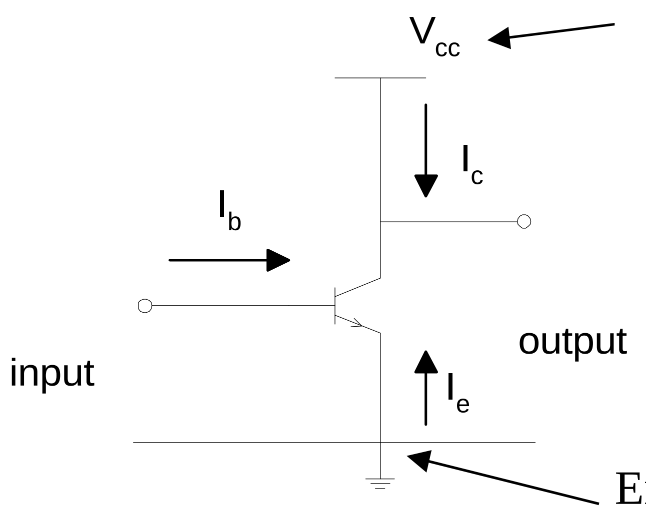
Transistor as an Amplifier

- How do we use the transistor as an amplifier?
- First, we must connect it appropriately to the supply voltages, input signal, and load, so it can be used
- A useful mode of operation is the common-emitter configuration

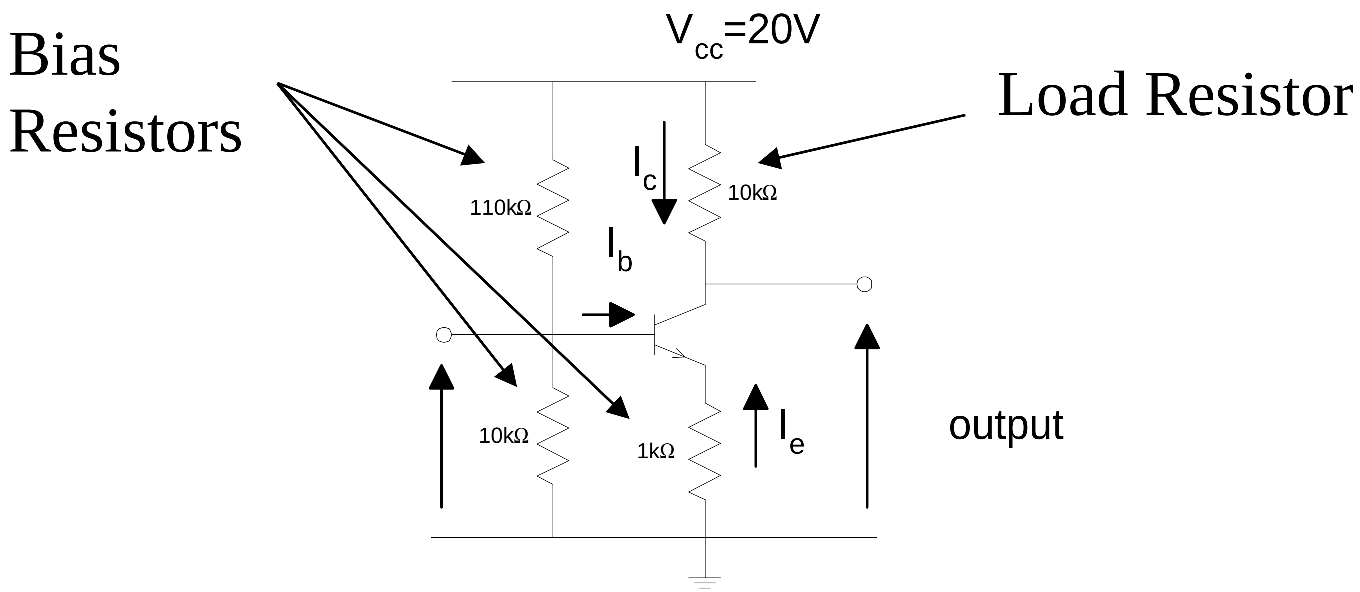


Voltage connected to collectors - positive supply voltage

Emitter common to both input and output

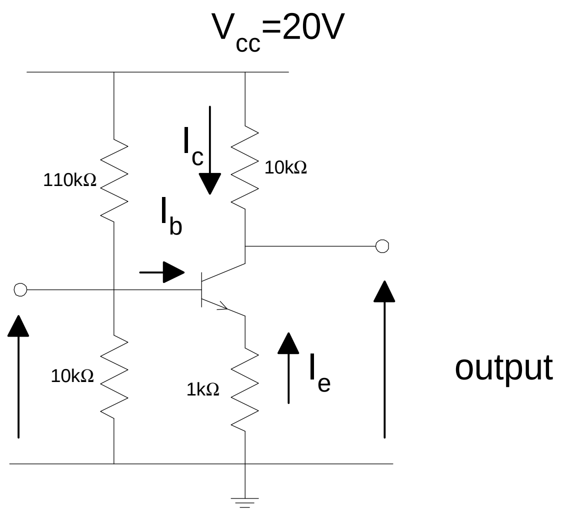
Common Emitter Configuration

- To make a practical circuit, we have to add bias and load resistors to ensure the transistor is at the desired operating point (operating in the right current range)

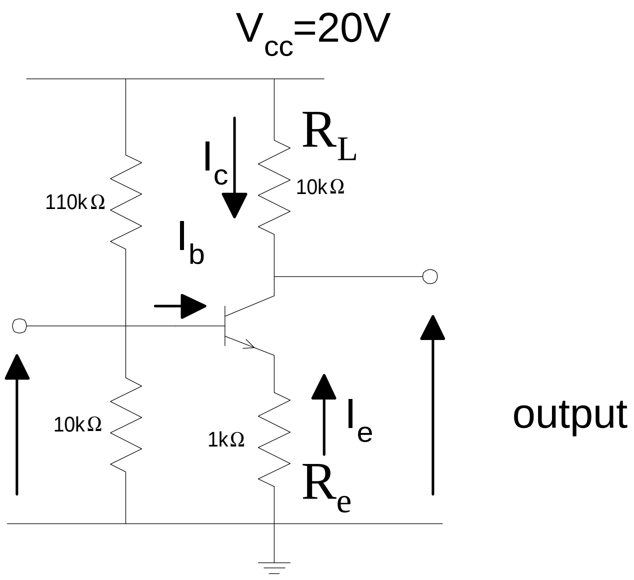


Bias and Load Resistors

- The resistors connected to the base ensure that the BE junction is forward biased. They effectively form a potential divider to reduce the voltage supplied to the base.
- The emitter resistor work with the base resistors to stabilise the operating point wrt variations in β due to component variation and temperature by providing negative feedback.
- Finally, the collector resistor provides the load



Circuit Analysis



- Assume I_b is small so can be neglected
- Current through base resistors is 20/(110+10) =1/6 mA
- Voltage at base =1/6 * 10 ≅ 1.7V
- Therefore EB junction is forward biased
- Voltage at emitter ≅ 1.7-0.7=1.0V
- Current I_e = -1.0mA
- Current Ic = -αIe ≅ -Ie =1.0mA
- Voltage at collector = 20 -1*10=10V
- We usually set the collector voltage to be halfway between V_{cc} and 0V

- A number of approximations have been made, but a more careful analysis will yield much the same result

How it works

- A signal, such as music from a CD player, is applied to the input
- Let's examine what happens when such a signal increases the base voltage by ΔV_{in}.
- The emitter voltage is always 0.7V below V_b, so if V_b changes by ΔV_{in} , so does V_e.
- Thus the emitter current increases by $\Delta V_{in} /R_e$.
- But $I_c=-\alpha I_e \cong -I_e$, so it also increases by $\Delta V_{in} /R_e$.
- Thus the voltage at the collector will increase by $-\Delta V_{in} R_L/R_e$ (that is, it will decrease)
- In this case R_L/R_e is 10, so the circuit amplifies the input voltage signal by a factor of -10.
- In general, the gain is $-R_L/R_e$. The negative sign indicates that a increase in input voltage leads to a decrease in output voltage.
- This is an example of an inverting amplifier

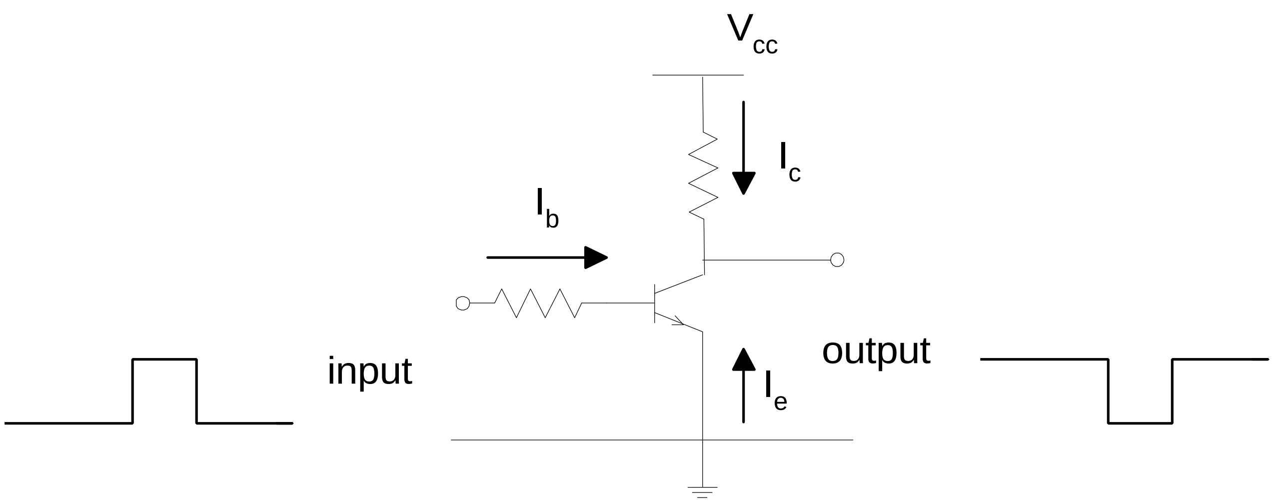
Do You Want More?

- If you want more gain, you can can connect the output of one amplifier stage to the input of another resulting in an overall gain of 10x10=100.
- Another way to increase gain is to decrease R_L or decrease R_e, but other factors come into play which limit this approach.
- For AC (e.g. music) signals, another method to increase the gain is to put a capacitor in series with R_e.
- This effectively shorts R_e at high frequencies and leads to large increases in gain.

- Detailed design issues will be covered in 3E202 in second year.
- If you want even more gain, use an op amp (see later)

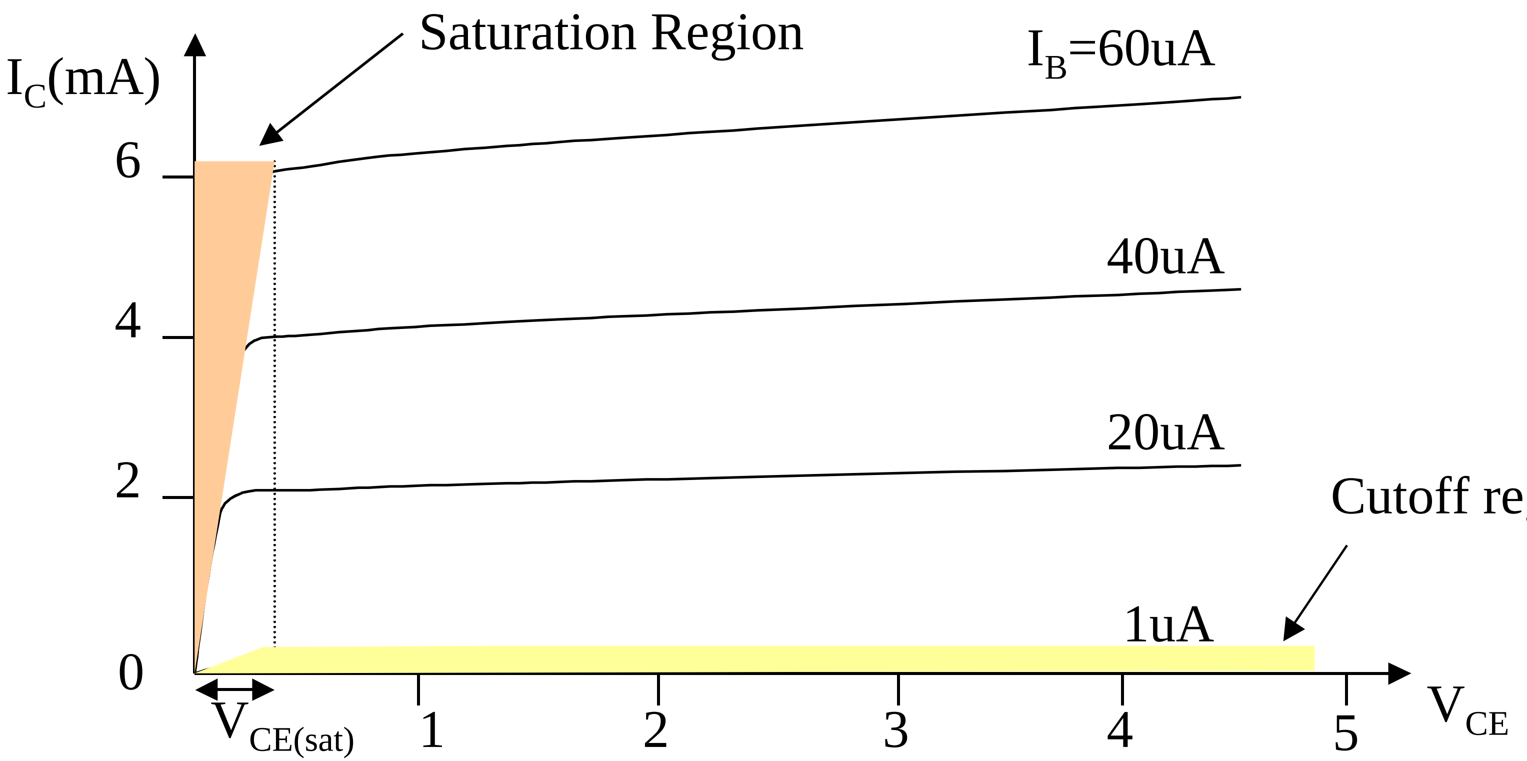
Transistor as a Switch

- In many digital circuit applications, the transistor is merely used as a switch.
- This means we can ignore fancy biasing circuitry and just turn the device off (*cut-off region*) or on (*saturation region*)
- Some early digital circuitry used resistors and transistors as indicated (RTL)

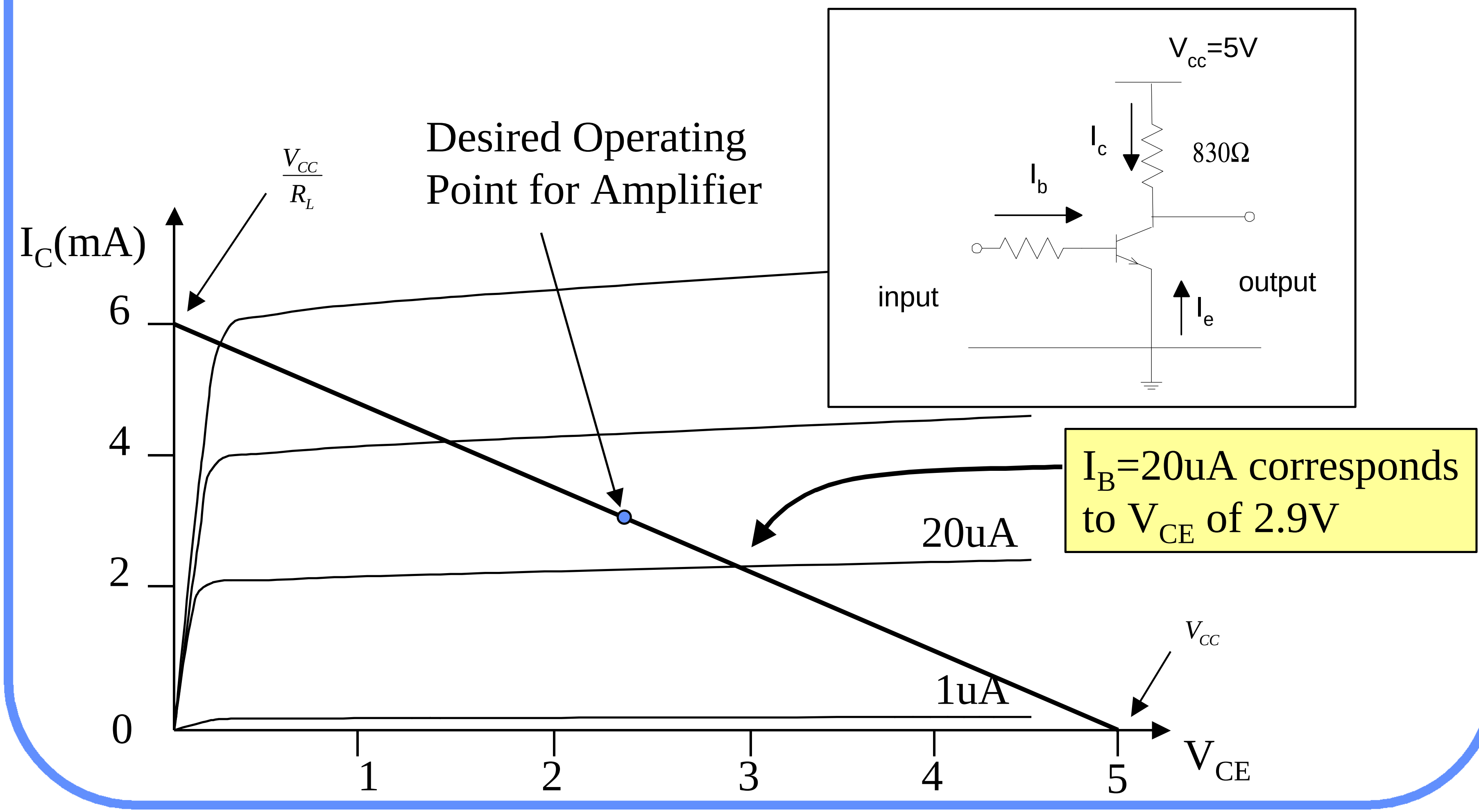


Characteristic Curves

- Characteristic curves fully describe the operation of a transistor



Load Lines

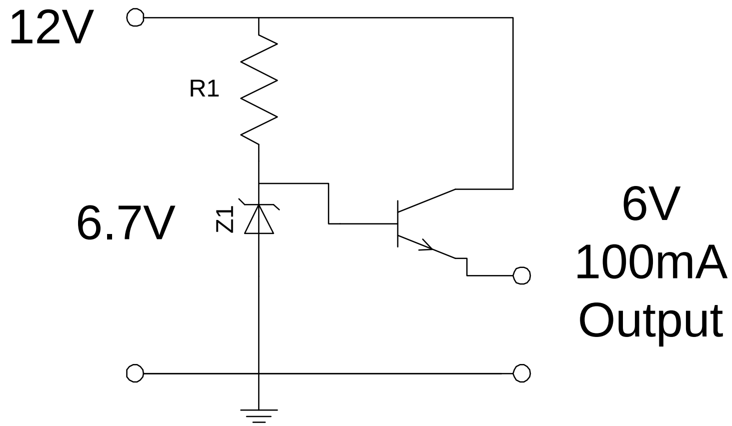

$\frac{V_{CC}}{R_L}$
Desired Operating Point for Amplifier
I_C(mA)
6
4
2
0
20uA
1uA
V_{CC}
1
2
3
4
5
V_{CE}
V_{cc}=5V
I_c
830Ω
I_b
input
output
I_e
I_B=20uA corresponds to V_{CE} of 2.9V

Comments

- For an amplifier, we want the transistor to operate in the linear region between cutoff and saturation.
- For a switch, we drive the transistor between cutoff and saturation regions.

Improved Voltage Regulator

- Buffer regulated zener diode output with transistor in *emitter follower* (common collector) configuration.
- Current output from zener boosted by β (50-200)
- Less current drawn in standby mode
- Need to boost zener voltage by 0.7V.



Relay Driver

- Here the transistor is used as a switch to close relay contacts by driving the coil.
- Note the need for the *flyback* diode to prevent damage to the transistor from the high voltages created by the coil when the current is switched off.