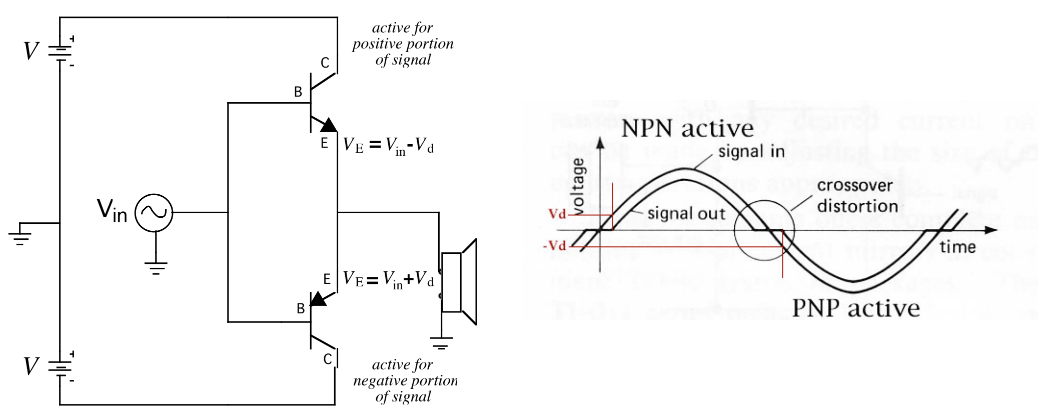
Push-Pull Transistor Amplifier

Class A Amplifier

Class A operation (like the common-emitter/common-collector transistor circuits previously discussed) is defined by having a bias level that maintains an output current at all times, irrespective of the input signal level. This is typical of small signal amplifiers and results in a low distortion output. Amplifier circuits designed to deliver large output currents capable of driving low impedance loads result in transistor heating and without proper heat sinking thermal runaway can cause destruction of the amplifier circuit. Because of the need for large output current it becomes impractical and inefficient to run the transistors such that they only operate over a very small proportion of their available range. This is the how all small signal amplifiers produce approximately linear characteristics.

Class B Amplifier

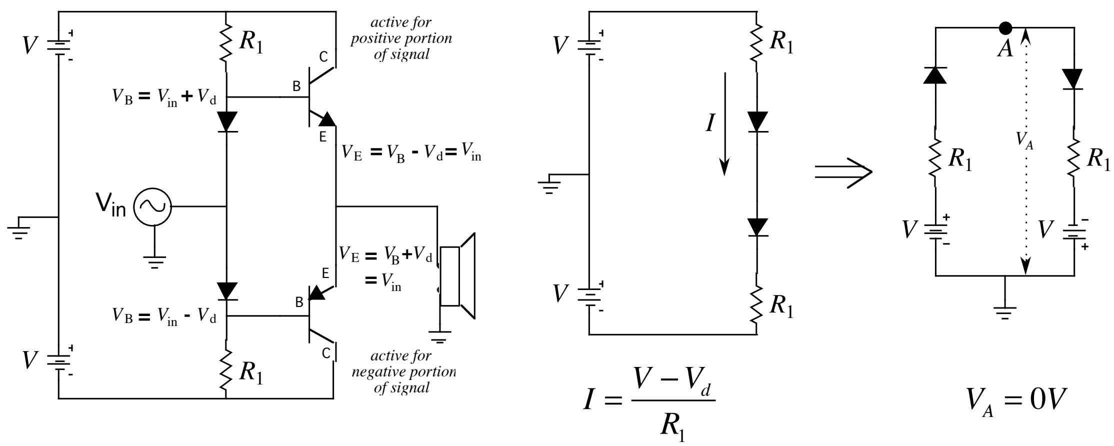
Most audio power amplifiers use a Class B configuration which employs two common-collector (emitter-follower) stages as displayed in Figure 1, where one transistor provides power to the load during one-half of the waveform cycle (it pushes) and a second transistor provides power to the load for the other half of the cycle (it pulls). Neither transistor remains on for the entire cycle, giving each transistor time to rest and cool during the waveform cycle. This makes for a more power-efficient amplifier circuit, but leads to a distinct type of nonlinearity known as *crossover distortion.* Distortion occurs because there is a delay between the time one transistor turns off and the other transistor turns on. There will be no output signal until $|V_{in}| \geq 0.6V$.



a) b)

Figure 1

One common approach to remove crossover distortion is to insert a base biasing network as displayed in Figure 2. This method biases the transistors so that their turn-on/off points actually overlap. That is, both transistors are in a state of conduction for a brief moment during the crossover period. The addition of the resistor and diode effectively raises the base voltage a diode drop above/below the emitter junction of the NPN/PNP transistors. Thus, each transistor is biased so that their quiescent currents are just on the verge of turning on when $V_{in} = 0$. This form of amplification is technically known as Class AB rather than Class B, because each transistor is on for more than 50% of the time during a complete waveform cycle. A disadvantage is increased power consumption of the amplifier circuit.



if all components are identical

a) b)

Figure 2

As transistors heat up their V_{BE} forward voltage drops decrease (from ~0.6V down to ~0.5V or lower). (In addition, β and junction resistances are temperature dependent.) The diodes are not subject to the same heating effect because they do not conduct any substantial current and thus, do not experience the same change in forward voltage drop. The diodes continue to supply a 0.6V voltage drop even though the transistor requires less bias voltage ($V_{BE} < 0.6V$) due to heating. Thus, the circuit drifts into Class AB operation where both transistors will be in a state of conduction part of the time. This causes more heat dissipation through the transistors, adding to the problem of forward voltage drop (V_{BE}) change.

A common solution is to insert temperature-compensation feedback resistors in the emitter legs of the push-pull amplifier as displayed in Figure 3 (just as we did for the common-emitter circuit). This doesn't prevent simultaneous turn on of the two transistors but does reduce the severity of the problem and helps prevent thermal runaway. Unfortunately, the addition of the emitter resistors limits the output current of the amplifier (care should be taken in choosing the wattage for the emitter resistors). In addition, placing the biasing diodes in close proximity to the transistors can help reduce thermal runaway.

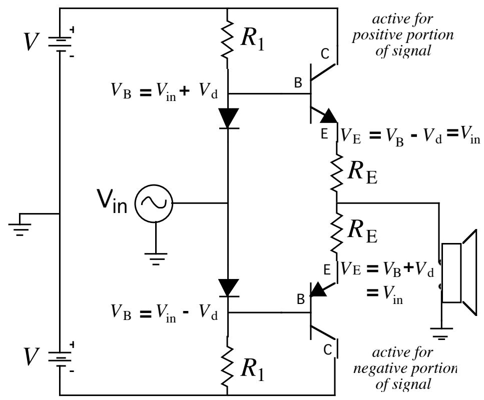


Figure 3

Class AB Amplifier

A Class AB output stage is biased to carry a quiescent current significantly less than half the maximum output current (as needed by a full Class A amplifier) but sufficient to keep both transistors running in Class A mode for small input signals. As the input signal increases the amplifier circuit becomes Class B with one transistor cutting off on each half cycle. This biasing scheme effectively moves the two V_{BE} curves toward one another resulting in a transfer curve that is more linear as it passes through the origin (0V). This scheme approaches the efficiency of a Class B yet offers Class A distortion levels for small output levels. Distortion is reduced at small signal levels where the human ear is most sensitive to distortion.