Contents

Power Amplifiers

So far we have dealt with only small-signal amplifiers. In small-signal amplifiers the main factors were

- amplification
- linearity
- gain

Large-signal or **power amplifiers** function primarily to provide sufficient power to drive the output device. These amplifier circuits will handle large voltage signals and high current levels. The main factors are

- efficiency
- maximum power capability
- impedance matching to the output device

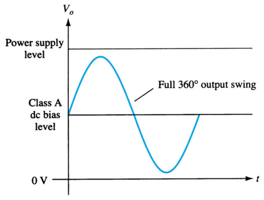
Power Amplifier Types

Main classes of power amplifiers are given below

1. Class A
2. Class B
3. Class AB
4. Class C
5. Class D

Class A Operation

The output of a Class A amplifier conducts for the full 360° of the cycle as shown below.

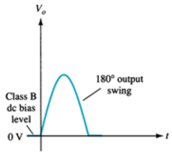


The Q-point (bias level) must be biased towards the middle of the load line so that the AC signal can swing a full cycle. Remember that the DC load line indicates the maximum and minimum limits set by the DC power supply.

The efficiency is **low**, because the transistor is **always on**, even when there is no AC input.

Class B Operation

A Class B amplifier output only conducts for 180° or half-cycle of the input signal as shown below.



The Q-point (bias level) is at **cut-off** (i.e., current is zero) on the load line, so that the AC signal can only swing for one half of a cycle.

The efficiency is **high**, because the transistor is **off**, when there is no AC input. However, we will need two transistor in order to produce a full cycle-output.

Class AB Operation

A Class AB amplifier output conducts between 180° and 360° of the AC input signal.

This amplifier is in between the Class A and Class B. The Q-point (bias level) is above the Class B but below the Class A.

Class C Operation

The output of the Class C conducts for less than 180° of the AC cycle and will operate only with a tuned (resonant) circuit. The Q-point (bias level) is at cutoff, the output signal is very small.

Class D Operation

The Class D output is more like pulse signals which are on for a short interval and off for a longer interval. It does not resemble the AC sine wave input, however it is possible to obtain full sine wave output using digital signal processing techniques.

Amplifier Efficiency

Efficiency refers to the ratio of output to input power. The lower the amount of conduction of the amplifier the higher the efficiency, so the efficiency improves (gets higher) going from Class A to Class D.

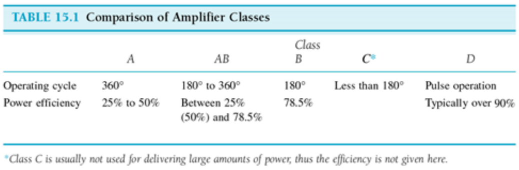


TABLE 15.1 Comparison of Amplifier Classes

	Class A	AB	B	C*	D
Operating cycle	360°	180° to 360°	180°	Less than 180°	Pulse operation
Power efficiency	25% to 50%	Between 25% (50%) and 78.5%	78.5%		Typically over 90%

*Class C is usually not used for delivering large amounts of power, thus the efficiency is not given here.

Efficiency η is defined as the ratio of the power output to the power input, i.e.,

$$\boxed{\eta\% = \frac{P_L}{P_{CC}} \times 100}$$

where P_L is the **power output** and P_{CC} is the **power input**.

Power Input

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

Thus, power input P_{CC} is defined as the power drawn from the power supply

$$P_{CC} = V_{CC} I_{CQ}$$

Power Output

$$\begin{aligned} P_L &= v_{o(rms)} i_{o(rms)} \\ &= \frac{v_{o_{peak}} i_{o_{peak}}}{2} \\ &= \frac{v_{o_{peak}}^2}{2R_L} \\ &= \frac{v_{o_{peak-peak}}^2}{8R_L} \end{aligned}$$

Transistor Power Dissipation

Power dissipated as heat across a transistor is given as

$$P_Q = \frac{1}{N_Q} \left(P_{CC} - P_L \right)$$

where N_Q is the number of transistors used in the power amplifier configuration.

NOTE: The larger the output signal, the lower the heat dissipation.

Figure of Merit

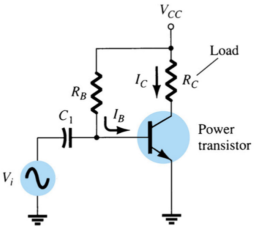
Figure of Merit (FoM) is a quantity used to characterize the cost performance of the power amplifier in terms of the ratio of the maximum power dissipated by a transistor and the maximum power delivered to the load, i.e.,

$$\text{FoM} = \frac{P_{Q_{max}}}{P_{L_{max}}}$$

NOTE: The **lower** the FoM, the **better** the cost performance. Because the higher the maximum power rating of a transistor, the higher the price.

Series-Fed Class A Amplifier

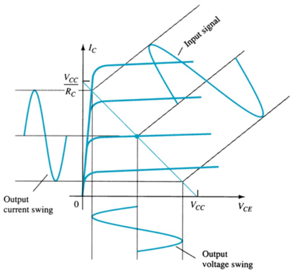
This is similar to the small-signal amplifier except that it will handle higher voltages. The Q-point (bias level) is biased in the middle of the load line for maximum efficiency.



The transistor used is a high power transistor. The current gain β of a power transistor is generally less than 100. Power transistors are capable of handling large power or current while not providing much voltage gain.

AC-DC Load Lines

As overall resistances of DC and AC output-loops are equal to each other, i.e., $R_{DC} = R_{ac} = R_C$, AC load line is equal to the DC load line ($V_{CE} = V_{CC} - I_C R_C$).



For maximum undistorted output swing, we need to set the Q-point at the middle of the AC load line, i.e., $V_{CEQ} = \frac{V_{CC}}{2}$ and $I_{CQ} = \frac{V_{CC}}{2R_C}$.

Thus, peak value of the maximum output voltage swing is given by

$$\boxed{v_{o(max)_{peak}} = v_{ce(max)_{peak}} = \frac{V_{CC}}{2}}.$$

Then, we can choose a value for R_B in order to obtain the desired Q-point values, i.e.,

$$R_B = \frac{V_{CC} - V_{BE(ON)}}{I_{BQ}} = \frac{V_{CC} - V_{BE(ON)}}{I_{CQ}/\beta}$$

NOTE: Once the value of R_B is given, it means that the Q-point is already set. Then, we have to make (or adjust) our calculations according to the given Q-point. For example, according to a given Q-point maximum undistorted output voltage swing will be the minimum of V_{CEQ} and $V_{CC} - V_{CEQ}$, i.e.,

$$v_{ce(max)_{peak}}\Big|_{Q\text{-point}} = \min\left(V_{CEQ}, V_{CC} - V_{CEQ}\right)$$

Power Input, Power Output and Efficiency

Power Input

$$P_{CC} = V_{CC} I_{CQ}$$

Power Output

$$P_L = \frac{v^2_{o_{peak}}}{2R_C} = \frac{v^2_{o_{peak-peak}}}{8R_C}$$

Efficiency

$$\eta\% = \frac{P_L}{P_{CC}} \times 100 = \frac{v^2_{o_{peak}}/(2R_C)}{V_{CC} I_{CQ}} \times 100$$

Transistor Power Dissipation

Power dissipated as heat across a transistor is given as

$$P_Q = P_{CC} - P_L = V_{CC} I_{CQ} - \frac{v^2_{o_{peak}}}{2R_C}$$

Maximum Efficiency

Maximum efficiency η_{max} is achieved at the maximum output power $P_{L(max)}$, i.e., at the maximum output swing $v_{o(max)_{peak}} = \frac{V_{CC}}{2}$. Thus,

$$P_{L(max)} = \frac{v^2_{o(max)_{peak}}}{2R_C} = \frac{(V_{CC}/2)^2}{2R_C} = \frac{V^2_{CC}}{8R_C}$$

Similarly, the input power at the maximum undistorted swing is given as

$$P_{CC}\big|_{P_{L(max)}} = V_{CC}\; I_{CQ}\big|_{v_{o(max)}} = V_{CC}\left(\frac{V_{CC}}{2R_C}\right) = \frac{V^2_{CC}}{2R_C}$$

Thus, maximum efficiency η_{max} is given as

$$\eta_{max}\% = \frac{P_{L(max)}}{P_{CC}\big|_{P_{L(max)}}} \times 100 = \frac{V^2_{CC}/(8R_C)}{V^2_{CC}/(2R_C)} \times 100 = \frac{1}{4} \times 100 = 25\%.$$

Figure of Merit

As transistor power dissipation is given by $P_Q = P_{CC} - P_L$, maximum transistor power is dissipated when there is no AC input and output, i.e., $P_L = 0$

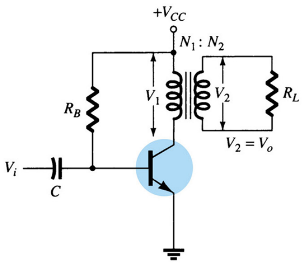
$$P_{Q(max)} = P_{CC}\big|_{P_{L(max)}} - 0 = P_{CC}\big|_{P_{L(max)}} = \frac{V^2_{CC}}{2R_C}.$$

Thus, figure of merit (FoM) is given as

$$\text{FoM} = \frac{P_{Q(max)}}{P_{L(max)}} = \frac{V^2_{CC}/(2R_C)}{V^2_{CC}/(8R_C)} = 4.$$

This FoM value shows that a series-fed Class A amplifier is not a good choice as a power amplifier. Because, if we want to deliver 10 W to the load, we need to select a 40 W-transistor.

Transformer-Coupled Class A Amplifier



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

AC-DC Load Lines

DC Load-Line

In DC operation, transformer action is not present we only have the DC resistance of the primary winding which is taken as **zero**. So, the overall DC resistance of the output-loop, R_{DC} is also zero, i.e.,

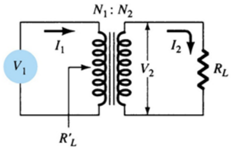
$$R_{DC} = 0.$$

Thus, the **DC load-line equation** is given by

$$\boxed{V_{CE} = V_{CC}}.$$

AC Load-Line

In AC operation, transformer action is present as shown in below. Transformers transform voltage, current and **impedance**.



$a = \frac{N_1}{N_2}$, $V_1 = aV_2$, $I_2 = aI_1$ and

$$\boxed{R'_L = a^2 R_L}$$

So, overall AC resistance of the output-loop, R_{ac} is equal to the equivalent primary-side load R'_L, i.e.,

$$R_{ac} = R'_L$$

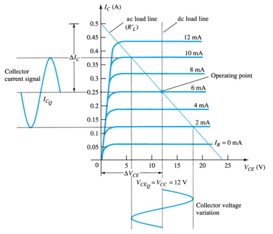
where

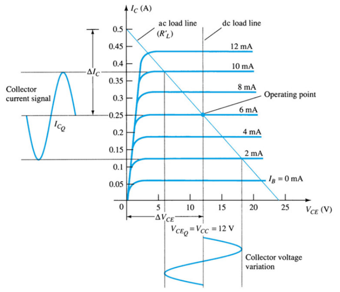
$$R'_L = a^2 R_L,$$

and a is the turns ratio of the transformer, i.e., $a = \frac{N_1}{N_2}$. Thus, **AC load-line equation** is then given by

$$\boxed{i_C = \frac{-1}{R'_L} v_{CE} + I_{CQ} + \frac{V_{CEQ}}{R'_L}}.$$

Finally, we can plot the AC-DC load-lines together as shown below.





For maximum undistorted output swing, we need to set the Q-point at the middle of the AC load line, to satisfy

$$v_{o(max)_{peak}} = v_{ce(max)_{peak}} = V_{CEQ} = V_{CC}$$

with $I_{CQ} = \frac{V_{CEQ}}{R'_L} = \frac{V_{CC}}{R'_L}$.

Then, we can choose a value for R_B in order to obtain the desired Q-point values, i.e.,

$$R_B = \frac{V_{CC} - V_{BE(ON)}}{I_{BQ}} = \frac{V_{CC} - V_{BE(ON)}}{I_{CQ}/\beta}$$

NOTE: Once the value of R_B is given, it means that the Q-point is already set. Then, we have to make (or adjust) our calculations according to the given Q-point. For example, according to a given Q-point maximum undistorted output voltage swing will be the minimum of V_{CEQ} and $I_{CQ}R'_L$, i.e.,

$$v_{ce(max)_{peak}}\Big|_{Q\text{-point}} = \min\left(V_{CC}, I_{CQ}R'_L\right)$$

Power Input, Power Output and Efficiency

Power Input

$$P_{CC} = V_{CC} I_{CQ}$$

Power Output

$$P_L = \frac{v_{o_{peak}}^2}{2R'_L}$$

Efficiency

$$\begin{aligned}\eta\% &= \frac{P_L}{P_{CC}} \times 100 \\ &= \frac{v_{o_{peak}}^2/(2R'_L)}{V_{CC} I_{CQ}} \times 100\end{aligned}$$

Transistor Power Dissipation

Power dissipated as heat across a transistor is given as

$$
\begin{aligned}
P_Q &= P_{CC} - P_L \\
&= V_{CC} I_{CQ} - \frac{v_{o_{peak}}^2}{2R_L'}
\end{aligned}
$$

Maximum Efficiency

Maximum efficiency η_{max} is achieved at the maximum output power $P_{L(max)}$, i.e., at the maximum output swing $v_{o(max)_{peak}} = V_{CC}$. Thus,

$$
P_{L(max)} = \frac{v_{o(max)_{peak}}^2}{2R_L'} = \frac{V_{CC}^2}{2R_L'}
$$

Similarly, the input power at the maximum undistorted swing is given as

$$
P_{CC}\big|_{P_{L(max)}} = V_{CC}\, I_{CQ}\big|_{v_{o(max)}} = V_{CC}\left(\frac{V_{CC}}{R_L'}\right) = \frac{V_{CC}^2}{R_L'}
$$

Thus, maximum efficiency η_{max} is given as

$$
\begin{aligned}
\eta_{max}\% &= \frac{P_{L(max)}}{P_{CC}|_{P_{L(max)}}} \times 100 \\
&= \frac{V_{CC}^2/(2R_L')}{V_{CC}^2/R_L'} \times 100 \\
&= \frac{1}{2} \times 100 \\
&= 50\%.
\end{aligned}
$$

Figure of Merit

As transistor power dissipation is given by $P_Q = P_{CC} - P_L$, maximum transistor power is dissipated when there is no AC input and output, i.e., $P_L = 0$

$$
P_{Q(max)} = P_{CC}|_{P_{L(max)}} - 0 = P_{CC}|_{P_{L(max)}} = \frac{V_{CC}^2}{R_L'}.
$$

Thus, figure of merit (FoM) is given as

$$
\begin{aligned}
\text{FoM} &= \frac{P_{Q(max)}}{P_{L(max)}} \\
&= \frac{V_{CC}^2/R_L'}{V_{CC}^2/(2R_L')} \\
&= 2.
\end{aligned}
$$

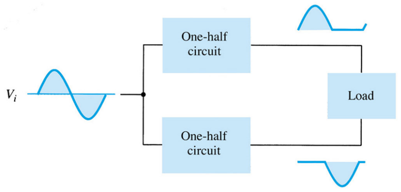
This FoM value is not also very good. Because, if we want to deliver $10\,\text{W}$ to the load, we need to select a $20\,\text{W}$-transistor.

Class B Amplifiers

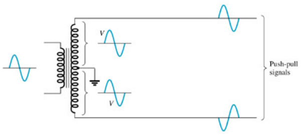
In Class B the DC bias leaves the transistor biased just off (i.e., at cut-off). The AC signal turns the transistor on. This is essentially no bias. The transistor only **conducts** when it is turned on by **half** of the AC cycle.

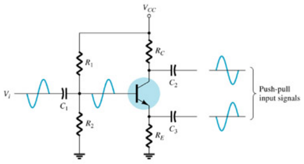
In order to get a **full** AC cycle out of a Class B amplifier, you need **two** transistors.

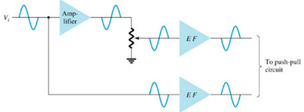
In a transformer-coupled push-pull arrangement, two npn-transistors are one works on the positive half of the input signal and the other works on the inverted negative half of the input signal. In a complementary-symmetry push-pull arrangement, one is an npn-transistor that provides the positive half of the AC cycle and the other is a pnp transistor that provides the negative half.



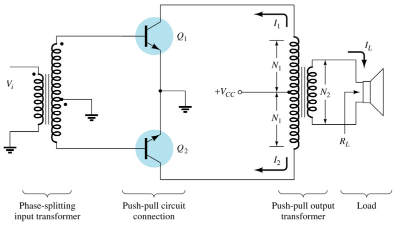
Phase Splitter Circuits







Transformer-Coupled Push-Pull Class B Amplifier



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

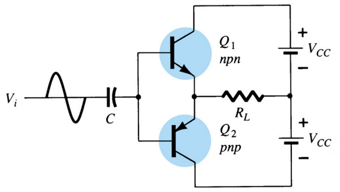
The center-tapped transformer on the output **combines** the two halves of the AC waveform together.

Push-Pull Operation

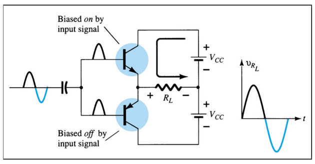
- During the **positive half** of the AC input cycle:
  - Transistor Q_1 is conducting and Q_2 is off.
- During the **negative half** of the AC input cycle:
  - Transistor Q_2 is conducting and Q_1 is off.

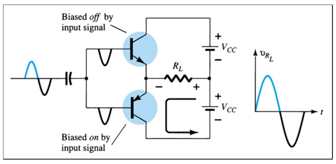
Each transistor produces half of an AC cycle. The output transformer combines the two outputs to form a full AC cycle.

Complementary-Symmetry Push-Pull Class B Amplifier



One big advantage of this configuration is avoiding the need for a transformer.





Power Input, Power Output and Efficiency

Power Input

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

$$P_{CC} = V_{CC} I_{CC}$$

where I_{CC} 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, while 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

$$I_{CC} = \frac{2}{\pi} i_{o_{peak}} = \frac{2}{\pi} \frac{v_{o_{peak}}}{R_L}$$

where $i_{o_{peak}}$ and $v_{o_{peak}}$ are the peak values of the output current and voltage waveforms, respectively. Thus, the power input equation becomes

$$P_{CC} = \frac{2}{\pi} \frac{V_{CC}\, v_{o_{peak}}}{R_L}$$

Power Output

$$P_L = \frac{v_{o_{peak}}^2}{2R_L}$$

Efficiency

$$\begin{aligned}
\eta\% &= \frac{P_L}{P_{CC}} \times 100 \\
&= \frac{v_{o_{peak}}^2/(2R_L)}{(2/\pi)(V_{CC}\, v_{o_{peak}}/R_L)} \times 100 \\
&= \frac{\pi}{4} \frac{v_{o_{peak}}}{V_{CC}} \times 100 \\
&= \frac{v_{o_{peak}}}{V_{CC}} \times 78.54
\end{aligned}$$

Transistor Power Dissipation

Power dissipated as heat across a transistor in a Class B push-pull configuration is given as

$$\begin{aligned}
P_Q &= \frac{1}{2}(P_{CC} - P_L) \\
&= \frac{1}{2}\left(\frac{2}{\pi}\frac{V_{CC}\, v_{o_{peak}}}{R_L} - \frac{v_{o_{peak}}^2}{2R_L}\right) \\
&= \frac{1}{\pi}\frac{V_{CC}\, v_{o_{peak}}}{R_L} - \frac{v_{o_{peak}}^2}{4R_L}
\end{aligned}$$

Maximum Efficiency

Maximum efficiency η_{max} is achieved at the maximum output power $P_{L(max)}$, i.e., at the maximum output swing

$$v_{o(max)_{peak}} = V_{CC}.$$

where each transistor provides half cycle of the output swing.

Thus, maximum efficiency η_{max} is given as

$$\begin{aligned}
\eta_{max}\% &= \frac{P_{L(max)}}{P_{CC}|_{P_{L(max)}}} \times 100 \\
&= \frac{\pi}{4}\frac{v_{o(max)_{peak}}}{V_{CC}} \times 100 \\
&= \frac{\pi}{4}\frac{V_{CC}}{V_{CC}} \times 100 \\
&= \frac{\pi}{4} \times 100 \\
&= 78.54\%.
\end{aligned}$$

Figure of Merit

$$P_Q = \frac{1}{\pi}\frac{V_{CC}\,v_{o_{peak}}}{R_L} - \frac{v_{o_{peak}}^2}{4R_L}$$

Let us find the value of $v_{o_{peak}}$ to give the maximum transistor power dissipation $P_{Q(max)}$ as follows

$$\left.\frac{dP_Q}{dv_{o_{peak}}}\right|_{P_{Q(max)}} = 0$$

$$\frac{V_{CC}}{\pi} - \frac{v_{o_{peak}}}{2} = 0$$

$$\left.v_{o_{peak}}\right|_{P_{Q(max)}} = \frac{2}{\pi}V_{CC}.$$

Substituting the result above in the transistor power dissipation equation we obtain $P_{Q_{max}}$ as follows

$$P_{Q(max)} = \frac{1}{\pi^2}\frac{V_{CC}^2}{R_L}.$$

As $v_{o(max)_{peak}} = V_{CC}$, we obtain the maximum output power as

$$P_{L(max)} = \frac{V_{CC}^2}{2R_L}.$$

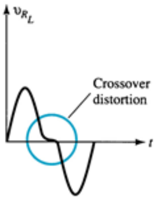
Thus, figure of merit (FoM) is given as

$$\begin{aligned}\text{FoM} &= \frac{P_{Q(max)}}{P_{L(max)}}\\ &= \frac{V_{CC}^2/(\pi^2 R_L)}{V_{CC}^2/(2R_L)}\\ &= \frac{2}{\pi^2}\\ &\cong \frac{1}{5}.\end{aligned}$$

This FoM value is quite good. Because, if we want to deliver $10\,$W to the load, we only need to select **two** $2\,$W-transistors.

Crossover Distortion

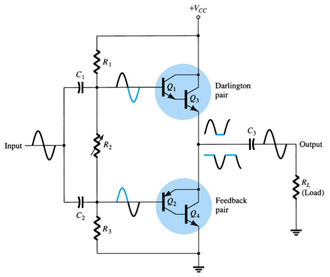
One big disadvantage of the Class B amplifiers is the **crossover distortion** produced at the output as shown in the figure below.



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. This results from the fact that transistor turn-on voltage is not actually zero volts, i.e., $V_{BE(ON)} \neq 0\,$V. Input voltage $v_i(t)$ itself turns the transistors ON and OFF. So, during the time when the magnitude of the input signal is less than the turn-on voltage, i.e., $|v_i(t)| < V_{BE(ON)}$, **both** transistors are **OFF** producing zero output and causing the crossover distortion.

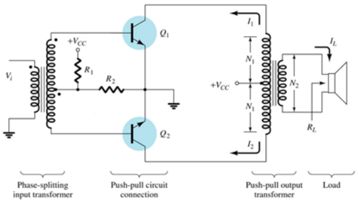
Biasing the transistors just to the turn-on level $V_{BEQ} \cong V_{BE(ON)}$, will be the solution. However, this DC biasing causes static power dissipation, even when there is no AC input. So, the amplifier now becomes a **Class AB amplifier**.

Class AB Amplifiers



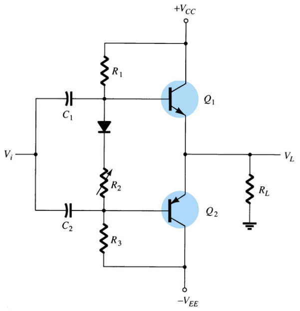
This configuration uses Darlington and feedback pairs for npn and pnp transistors, respectively. The voltage across over R_2 is adjusted to provide turn-on voltages for the Darlington and feedback pairs, i.e.,

$$V_{R_2} \cong \frac{R_2}{R_1+R_2+R_3}V_{CC} = 2V_{BE(ON)} + V_{EB(ON)} = 3V_{BE(ON)}.$$



This configuration uses R_1 and R_2 resistors to bias the two transistors, as shown below

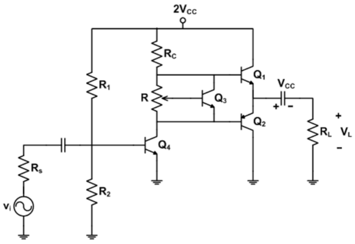
$$\frac{R_2}{R_1+R_2}V_{CC} = V_{BE(ON)}.$$



This configuration uses a diode (matched to the Q_1 transistor, i.e., $V_{D(ON)} = V_{BE(ON)}$) and an adjustable R_3 resistor to bias the two transistors, as shown below

$$V_{R_2} \cong \frac{R_2}{R_1+R_2+R_3}\left(V_{CC}+V_{EE}-V_{D(ON)}\right) = V_{BE(ON)}.$$

As the diode is matched with one of the transistors, any changes on the turn-on voltage of this transistor will be compensated by the change in the turn-on voltage of the diode, e.g., changes due to temperature.

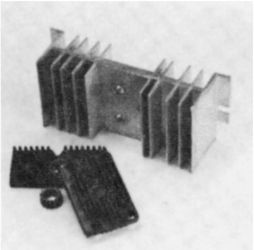


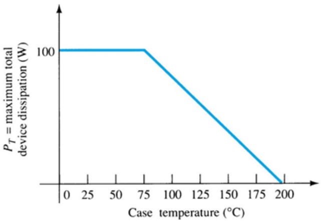
This configuration uses variable R resistor (or potentiometer) to bias the transistors. Note that, Q_3 transistor increases the turn-off speeds of the power transistors Q_1 and Q_2.

Power Transistor Heat Sinking

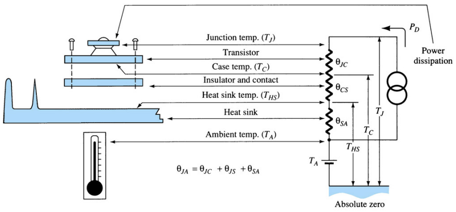
High power transistors dissipated a lot of power in heat. This can be destructive to the amplifier as well as to surrounding components. These transistors will require **heat-sinking**. A few heat sinks are shown in the figure left below.

A typical power derating curve for a silicon transistor is shown on figure right below.





Thermal-to-Electrical Analogy



- θ_{JC} = transistor thermal resistance (junction to case)
- θ_{CS} = insulator thermal resistance (case to heat sink)
- θ_{SA} = heat-sink thermal resistance (heat sink to ambient)
- θ_{JA} = total thermal resistance (junction to ambient)

Using the electrical analogy for thermal resistances, we can write:

$$\theta_{JA} = \theta_{JC} + \theta_{CS} + \theta_{SA}$$

The analogy can also be used in applying Kirchhoff's law to obtain:

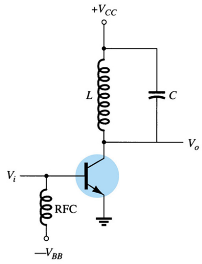
$$T_J = P_D\theta_{JA} + T_A$$

Example 1: A silicon power transistor is operated with a heat sink ($\theta_{SA} = 1.5\,°\text{C/W}$). The transistor, rated at $150\,\text{W}$ ($25\,°\text{C}$), has $\theta_{JC} = 0.5\,°\text{C/W}$, and the mounting insulation has $\theta_{CS} = 0.6\,°\text{C/W}$. What maximum power can be dissipated if the ambient temperature is $40\,°\text{C}$ and $T_{J_{max}} = 200\,°\text{C}$?

Solution:

$$P_D = \frac{T_J - T_A}{\theta_{JC} + \theta_{CS} + \theta_{SA}} = \frac{200 - 40}{0.5 + 0.6 + 1.5} \approx 61.5\,\text{W}.$$

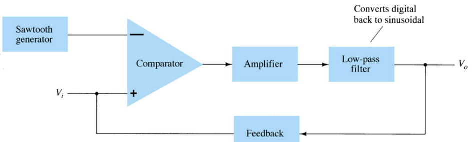
Class C Amplifiers



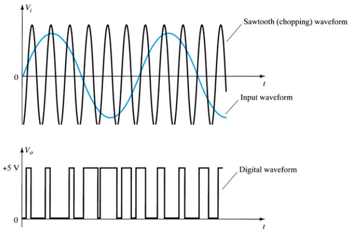
A Class C amplifier is biased to operate for less than $180°$ of the input signal cycle. The tuned circuit in the output, however, will provide a full cycle of output signal for the fundamental or resonant frequency of the tuned circuit (L and C tank circuit) of the output. This type of operation is therefore limited to use at one fixed frequency, as occurs in a **communications** circuit, for example.

Operation of a Class C circuit is **not intended** for large-signal or power amplifiers.

Class D Amplifiers



A Class D amplifier amplifies pulses. There are many circuits that can convert a sine-wave to a pulse, as well as circuits that convert a pulse to a sine-wave. This circuit has applications in digital circuitry.



Class B Power Amplifier Example

Example 2: (2005-2006 MII) Consider the amplifier circuits given in the figures below where $V_{BE(ON)} = 0.7\,\text{V}$.

For the circuit shown in Fig-A with $v_i = 1\,\text{V}\sin(\omega t)$

a) Draw v_o,

b) Calculate the power P_L dissipated over R_L,

c) Calculate the efficiency of the power amplifier consisting of transistors Q_1 and Q_2.

For the circuit shown in Fig-B with $v_i = 1\,\text{V}\sin(\omega t)$

d) Draw v_o,

e) Compare the two amplifier circuit designs given in Fig-A and Fig-B, and express which design is more preferable. Briefly explain your answer.
HINT: Consider your answers to items "a)" and "d)".

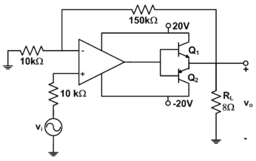


Fig-A

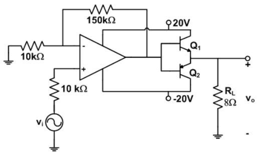
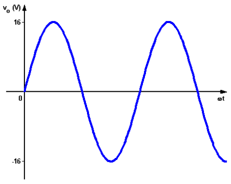


Fig-B

Solution: a) We can calculate the voltage gain A_v as $A_v = \frac{v_o}{v_i} = 1 + \frac{150k}{10k} = 16$.
So, the output v_o is given by $v_o = A_v v_i = 16\,\text{V}\sin(\omega t)$.



b) $P_L = \dfrac{v_{o(peak)}^2}{2R_L} = \dfrac{16^2}{2(8)} = 16\,\text{W}$

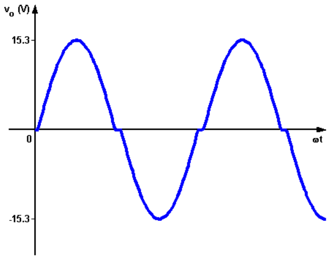
c) As we know the output power let us calculate the total power P_{CC} drawn from the voltage supplies

$$\begin{aligned} P_{CC} &= V_{CC} I_{CC} \\ &= V_{CC} \frac{2}{\pi} \frac{v_{o(peak)}}{R_L} \\ &= 20 \frac{2}{\pi} \frac{16}{8} \\ &= 25.465\,\text{W}. \end{aligned}$$

Now, efficiency η is given by

$$\begin{aligned} \eta\% &= \frac{P_L}{P_{CC}} \times 100 \\ &= \frac{16}{25.465} \times 100 \\ &= 62.83\%. \end{aligned}$$

d) There is a cross-over distortion at the output due to the $0.7\,\text{V}$ turn-on voltage drop across the base-emitter junctions of the transistors Q_1 and Q_2. So, the output v_o of Fig-B will be plotted as below



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e) In Fig-B, Class B power amplifier (in a complementary push-pull structure) is connected after a pre-amplifier stage consisting of a non-inverting opamp amplifier. This complementary push-pull Class B amplifier configuration acts like a voltage-buffer amplifier (i.e. like an emitter-follower).

However the complementary (npn-pnp) BJT amplifiers turn-on when sufficient voltage difference($\geq 0.7\,\text{V}$) exists between their base-emitter terminals (BE-EB). Q_1 is ON at the positive-half cycle when $(V_{B_1} V_{E_1}) \geq 0.7\,\text{V}$ and similarly Q_2 is ON at the negative-half cycle when $(V_{B_2} V_{E_2}) \leq -0.7\,\text{V}$.

Due to this $0.7\,\text{V}$ turn-on voltage drop across the base-emitter junctions of the complementary BJT transistors, we observe a **cross-over distortion** at the output of Fig-B as shown in the answer of item "d)".

In Fig-A, negative feedback is connected to the output of the power amplifier eliminating the cross-over distortion by enforcing the suitable biasing voltage at the transistor bases. So, the configuration in **Fig-A** is **more preferable** to the configuration in Fig-B.