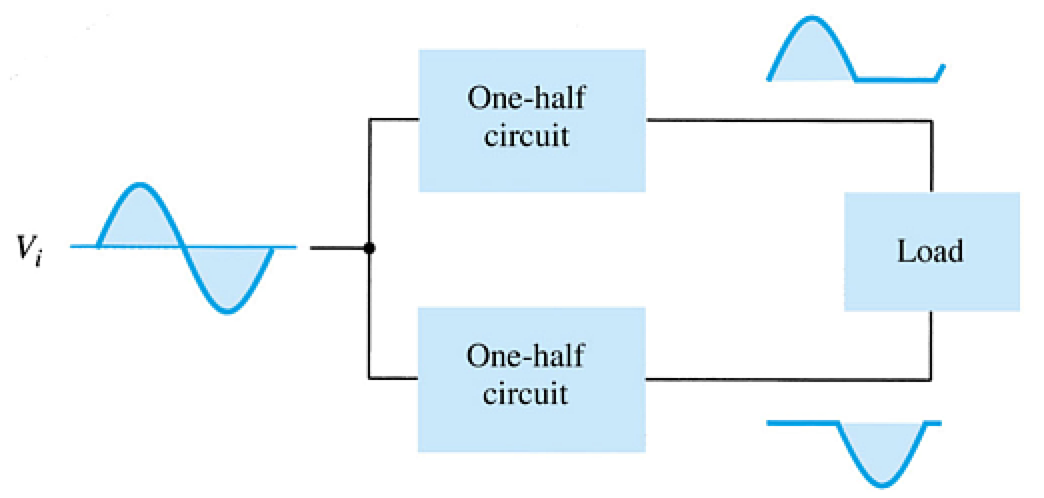
Class B Amplifier

In class B, the transistor is biased just off. The AC signal turns the transistor on.

The transistor only conducts when it is turned on by one-half of the AC cycle.

In order to get a full AC cycle out of a class B amplifier, you need two transistors:

- An *npn* transistor that provides the negative half of the AC cycle
- A *pnp* transistor that provides the positive half.



Class B Amplifier

- 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

Input DC power

- The power supplied to the load by an amplifier is drawn from the power supply
- The amount of this DC power is calculated using

$$P_{i(dc)} = V_{CC} I_{dc}$$

- The DC current drawn from the source is the average value of the current delivered to the load

Input DC power

- The current drawn from a single DC supply has the form of a full wave rectified signal, while that drawn from two power supplies has the form of half-wave rectified signal from each supply
- On either case the average value for the current is given by

$$I_{dc} = \frac{2}{\pi} \times I_p$$

- The input power can be written as

$$P_{i(dc)} = \frac{2}{\pi} V_{CC} I_p$$

Output AC power

- The power delivered to the load can be calculated using the following equation $P_{o(ac)} = \frac{V_{L(p-p)}}{8R_L} = \frac{V_{L(p)}}{2R_L}$
- The efficiency of the amplifier is given by

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

- Not that $I_p = \frac{V_{L(p)}}{R_L}$
- Therefore the efficiency can be re-expressed as

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

Output AC power

- The maximum efficiency can be obtained if $V_L(p) = V_{CC}$
- The value of this maximum efficiency will be

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

Power dissipated by the output transistors

- The power dissipated by the output transistors as heat is given by $P_{2Q} = P_i(\text{dc}) - P_o(\text{ac})$
- The power in each transistor is given by $P_Q = \frac{P_{2Q}}{2}$

Example

<u>Example 1:</u> For class B amplifier providing a 20-V peak signal to a 16-Ω speaker and a power supply of $V_{CC}=30\ V$, determine the input power , output power and the efficiency

<u>Solution:</u>

The input power is given by

$$P_{i(dc)} = \frac{2}{\pi} V_{CC} I_p$$

The peak collector load current can be found from

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

Example

Solution:

The input power is $P_{i(dc)} = \frac{2}{\pi} 30(1.25) = 23.9\ W$

The output power is given by $P_o(\text{ac}) = \frac{V_L^2(\text{p})}{2R_L} = \frac{(20\ \text{V})^2}{2(16\ \Omega)} = 12.5\ \text{W}$

The efficiency is $\%\ \eta = \frac{P_o(\text{ac})}{P_i(\text{dc})} \times 100\% = \frac{12.5\ \text{W}}{23.9\ \text{W}} \times 100\% = 52.3\%$

Maximum power dissipated by the output transistors

- The maximum power dissipated by the two transistors occurs when the output voltage across the load is given by $V_L(\text{p}) = 0.636V_{CC} \quad \left(= \frac{2}{\pi}V_{CC}\right)$

- The maximum power dissipation is given by

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

Example

Example 2: For class B amplifier using a supply of V_{CC}*=30 V and driving a load of 16-Ω*, determine the input power , output power and the efficiency

Solution:

The maximum output power is given by

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

The maximum input power drawn from the supply is

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

Example

Solution:

The efficiency is given by

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

The maximum power dissipated by each transistor is

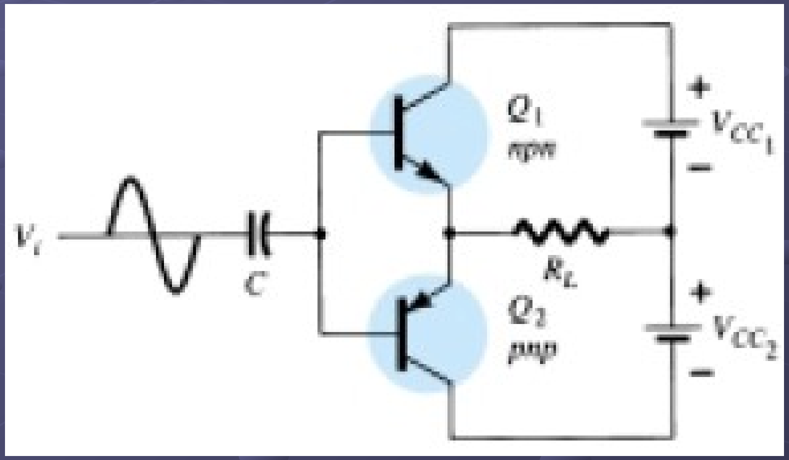
$$\text{maximum } P_Q = \frac{\text{maximum } P_{2Q}}{2} = 0.5\left(\frac{2V_{CC}^2}{\pi^2 R_L}\right) = 0.5\left[\frac{2(30 \text{ V})^2}{\pi^2 16\ \Omega}\right] = \mathbf{5.7\ W}$$

Class B Amplifier circuits

- A number of circuit arrangements can be used to realize class B amplifier
- We will consider in this course two arrangements in particular
  1. The first arrangement uses a single input signal fed to the input of two complementary transistors (complementary symmetry circuits)
  2. The second arrangement uses two out of phase input signals of equal amplitudes feeded to the input of two similar NPN or PNP transistors (quasi-complementary push-pull amplifier)

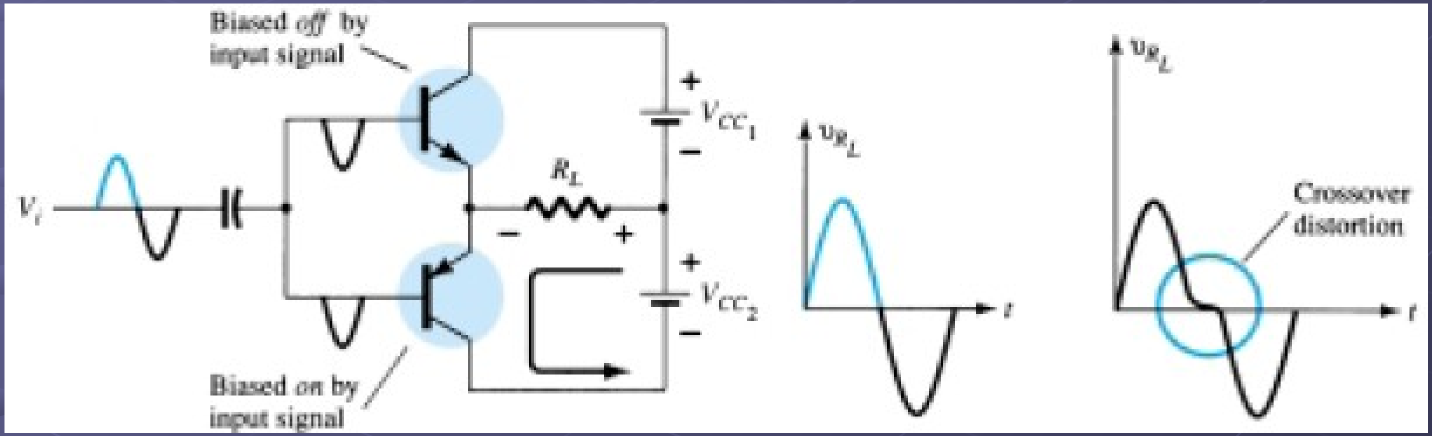
Complementary symmetry circuits first arrangement

- This circuit uses both npn and pnp transistor to construct class B amplifier as shown to the left
- One disadvantage of this circuit is the need for two separate voltage supplies



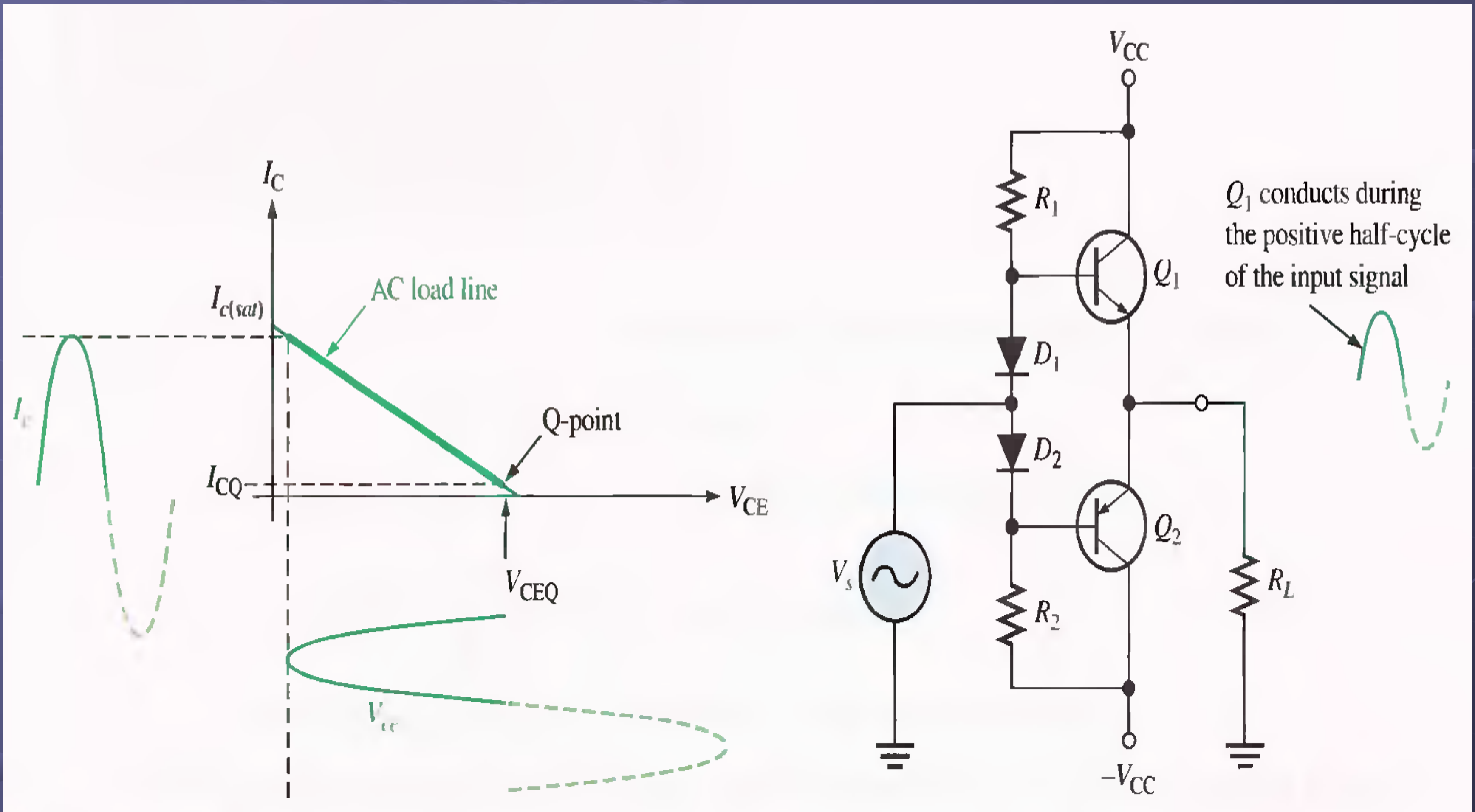
Complementary symmetry circuits

- another disadvantage of this circuit is the resulting cross over distortion



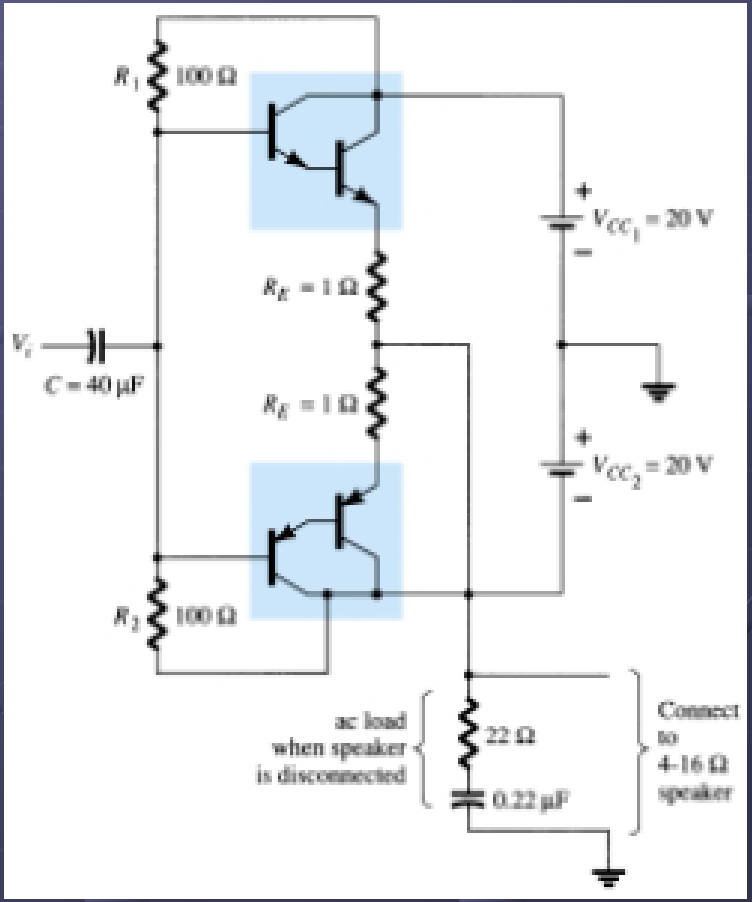
- Cross over distortion can be eliminated the by biasing the transistors in class AB operation where the transistors are biased to be on for slightly more than half a cycle

Class AB biasing to solve crossover distortion



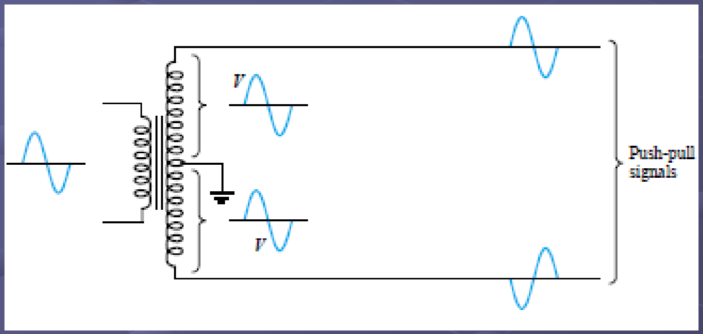
Complementary symmetry circuits

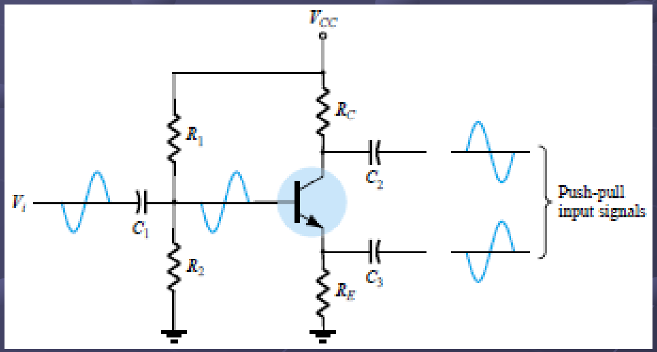
- A more practical version of a push-pull circuit using complementary transistors is shown to the right
- This circuit uses to complementary Darlington pair transistors to achieve larger current driving and lower output impedance

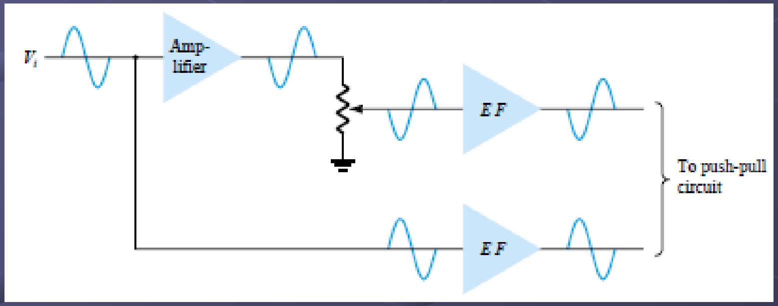


Second arrangement

- As stated previously the second arrangement which uses two equal input signals of opposite phase has to be preceded by a phase inverting network as shown below

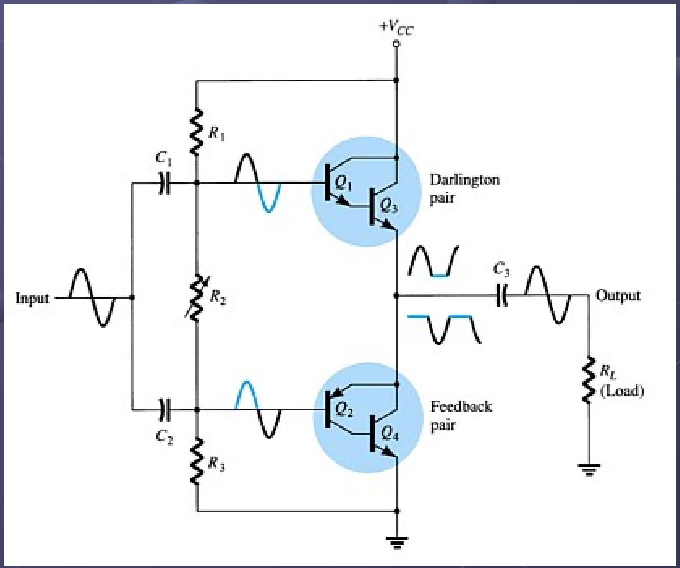






Quasi-complementary push pull amplifier second arrangement

- In practical power amplifier circuits it is preferable to uses npn for both transistors
- Since the push pull connection requires complementary devices, a pnp high power transistor must be used.
- This can be achieved by using the circuit shown



Example

Example: For the circuit shown, calculate the input power, output power and the power handled by each transistor and the efficiency if the input signal is 12 V_{rms}

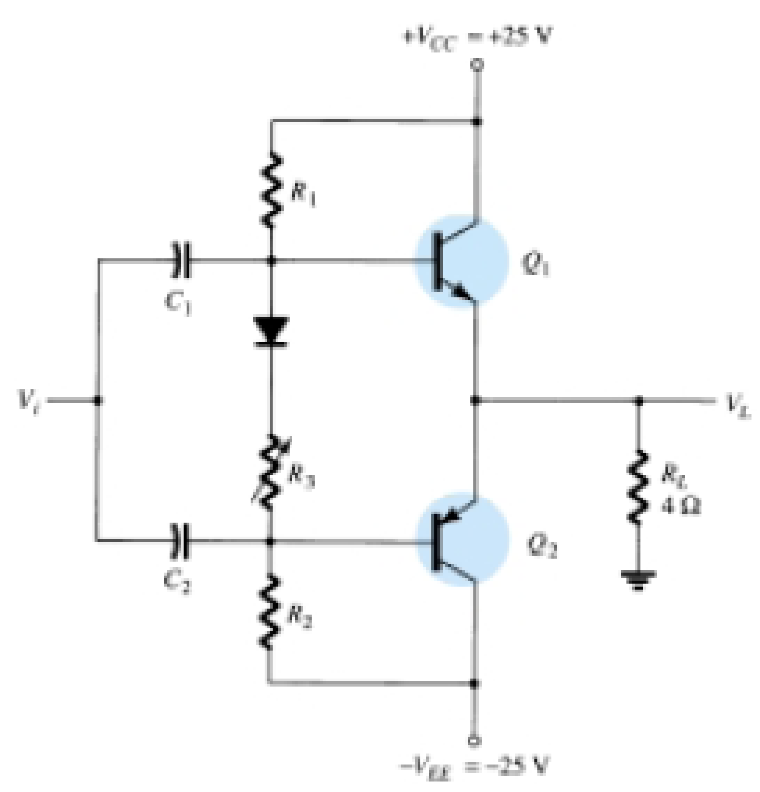
Solution:

The peak input voltage is

$$V_i(\text{p}) = \sqrt{2}\, V_i\,(\text{rms}) = \sqrt{2}\,(12\text{ V}) = 16.97\text{ V} \approx 17\text{ V}$$

The output power is

$$P_o(\text{ac}) = \frac{V_L^2(\text{p})}{2R_L} = \frac{(17\text{ V})^2}{2(4\ \Omega)} = 36.125\text{ W}$$



Example

<u>*Solution:*</u>

The peak load current is $I_L(\text{p}) = \dfrac{V_L(\text{p})}{R_L} = \dfrac{17\text{ V}}{4\ \Omega} = 4.25\text{ A}$

The dc current can be found from the peak as

$$I_{\text{dc}} = \frac{2}{\pi}I_L(\text{p}) = \frac{2(4.25\text{ A})}{\pi} = 2.71\text{ A}$$

The input power is given by

$$P_i(\text{dc}) = V_{CC}I_{\text{dc}} = (25\text{ V})(2.71\text{ A}) = 67.75\text{ W}$$

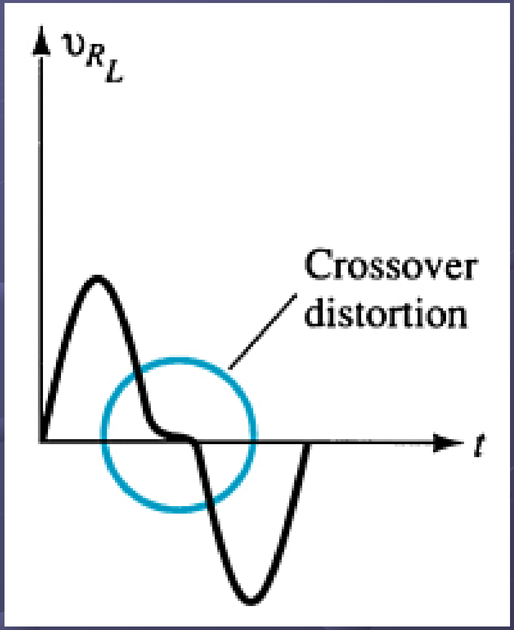
The power dissipated by each transistor is given by

$$P_Q = \frac{P_{2Q}}{2} = \frac{P_i - P_o}{2} = \frac{67.75\text{ W} - 36.125\text{ W}}{2} = 15.8\text{ W}$$

$$\%\ \eta = \frac{P_o}{P_i} \times 100\% = \frac{36.125\text{ W}}{67.75\text{ W}} \times 100\% = 53.3\%$$

Crossover Distortion

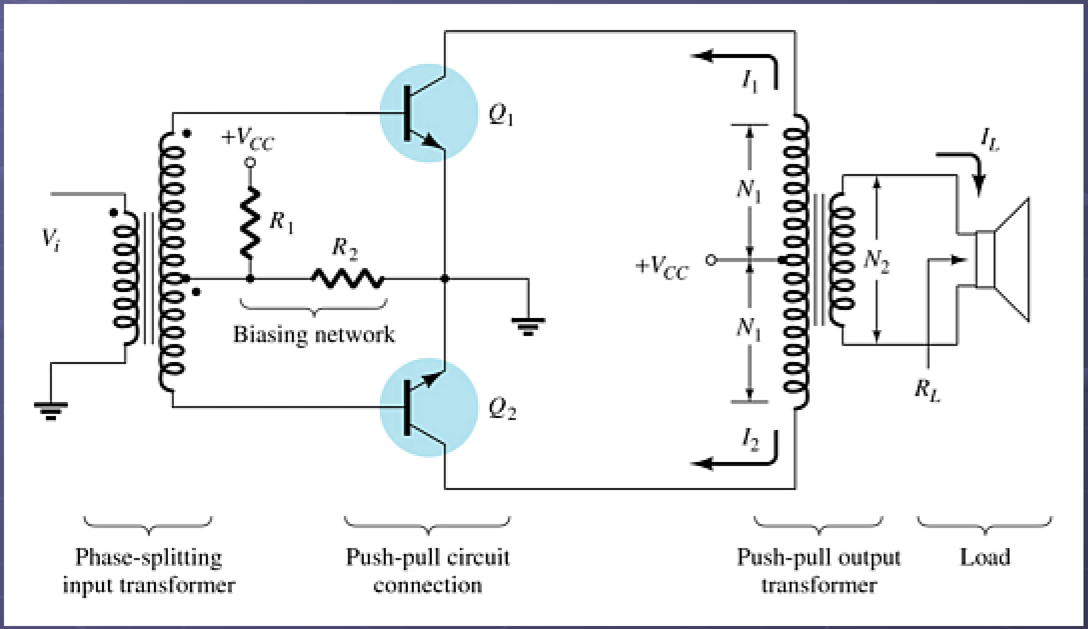
If the transistors Q_1 and Q_2 do not turn on and off at exactly the same time, then there is a gap in the output voltage.



Class B Amplifier Push-Pull Operation

- **During the positive half-cycle of the AC input, transistor Q_1 (*npn*) is conducting and Q_2 (*pnp*) is off.**

- **During the negative half-cycle of the AC input, transistor Q_2 (*pnp*) is conducting and Q_1 (*npn*) is off.**



Each transistor produces one-half of an AC cycle. The transformer combines the two outputs to form a full AC cycle.

This circuit is less commonly used in modern circuits

Amplifier Distortion

If the output of an amplifier is not a complete AC sine wave, then it is distorting the output. The amplifier is non-linear.

This distortion can be analyzed using Fourier analysis. In Fourier analysis, any distorted periodic waveform can be broken down into frequency components. These components are harmonics of the fundamental frequency.

Harmonics

Harmonics are integer multiples of a fundamental frequency.

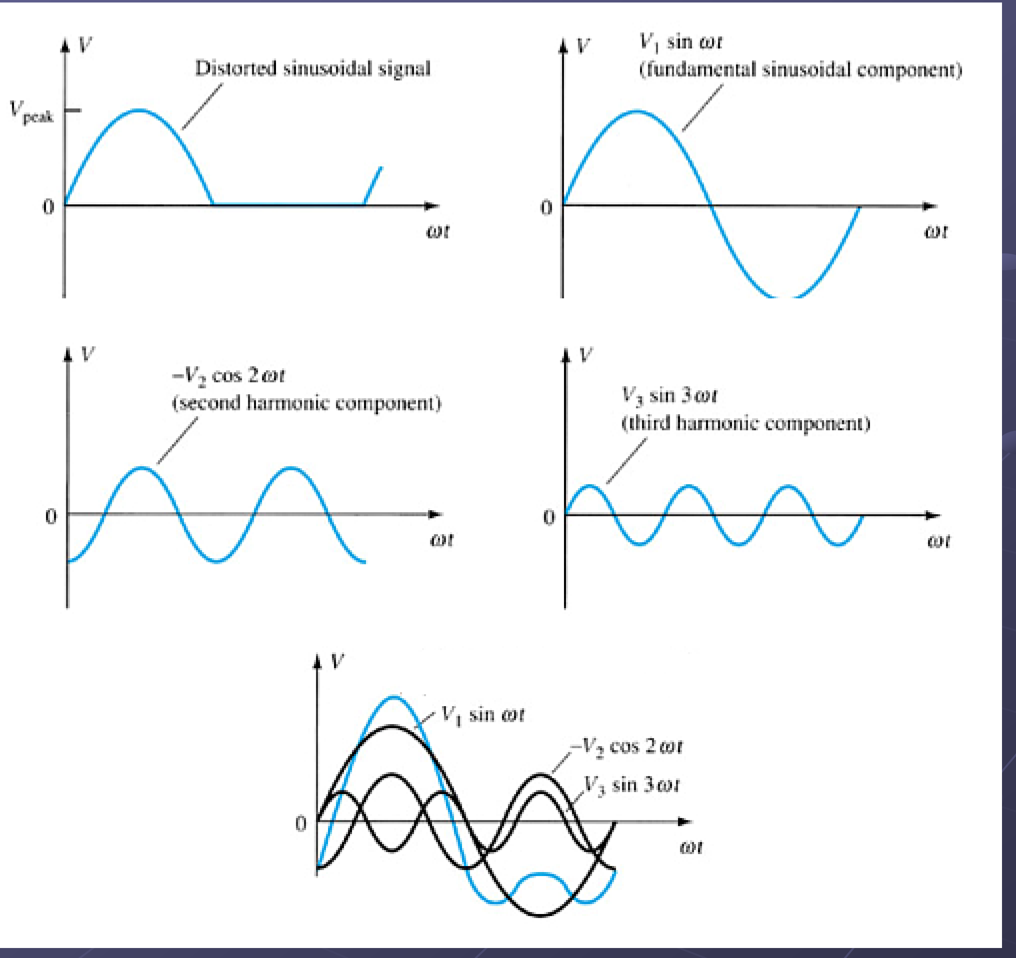
If the fundamental frequency is 5kHz:

1^{st} harmonic	**1 x 5kHz**
2^{nd} harmonic	**2 x 5kHz**
3^{rd} harmonic	**3 x 5kHz**
4^{th} harmonic	**4 x 5kHz**
etc.	

Note that the 1^{st} and 3^{rd} harmonics are called odd harmonics and the 2^{nd} and 4^{th} are called even harmonics

Harmonic Distortion

According to Fourier analysis, if a signal is not purely sinusoidal, then it contains harmonics.



Harmonic Distortion Calculations

Harmonic distortion (D) can be calculated:

$$\%\,\text{nth harmonic distortion} = \%D_n = \left|\frac{A_n}{A_1}\right| \times 100$$

where

A_1 is the amplitude of the fundamental frequency

A_n is the amplitude of the highest harmonic

The total harmonic distortion (THD) is determined by:

$$\%\,THD = \sqrt{D_2^2 + D_3^2 + D_3^2 + \cdots} \times 100$$

EXAMPLE 16.13 Calculate the harmonic distortion components for an output signal having fundamental amplitude of 2.5 V, second harmonic amplitude of 0.25 V, third harmonic amplitude of 0.1 V, and fourth harmonic amplitude of 0.05 V.

Solution

Using Eq. (16.30) yields

$$\% D_2 = \frac{|A_2|}{|A_1|} \times 100\% = \frac{0.25 \text{ V}}{2.5 \text{ V}} \times 100\% = \mathbf{10\%}$$

$$\% D_3 = \frac{|A_3|}{|A_1|} \times 100\% = \frac{0.1 \text{ V}}{2.5 \text{ V}} \times 100\% = \mathbf{4\%}$$

$$\% D_4 = \frac{|A_4|}{|A_1|} \times 100\% = \frac{0.05 \text{ V}}{2.5 \text{ V}} \times 100\% = \mathbf{2\%}$$

EXAMPLE 16.14 Calculate the total harmonic distortion for the amplitude components given in Example 16.13.

Solution

Using the computed values of $D_2 = 0.10$, $D_3 = 0.04$, and $D_4 = 0.02$ in Eq. (16.31),

$$\begin{aligned}\% \text{THD} &= \sqrt{D_2^2 + D_3^2 + D_4^2} \times 100\% \\ &= \sqrt{(0.10)^2 + (0.04)^2 + (0.02)^2} \times 100\% = 0.1095 \times 100\% \\ &= \mathbf{10.95\%}\end{aligned}$$

Power Transistor Derating Curve

Power transistors dissipate a lot of power in heat. This can be destructive to the amplifier as well as to surrounding components.