Electronics II

Lecture 28
Power Amplifiers II
Class A, Class B & Class AB Amplifiers

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Previous Lecture

- Power Amplifiers
  - Basics of Power Amplifiers.
  - Classes of Power Amplifiers.
  - Class A Power Amplifier.

Session Overview

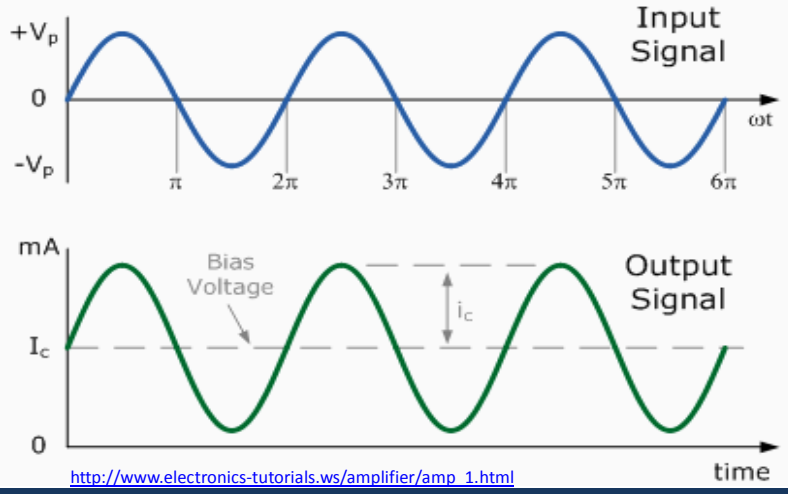
Topic	Power Amplifiers
Concepts	Class A Power Amplifier, Class B Amplifier. Push Pull Circuits, Class AB Amplifiers.
Recommended Reading	Sections 15.2, 15.4 and 15.5(Partial), 15.6 of [1].
Keywords	Power Amplifier, Class A Class B, Class AB, Push-Pull, Push Pull.

Class A Power Amplifier

- Low efficiency but better signal reproduction and linearity.
- In class A amplifier operation, the complete input waveform is reproduced at the output.
- This exact amplified reproduction at the output is possible because the Class A amplifier is perfectly biased within its active region.
- Due the this biasing it never enters the cut-off or saturation region.
- Class A amplifier uses a single transistor for both input cycles. Because of its biasing arrangements, this amplifier always has the current flowing at the output.
- This causes the poor efficiency as the actual power delivered to the load is quite less than the actual power converted.
- Most the power converted is wasted as heat thereby risking the device burn out if proper sinking is not provided. Additionally sinks also increase the cost.

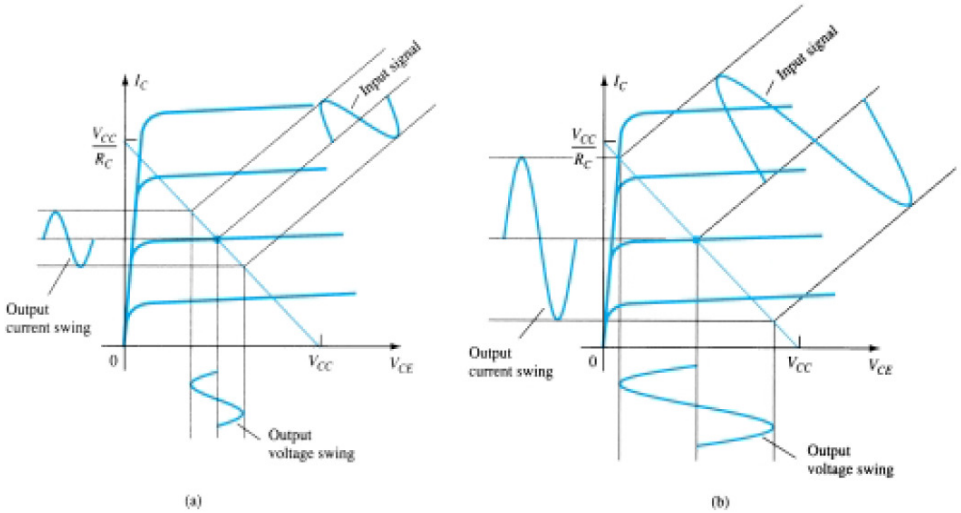
Class A Power Amplifier

Class A Output Waveform



http://www.electronics-tutorials.ws/amplifier/amp_1.html

Class A Power Amplifier- AC Operation



Robert L. Boylestad, *Electronic Devices and Circuit Theory*, 8th Edition, Pearson Education Inc, ISBN: 81-7808-590-9.

Power Considerations- Class A power Amplifier

- Input power is given as
  - $P_{i(dc)} = V_{CC} * I_{CQ}$
- Output power
  - RMS: $P_{o(ac)} = V_{c(rms)}^2 / R_c$
  - Peak: $P_{o(ac)} = V_{CE(p)}^2 / 2R_c$
  - Peak-Peak: $P_{o(ac)} = V_{CE(p\text{-}p)}^2 / 8R_c$
- Efficiency
  - $\%\eta = [\, P_{o(ac)}/P_{i(dc)} \,] \times 100\%$
- Maximum Power Efficiency

$$\text{maximum } V_{CE}(\text{p-p}) = V_{CC}$$

$$\text{maximum } I_C(\text{p-p}) = \frac{V_{CC}}{R_C}$$

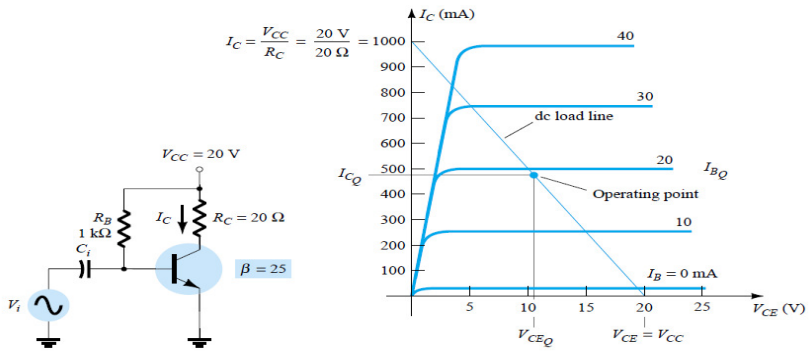
$$\text{maximum } P_o(\text{ac}) = \frac{V_{CC}(V_{CC}/R_C)}{8} = \frac{V_{CC}^2}{8R_C}$$

$$\text{maximum } P_i(\text{dc}) = V_{CC}(\text{maximum } I_C) = V_{CC}\frac{V_{CC}/R_C}{2} = \frac{V_{CC}^2}{2R_C}$$

$$\text{maximum } \%\ \eta = \frac{\text{maximum } P_o(\text{ac})}{\text{maximum } P_i(\text{dc})} \times 100\% = \frac{V_{CC}^2/8R_C}{V_{CC}^2/2R_C} \times 100\% = 25\%$$

Class A Power Amplifier- Example

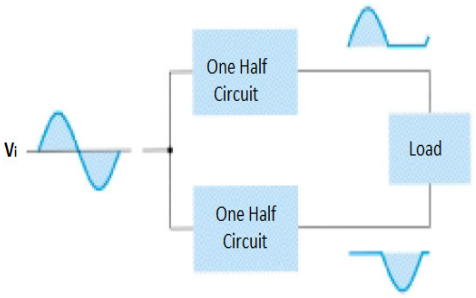
- **Example 15.1 (Boylestad):** Calculate input power, output power and power efficiency of the given power amplifier for input voltage that causes the base current of 10mA peak.



Robert L. Boylestad, *Electronic Devices and Circuit Theory*, 8th Edition, Pearson Education Inc, ISBN: 81-7808-590-9.

Class B Power Amplifier

- Class B amplifier works only for 180^0 of output cycle. The DC biasing leaves the transistor turned off when there is not input ac signal.
- To obtain the output for full 360^0 cycle of operation, two transistor with output at the opposite cycles are coupled together.
- This is termed as the ***push-pull configuration***. During one half cycle, one transistor causes the output to be high and during other half cycle, the second transistor causes the output to go low.
- The efficiency of class B amplifier is better than the class A amplifier. Why ?



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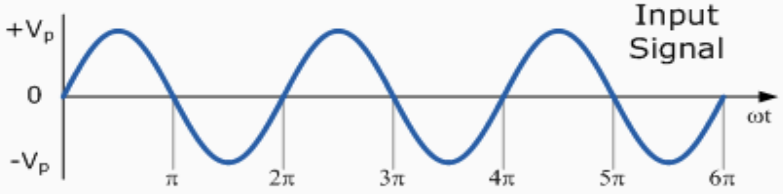
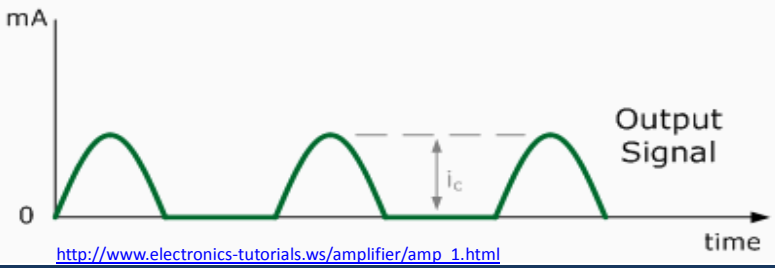
Class B Power Amplifier

Class B Output Waveform

Better Efficiency, Poor signal reproduction at the output, Distorted output

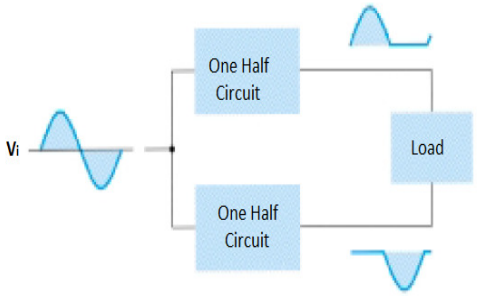




http://www.electronics-tutorials.ws/amplifier/amp_1.html

Power Considerations- Class B Power Amplifier

- Input DC power
  - $P_{i(dc)} = V_{cc} * I_{dc}$.
  - I_{dc}= average or DC current.
  - $I_{dc} = (2/\pi) * I_p$.
  - $P_{i(dc)} = V_{cc} * (2/\pi) * I_p$.
- Output AC Power
  - $P_{o(ac)} = V_{L(rms)}^2 / R_L$.
  - $P_{o(ac)} = V_{L(p-p)}^2 / 8R_L$.
  - $P_{o(ac)} = V_{L(p)}^2 / 2R_L$.
- Efficiency



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

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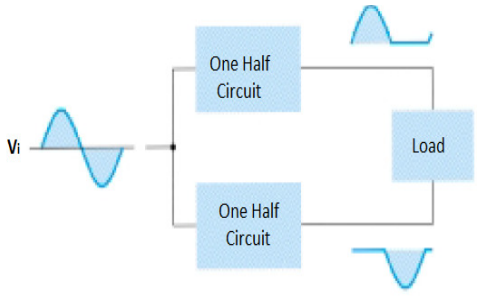
$$\% \ \eta = \frac{P_o(\text{ac})}{P_i(\text{dc})} \times 100\% = \frac{V_L^2(\text{p})/2R_L}{V_{CC}[(2/\pi)I(\text{p})]} \times 100\% = \frac{\pi}{4} \frac{V_L(\text{p})}{V_{CC}} \times 100\%$$

Power Considerations- Class B Power Amplifier

- Example 15.7(Boylestad):

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.



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Maximum Power Considerations Class B Power Amplifier

- Maximum output power is delivered when $V_{L(p)}=V_{cc}$.
  - Maximum $P_{o(ac)}=V_{cc}^2/2R_L$
- Corresponding maximum Peak ac current
  - $I_{(p)}= V_{cc}/R_L$
- Maximum average current from power supply
  - Max $I_{dc}= (2/\pi)\ I_{(p)}=2V_{cc}^2/\pi R_L$
- Maximum input power
  - Max $P_{i(dc)}= V_{cc}*(\text{max } I_{dc})$
  - Max $P_{i(dc)}= 2V_{cc}^2/\pi R_L$
- Maximum % Efficiency, η
  - $\eta\%$ = [$P_{o(ac)}$/ $P_{i(dc)}$]* 100
  - $\eta\% = \dfrac{V_{CC}^2/2R_L}{V_{CC}[(2/\pi)(V_{CC}/R_L)]} \times 100\%$
  - $\eta\% = \dfrac{\pi}{4} \times 100\% = \mathbf{78.54\%}$
- Check the formulae for Maximum power dissipated.

Maximum Power Considerations Class B Power Amplifier

- Example 15.8 (Boylestad):

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.

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Maximum Power Considerations Class B Power Amplifier

- Example 15.9 (Boylestad):

  Calculate the efficiency of a class B amplifier for a supply voltage of $V_{CC} = 24$ V with peak output voltages of:
  (a) $V_L(p) = 22$ V.
  (b) $V_L(p) = 6$ V.

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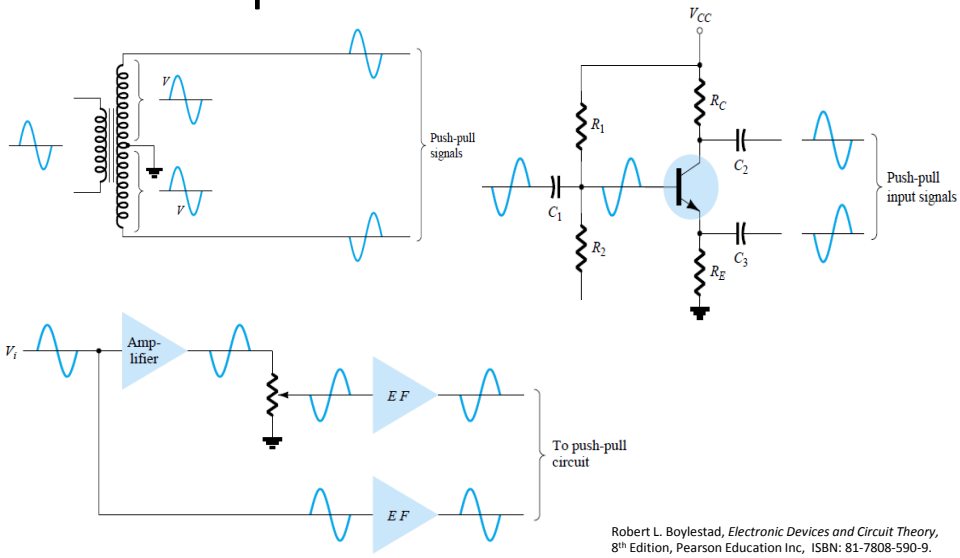
Class B Power Amplifier Circuit

- There are multiple circuits to obtain a class B power amplifier operation.
- For a push-pull configuration, one possible method is to split a single input signal into two opposite polarity signals.
- These opposite polarity signals are fed into two similar input circuits (with each operating for alternate cycle) to get a full 360 degrees of operation.
- There are many arrangements to split a single input into two opposite polarity signals.
- These arrangements include
  - Transformer Coupled Method.
  - BJT Method.
  - Op-amp Method.
- All these arrangements are known as phase splitter circuits.

Phase Splitter Circuit for Class B PA



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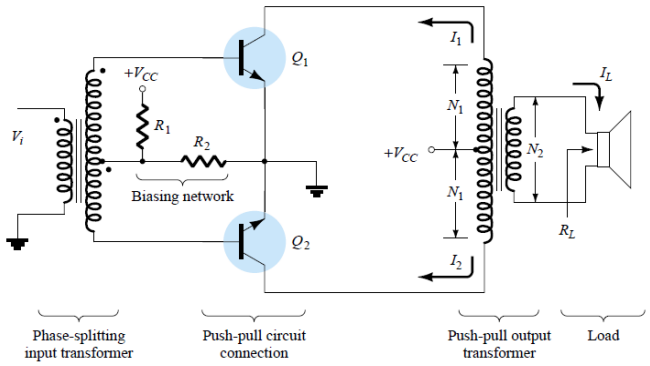
Transformer Coupled Push Pull Circuits

- A transformer splits the input signals into opposite polarity signals which are connected to the input of two transistors.

Output transformer drives the load in push pull fashion.

Q1 operates during 1st half cycle and Q2 in 2nd half cycle.



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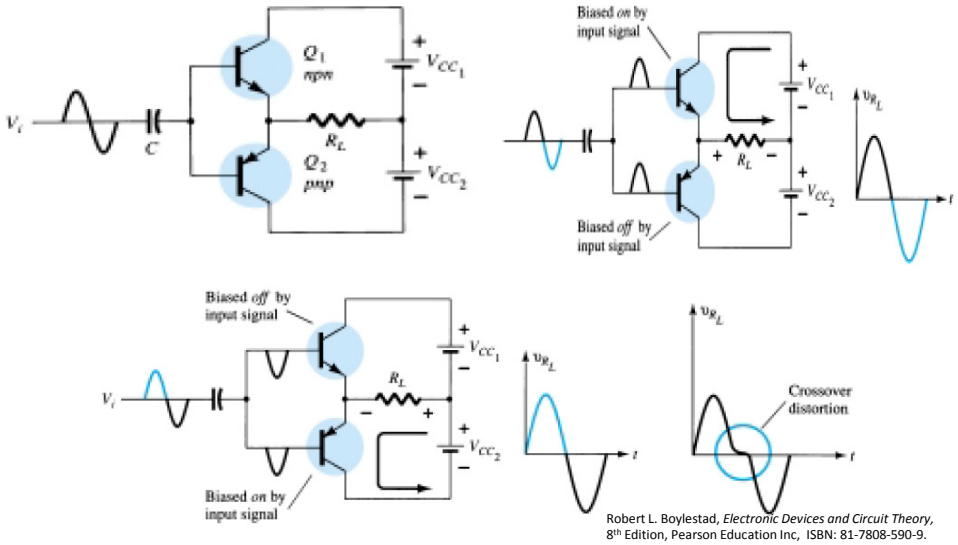
Complementary Symmetry Circuit



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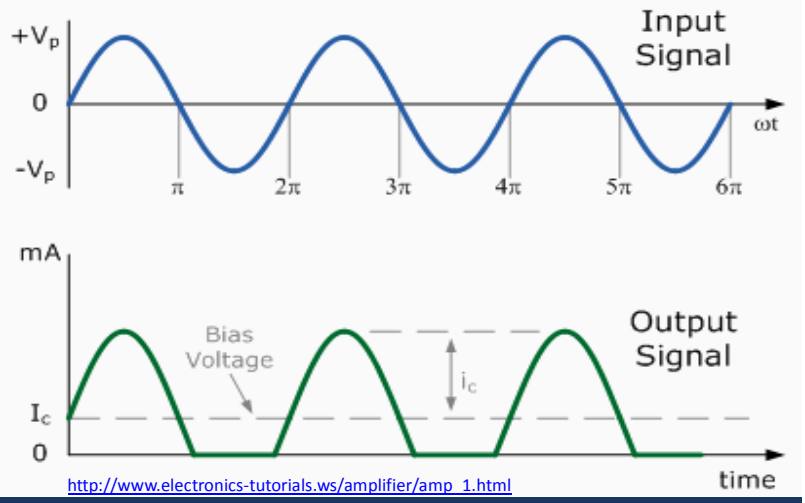
Class AB Power Amplifiers

- Class AB operation is a mode of operation in between Class A and Class B.
- Class AB operation two complimentary transistors biased with very small voltage at the base of the transistors.
- This biasing configuration keep the amplifier close to its cut off state.
- An input AC signal will cause the transistor to operate in its active region.
- In the absence of the input signal, a very small amount of collector current flows thereby preventing any crossover distortion.
- This arrangement causes the efficiency of Class AB better than Class A and removes the cross over distortion present in Class B amplifiers.

Class AB Power Amplifiers

Class AB Output Waveform



http://www.electronics-tutorials.ws/amplifier/amp_1.html

Next Lecture

- Power Amplifiers
  - Amplifier Distortion.
  - Class C Amplifier.
  - Class D Amplifier.

References

[1] Robert L. Boylestad, *Electronic Devices and Circuit Theory,* 8th Edition, Pearson Education Inc, ISBN: 81-7808-590-9.

[2] Theodore F. Bogart, Jeffery S. Beasley, Guilermo Rico, Electronics Devices and Circuits, 6th Edition, Pearson Education Inc, ISBN: 978-81-775-8887-3