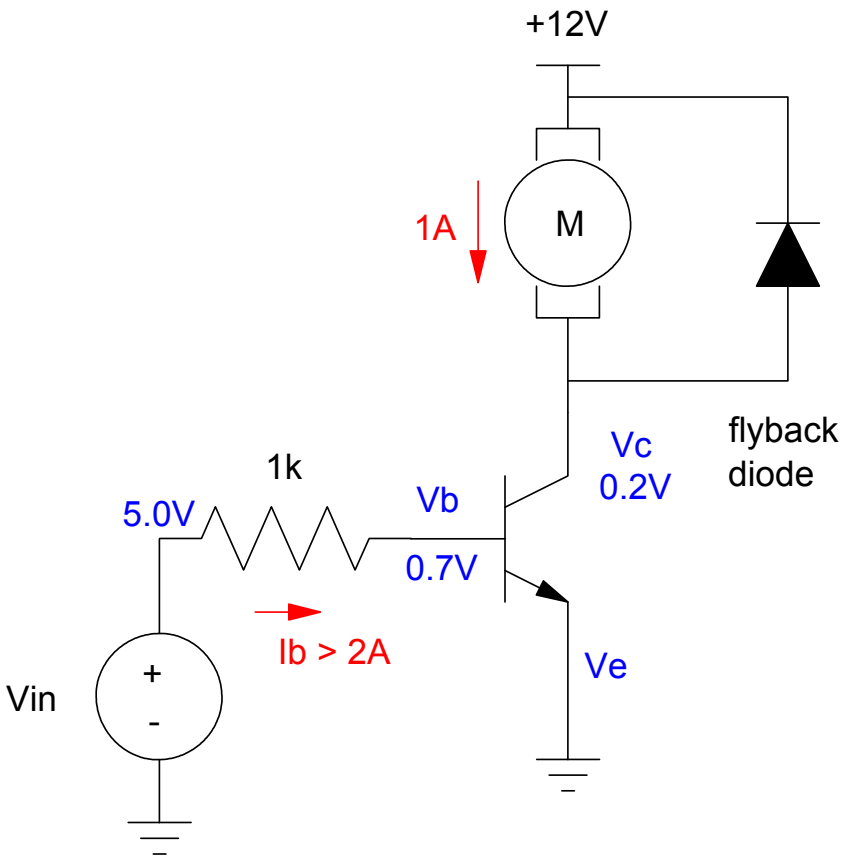
$$I_b = \frac{1A}{500} = 2mA$$

To put you on th eedge of saturation

$$R_b = \frac{5V - 0.7V}{2mA} = 2150\Omega$$

To make sure you're saturated, pick something smaller, say

Rb = 1k



Lab

8) Simulate one of these circuits (problem 5 / 6 / 7) in PartSim or similar program

9) Build this circuit in lab and collect data to verify your analysis

- Is the transistor off when Vin = 0V?
- Is the transistor saturated when Vin = 5V?

10) Measure and plot the the current (Ice) vs input voltage of 0V < Vin < 5V. Label on your plot when the transistor is in the off state / active state / saturated state