Electronics II

Lecture 27
Power Amplifiers

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Previous Lecture

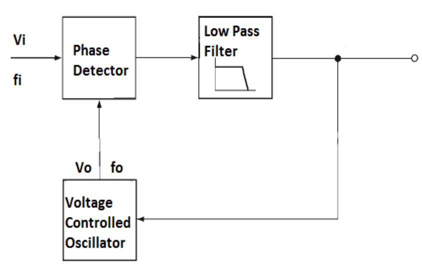
- Voltage Controlled Oscillator (VCO)
  - Basic Structure and Operation.
- Phase Locked Loop (PLL)
  - Basic Structure and Operation.

Session Overview

Topic	Phase Locked Loop, Power Amplifiers
Concepts	PLL operation, Power Amplifiers Basics, Classes of Power Amplifiers, Class A Power Amplifier.
Recommended Reading	Section 17-8 of [1]. Section 18-4 of [1]. Sections 15.1, 15.2, 15.4 and 15.5 of [1].
Keywords	PLL, Power Amplifier, Class A, Class B, Class AB, Class C, Class D.

Phase Locked Loop (PLL)

- The phase locked loop is a feedback circuit, consisting of phase detector, voltage controlled oscillator and a low pass filter.
- Some PLL circuit can have an amplifier in the loop while some others can also work without the low pass filter.
- The basic function of the PLL is to lock onto the incoming signal using above mentioned components.
- This implies that the voltage controlled oscillator will have the same frequency as the input signal.



Thomas L. Floyd, Electronic Devices (Conventional Current Version), 7th Edition, Pearson Education Inc, ISBN: 9780131140806.

General Operation of PLL

- The phase detector compares the phase difference between the input signal Vi and the VCO signal Vo.
- If the frequencies of both the inputs to phase detector are different, there will be a phase difference between the two signals.
- Phase detector generates a voltage that is proportional to this phase difference.
- This voltage is fed to the VCO thereby forcing the frequency of the VCO towards the frequency of the incoming signal until both the frequencies are equal.
- Any change in the frequency of the input signal causes the phase detector's output to change. This forces the VCO to change its frequency accordingly.

Phase Detector

- The phase detector will have two inputs that are

$$v_i = V_i \sin(2\pi f_i t + \theta_i)$$
$$v_o = V_o \sin(2\pi f_o t + \theta_o)$$

- Phase detector multiplies the two signals and produces a sum and difference frequency output

$$V_d = V_i \sin(2\pi f_i t + \theta_i) \times V_o \sin(2\pi f_o t + \theta_o)$$

- When phase locked loop is locked

$$f_i = f_o \qquad 2\pi f_i t = 2\pi f_o t$$

- Detector's output voltage is

$$V_d = \frac{V_i V_o}{2}[\cos(\theta_i - \theta_o) - \cos(4\pi f_i t + \theta_i + \theta_o)]$$

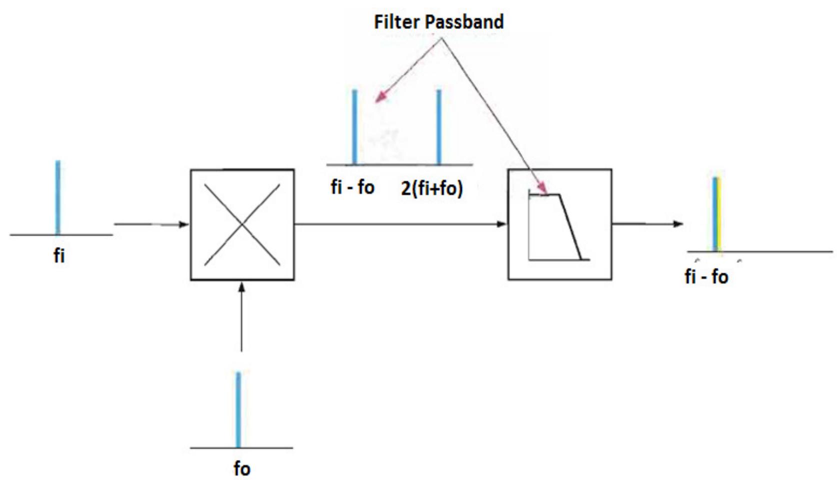
- The second cosine term in the detector output is second harmonic and filtered by the low pass filter. The voltage at the output of the filter reduces to

$$V_c = \frac{V_i V_o}{2} \cos \theta_e$$

- Where θ_e is the phase error and given as

$\theta_e = \theta_i - \theta_o$.

Phase Detector



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Phase Detector

- Example 17-7 (Floyd):

  A PLL is locked onto an incoming signal with a frequency of 1 MHz at a phase angle of 50°. The VCO signal is at a phase angle of 20°. The peak amplitude of the incoming signal is 0.5 V and that of the VCO output signal is 0.7 V.

  (a) What is the VCO frequency?

  (b) What is the value of the control voltage being fed back to the VCO at this point?

Voltage Controlled Oscillator (VCO)

- VCO have can have multiple forms including RC, LC etc. the VCO incorporated in PLL uses varactor diode for variable reactance.
- Capacitance of varactor diode varies inversely with the reverse bias voltage.
- For RC oscillators, the frequency of oscillation is given as

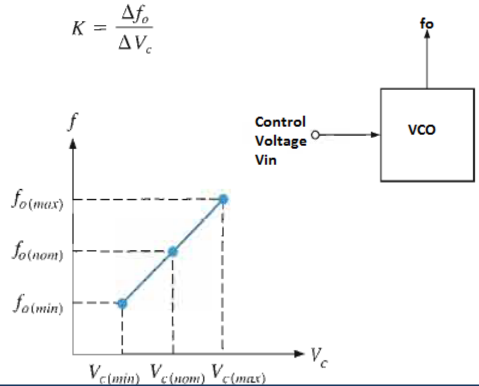
$$f_o = \frac{1}{2\pi RC}$$

- For LC oscillators

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

- Conversion gain/ transfer function of VCO is defined as frequency deviation per unit change in control voltage

$$K = \frac{\Delta f_o}{\Delta V_c}$$



Voltage Controlled Oscillator (VCO)

- Example 17-8 (Floyd):

The output frequency of a certain VCO changes from 50 kHz to 65 kHz when the control voltage increases from 0.5 V to 1 V. What is the conversion gain, K?

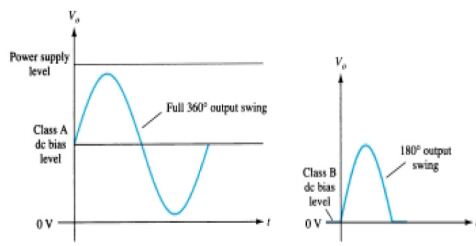
Basic PLL Operation

Power Amplifiers

- An amplifier receives an input signal from a source and provides an amplified version of the same signal to an output device.
- In small signal amplifiers, the major factors of concern are
  - Amplification Linearity.
  - Magnitude of Gain.
- The major concern in power amplifiers is power amplification instead of voltage amplification.
- In power amplifiers, the major factors of concern are
  - Power Efficiency.
  - Maximum Power Handling.
  - Impedance Matching at Output.
- Major classification of Power amplifiers is done on the basis of the variation of the output cycle
  - Class A.
  - Class B.
  - Class AB.
  - Class C.
  - Class D.

Classes of Power Amplifiers

- ***Class A***
  The output signal varies over full 360^0 of operation cycle. Q point biasing should be such as to allow the full swing between maximum and minimum signal level.
- ***Class B***
  The output signal varies over 180^0 of operation cycle. The bias point for class B amplifier is at 0V.
- ***Class AB:*** The output signal varies between 180^0 to 360^0 of cycle. The bias conditions in class AB is above zero current level and above ½ of the supply voltage of class A operation.
- ***Class C:*** The output signal varies over less than 180^0 of cycle. The biasing of this class is adjusted accordingly.
- ***Class D:*** Class D amplifier has pulsed operation and the biasing arrangements are adjusted accordingly.



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

Power Amplifier Efficiency

- The efficiency of the power amplifier is the ratio of the output power to the input power.
- The efficiency of the power amplifiers improves/ increases while going from class A to class D.
- As the bias point in class A amplifier is at ½ of supply voltage so most of the power is utilized just to maintain the bias point. This results in very less power actually delivered to the load.
- Class B amplifier doesn't require any power to maintain the bias point at 0V so this class have 78.5% efficiency.
- Class AB efficiency falls between that of class A and class B i.e. 25% - 78.5%.
- Class C: Power Efficiency ?
- Class D can have power efficiency above 90%.

Power Amplifier Efficiency

TABLE 16.1 Comparison of Amplifier Classes

	Class A	Class AB	Class B	Class C*	Class 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.

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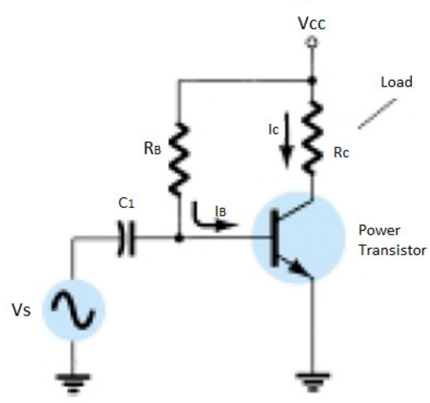
Class A Power Amplifier (Series-Fed)

- The class A amplifier is shown in the given figure. This one is identical to any small signal amplifier.
- The difference is that the power amplifiers use power transistors that are capable of handling high voltage signals.



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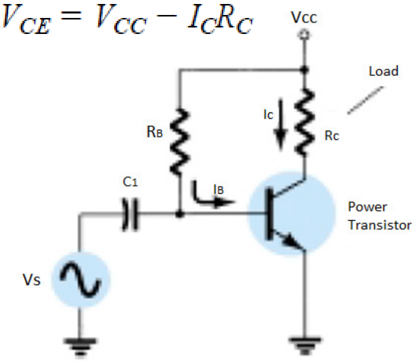
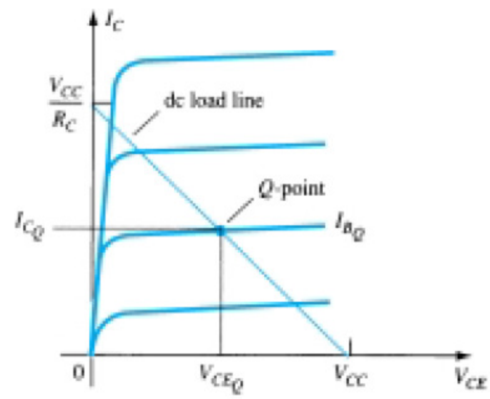
Class A Power Amplifier- DC Bias Operation

$$I_B = \frac{V_{CC} - 0.7\text{ V}}{R_B}$$

$$V_{CE} = V_{CC} - I_C R_C$$





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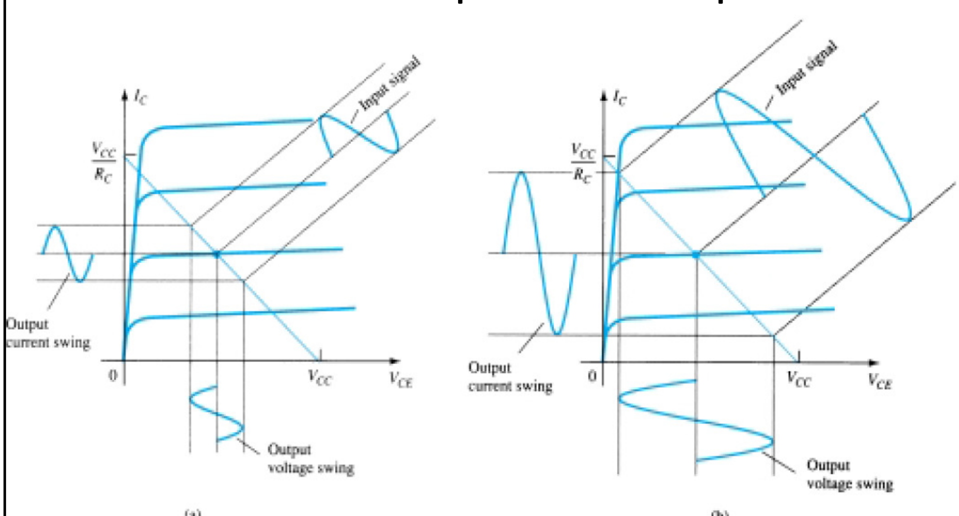
Class A Power Amplifier- AC Operation



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Next Lecture

- Power Amplifiers
  - Class A Amplifier.
  - Class B Amplifier.
  - Class AB 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