BME 202 Electronics

Lecture 14: Power Amplifiers

Amplifier Primary Characteristics

In small-signal amplifiers the primary characteristics are:

Amplification
Linearity
Gain

Large signal amplifiers, or power amplifiers handle relatively large voltage signals and current levels. As such, the primary characteristics are:

Efficiency
Maximum power capability
Impedance matching

Amplifier Types

Class A

The amplifier transistor conducts through the full 360° of the input. The *Q*-point is set near the middle of the load line.

Class B

Each amplifier transistor conducts through 180° of the input, with the two combining to provide 360° conduction. The *Q*-point for each transistor is set at the cutoff point.

Class AB

This is a compromise between the class A and B amplifiers. The amplifier transistors conduct between 180° and 360°. The *Q*-point is located between the mid-point and cutoff.

Amplifier Types

Class C

The amplifier conducts for less than 180° of the input. The *Q*-point is located below the cutoff level.

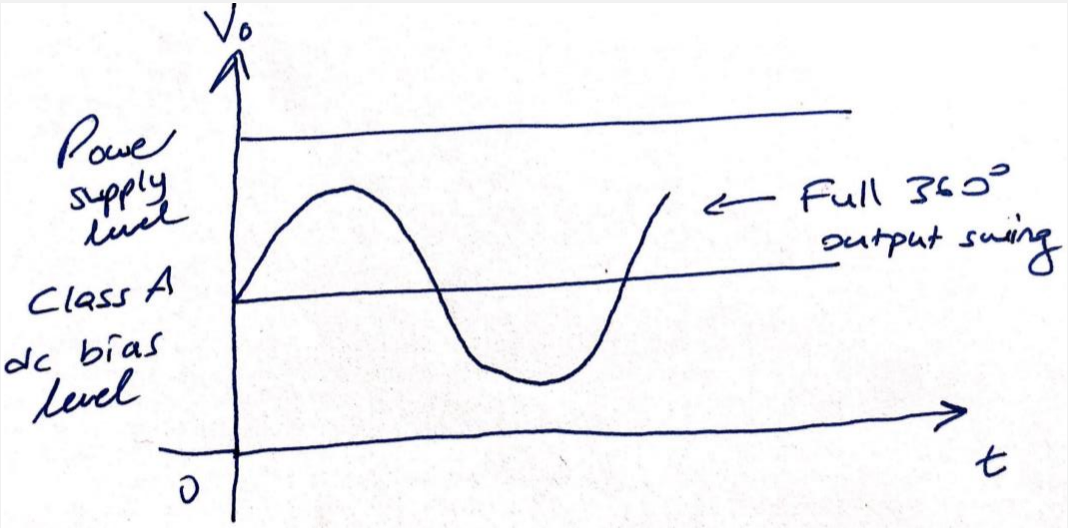
Class D

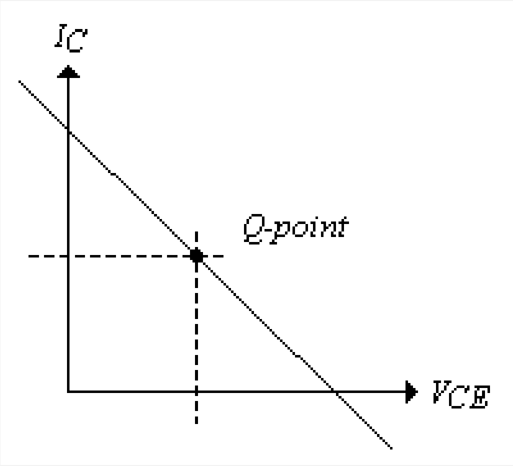
This is an amplifier that is biased especially for digital signals.

Class A Amplifier

The transistor in a class A amplifier conducts for the full 360° of the cycle.

The *Q*-point is set at the middle of the load line so that the AC signal can swing a full cycle.

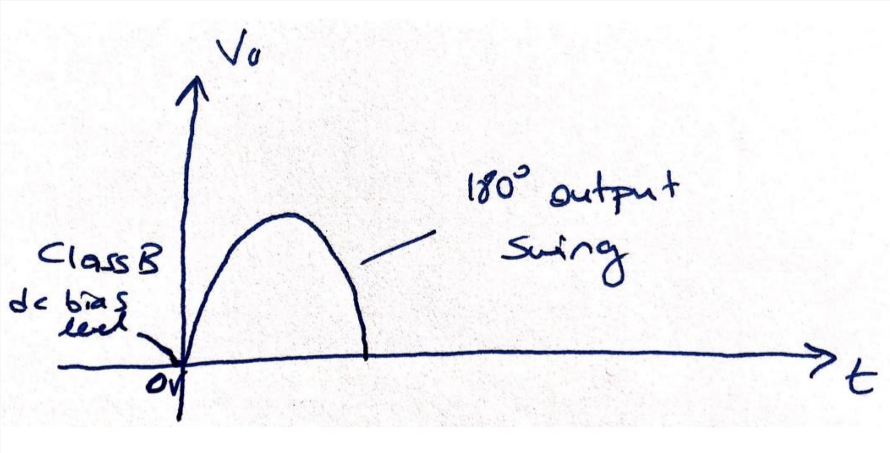


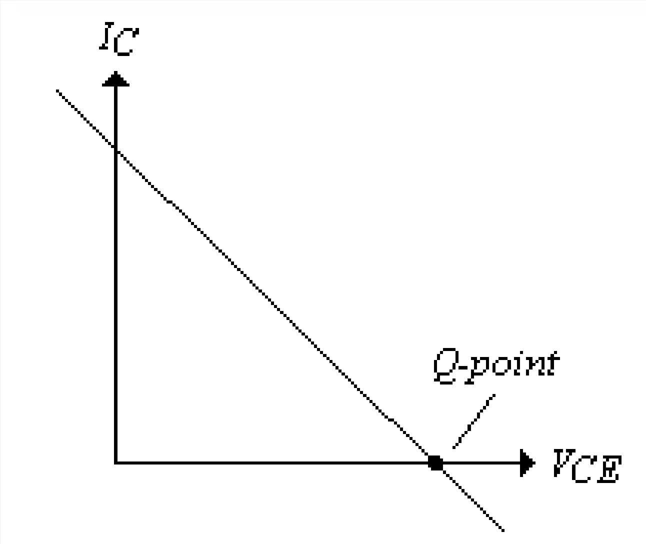


Remember that the DC load line indicates the minimum & maximum output voltage and current allowed by the DC power supply.

Class B Amplifier

Each transistor in a class B amplifier conducts for 180° (half) of the AC input signal.



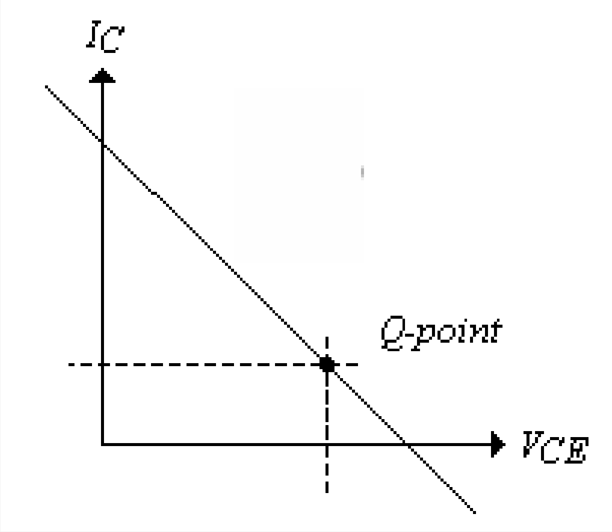


The *Q*-point is at 0 V on the load line, so that the AC signal can only swing for one-half cycle.

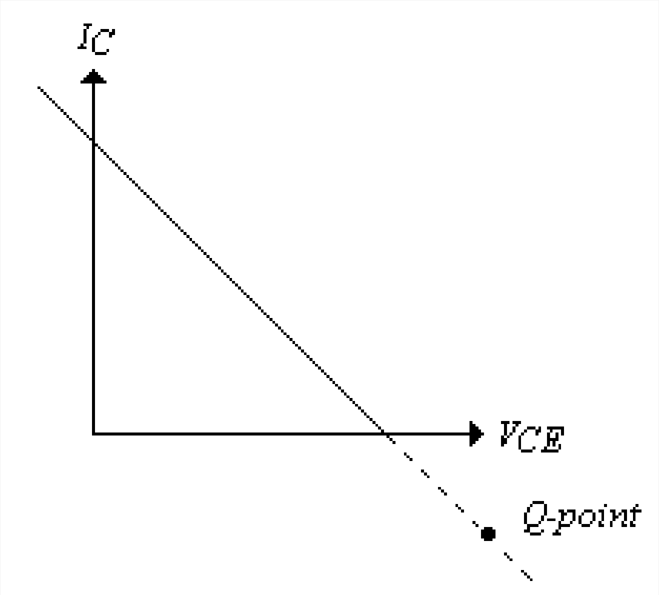
Class AB Amplifier

This amplifier is a compromise between the class A and class B amplifier—the *Q*-point for each transistor is above that of the Class B but below the class A.

Each transistor conducts for more than 180° of the AC input signal.



Class C Amplifier



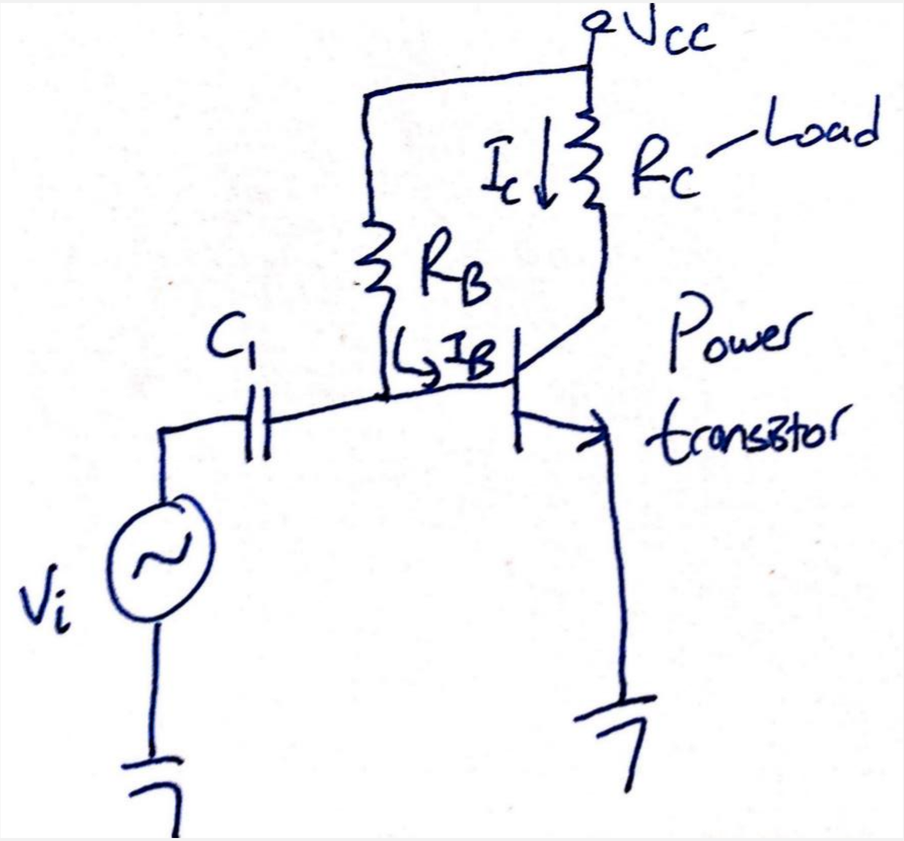
The output of the class C conducts for less than 180° of the AC cycle. The Q-point is below cutoff.

Amplifier Efficiency

Efficiency refers to the ratio of output power to input power. The lower the degrees of conduction of the transistor(s) the higher the efficiency.

Series-Fed Class A Amplifier

This is similar to the small-signal amplifier except that it will handle higher voltages and currents. The transistor used is a high-power transistor.



Series-Fed Class A Amplifier

A small input signal causes the output voltage to swing to a maximum of V_{CC} and a minimum of 0 V. The current can also swing from 0 mA to I_{CSAT} (V_{CC}/R_C)

Series-Fed Class A Amplifier

Input Power

The power into the amplifier comes from the DC supply. With no input signal, the DC current drawn is the quiescent collector current, I_{CQ}.

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

Output Power

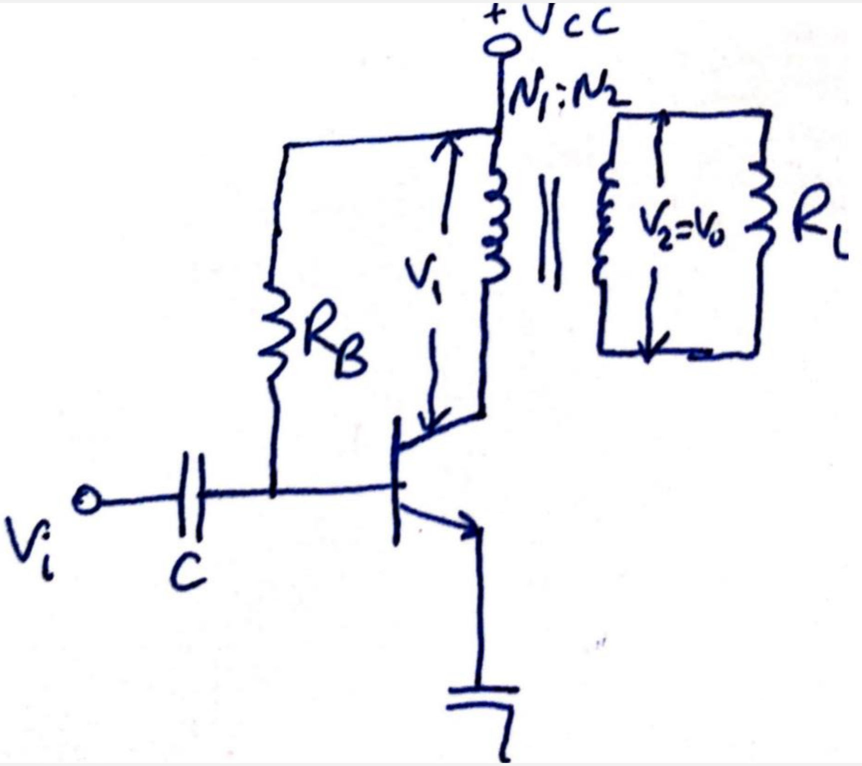
$$P_{o(ac)} = \frac{V_{C(rms)}^2}{R_C} \quad \text{or} \quad P_{o(ac)} = \frac{V_{CE(p\text{-}p)}^2}{8R_C}$$

Efficiency

$$\%\eta = \frac{P_{o(ac)}}{P_{i(ac)}} \times 100$$

Transformer-Coupled Class A Amplifier

This circuit uses a transformer to couple to its load. This improves the efficiency of the Class A to 50%.



Transformer Action

A transformer improves the efficiency of a class A amplifier because it is able to transform the voltage, current, and impedance

Voltage Ratio

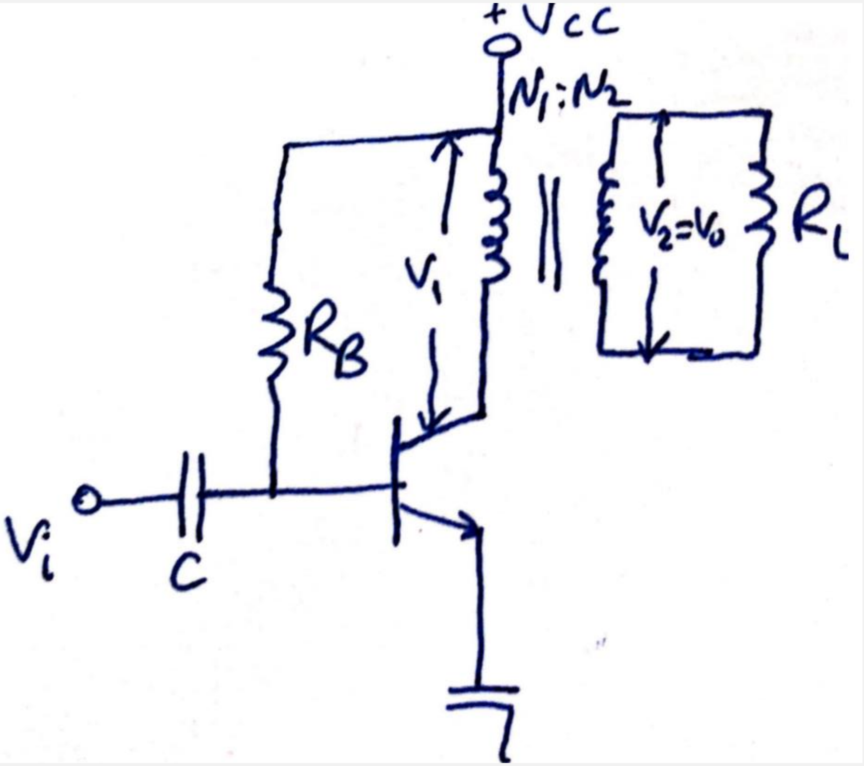
$$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$

Current Ratio

$$\frac{I_2}{I_1} = \frac{N_1}{N_2}$$

Impedance Ratio

$$\frac{R_L'}{R_L} = \frac{R_1}{R_2} = \left(\frac{N_1}{N_2}\right)^2 = a^2$$



Transformer-Coupled Class A Amplifie

DC Load Line

The *Q*-point for a transformer-coupled class A amplifier is set close to the midpoint of the DC load line

Transformer-Coupled Class A Amplifie

AC Load Line

The saturation point (I_{Cmax}) is at V_{CC}/R'_L and the cutoff point is at V_2 (the transformer secondary voltage). This increases the maximum output swing because the minimum and maximum values of I_C and V_{CE} are spread further apart.

Transformer-Coupled Class A Amplifier

Voltage Swing

$$V_{CE(p-p)} = V_{CE\max} - V_{CE\min}$$

Current Swing

$$I_{C\max} - I_{C\min}$$

AC Power

$$P_{o(ac)} = \frac{(V_{CE\max} - V_{CE\min})(I_{C\max} - I_{C\min})}{8}$$

Transformer-Coupled Class A Amplifier Efficiency

Power input from the DC source

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

Power dissipated as heat across the transistor

$$P_Q = P_{i(dc)} - P_{o(ac)}$$

Note: The larger the input and output signal, the lower the heat dissipation.

Maximum efficiency

$$\%\eta = 50\left(\frac{V_{CE\max} - V_{CE\min}}{V_{CE\max} + V_{CE\min}}\right)^2$$

Note: The larger V_{CEmax} and lower V_{CEmin}, the closer the circuit efficiency approaches the theoretical maximum of 50%.

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: Efficiency

The maximum efficiency of a class B is 78.5%

$$\%\eta = \frac{P_{o(ac)}}{P_{i(dc)}} \times 100 \qquad P_{o(ac),MAX} = \frac{V_{CC}^2}{2R_L}$$

For maximum power, $V_L = V_{CC}$

$$P_{i(dc)MAX} = V_{CC}(I_{dc,MAX}) = V_{CC}\left(\frac{2V_{CC}}{\pi R_L}\right) = \frac{2V_{CC}^2}{\pi R_L}$$

Transformer-Coupled Push-Pull Class B Amplifier

The center-tapped transformer on the input produces opposite polarity signals to the two transistor inputs.

The center-tapped transformer on the output combines the two halves of the AC waveform together.

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.

Amplifier Distortion

If the output of an amplifier is not a true replica of the AC input signal, then it is distorting the output. The amplifier is non-linear.

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

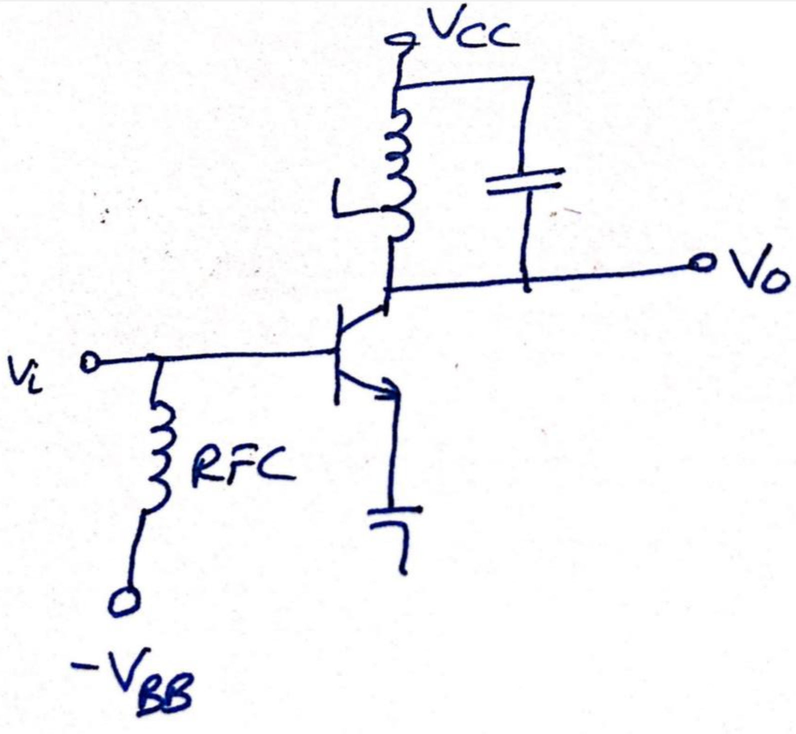
etc.

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

Class C Amplifier

A class C amplifier conducts for less than 180°. In order to produce a full sine wave output, the class C uses a tuned circuit (LC tank) to provide the full AC sine wave.

Class C amplifiers are used extensively in radio communications circuits.



Class D Amplifier

A class D amplifier amplifies pulses, and requires a pulsed input.

There are many circuits that can convert a sinusoidal waveform to a pulse, as well as circuits that convert a pulse to a sine wave. This circuit has applications in digital circuitry.