6872 Foundations of Electronics

Lecture 10: Power Amplifier

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Abstract

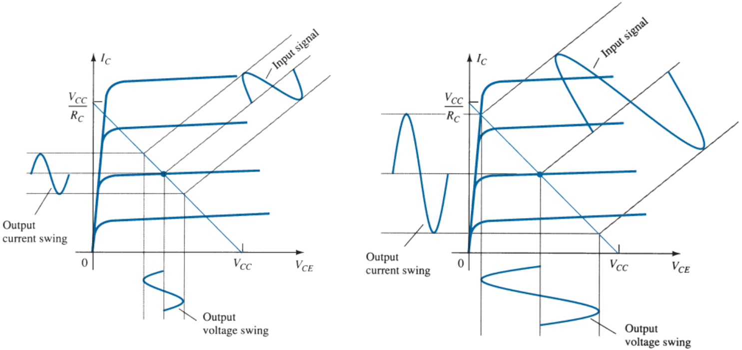
- Power Amplifier Operation Classes
- Class A Operation
- Class B Operation

Amplifiers

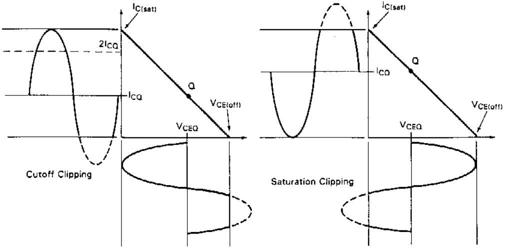
- Amplifier receives a signal from some input source and provides a larger version of the signal to some output device (or to another amplifier stage)
  - Input signal is generally small (few microvolts (antenna) to few millivolts (audio transducer)
  - **Small-signal amplifiers** (a.k.a. preamplifier or preamp) are usually concerned with amplification linearity and magnitude of gain
  - Preamps are usually voltage amplifiers
  - **Large-signal amplifiers** (a.k.a. power amplifiers) provide sufficient power to an output load (a speaker or other power device), typically from a few watts to tens of watts
  - Power amplifier is generally the last stage of a multistage amplifier
  - Power amplifiers are concerned power efficiency, distortion, maximum amount of power that the circuit is capable of handling, and impedance matching to the output device

Power efficiency: $\eta = \dfrac{P_{out(ac)}}{P_{in(dc)}} \times 100\%$

Load-Line and Q-Point

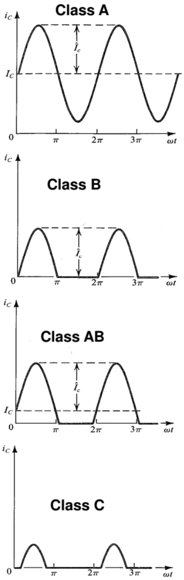


- Load-line is limitted by transistor saturation and cut-off
  - The signal is clipped off if transistor saturates or cuts-off



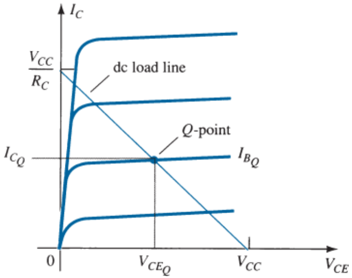
Power Amplifiers Classes

- **Class A:** output signal varies for a full 360° of the input signal and the Q-point is around the middle of the active region
- **Class B:** output signal varies for one-half the input signal cycle, or for 180° of signal, and the Q-point is at 0 V
  - Two class B operations are required (one for the positive-output half-cycle and another for the negative-output half-cycle)
- **Class AB:** Q-point is above 0 V (class B) but below the middle of the active region (class A)
  - Also requires two operations (same as class B)
- **Class C:** output signal varies for less than 180° of signal
  - Used only in special areas, such as radio or communications
- **Class D:** operation using pulse (digital) signals, which are on for a short interval and off for a longer interval
  - Uses digital techniques to obtain a signal that varies over the full cycle

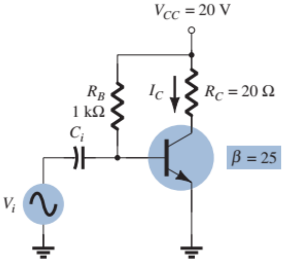


Series-Fed Class A Amplifier Example

- Power considerations:
  - Input DC Power: $P_{in(DC)} = V_{CC} I_{C(Q)}$
  - Output AC Max Power: $P_{out(AC)} = \frac{V_{CE(pp)}}{2\sqrt{2}} \frac{I_{C(pp)}}{2\sqrt{2}} = \frac{V_{CC}}{2\sqrt{2}} \frac{2I_{C(Q)}}{2\sqrt{2}} = \frac{V_{CC} I_{C(Q)}}{4}$
  - Max Efficiency: $\eta = \frac{V_{CC} I_{C(Q)}/4}{V_{CC} I_{C(Q)}} = 25\%$

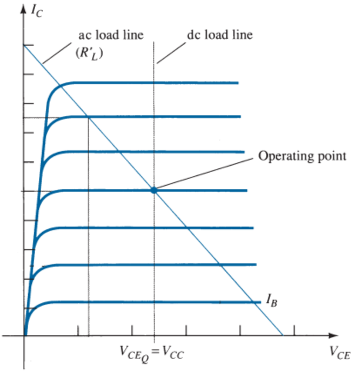


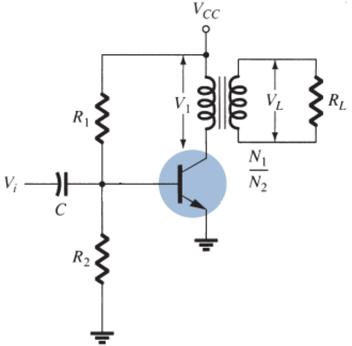
- Example
  - $I_{B(Q)} = \frac{V_{CC} - V_{BE}}{R_B} = \frac{20 - 0.7}{1\text{k}} = 19.3$ mA
  - $I_{C(Q)} = \beta I_{B(Q)} = 25 \times 19.3\text{m} = 483$ mA
  - $P_{in(DC)} = V_{CC} I_{C(Q)} = 20 \times 483\text{m} = 9.65$ W
  - Assuming $\hat{I}_C = 250$ mA, $P_{out(AC)} = \left(\frac{\hat{I}_C}{\sqrt{2}}\right)^2 R_C = \left(\frac{250\text{m}}{\sqrt{2}}\right)^2 20 = 625$ mW
  - $\eta = \frac{P_{out(AC)}}{P_{in(DC)}} = \frac{0.625}{9.65} = 6.5\%$



Transformer-Coupled Class A Amplifier

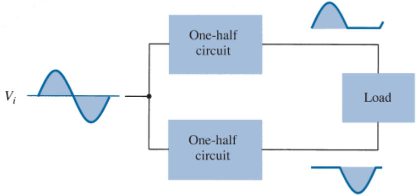
- Lower DC power loss due to very small resistance of transformer primary coil
- Max Efficiency: $\eta = 50\%$
- Reflected load resistance: $R'_L = \left(\frac{N_1}{N_2}\right)^2 R_L$
- Note the difference between the DC anc AC load-lines

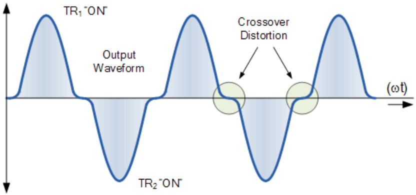




Class B Amplifier

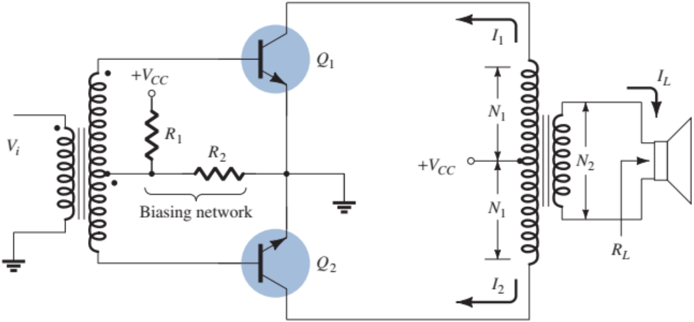
- DC bias leaves transistor on the edge of the active region
- Transistor turns on when the AC signal is applied
- Transistor conducts for only one-half of the signal cycle
- For the full cycle of signal, it is necessary to use two transistors, each conducting on opposite half-cycles
- This circuit is referred to as a **push-pull circuit**
- Max Efficiency: $\eta = 78.5\%$
- **Crossover Distortion** caused by switching between transistors





Transformer Coupled Push-Pull Circuit

- First half-cycle of operation:
  - Transistor Q_1 conducts, whereas transistor Q_2 stays off
  - Current I_1 through the transformer results in the first halfcycle of signal to the load
- Second half-cycle of operation:
  - Transistor Q_2 conducts, whereas transistor Q_1 stays off
  - Current I_2 through the transformer results in the second halfcycle of signal to the load



Complementary Push-Pull Circuit

- Uses complementary transistors (NPN and PNP types)
- The same signal is applied to the base of both transistors
- The transistors, being of opposite type, will conduct on opposite half-cycles of the input