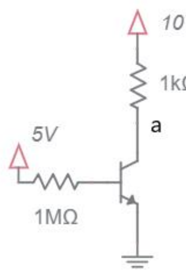
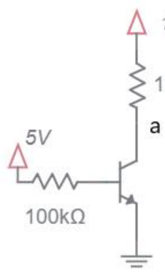
DC circuits with NPN BJTs and resistors

Determine the voltage at labeled nodes and determine i_c, i_b and i_e in the following circuit. If the BJT is in the active region, assume V_{be} = 0.7V, ß = 100, i_c=i_e. If the BJT is in saturation, assume that V_{ce} = 0.2V. Only compute ß when the BJT is in saturation. Round you answer to 2-significant figures and include units. If the circuit does not have the variable asked for in the table, leave that entry blank.



001



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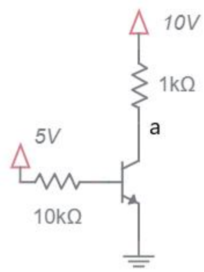

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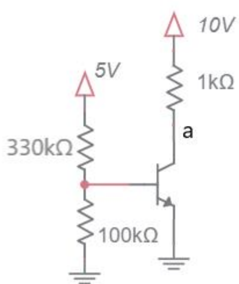

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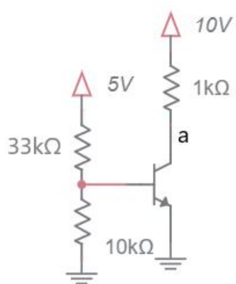

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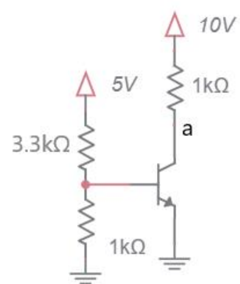

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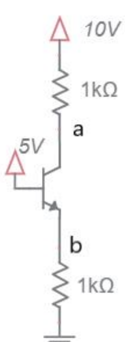

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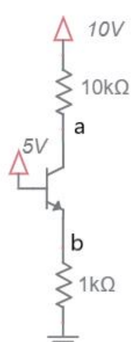

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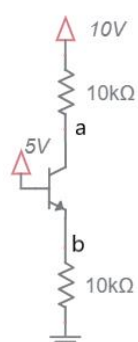

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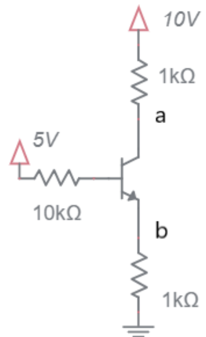

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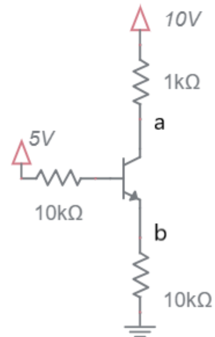

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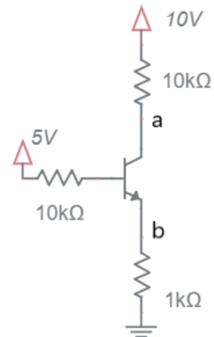

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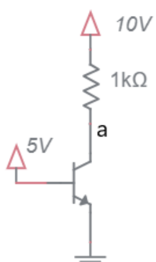

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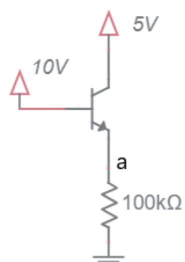

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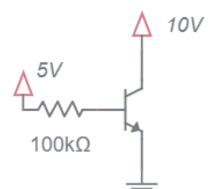

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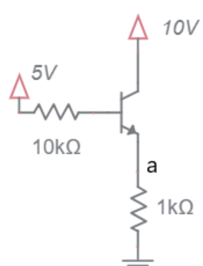

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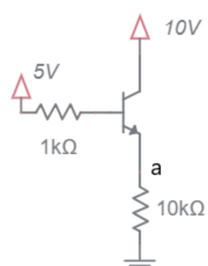

017

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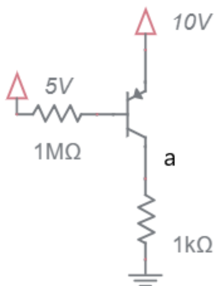
DC circuits with PNP BJTs and resistors

Determine the voltage at labeled nodes and determine i_c, i_b and i_e in the following circuit. If the BJT is in the active region, assume V_{eb} = 0.7V, ß = 100, i_c=i_e. If the BJT is in saturation, assume that V_{ec} = 0.2V. Only compute ß when the BJT is in saturation. Round you answer to 2-significant figures and include units. If the circuit does not have the variable asked for in the table, leave that entry blank.



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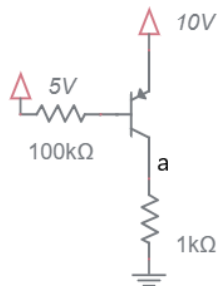

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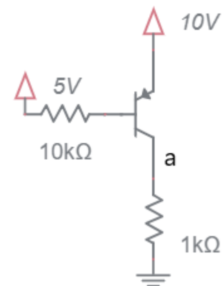

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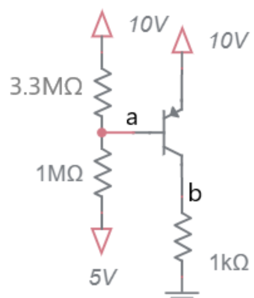

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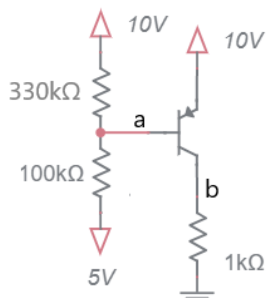

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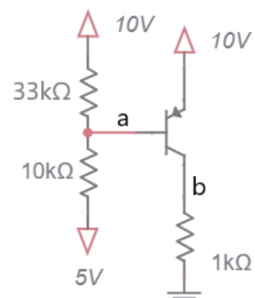

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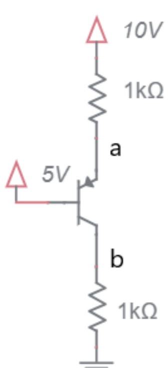

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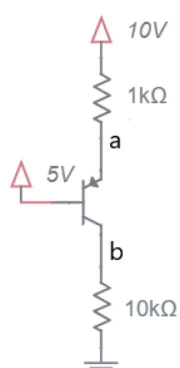

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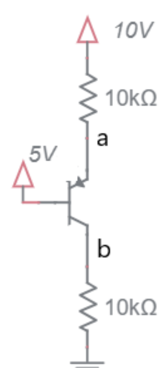

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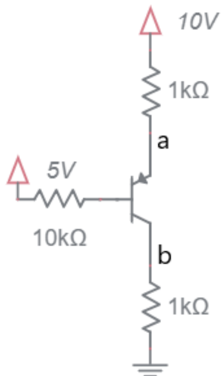

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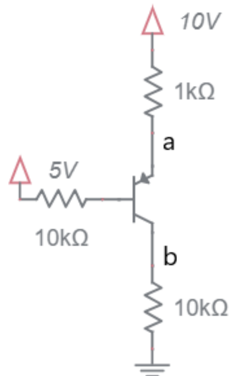

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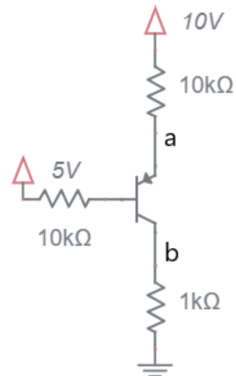

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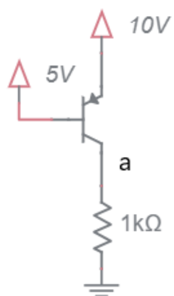

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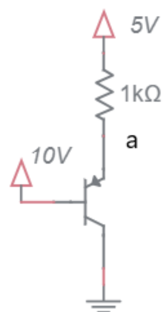

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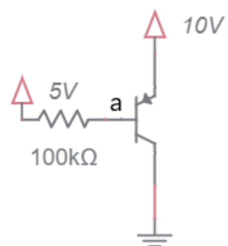

015

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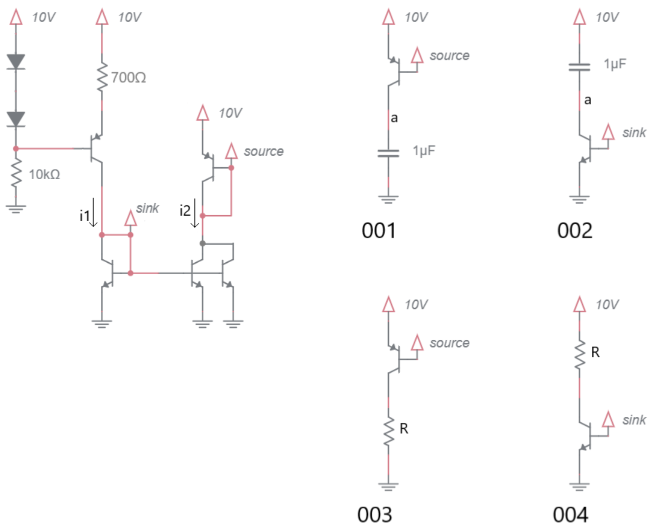
BJT Current Sources and mirrors

If the BJT is in the active region, assume V_{be} = 0.7V, ß = 100, i_c=i_e.



1. Determine the currents i1 and i2.
2. What is the range of resistance in the circuits 003 and 004 to keep their BJTs in the active region?
3. Plot the volage at point a in circuits 001 and 002 assuming the capacitor is discharge at time 0. You can use the following questions to help.
    a. Use the voltage/current equation for a capacitor to determine dv/dt for the capacitor.
    b. The initial voltage drop across the capacitors is 0V. What is the voltage at point a?
    c. The final voltage drop across the capacitors is 10V. What is the voltage at point a?

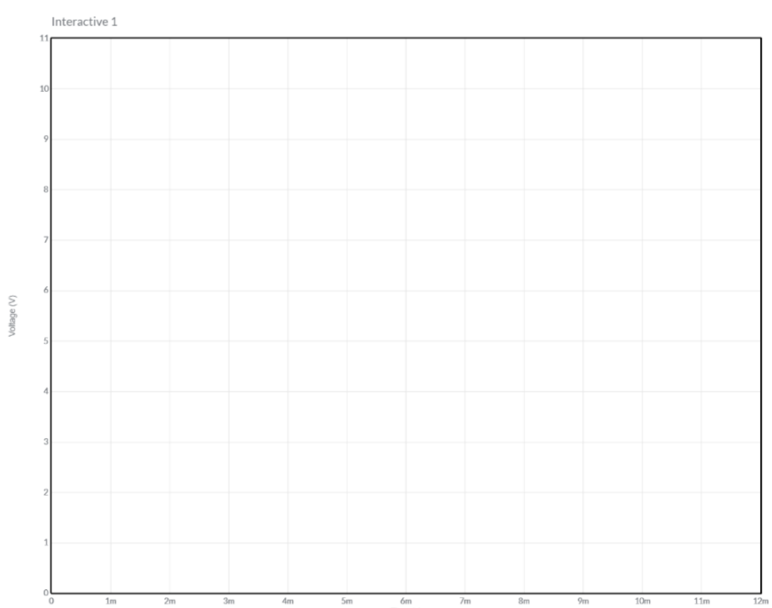
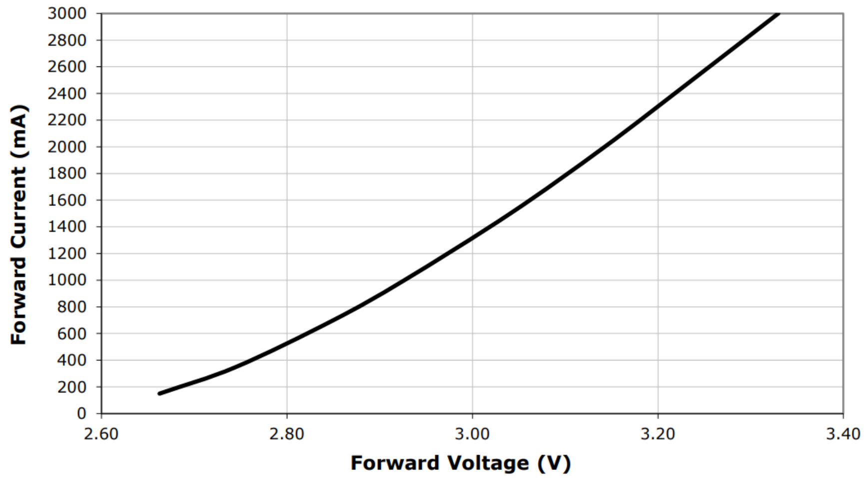


*Figure 1: Plot the voltage at node **a** for the circuits shown in 001 and 002*

Practical Application – Power dissipated by BJT

You are required to illuminate a Cree Xlamp XM-L2 High Power LED using a current source. The LED has a I vs. V curve is shown at left in **Error! Reference source not found.**. Your current source, shown at right in **Error! Reference source not found.**, uses a TIP31 (a high powered NPN transistor) and a 2.7V Zener diode. You need to run the LED at 2 amps.



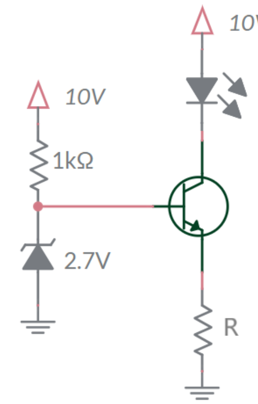


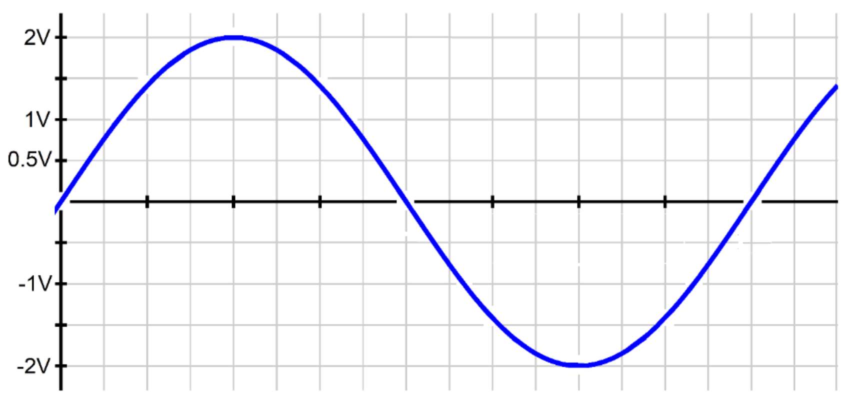
Figure 2: (Left) I/V curve for a Cree Xlamp XM-L2 High Power LED. (Right) The constant current source used to drive the LED.

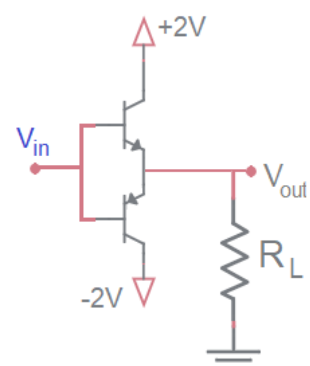
a. What is the emitter voltage?
b. What value of emitter resistor, R, will produce the needed 2A through the LED?
c. What is the voltage drop across the LED at 2A?
d. What is the power dissipated by the LED at 2A?
e. What is the power dissipated by the resistor R at 2A?
f. What is the voltage across the BJT at 2A?
g. What is the power dissipated by the BJT at 2A?

How can you reduce the power dissipation of the BJT while keeping 2A running through the LED? Do not change the circuit topology.

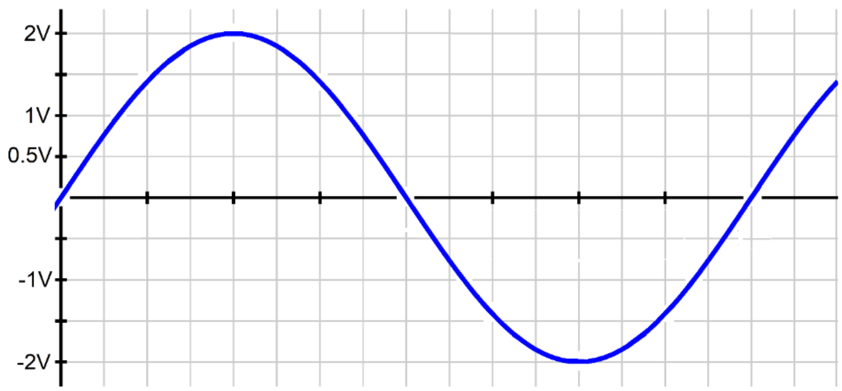
Practical Application - Cross Over Distortion

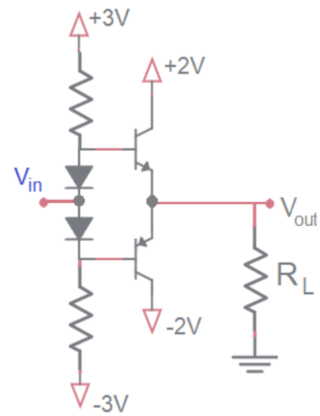
The blue sine wave shown in the graph below is applied as the input, V_{in}, to the circuit shown below at right. Determine the output, V_{out}, and graph it on the graph below. The value of the load resistor, R_L is unimportant.



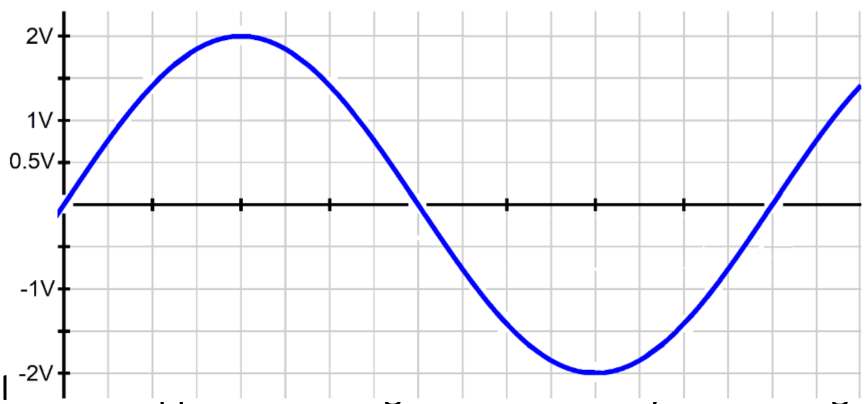


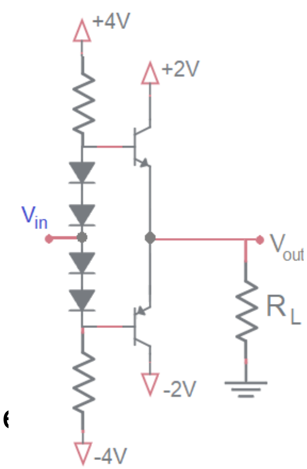
The blue sine wave shown in the graph below is applied as the input, V_{in}, to the circuit shown below at right. Determine the output, V_{out}, and graph it on the graph below. The value of the resistors are unimportant.





The blue sine wave shown in the graph below is applied as the input, V_{in}, to the circuit shown below at right. Determine the output, V_{out}, and graph it on the graph below. The value of the resistors are unimportant.

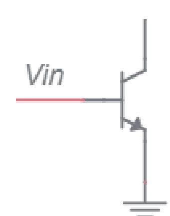




In the Ebers-Moll equation of a BJTs the collector current is described as

$$I_C = I_S e^{\frac{V_{BE}}{V_T}}$$

The I_S term, the reverse saturation current, is strongly temperature dependent. According to multiple sources, it doubles for every 10°C rise in temperature. This dependency can lead to thermal runaway in the common emitter circuit show at right. In the following questions assume that Vin is constant and that the BJT is operating in the active region.

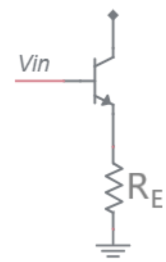


1. Look at the schematic at right, does the base emitter voltage depend on the collector current?
2. If the temperature of the BJT increases, does I_s increase or decrease?

3. If I_S increases, does I_C increase or decrease?
4. If I_C increases does the power dissipated by the BJT increase or decrease? Assume V_C is constant.
5. If the power dissipated by the BJT increases, does the temperature of the BJT increase or decrease?

From these inferences you should see that an increase in the BJT's temperature causes further increase in the temperature of the BJT – thermal runaway. This is an example of positive feedback – a tendency of a system to increase a parameter without bound. While you may like positive feedback, electrical systems can do bad things when they have too much positive feedback.

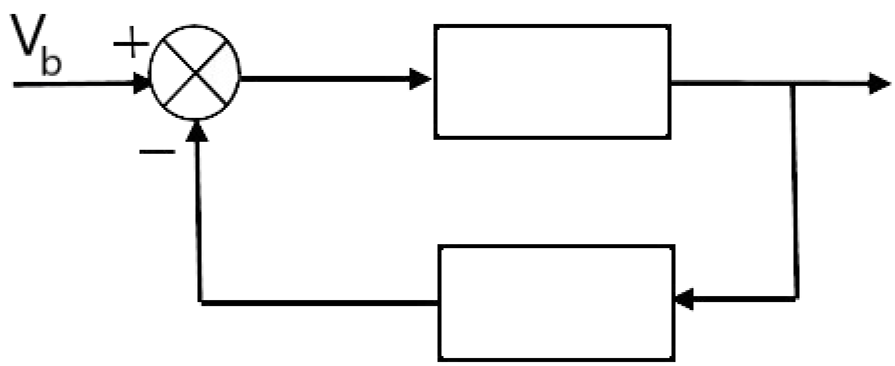
Now consider the circuit shown at right. This is a common emitter with emitter degeneration resistor. As we will see, the addition of a resistor to the emitter adds negative feedback which greatly decreases the tendency of the BJT to experience thermal runaway. In the following questions assume that Vin is constant and that the BJT is operating in the active region.



1. Look at the schematic at right. Does the base emitter voltage increase or decrease when the emitter current increases?
2. When the collector current increase, does the emitter current increase or decrease?
3. If the temperature of the BJT increases, does I_s increase or decrease?
4. If I_S increases, does I_C increase or decrease?
5. If I_C increases, does I_E increase or decrease?
6. If I_E increases, does V_E increase or decrease?
7. If V_E increases, does V_{BE} increase or decrease?
8. If V_{BE} decreases, does I_C increase or decrease?
9. If I_C decreases, does the power dissipated by the BJT increase or decrease?
10. If the power dissipated by the BJT decreases, does the temperature of the BJT increase or decrease?

The ability of the deceasing V_{BE} being able to keep the increasing I_S in check depends on the magnitude of the emitter resistor. If it the emitter resistor is too small, then the BJT may still exhibit thermal runaway. In that case, you should increase the emitter resistor until thermal runaway is kept in check.

Now, let's see if you can make a feedback diagram to describe this negative feedback using the diagram below.



1. Make the reference input equal to V_b
2. What must the inverting input to the summer junction be for the output of the summer junction to be V_{be}? Write this signal and V_{be} on the diagram.
3. Fill in the upper block with the RHS of the Ebers-Moll equation.
4. Label the output of the block diagram with the LHS of the Ebers-Moll equation. This should make sense because the Ebers-Moll equation is a bunch of constants with two variables.
5. Fill in the lower block with an equation which converts the block diagram output into the variable used in the inverting input to the summer junction. Hint, its Ohm's law.

This block diagram shows the If I_S variable on the forward path and the R_E variable on the backward path. The interplay between these two determines the thermal stability of the common emitter with emitter degeneration resistor circuit.