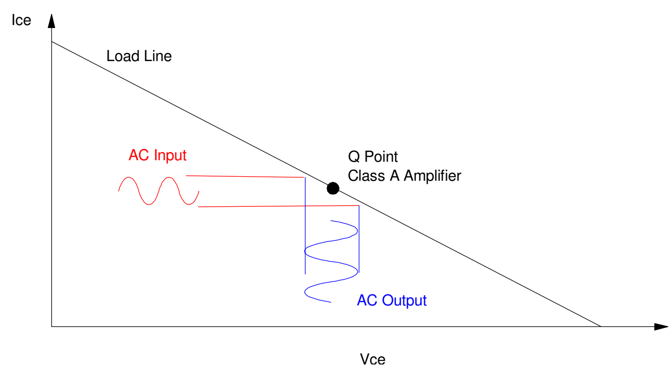
Push-Pull Amplifiers

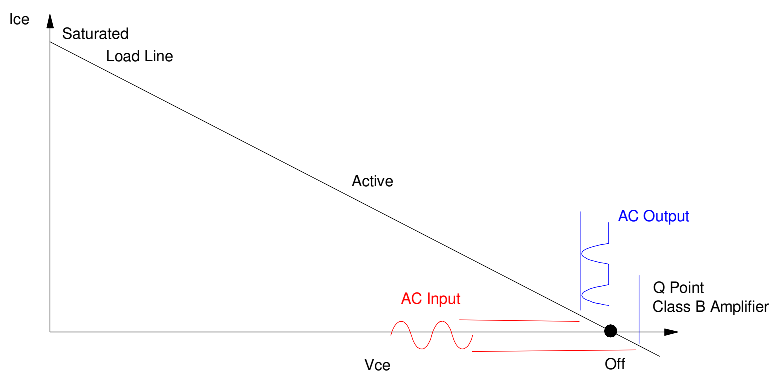
Background:

The amplifiers we have been looking at are termed Cass-A amplifiers. They bias the transistor in the active region, and vary the operating point on the load-line according to the AC input.



A problem with Class-A amplifiers is they are very inefficient: with no input signal (and hence no output power), they still consume power to bias the transistor.

A Class B amplifier (termed a push-pull amplifier) biases the transistor so that it is off when there is no AC input. This results in a much mor efficient amplfier - but it also results in a sine wave that is clipped.



To prevent clipping, a second transistor is used to suply the missing half of the sine-wave output.

Push-Pull Amplifier

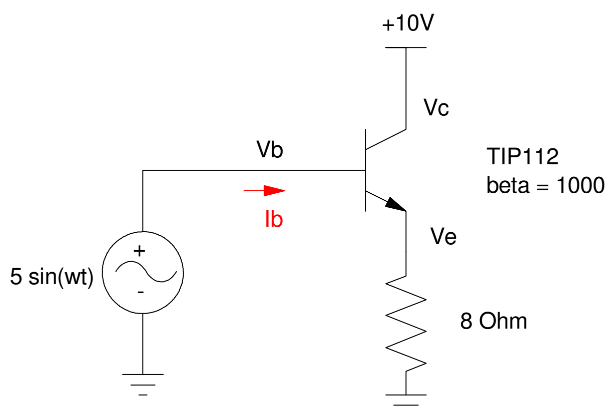
Problem: Drive an 8-Ohm speaker where the voltage at the speaker (Vout) follows the voltage at the input (Vin)

Input: 0..10V analog signal, capable of 20mA (i.e. a function generator)

Output: 8 Ohm speaker

Relationship: Y = X

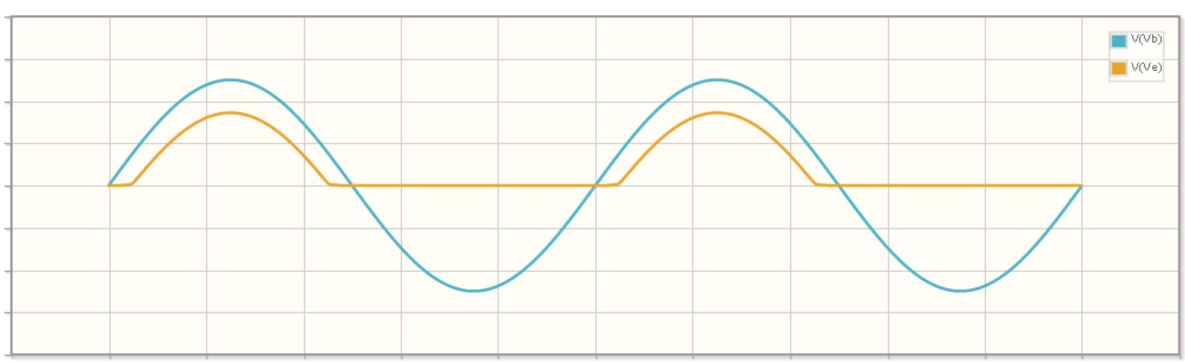
Solution (+ input): In digital electronics, we use a transistor with the load on the collector side. In analog electronics, we place the load at the emitter.



What this does is

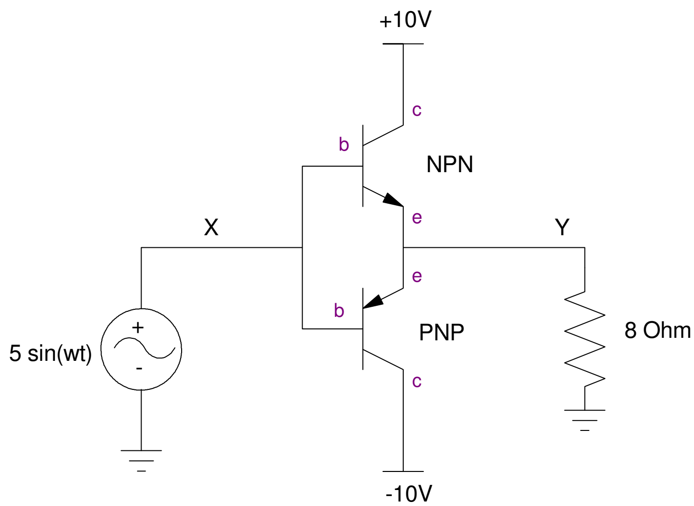
- When Vb > 0, Ve follows Vb up and down, minus a 1.4V drop across Vbe
- When Vb < 0, the diode turns off and Ve = 0.

In CircuitLab, you can see this:

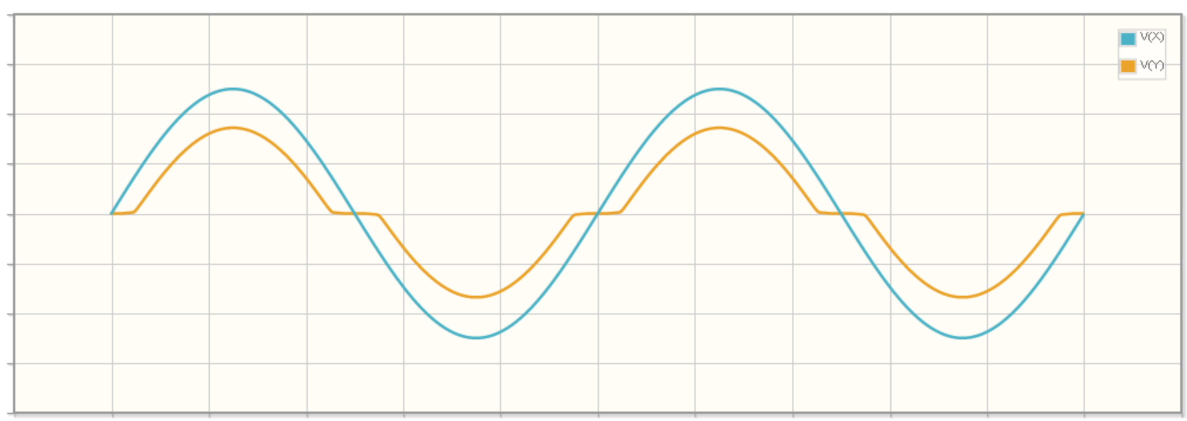


CircuitLab simulation of the push-pull amplifier. Note that only the positive portion works and that the output lags by 1.4V (Vbe)

To follow the negative half of the sine wave, add a PNP transistor:



This results in Y following X, lagging behind by 1.4V (Vbe).



CircuitLab simulation of the push-pull amplifier. Note there is cross-over distortion when you go from push (+) to pull (-)

To remove the cross-over distortion, add an op-amp.

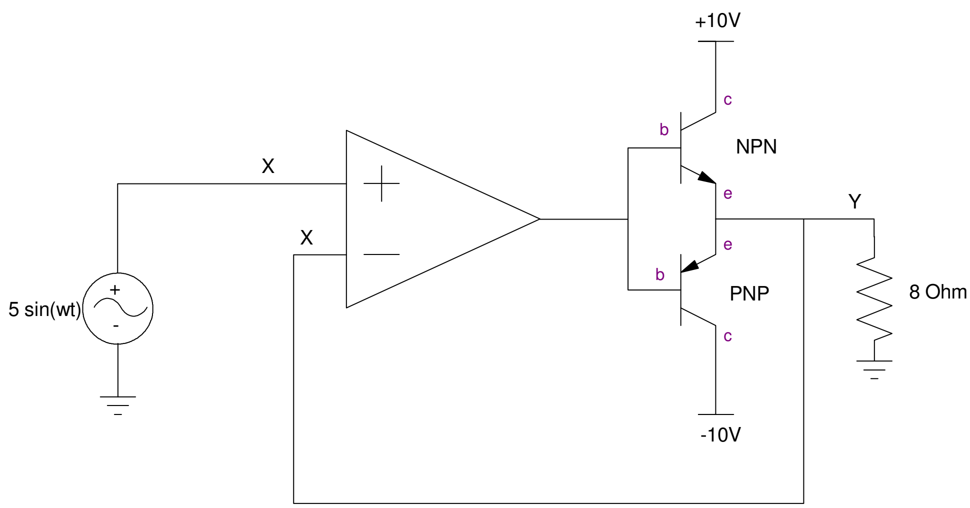
- With negative feedback, you have

  Vp = Vm

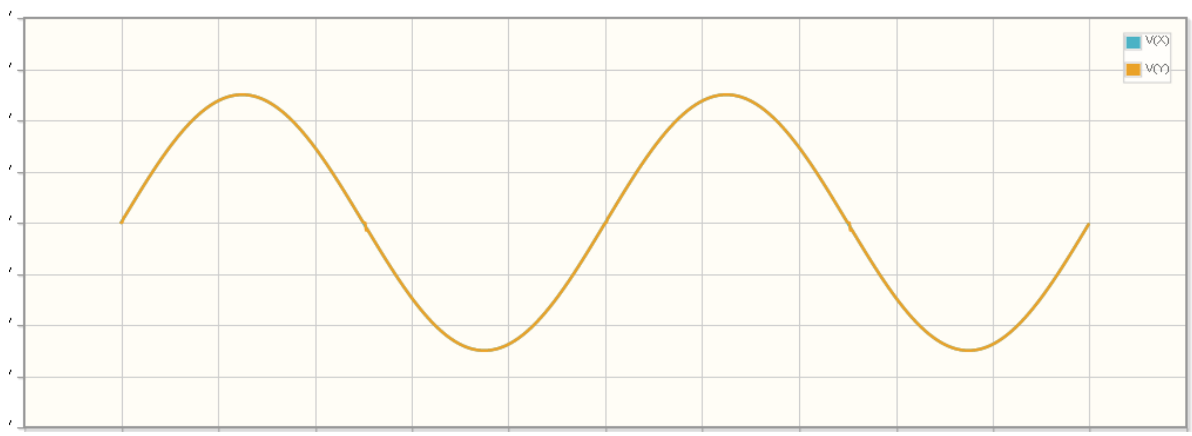
- Connect the negative feedback to the output and you get

  Y = X

(i.e. the cross-over distortion is removed)



The result from CircuitLab is



CircuitLab Simulation: Note that Y = X (i.e. the cross-over distortion is removed).

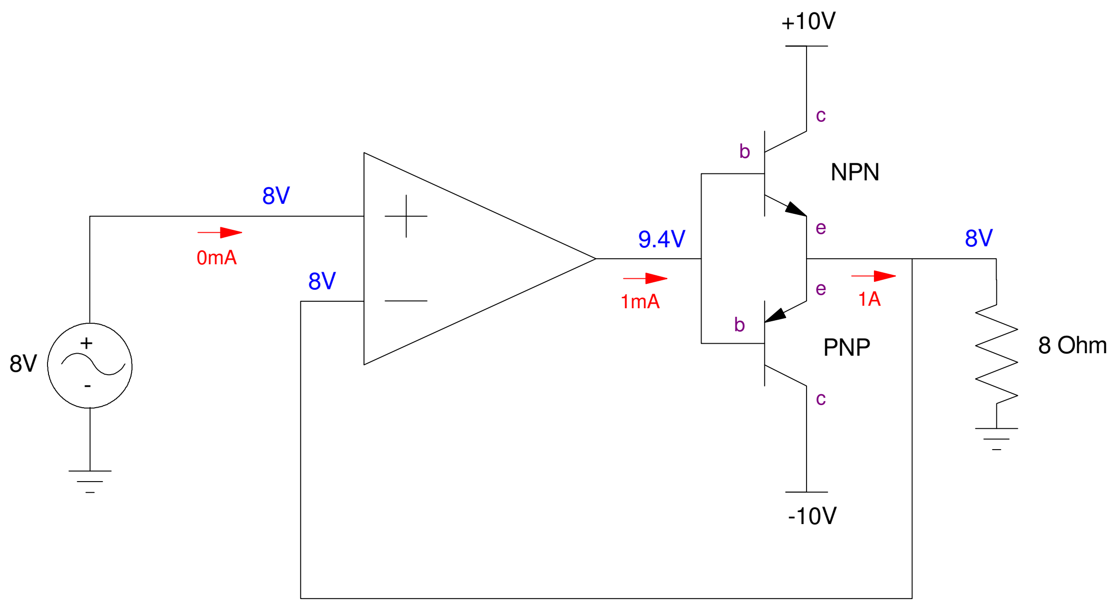
While this may seem silly (all this for a gain of one), there is an amplification in current (and power). Assume to get numbers that

X = 8.00V

The currents are then

- I3 = 1.00A (8V @ 8 Ohms)
- I2 = 1.00 mA (β = 1000)
- I1 = 0.00 mA (ideal op amp)

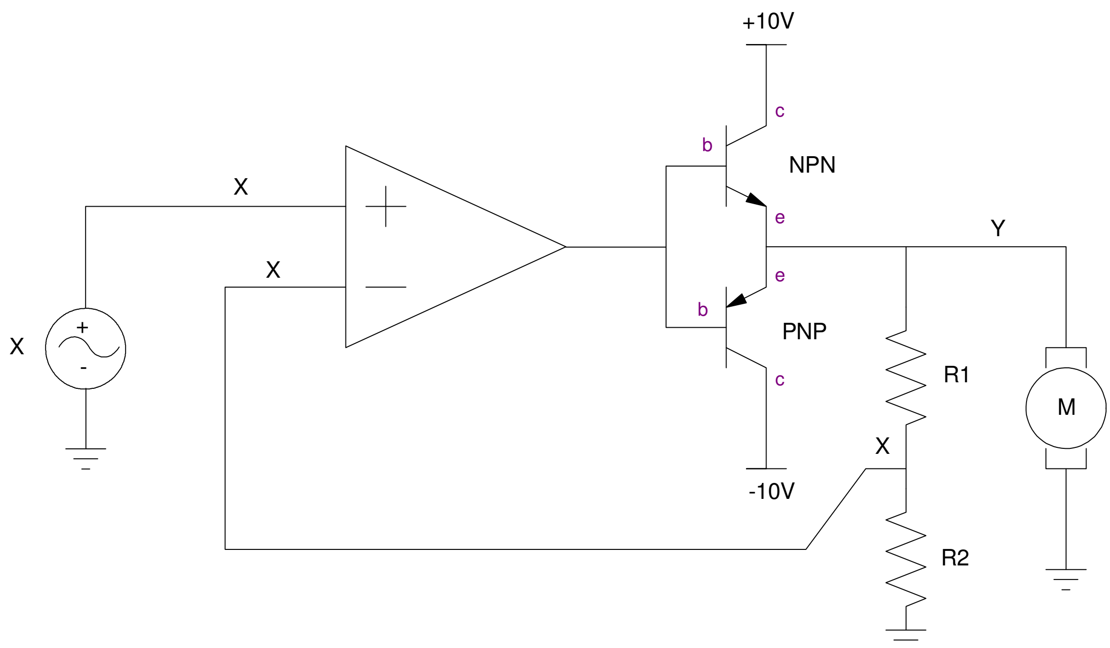
This circuit acts as a buffer: it takes a +/- 10V analog signal which is not capable of much current and drives an 8 Ohm speaker at up to 1A (limited by the 10V power supply).



Push-Pull Amplifier: Voltage Output

For DC motors, voltage is speed (approximately). If you add a voltage divider at the output, you can get voltage amplification:

$$Y = \left(1 + \frac{R_1}{R_2}\right) X$$



Push-Pull Amplfier: Current Output

For DC motors, current is torque. For LED's, current is brightness. The following circuit sets

$$I_m = \frac{X}{1\Omega}$$

so 1V in means 1A at the motor.