Work-Ready Electronics

Synchronizing Curriculum to the Rapidly Changing Workplace

Module: Switching Amplifiers

WORKREADY ELECTRONICS

Switching Amplifiers

Switching amplifiers are amplifiers that use switching techniques instead of linear bias operation to perform power amplification. Their most common use is in audio power amplifiers; however, they are also used as RF power amplifiers in some radio transmitters.

Switching amplifiers have grown in popularity over the years because of their very high efficiency, low heat, and small size. They are replacing standard linear audio power amplifiers in many audio applications, especially in portable and mobile equipment using battery power.

At one time, switching amplifiers were a special form of amplification. But today, thanks to modern MOSFET technology, switching amplifiers have become a mainstream circuit.

What Technicians Need to Know

Two basic types of amplifiers: linear and switching

Types of switching amplifiers

Switching amplifier operation

Advantages and disadvantages of switching amplifiers

Applications of switching amplifiers

Switching amplifier troubleshooting

Amplifier Fundamentals

Classified by Signal

Small signal amplifiers are the most common. They are used to boost the voltage level of very small signals in the microvolt or millivolt range. Small signals are those with amplitudes up to about 1 or 2 volts.

Large signal amplifiers amplify signals of many volts and are usually classified as power amplifiers. Power amplifiers are those that must drive heavy loads. The most common power amplifiers are those that drive loud speakers in audio applications, motors, long cables in communications systems, or antennas in radio transmitters.

Classification by Application

Application is usually defined by the frequency of operation.

Audio amplifiers are power amplifiers used in stereo systems, TV sets, radios, cell phones, MP3 players, public address systems, and audio signals in the 20 Hz to 20 kHz range.

Radio frequency (RF) amplifiers are used in radio transmitters and receivers. The frequency range is about 1 MHz to many 100 GHz.

Video amplifiers are used to amplify signals representing video or TV pictures. The frequency range is DC to hundreds of MHz.

Direct current (DC) amplifiers amplify direct current and are used to operate motors or other heavy loads like actuators or heating elements.

Comparing Linear and Switching Amplifiers

Linear amplifiers have an output that is directly proportional to the input. The transistors are biased in the linear region of their characteristics. They accurately reproduce the input signal at a higher voltage or power level.

Switching amplifiers use special techniques that employ transistors as on-off switches. Switching amplifiers are more efficient than linear amplifiers because the transistors are either not conducting or conducting very hard so they have a very low resistance. These conditions use less power and generate less heat.

Classes of Amplifiers

Class designation defines how an amplifier is biased to conduct in reference to the conduction of a sine wave input signal.

- **Class A** amplifiers conduct continuously for the complete sine wave input cycle of 360°.
- **Class B** amplifiers conduct for only one half cycle or 180°.
- **Class AB** amplifiers conduct for just over 180°.
- **Class C** amplifiers conduct for less than 180° degrees and are used as an RF amplifier with a resonant circuit to provide a sine wave output.
- **Classes D and S** are switching amplifiers that are either off or on and use pulse width modulation for DC and audio amplification.
- **Classes E and F** are switching amplifiers used in radio transmitters.

Amplifier Performance

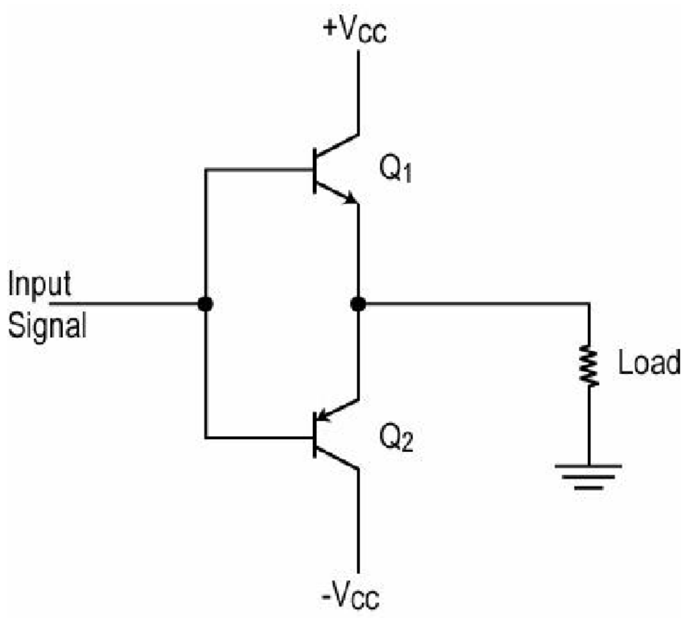
Amplifier performance is specified by gain, frequency response, the power output, efficiency, and the total harmonic distortion.

- **Gain** is the ratio of power output (P_o) to power input (P_i) where gain A is P_o/P_i. Gain can also be expressed in decibels (dB) where dB = 10logA.
- **Frequency response** is the operating frequency range of the amplifier, usually in the 20 Hz to 20 kHz range for audio or a fixed frequency with a narrow bandwidth for RF.

Amplifier Performance

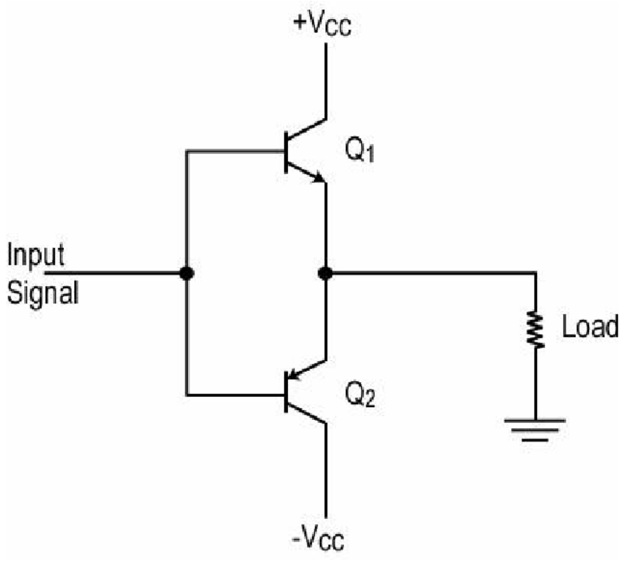
- **Power output** is the amount of power capable of being supplied to the load usually expressed in watts or dBm for RF amplifiers.
- **Efficiency** is the ratio of power output to total DC power input. This is a measure of how much power is converted to useful output power versus the amount of power dissipated as heat.
- **Total harmonic distortion (THD)** is the percentage of harmonic power to signal power in the output expressed in dB.
- **TDH+N (noise)** is the measure of how much harmonic distortion and noise is contained in the output compared to the actual audio signal. It is the ratio of harmonic and noise power combined to the output power expressed as a percentage.

Complementary Symmetry Amplifier



A discussion of this graphic is presented in the pages that follow. You can print this graphic for study purposes before going on.

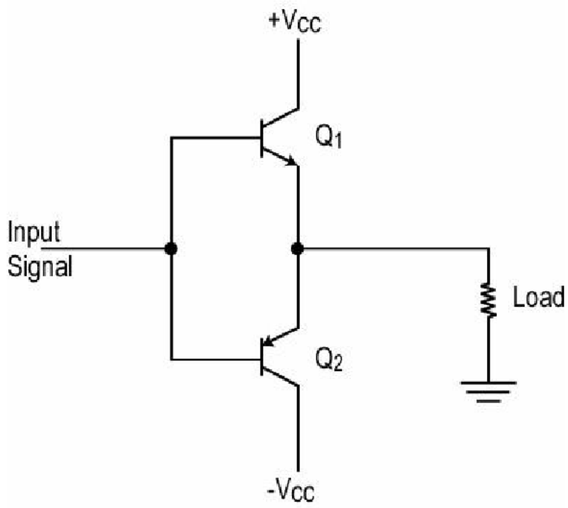
Complementary Symmetry Amplifier



A complementary symmetry amplifier is a good illustration to show the characteristics and limitations of linear power amplifiers. It is used in over 90% of all linear power amplifier applications.

It uses NPN and PNP transistors as emitter followers in a push pull configuration. The circuit does not have a transformer.

Complementary Symmetry Amplifier

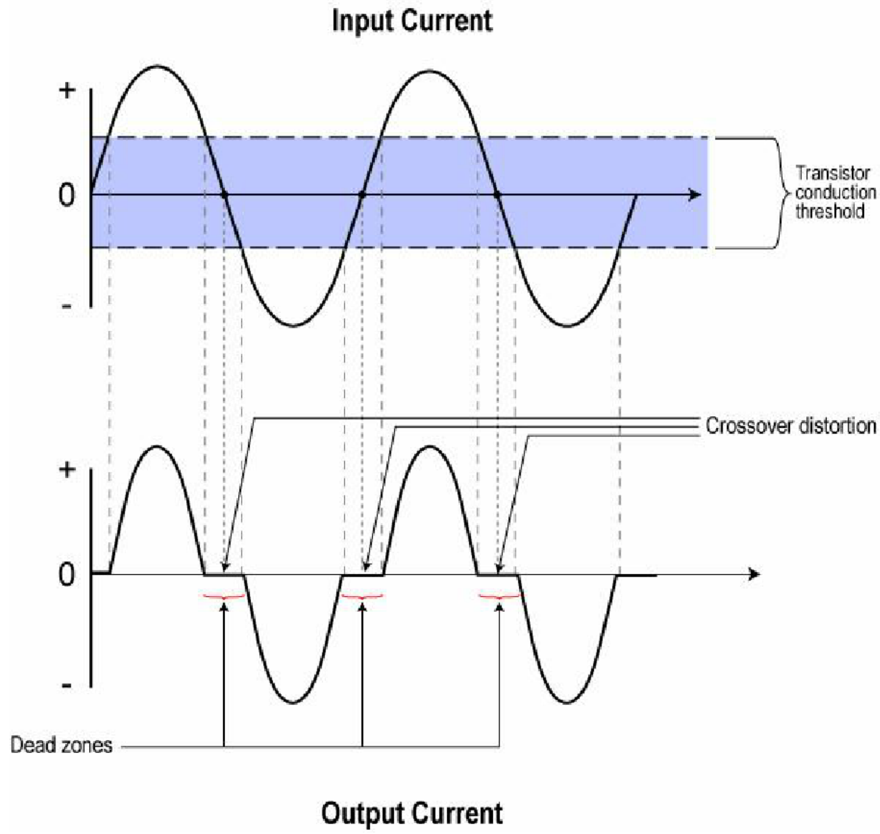


The circuit operates as a class B amplifier. The NPN transistor conducts on the positive half cycles and the PNP transistor conducts on the negative half cycles.

The output appears across the load.

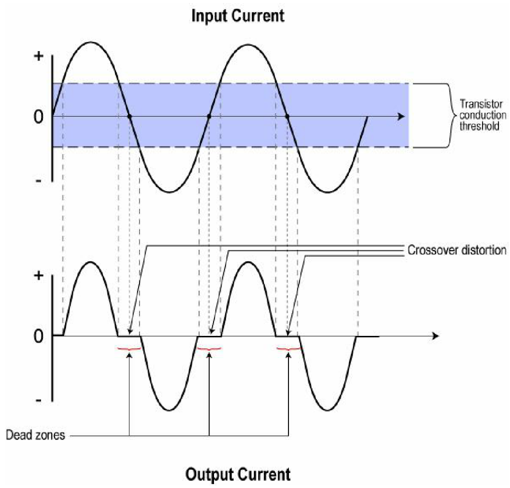
It is a good power amplifier because the emitter follower has a high input impedance, low output impedance, and a unity voltage gain.

Disadvantages Illustration



A discussion of this graphic is presented in the pages that follow. You can print this graphic for study purposes before going on.

Disadvantages



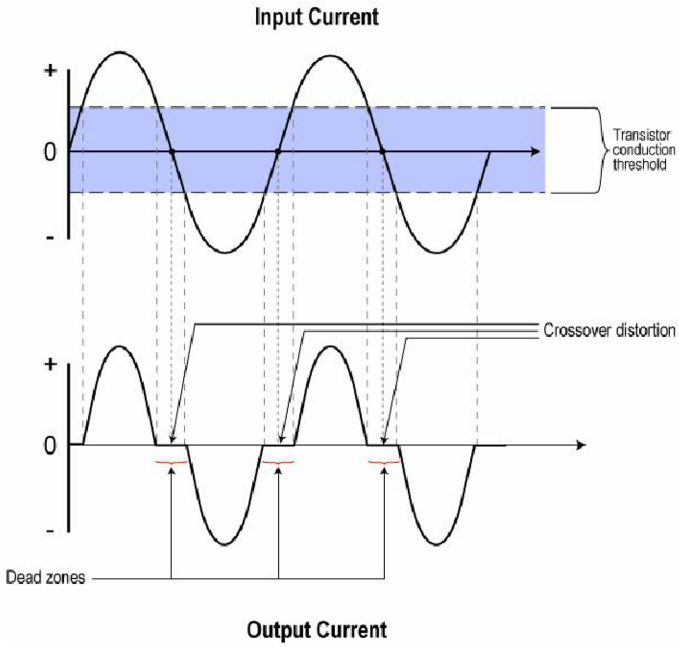
The primary disadvantage of this circuit is that it produces considerable distortion. Distortion is caused because a voltage signal from 0.5 to 0.7 volts is needed at the base of each transistor to bias it on. The result is that the output signal does not occur until conduction is achieved. This leaves a dead zone in the output called **crossover distortion**. The crossover occurs as the input signal goes from positive to negative or from negative to positive. In audio amplifiers, this distortion is very noticeable and objectionable especially at low signal levels.

Solutions

The cure for the crossover distortion problem is to apply a small amount of forward bias to the base of each transistor so that it is just at or slightly beyond the threshold of conduction.

The transistors are biased to conduct slightly and continuously but near the class B condition.

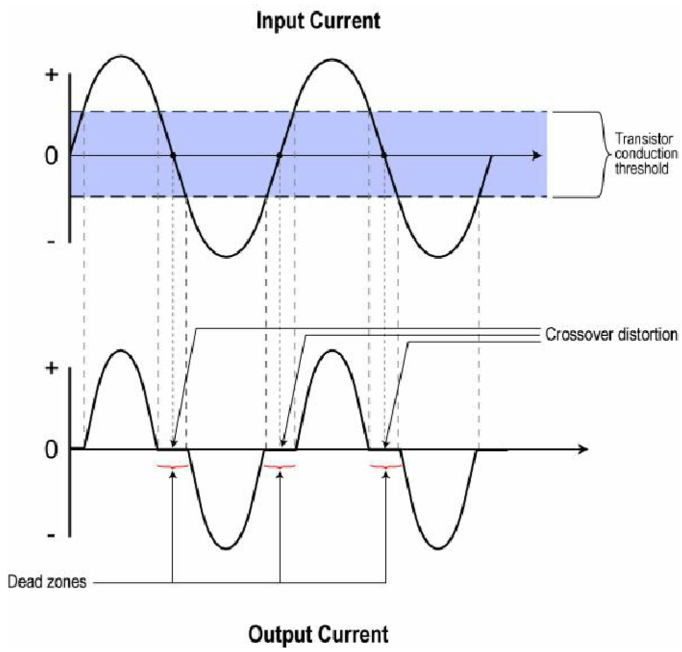
This amplifier is usually referred to as a class AB amplifier. Class AB amplifiers conduct for just over 180°.



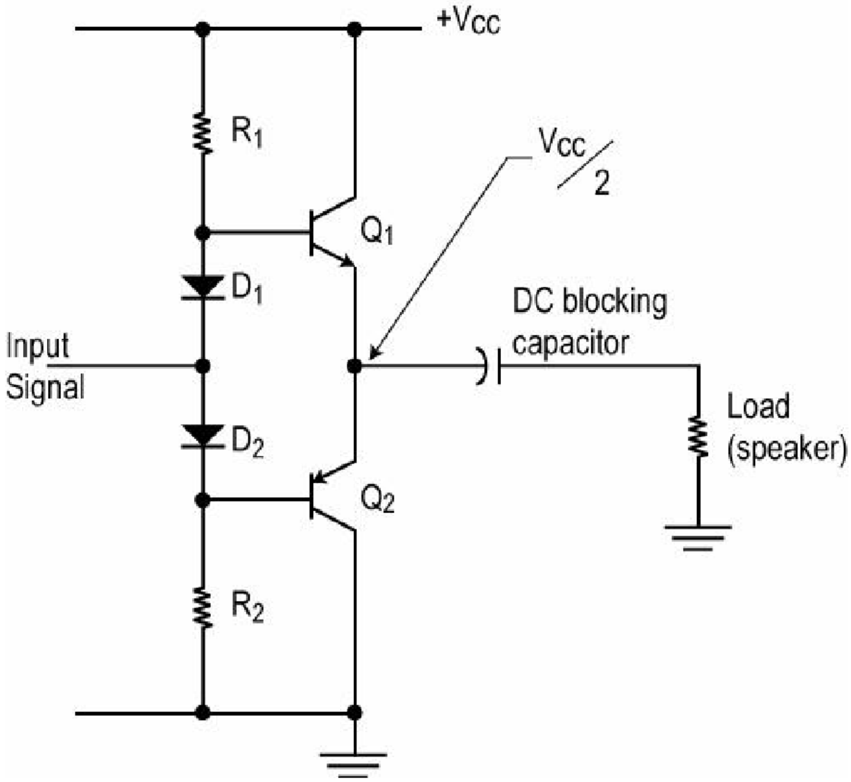
Solutions

Applying a forward bias successfully eliminates the crossover distortion and provides an incredibly linear amplifier with very low harmonic distortion.

However, another disadvantage is that both a positive and a negative power supply are required.



A Practical Complementary Symmetry Amplifier



A discussion of this graphic is presented in the pages that follow. You can print this graphic for study purposes before going on.

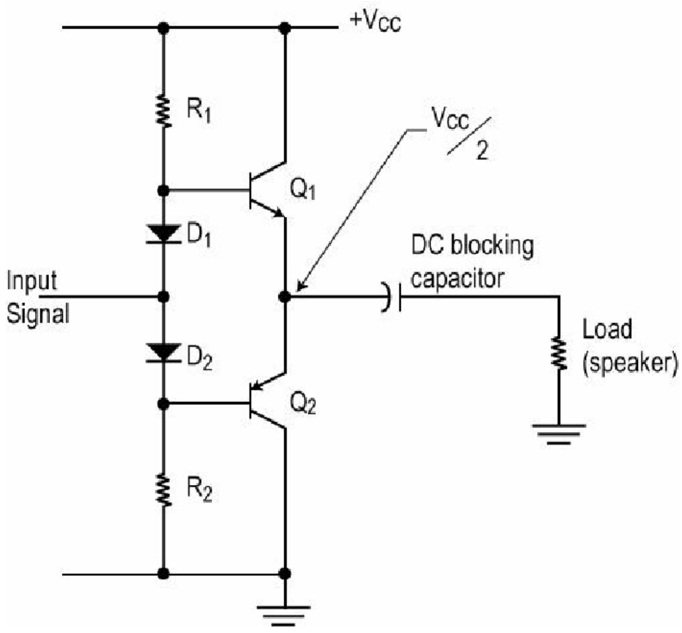
A Practical Complementary Symmetry Amplifier

To overcome both the distortion and power supply problems, bias resistors R_1 and R_2 along with diodes D_1 and D_2 are used to provide the base bias.

The diodes also protect the circuit from a condition known as thermal runaway that can occur in complementary circuits and cause their destruction.

The output is coupled to the load via a large capacitor to block the DC output but pass the AC.

This circuit also uses a single power supply.



Power Level in Complementary Amplifiers

Variations of this circuit are widely used in audio amplifiers of all types.

The circuit is available in integrated circuit (IC) form for power levels up to about 50 watts.

For higher power levels, an IC is used as the driver amplifier for a higher power output circuit made up of discrete power transistors in a complementary configuration. Power levels over 1000 watts are possible.

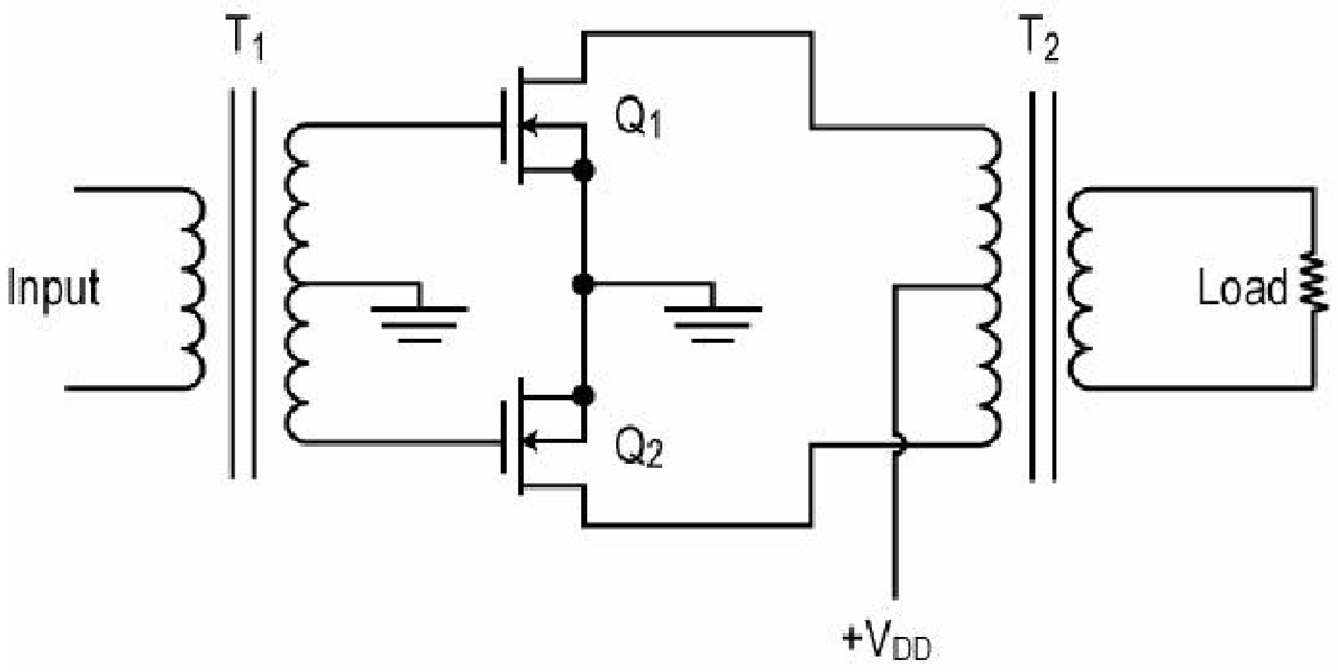
Efficiency of Complementary Amplifiers

Each transistor in a class B circuit conducts for one half of the signal input cycle. Even though it is rarely achieved in practice, the theoretical efficiency is a maximum of 78.5% under ideal conditions.

In class AB operation, the conduction is somewhat greater than 180° of the input cycle. The maximum practical efficiency is 60% but that is rarely achieved in the real world. Typical efficiencies are in the 45 to 55% range.

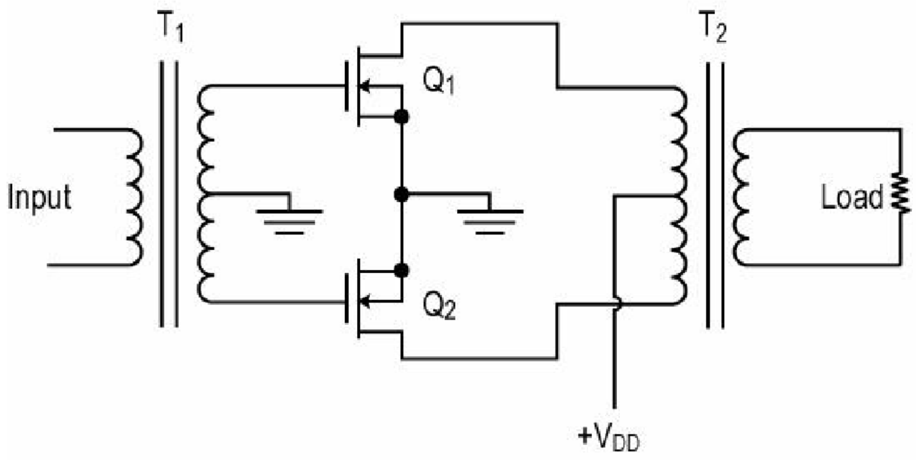
One major problem is that almost half of the power is lost either as heat or at the higher power levels in linear amplifiers. Heat sinks and other heat dissipating methods must be used.

Transformer Coupled Class AB Amplifier



A discussion of this graphic is presented in the pages that follow. You can print this graphic for study purposes before going on.

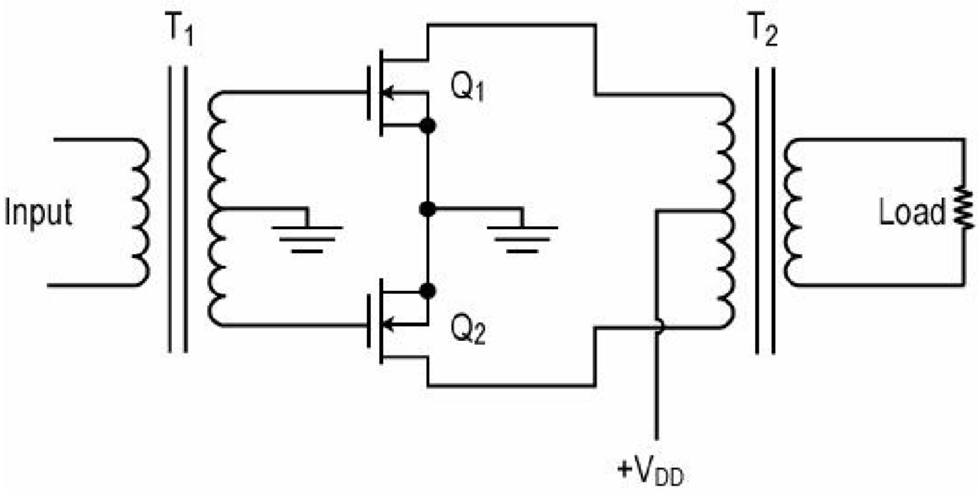
Transformer Coupled Class AB Amplifier



An older form of power amplifier is the transformer coupled push pull circuit. It was once widely used in audio amplifiers but has been replaced by the complementary symmetry circuit described earlier because no heavy and expensive transformers are needed.

However, this circuit is still widely in radio frequency applications as a power amplifier. At radio frequencies, transformers are much smaller, lighter, simpler, and less expensive.

Transformer Coupled Class AB Amplifier

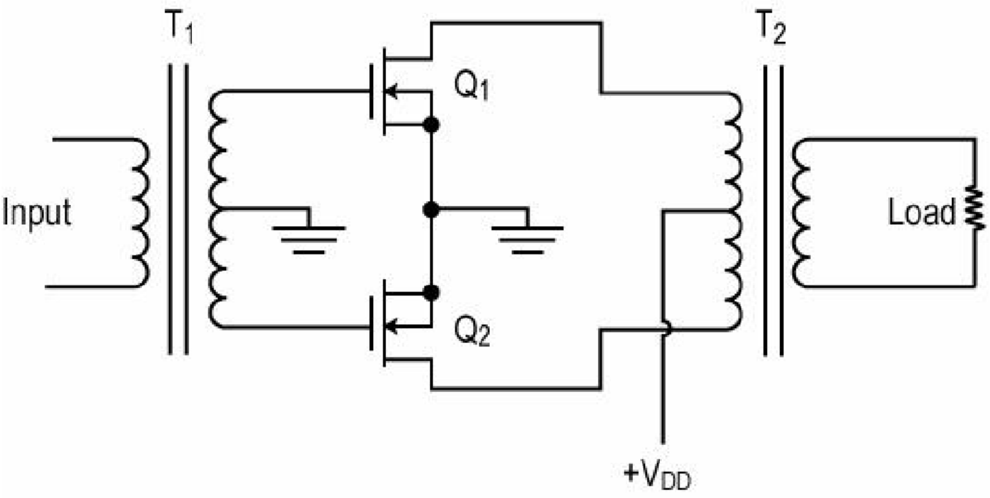


The circuit operates class B.

The input signal is transformed by T_1 into two equal voltage drive signals 180° out of phase. Transistor Q_1 conducts on the positive half cycle of the input and Q_2 conducts on the negative half cycles.

The two half cycles of current are combined in the primary of T_2 to produce a complete output cycle across the secondary of T_2 to drive the load.

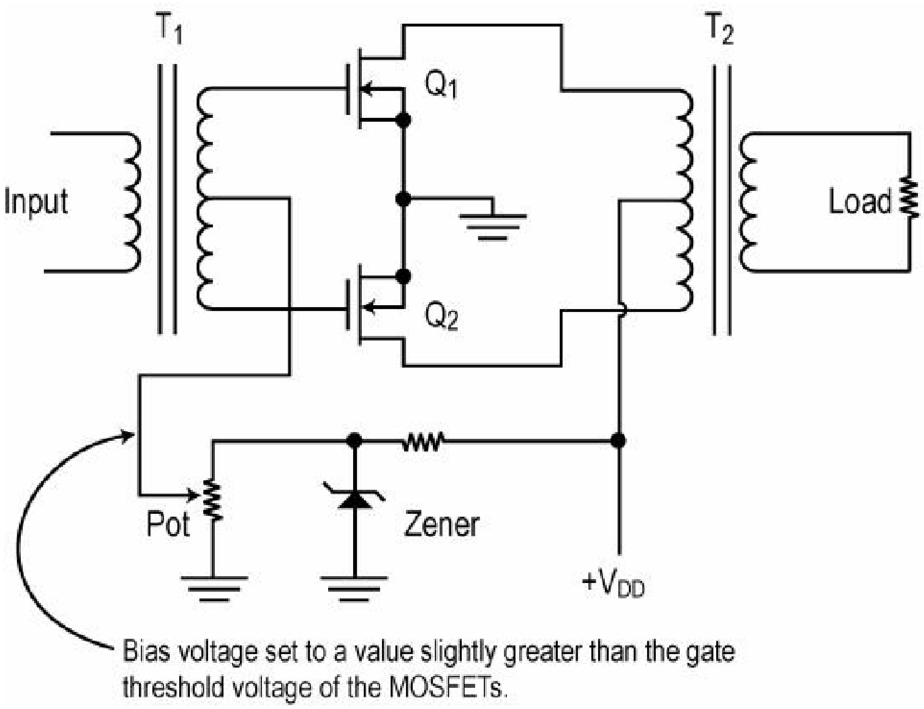
Transformer Coupled Class AB Amplifier



However, this circuit suffers from crossover distortion because Q_1 and Q_2 are enhancement mode MOSFETs that require a gate voltage higher than the threshold to conduct.

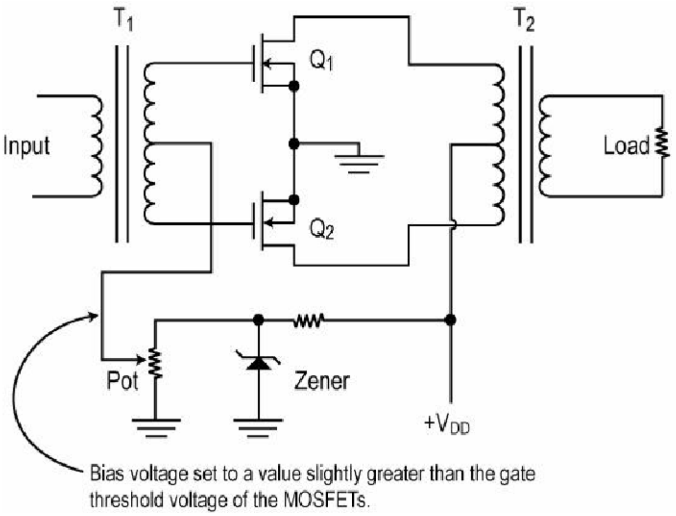
Crossover distortion is overcome by applying some bias to each transistor so that it is on the threshold of conduction.

Transformer Coupled Amplifier



A discussion of this graphic is presented in the pages that follow. You can print this graphic for study purposes before going on.

Transformer Coupled Amplifier



In this circuit, a Zener diode is biased into conduction and a pot is used to apply a bias voltage to the center tap of the secondary of T_1. This bias voltage appears at the gates of Q_1 and Q_2.

The result is a class AB linear amplifier with no crossover distortion.

Typical efficiency is in the 45 to 55% range. High power is still dissipated in the transistors so heat sinks must be used. In some applications, fans or water cooling are needed to get rid of the heat.

Switching amplifiers solve this problem.

Test your knowledge

Switching Amplifiers
Knowledge Probe 1

Amplifier Fundamentals

Click on Course Materials at the top of the page.

Then choose **Knowledge Probe 1**.