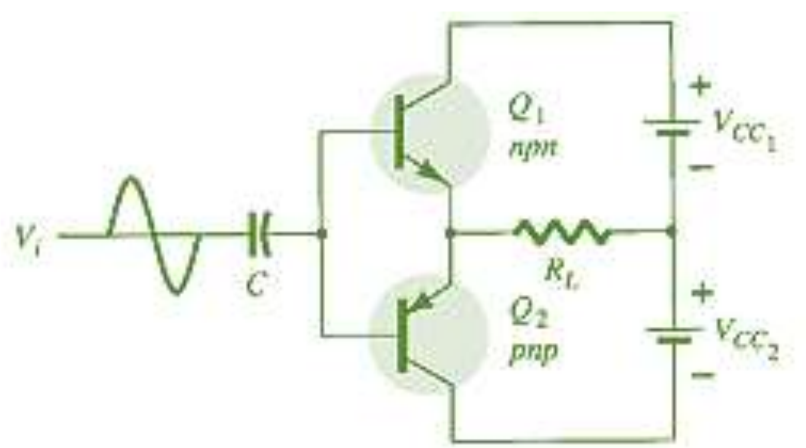
Electronic Circuit

Lecture 5 (9^{th} Week)

Class B, C and D amplifiers



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1.1. Class B Amplifiers Operation

Class B operation is provided when the dc bias leaves the transistor biased just off, the transistor turning on when the ac signal is applied. This is essentially no bias, and the transistor conducts current for only one-half of the signal cycle. To obtain output for the full cycle of signal, it is necessary to use two transistors and have each conduct on opposite half-cycles, the combined operation providing a full cycle of output signal. Since one part of the circuit pushes the signal high during one half-cycle and the other part pulls the signal low during the other half-cycle, the circuit is referred to as a push–pull circuit. Figure.1. shows a diagram for push–pull operation. An ac input signal is applied to the push–pull circuit, with each half operating on alternate half-cycles, the load then receiving a signal for the full ac cycle. The power transistors used in the push–pull circuit are capable of delivering the desired power to the load, and the class B operation of these transistors provides greater efficiency than was possible using a single transistor in class A operation.

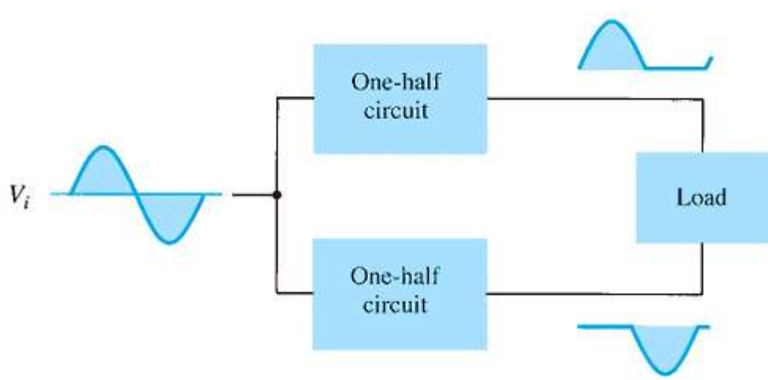

Fig.1. Block representation of push–pull operation.

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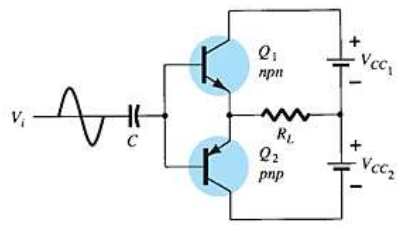
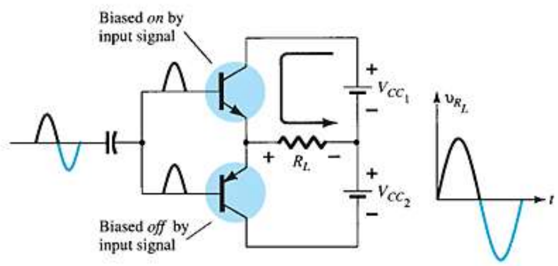
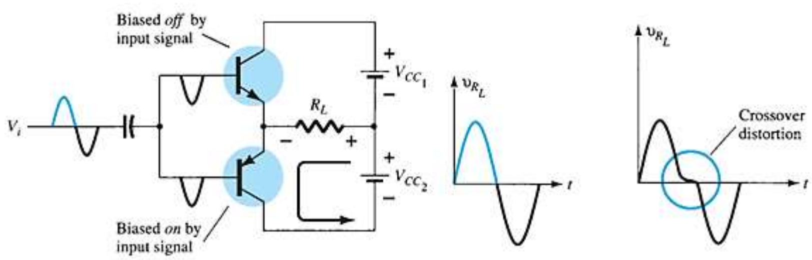
Complementary-Symmetry Circuits



(a)



(b)



Push–pull output transformer Load Using complementary transistors (npn and pnp) it is possible to obtain a full cycle output across a load using half-cycles of operation from each transistor, as shown in Fig. Whereas a single input signal is applied to the base of both transistors, the transistors, being of opposite type, will conduct on opposite half-cycles of the input. The npn transistor will be biased into conduction by the positive half-cycle of signal, with a resulting half cycle of signal across the load as shown in Fig. During the negative half-cycle of signal, the pnp transistor is biased into conduction when the input goes negative, as shown in Figure below. During a complete cycle of the input, a complete cycle of output signal is developed across the load. One disadvantage of the circuit is the need for two separate voltage sup plies. Another, less obvious disadvantage with the complementary circuit is shown in the resulting crossover distortion in the output signal. Crossover distortion refers to the fact that during the signal crossover from positive to negative (or vice versa) there is some nonlinearity in the output signal.

Input (DC) Power

The power supplied to the load by an amplifier is drawn from the power supply (or power supplies; see Fig. 2) that provides the input or dc power. The amount of this input power can be calculated using

$$\boxed{P_i(\text{dc}) = V_{CC} I_{\text{dc}}}$$

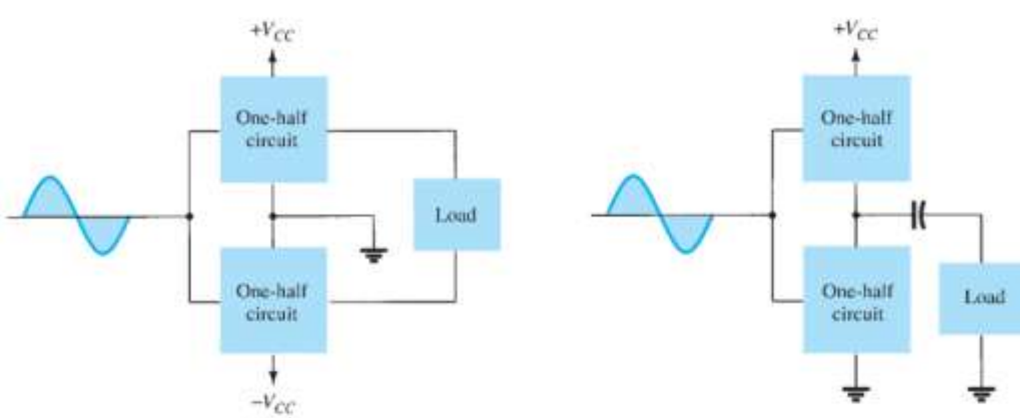


Fig.2. Connection of push–pull amplifier to load: (a) using two voltage supplies; (b) using one voltage supply.

where I_{dc} is the average or dc current drawn from the power supplies. In class B operation, the current drawn from a single power supply has the form of a full-wave rectified signal, whereas that drawn from two power supplies has the form of a half-wave rectified signal from each supply. In either case, the value of the average current drawn can be expressed as:

$$I_{dc} = \frac{2}{\pi} I(p)$$

where $I(p)$ is the peak value of the output current waveform. Using Equation above in the power input equation results in:

$$P_i(dc) = V_{CC}\left(\frac{2}{\pi} I(p)\right)$$

Output (AC) Power

The power delivered to the load (usually referred to as a resistance R_L) can be calculated using any one of a number of equations. If one is using a rms meter to measure the volt age across the load, the output power can be calculated as

$$P_o(ac) = \frac{V_L^2(rms)}{R_L}$$

If one is using an oscilloscope, the measured peak or peak-to-peak output voltage can be used:

$$P_o(ac) = \frac{V_L^2(p\text{-}p)}{8R_L} = \frac{V_L^2(p)}{2R_L}$$

Efficiency

The efficiency of the class B amplifier can be calculated using the basic equation

$$\% \, \eta = \frac{P_o(\text{ac})}{P_i(\text{dc})} \times 100\%$$

$$\% \, \eta = \frac{P_o(\text{ac})}{P_i(\text{dc})} \times 100\% = \frac{V_L^2(\text{p})/2R_L}{V_{CC}[(2/\pi)I(\text{p})]} \times 100\% = \frac{\pi}{4}\frac{V_L(\text{p})}{V_{CC}} \times 100\%$$

$$\text{maximum efficiency} = \frac{\pi}{4} \times 100\% = 78.5\%$$

Power Dissipated by Output Transistors

The power dissipated (as heat) by the output power transistors is the difference between the input power delivered by the supplies and the output power delivered to the load,

$$P_{2Q} = P_i(\text{dc}) - P_o(\text{ac})$$

where P_{2Q} is the power dissipated by the two output power transistors. The dissipated power handled by each transistor is then

$$P_Q = \frac{P_{2Q}}{2}$$

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EXAMPLE 1. For a class B amplifier providing a 20 V peak signal to a 16 **Ω** load (speaker) and a power supply of V_{CC} = 30 V, determine the input power, output power, and circuit efficiency.

Solution

A 20-V peak signal across a 16-Ω load provides a peak load current of

$$I_L(\mathrm{p}) = \frac{V_L(\mathrm{p})}{R_L} = \frac{20\ \mathrm{V}}{16\ \Omega} = 1.25\ \mathrm{A}$$

The dc value of the current drawn from the power supply is then

$$I_{dc} = \frac{2}{\pi} I_L(\mathrm{p}) = \frac{2}{\pi}(1.25\ \mathrm{A}) = 0.796\ \mathrm{A}$$

and the input power delivered by the supply voltage is

$$P_i(\mathrm{dc}) = V_{CC} I_{dc} = (30\ \mathrm{V})(0.796\ \mathrm{A}) = \mathbf{23.9\ W}$$

The output power delivered to the load is

$$P_o(\mathrm{ac}) = \frac{V_L^2(\mathrm{p})}{2R_L} = \frac{(20\ \mathrm{V})^2}{2(16\ \Omega)} = \mathbf{12.5\ W}$$

for a resulting efficiency of

$$\%\,\eta = \frac{P_o(\mathrm{ac})}{P_i(\mathrm{dc})} \times 100\% = \frac{12.5\ \mathrm{W}}{23.9\ \mathrm{W}} \times 100\% = \mathbf{52.3\%}$$

Maximum Power Considerations

For class B operation, the maximum output power is delivered to the load when $V_L(p) = V_{CC}$:

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$$\text{maximum } P_o(\text{ac}) = \frac{V_{CC}^2}{2R_L}$$

The corresponding peak ac current $I(\text{p})$ is then

$$I(\text{p}) = \frac{V_{CC}}{R_L}$$

so that the maximum value of average current from the power supply is

$$\text{maximum } I_{\text{dc}} = \frac{2}{\pi} I(\text{p}) = \frac{2V_{CC}}{\pi R_L}$$

Using this current to calculate the maximum value of input power results in

$$\text{maximum } P_i(\text{dc}) = V_{CC}(\text{maximum } I_{\text{dc}}) = V_{CC}\left(\frac{2V_{CC}}{\pi R_L}\right) = \frac{2V_{CC}^2}{\pi R_L}$$

The maximum circuit efficiency for class B operation is then

$$\text{maximum } \%\,\eta = \frac{P_o(\text{ac})}{P_i(\text{dc})} \times 100\% = \frac{V_{CC}^2/2R_L}{V_{CC}[(2/\pi)(V_{CC}/R_L)]} \times 100\%$$

$$= \frac{\pi}{4} \times 100\% = \mathbf{78.54\%}$$

When the input signal results in less than the maximum output signal swing, the circuit efficiency is less than 78.5%.

For class B operation, the maximum power dissipated by the output transistors does not occur at the maximum power input or output condition. The maximum power dissipated by the two output transistors occurs when the output voltage across the load is

$$V_L(\text{p}) = 0.636V_{CC} \qquad \left(= \frac{2}{\pi}V_{CC}\right)$$

for a maximum transistor power dissipation of

$$\text{maximum } P_{2Q} = \frac{2V_{CC}^2}{\pi^2 R_L}$$

EXAMPLE.2. For a class B amplifier using a supply of V_{CC} = 30 V and driving a load of 16 **Ω**, determine the maximum input power, output power, and transistor dissipation.

Solution:

The maximum output power is

$$\text{maximum } P_o(\text{ac}) = \frac{V_{CC}^2}{2R_L} = \frac{(30\text{ V})^2}{2(16\ \Omega)} = \mathbf{28.125\ W}$$

The maximum input power drawn from the voltage supply is

$$\text{maximum } P_i(\text{dc}) = \frac{2V_{CC}^2}{\pi RL} = \frac{2(30\text{ V})^2}{\pi(16\ \Omega)} = \mathbf{35.81\ W}$$

The circuit efficiency is then

$$\text{maximum } \%\ \eta = \frac{P_o(\text{ac})}{P_i(\text{dc})} \times 100\% = \frac{28.125\text{ W}}{35.81\text{ W}} \times 100\% = 78.54\%$$

as expected. The maximum power dissipated by each transistor is

$$\text{maximum } P_Q = \frac{\text{maximum } P_{2Q}}{2} = 0.5\left(\frac{2V_{CC}^2}{\pi^2 R_L}\right) = 0.5\left[\frac{2(30\text{ V})^2}{\pi^2 16\ \Omega}\right] = \mathbf{5.7\ W}$$

Under maximum conditions a pair of transistors each handling 5.7 W at most can deliver 28.125 W to a 16-Ω load while drawing 35.81 W from the supply.

1.2. Class B Amplifiers Circuits

A number of circuit arrangements for obtaining class B operation are possible. We will consider the advantages and disadvantages of a number of the more popular circuits in this section. The input signals to the amplifier could be a single signal, the circuit then providing two different output stages, each operating for one-half the cycle. If the input is in the form of two opposite-polarity signals, two similar stages could be used, each operating on the alternate cycle because of the input signal. One means of obtaining polarity or phase inversion is using a transformer, and the transformer-coupled amplifier has been very popular for a long time. Opposite-polarity inputs can easily be obtained using an op-amp having two opposite outputs or using a few op-amp stages to obtain two opposite-polarity signals. An opposite-polarity operation can also be achieved using a single input and complementary transistors (npn and pnp, or n MOS and p MOS). Figure .3. shows different ways to obtain phase-inverted signals from a single input signal. Figure.3. a show a center-tapped transformer to provide opposite-phase signals. If the transformer is exactly center-tapped, the two signals are exactly opposite in phase and of the same magnitude.

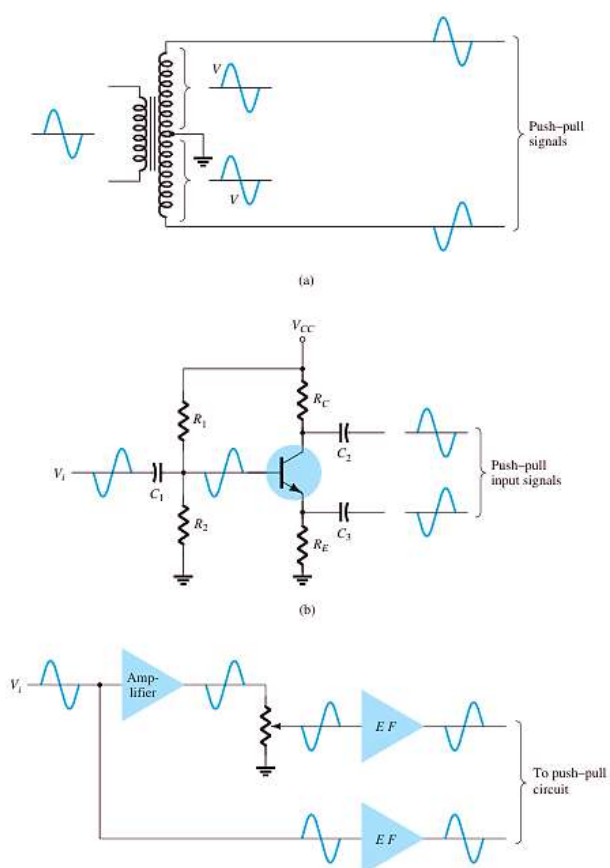

Fig.3. Phase-splitter circuits.

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Transformer-Coupled Push–Pull Circuits The circuit of Fig.3. uses a center-tapped input transformer to produce opposite-polarity signals to the two transistor inputs and an output transformer to drive the load in a push–pull mode of operation described next. During the first half-cycle of operation, transistor Q1 is driven into conduction, whereas transistor Q2 is driven off. The current I1 through the transformer results in the first half cycle of signal to the load. During the second half-cycle of the input signal, Q2 conducts, whereas Q1 stays off, the current I2 through the transformer resulting in the second half cycle to the load. The overall signal developed across the load then varies over the full cycle of signal operation.

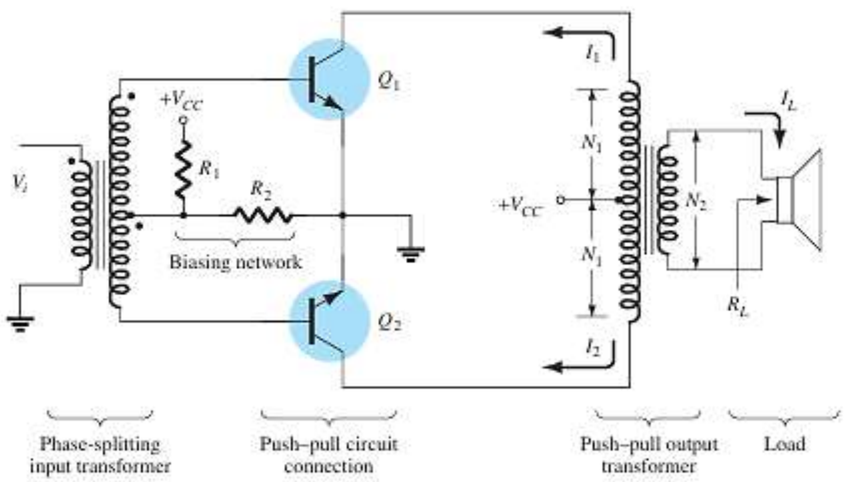

Fig.4. Push–pull circuit.

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