Amateur Extra License Class

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Amateur Extra Class

Chapter 6 Electronic Circuits (Part 1)

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Amplifiers

An amplifier is a circuit that increases the strength of a signal.

- An amplifier can increase the voltage, current, or power of the signal.
- Amplifiers can have input voltages from microvolts to hundreds of volts.
- Amplifiers can have output powers from billionths of a watt to thousands of watts.

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Amplifiers

Definitions:

- Driver -- The circuit that supplies the input signal to the amplifier.
- Load -- The circuit that receives the amplifier's output signal.
- Final Amplifier -- The last amplifier stage in a transmitter.
  - Often referred to as simply "the final".

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Amplifiers

Amplifier Gain

- The gain of an amplifier is the ratio of the output signal to the input signal.
  - Voltage gain = V_{OUT} / V_{IN}
  - Current gain = I_{OUT} / I_{IN}
  - Power gain = P_{OUT} / P_{IN}
- Gain can be expressed as a simple ratio.
  - e.g. – Voltage gain = 10
- Gain can be expressed in decibels.
  - e.g. – Power gain = 10 dB

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Amplifiers

Input and Output Impedances.

- The input impedance of an amplifier is the load seen by the driver.
- The output impedance is the source impedance of the amplifier.
- Maximum power transfer occurs when the source impedance of the amplifier equals the input impedance of the following circuit.

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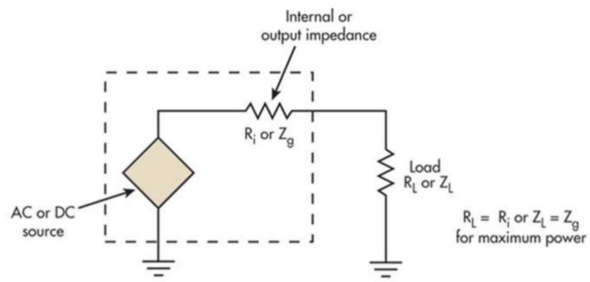
Amplifiers

Input and Output Impedances.



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Amplifiers

Basic Circuits

- Amplifiers constructed with bipolar transistors fall into one of three types:
  - Common emitter.
  - Common base.
  - Common collector.

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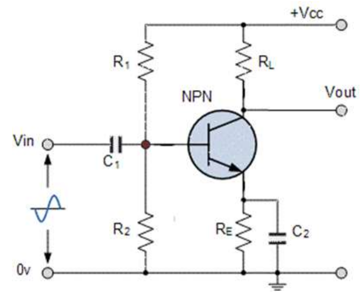
Amplifiers

Common Emitter and Common Collector Circuits

- Common emitter.
  - The most common amplifier type.
  - Can provide both voltage gain and current gain simultaneously.



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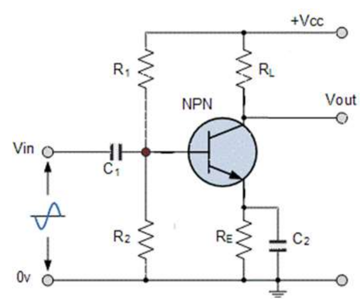
Amplifiers

Common Emitter and Common Collector Circuits

- Common emitter.
  - Input & output voltages are 180° out of phase.
  - Fairly high input impedance.
  - Output impedance depends on R_L.



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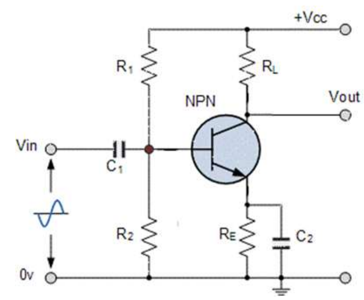
Amplifiers

Common Emitter and Common Collector Circuits

- Common emitter.
  - R_1 & R_2 provide voltage divider bias.
    - a.k.a. – fixed bias.
  - R_E provides bias point stability.
    - a.k.a. – Self-bias.
    - Prevents thermal runaway.
  - C_2 allows maximum AC signal gain.



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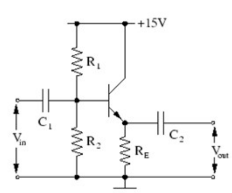
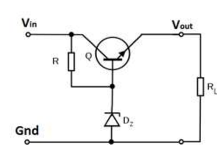
Amplifiers

Common Emitter and Common Collector Circuits

- Common collector.
  - a.k.a. - Emitter follower.
  - Provides current gain.
  - Voltage gain is slightly less than 1.
  - Input & output voltages are in phase.
  - Fairly high input impedance.
  - Low output impedance.
  - Linear voltage regulator.





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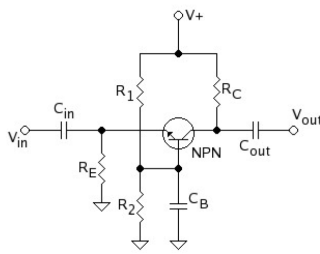
Amplifiers

Common Emitter and Common Collector Circuits

- Common base.
  - Provides voltage gain.
  - Current gain is slightly less than 1.
  - Input & output voltages are in phase.
  - Low input impedance.
  - High output impedance.



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Amplifiers

Similarities of Vacuum Tube Circuits

- Each type of transistor amplifier circuit has a corresponding vacuum tube amplifier circuit.
  - Common-Emitter ←→ Common-Cathode.
  - Common-Base ←→ Grounded-Grid.
  - Common-Collector ←→ Common-Anode.
    - a.k.a. -- Emitter Follower ←→ Cathode Follower.

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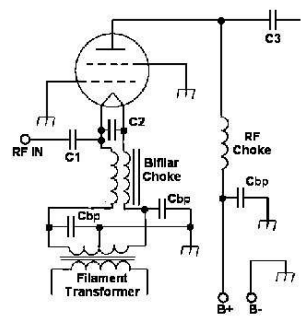
Amplifiers

Similarities of Vacuum Tube Circuits

- Grounded-Grid Amplifiers.
  - The most common RF power amplifier configuration.
  - Stable.
    - Easier to neutralize.
  - Low input impedance.
    - Little or no input impedance matching required.



E7B06 -- What is a characteristic of a grounded-grid amplifier?

A. High power gain

➡ B. Low input impedance

C. High electrostatic damage protection

D. Low bandwidth

E7B09 -- What is characteristic of an emitter follower (or common collector) amplifier?

A. Low input impedance and phase inversion from input to output
B. Differential inputs and single output
C. Acts as an OR circuit if one input is grounded
➡ D. Input and output signals in-phase

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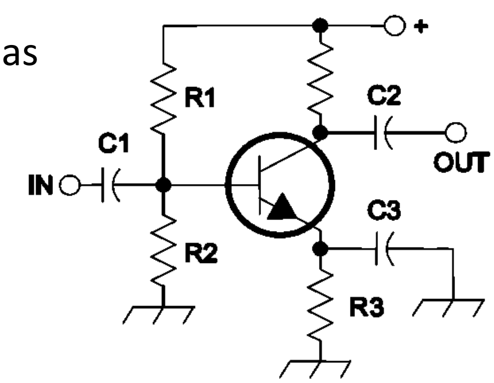
E7B10 -- In Figure E7-1, what is the purpose of R1 and R2?

A. Load resistors
➡ B. Voltage divider bias
C. Self bias
D. Feedback

Figure E7-1



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E7B11 -- In Figure E7-1, what is the purpose of R3?

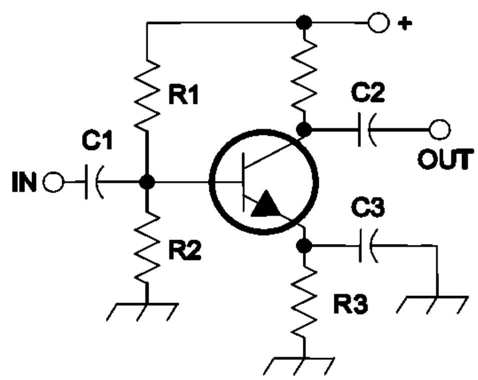
A. Fixed bias

B. Emitter bypass

C. Output load resistor

➡ D. Self bias

Figure E7-1



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E7B12 -- What type of amplifier circuit is shown in Figure E7-1?

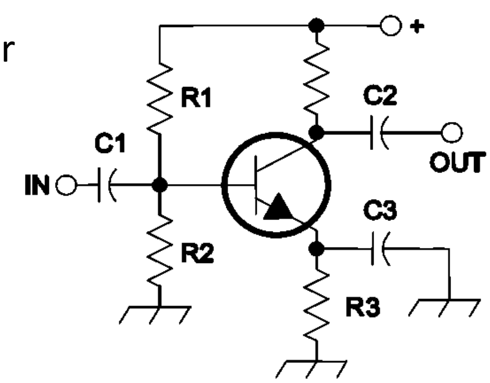
A. Common base

B. Common collector

➡ C. Common emitter

D. Emitter follower

Figure E7-1



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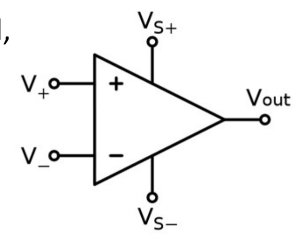
Amplifiers

Op Amp Amplifiers

- An operational amplifier (op-amp) is a high-gain, direct-coupled, differential amplifier.
  - The input signal is the difference between the inverting & the non-inverting inputs.
  - Since an op-amp is direct-coupled, it will amplify DC.



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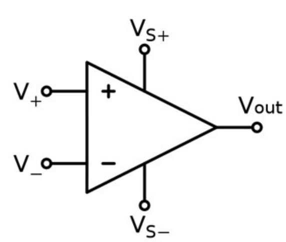
Amplifiers

Op Amp Amplifiers

- Op Amp Characteristics
  - The ideal operational amplifier has:
    - Infinite input impedance.
    - Zero output impedance.
    - Infinite gain.
    - Flat frequency response from DC to an extremely high frequency.
    - Zero offset voltage.
      - 0 V_{IN} → 0 V_{OUT}



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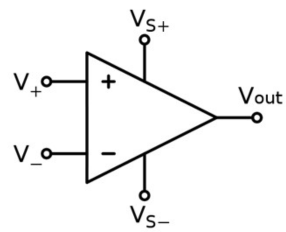
Amplifiers

Op Amp Amplifiers

- Op Amp Characteristics
  - The circuit performance is totally determined by the external components.
  - In a closed-loop configuration
    - The input voltage is always zero.
    - The input current is always zero.



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Amplifiers

Op Amp Amplifiers

- Op Amp Characteristics
  - The most important specifications of a non-ideal operational amplifier are:
    - Open-loop gain.
    - Gain-Bandwidth.
      - The frequency at which the open-loop gain drops to 1.
    - Slew rate.
      - How fast the output can change value.
    - Input offset voltage.
      - The voltage required to bring the open-loop output voltage to 0.
    - Input impedance.
    - Output impedance.

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Amplifiers

Op Amp Amplifiers

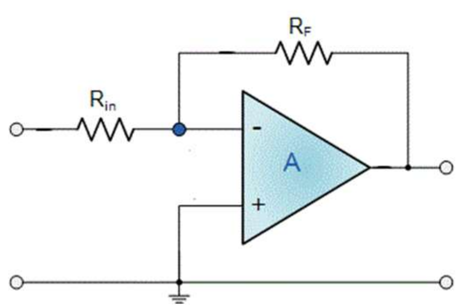
- A practical operational amplifier has:
  - Differential input.
  - Direct-coupled.
  - Very high input impedance.
  - Very low output impedance.
  - Very high voltage gain.
    - Up to 120 dB.
  - Wide bandwidth.

Amplifiers

Op Amp Amplifiers

- Basic Amplifier Circuits.
  - Inverting Amplifier.

Gain = $- R_F / R_{IN}$

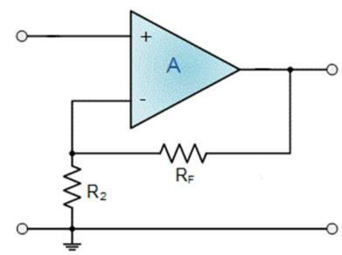


Amplifiers

Op Amp Amplifiers

- Basic Amplifier Circuits.
  - Non-inverting Amplifier.

Gain = $(R_F + R_2) / R_2$



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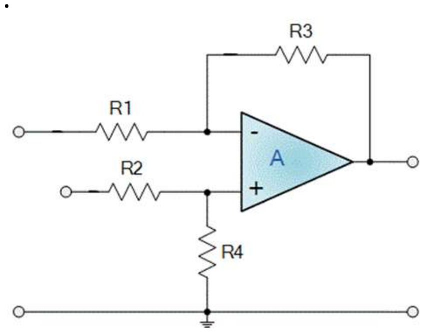
Amplifiers

Op Amp Amplifiers

- Basic Amplifier Circuits.
  - Differential Amplifier.

Gain = $(R_3 + R_1) / R_1$
or
Gain = $(R_4 + R_2) / R_2$

where: $R_1 = R_2$ and $R_3 = R_4$



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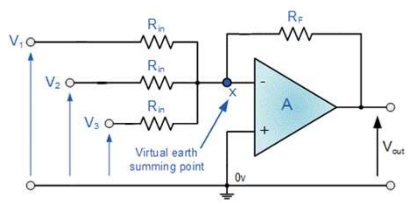
Amplifiers

Op Amp Amplifiers

- Basic Amplifier Circuits.
  - Summing Amplifier.
    - $V_{out} = - ((V_1 \times R_F / R_{in}) + (V_2 \times R_F / R_{in}) + (V_3 \times R_F / R_{in}))$
    - $V_{out} = - (V_1 + V_2 + V_3) \times R_F / R_{in}$



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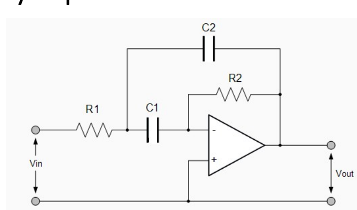
Amplifiers

Op Amp Amplifiers

- By adding capacitors and/or inductors in the feedback network, you can alter the frequency response of the amplifier and create a filter.
  - Usually only capacitors are used.



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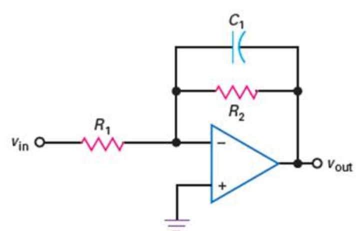
Amplifiers

Op Amp Amplifiers

- For example: Adding a capacitor in parallel with the feedback resistor will limit the high frequency response and create a low-pass filter.



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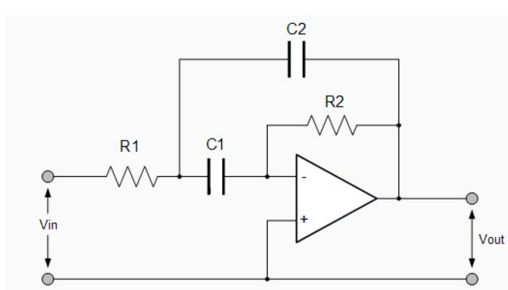
Filters and Impedance Matching

Active Filters

- An active audio band-pass filter.



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E7G01 -- What is the typical output impedance of an op-amp?

A. Very low
B. Very high
C. 100 ohms
D. 10,000 ohms

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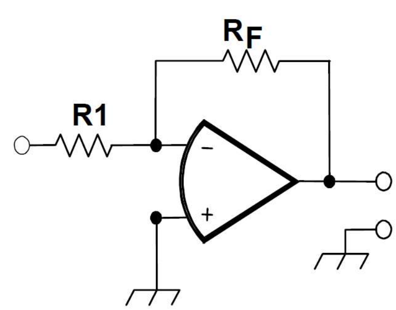
E7G02 -- What is the frequency response of the circuit in E7-3 if a capacitor is added across the feedback resistor?

A. High-pass filter
B. Low-pass filter
C. Band-pass filter
D. Notch filter

Figure E7-3



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E7G03 -- What is the typical input impedance of an op-amp?

A. 100 ohms
B. 10,000 ohms
C. Very low
D. Very high

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E7G04 -- What is meant by the term “op-amp input offset voltage”?

A. The output voltage of the op-amp minus its input voltage
B. The difference between the output voltage of the op-amp and the input voltage required in the immediately following stage
C. The differential input voltage needed to bring the open-loop output voltage to zero
D. The potential between the amplifier input terminals of the op-amp in an open-loop condition

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E7G06 -- What is the gain-bandwidth of an operational amplifier?

A. The maximum frequency for a filter circuit using that type of amplifier

B. The frequency at which the open-loop gain of the amplifier equals one

C. The gain of the amplifier at a filter's cutoff frequency

D. The frequency at which the amplifier's offset voltage is zero

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E7G07 -- What magnitude of voltage gain can be expected from the circuit in Figure E7-3 when R1 is 10 ohms and RF is 470 ohms?

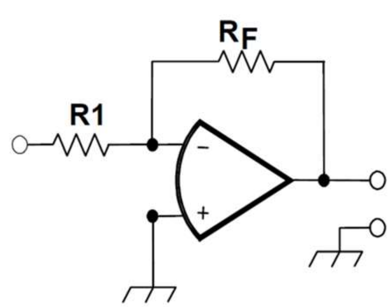
A. 0.21

B. 4700

C. 47

D. 24

Figure E7-3



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E7G08 -- How does the gain of an ideal operational amplifier vary with frequency?

A. It increases linearly with increasing frequency
B. It decreases linearly with increasing frequency
C. It decreases logarithmically with increasing frequency
D. It does not vary with frequency

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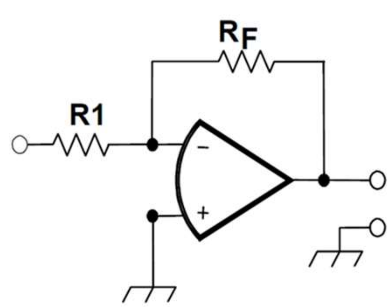
E7G09 -- What will be the output voltage of the circuit shown in Figure E7-3 if R1 is 1,000 ohms, RF is 10,000 ohms, and 0.23 volts DC is applied to the input?

A. 0.23 volts
B. 2.3 volts
C. -0.23 volts
D. -2.3 volts

Figure E7-3



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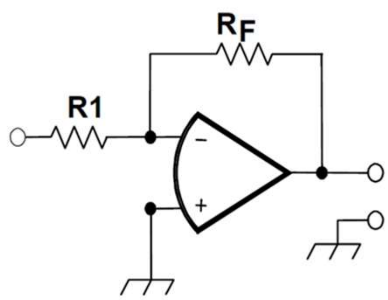
E7G10 -- What absolute voltage gain can be expected from the circuit in Figure E7-3 when R1 is 1800 ohms and RF is 68 kilohms?

A. 1
B. 0.03
➡ C. 38
D. 76

Figure E7-3



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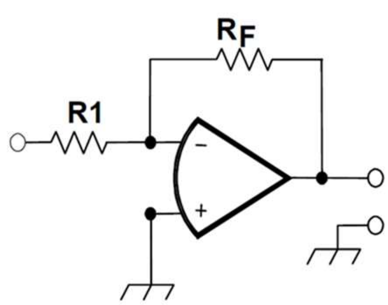
E7G11 -- What absolute voltage gain can be expected from the circuit in Figure E7-3 when R1 is 3,300 ohms and RF is 47 kilohms?

A. 28
➡ B. 14
C. 7
D. 0.07

Figure E7-3



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E7G12 -- What is an operational amplifier?

A. A high-gain, direct-coupled differential amplifier with very high input impedance and very low output impedance
B. A digital audio amplifier whose characteristics are determined by components external to the amplifier
C. An amplifier used to increase the average output of frequency modulated amateur signals to the legal limit
D. A RF amplifier used in the UHF and microwave regions

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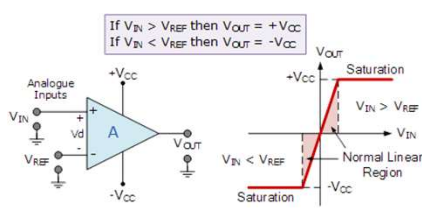
Amplifiers

Comparators

- Voltage Comparator.
  - Compares 2 voltages.
  - Apply a reference voltage to one input of an op amp with no feedback circuit.
  - Apply the unknown voltage to the other input.



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Amplifiers

Comparators

- Voltage Comparator.
  - If the input voltage is close to the threshold, minor variations (noise) can cause the output to rapidly & randomly change between states.
    - This is called *chattering*.
  - Adding hysteresis eliminates chattering.
    - The output changes state slightly above the threshold on the way up & slightly below the threshold on the way down.

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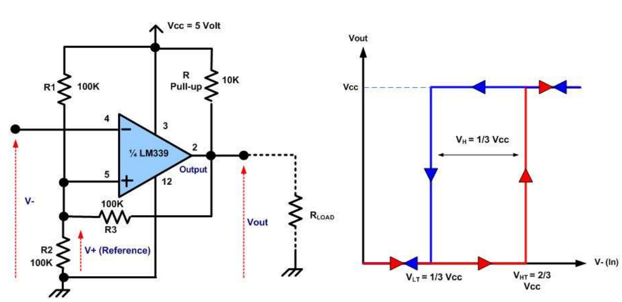
Amplifiers

Comparators

- Voltage Comparator.
  - Adding feedback resistors provides hysteresis.



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E6C01 -- What is the function of hysteresis in a comparator?

➡ A. To prevent input noise from causing unstable output signals

B. To allow the comparator to be used with AC input signals

C. To cause the output to continually change states

D. To increase the sensitivity

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E6C02 -- What happens when the level of a comparator's input signal crosses the threshold?

A. The IC input can be damaged

➡ B. The comparator changes its output state

C. The reference level appears at the output

D. The feedback loop becomes unstable

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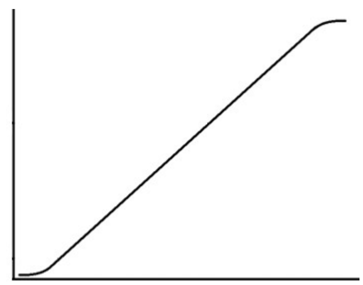
Amplifiers

Classes of Operation

- Amplifier Load Line.
  - Output vs Input.
    - Cutoff Region.
    - Linear Region.
    - Saturation Region.



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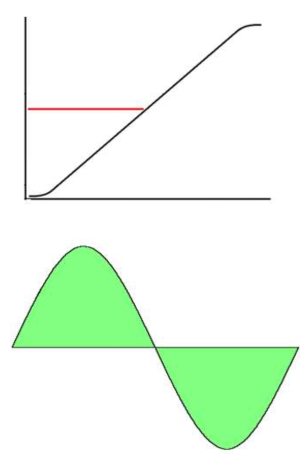
Amplifiers

Classes of Operation

- Class A
  - On for 360° of the cycle.
    - The entire cycle is within the linear region of the load line.
  - Best linearity.
  - Least efficient. (25%-30%)



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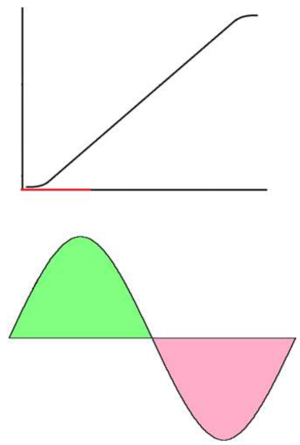
Amplifiers

Classes of Operation

- Class B
  - On for 180° of the cycle.
  - Non-Linear (if AF).
    - 2 devices in a push-pull configuration is linear.
  - Linear (if RF).
    - The flywheel action of the tank circuit provides the other half of the cycle.
  - More efficient. (Up to 60%)



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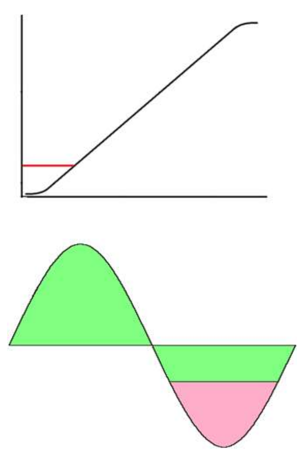
Amplifiers

Classes of Operation

- Class AB
  - On for >180° but < 360° of the cycle.
  - Non-Linear (if AF).
    - 2 devices in a push-pull configuration is linear.
  - Linear (if RF).
    - The flywheel action of the tank circuit provides the other portion of the cycle.
  - Compromise between classes A & B.



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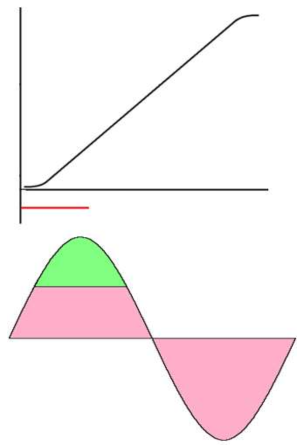
Amplifiers

Classes of Operation

- Class C
  - On for <180° of the cycle.
  - Highly non-linear.
    - Cannot be used for AM or SSB signals.
  - Most efficient.
    - Up to 80%.



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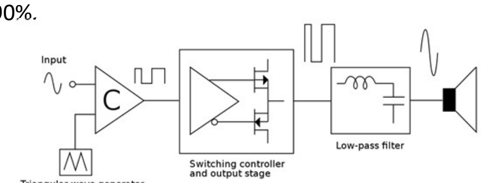
Amplifiers

Classes of Operation

- Switching or Switch Mode Classes.
  - Class D, E, or F.
  - Use switching techniques to achieve high efficiency.
    - Switching speed well above highest frequency to be amplified.
    - The transistor is either cut off or saturated most of the time.
      - Efficiency >90%.



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Amplifiers

Classes of Operation

- Selecting amplifier class.
  - For audio, AM or SSB, a linear amplifier is required.
  - For CW or FM, a non-linear amplifier may be used.

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Amplifiers

Classes of Operation

- Selecting amplifier class.
  - For best linearity & lowest efficiency, use Class A.
    - Low-level stages.
  - For a good compromise between linearity & efficiency, use Class AB.
    - Power amplifiers.

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Amplifiers

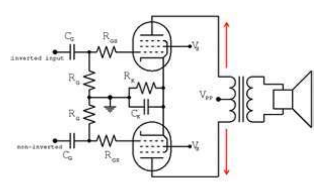
Classes of Operation

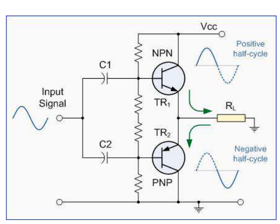
- Selecting amplifier class.
  - For highest efficiency or intentional harmonics, use Class C.
    - Frequency multiplier stages.
    - CW transmitters.
    - FM transmitters & receivers.

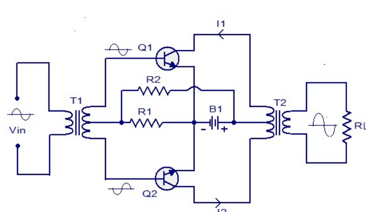
Amplifiers

Classes of Operation

- Selecting amplifier class.
  - Class B or AB push-pull circuits.
    - Audio power amplifiers.
    - Even harmonics are reduced.







Amplifiers

Distortion and Intermodulation

- Distortion
  - Non-linearity results in distortion.
  - **ALL** physical components have non-linearity.
  - Distortion results in harmonics.
  - You can have low distortion or high efficiency, but not both.

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Amplifiers

Distortion and Intermodulation

- Tuned amplifiers.
  - Power amplifiers are a compromise between linearity & efficiency.
  - A tuned output circuit acts like a “flywheel”, minimizing effects of distortion.
    - Single-ended class B & AB amplifiers.

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Amplifiers

Distortion and Intermodulation

- Intermodulation.
  - Intermodulation is distortion caused by 2 or more signals mixing together to produce other frequencies.
    - $F_{IMD} = (A \times F_1) \pm (B \times F_2)$.
    - If A+B is odd, then it is an odd-order intermodulation product.
      - F_{imd} is near the fundamental or the odd harmonics of F_1 & F_2.
    - If A+B is even then it is an even-order intermodulation product.
      - F_{imd} is near the even harmonics of F_1 & F_2.

61

Amplifiers

Distortion and Intermodulation

- Intermodulation.
  - Even-order IMD products are near the even harmonics of the desired frequency and not near the fundamental frequency. Therefore, they can be easily filtered out.
  - Odd-order IMD products are close to the desired frequency and cannot be filtered out.
    - Spurious signals and excessive bandwidth signals can be transmitted.

62

E7B01 -- For what portion of the signal cycle does each active element in a push-pull Class AB amplifier conduct?

A. More than 180 degrees but less than 360 degrees
B. Exactly 180 degrees
C. The entire cycle
D. Less than 180 degrees

63

E7B02 -- What is a Class D amplifier?

A. An amplifier that uses switching technology to achieve high efficiency
B. A low power amplifier that uses a differential amplifier for improved linearity
C. An amplifier that uses drift-mode FETs for high efficiency
D. An amplifier biased to be relatively free from distortion

64

E7B03 -- What circuit is required at the output of an RF switching amplifier?

A. A filter to remove harmonic content

B. A high-pass filter to compensate for low gain at low frequencies

C. A matched load resistor to prevent damage by switching transients

D. A temperature compensating load resistor to improve linearity

65

E7B04 -- What is the operating point of a Class A common emitter amplifier?

A. Approximately halfway between saturation and cutoff

B. Approximately halfway between the emitter voltage and the base voltage

C. At a point where the bias resistor equals the load resistor

D. At a point where the load line intersects the zero bias current curve

66

E7B07 -- Which of the following is the likely result of using a Class C amplifier to amplify a single-sideband phone signal?

A. Reduced intermodulation products
B. Increased overall intelligibility
C. Reduced third-order intermodulation
D. Signal distortion and excessive bandwidth

67

E7B08 -- Why are switching amplifiers more efficient than linear amplifiers?

A. Switching amplifiers operate at higher voltages
B. The switching device is at saturation or cutoff most of the time
C. Linear amplifiers have high gain resulting in higher harmonic content
D. Switching amplifiers use push-pull circuits

68

Signal Processing

Oscillator Circuits and Characteristics

- Oscillator circuits are used to generates sine wave signals.
- To build an oscillator, we need 3 things:
  - An amplifier to provide gain.
  - A circuit to feed a portion of the amplifier output signal back to the amplifier input.
    - The signal must be in-phase (positive feedback).
  - A filter to restrict the oscillation to the desired frequency.

69

Signal Processing

Oscillator Circuits and Characteristics

- A_V = Amplifier voltage gain.
- β = Feedback ratio.
- Loop Gain = $A_V \times \beta$
- If the loop gain is > 1 and the feedback signal is in phase, the circuit will oscillate.
- An LC circuit or equivalent acts as a filter to restrict the feedback to the resonant frequency.

70

Signal Processing

Instability and Parasitic Oscillation

- Sometimes we build an oscillator when we do not intend to.
  - Excessive gain or undesired positive feedback can cause an amplifier to oscillate.
  - Oscillation can occur in any amplifier stage, not just in power amplifiers.
  - Unwanted oscillation can result in:
    - Increased noise figure in a receiver.
    - Spurious radiations in a transmitter.
    - Excessive heating in power amplifiers.

71

Signal Processing

Instability and Parasitic Oscillation

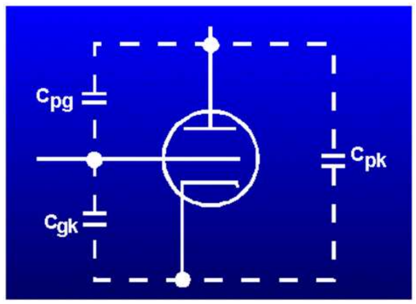
- Neutralization.
  - The inter-electrode capacitances in the amplifying device and/or stray capacitances in the associated circuitry can cause an amplifier to oscillate at the frequency of operation.
  - This type of oscillation can be prevented by "neutralizing" the amplifier.
    - Feed a small amount of signal back to the input out-of-phase.

72

Signal Processing

Instability and Parasitic Oscillation

- Neutralization.



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Signal Processing

Instability and Parasitic Oscillation

- Parasitic oscillation.
  - Resonances in the surrounding circuitry can cause oscillations that are not related to operating frequency.
  - Parasitic oscillations typically occur at VHF or UHF frequencies.
  - Parasitic oscillations in HF vacuum tube amplifiers are eliminated by adding parasitic suppressors to the plate or grid leads.
    - An inductor in parallel with a resistor.

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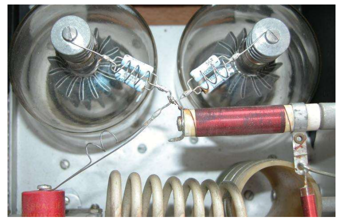
Signal Processing

Instability and Parasitic Oscillation

- Parasitic suppressor.



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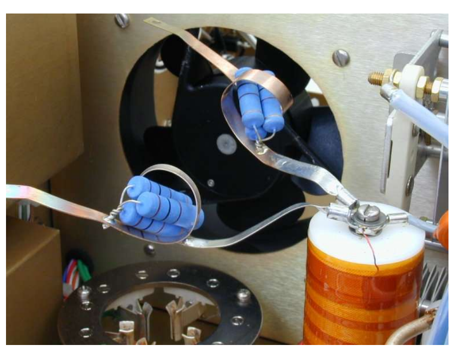
Signal Processing

Instability and Parasitic Oscillation

- Parasitic suppressor.



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E7B05 -- What can be done to prevent unwanted oscillations in an RF power amplifier?

A. Tune the stage for minimum loading
B. Tune both the input and output for maximum power
C. Install parasitic suppressors and/or neutralize the stage
D. Use a phase inverter in the output filter

77

Break

78

Signal Processing

RF Oscillators

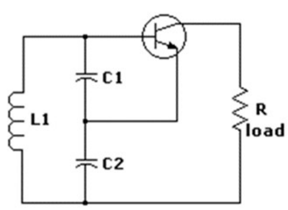
- There are three main types of oscillator circuits used in amateur radio equipment to generate RF signals:
  - Colpitts oscillator.
  - Hartley oscillator.
  - Pierce oscillator.

79

Signal Processing

RF Oscillators

- A Colpitts oscillator uses a tapped capacitance to provide the positive feedback.
  - a.k.a. – Capacitive divider.



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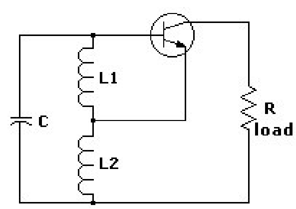
Signal Processing

RF Oscillators

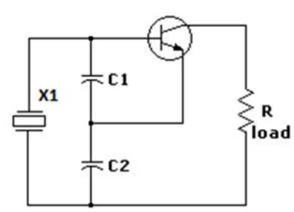
- A Hartley oscillator uses a tapped inductance to provide the positive feedback.



Signal Processing

RF Oscillators

- Pierce oscillator.
  - A Pierce oscillator is a Colpitts oscillator with the inductor replaced by a quartz crystal.
    - The crystal provides better frequency stability.



Signal Processing

RF Oscillators

- Oscillator stability.
  - Oscillator frequency can change with variations in power supply voltage, loading, temperature, and other factors.
  - Increased frequency stability can be achieved by using:
    - GPS signals.
    - Rubidium oscillators.
    - Temperature-stabilized dielectric resonators.

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Signal Processing

RF Oscillators

- Variable-frequency oscillators.
  - Often we need to be able to change the frequency of an oscillator.
  - This is accomplished by making either the inductor or the capacitor adjustable.
    - Usually a Colpitts oscillator with an adjustable capacitor.
  - The frequency is not as stable as a crystal-controlled (Peirce) oscillator.

84

E7H01 -- What are three common oscillator circuits?

A. Taft, Pierce, and negative feedback
B. Pierce, Fenner, and Beane
C. Taft, Hartley, and Pierce
➡ D. Colpitts, Hartley, and Pierce

85

E7H04 -- How is positive feedback supplied in a Colpitts oscillator?

A. Through a tapped coil
B. Through link coupling
➡ C. Through a capacitive divider
D. Through a neutralizing capacitor

86

E7H05 -- How is positive feedback supplied in a Pierce oscillator?

A. Through a tapped coil
B. Through link coupling
C. Through a neutralizing capacitor
➡ D. Through a quartz crystal

87

E7H13 -- Which of the following is a technique for providing highly accurate and stable oscillators needed for microwave transmission and reception?

A. Use a GPS signal reference
B. Use a rubidium stabilized reference oscillator
C. Use a temperature-controlled high Q dielectric resonator
➡ D. All of these choices are correct

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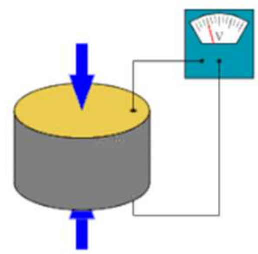
Signal Processing

Crystals for Oscillators

- Piezoelectric Effect.
  - Certain materials will:
    - Mechanically distort when a voltage is applied.
    - Generate a voltage when mechanically distorted.
  - Materials with these properties are called piezoelectric materials.



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Signal Processing

Crystals for Oscillators

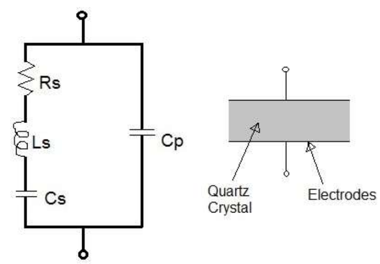
- Piezoelectric Effect.
  - Quartz is a natural piezoelectric material.
    - Electronic watches, radio equipment, etc.
  - Some ceramics are piezoelectric materials.
    - Cigarette lighters, barbeque grill lighters, etc.

90

Signal Processing

Crystals for Oscillators

- Quartz crystals.
  - Equivalent circuit.
    - C_s = Motional capacitance
    - L_s = Motional inductance
    - R_s = Loss resistance
    - C_p = Electrode & stray capacitance.



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Signal Processing

Crystals for Oscillators

- Quartz crystals.
  - Quartz crystals are designed to operate with a specified parallel capacitance.
    - This capacitance is part of the tuned circuit and is necessary for the crystal to operate on its designed frequency.

92

E6D01 -- What is piezoelectricity?

A. The ability of materials to generate electromagnetic waves of a certain frequency when voltage is applied
B. A characteristic of materials that have an index of refraction which depends on the polarization of the electromagnetic wave passing through it
C. A characteristic of materials that generate a voltage when stressed and that flex when a voltage is applied
D. The ability of materials to generate voltage when an electromagnetic wave of a certain frequency is applied

93

E6D02 -- What is the equivalent circuit of a quartz crystal?

A. Series RLC in parallel with a shunt C representing electrode and stray capacitance
B. Parallel RLC, where C is the parallel combination of resonance capacitance of the crystal and electrode and stray capacitance
C. Series RLC, where C is the parallel combination of resonance capacitance of the crystal and electrode and stray capacitance
D. Parallel RLC, where C is the series combination of resonance capacitance of the crystal and electrode and stray capacitance

94

E6D03 -- Which of the following is an aspect of the piezoelectric effect?

➡ A. Mechanical deformation of material by the application of a voltage
B. Mechanical deformation of material by the application of a magnetic field
C. Generation of electrical energy in the presence of light
D. Increased conductivity in the presence of light

95

E7H12 -- Which of the following ensures that a crystal oscillator operates on the frequency specified by the crystal manufacturer?

A. Provide the crystal with a specified parallel inductance
➡ B. Provide the crystal with a specified parallel capacitance
C. Bias the crystal at a specified voltage
D. Bias the crystal at a specified current

96

Signal Processing

Oscillator Circuits & Characteristics

- Microphonics & Thermal Drift.
  - Physical changes in the arrangement of the components of an oscillator can effect the frequency.
    - Moving components changes stray capacitances.
    - Vibrations, such as the impact of sound waves, can cause changes in physical arrangement of components.
    - Effect is known as "microphonics".
    - Reduce microphonics by mechanically isolating the oscillator from the rest of the equipment.
      - Shock absorbers, etc.

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Signal Processing

Oscillator Circuits & Characteristics

- Microphonics & Thermal Drift.
  - Changes in ambient temperature can cause the frequency of an oscillator to change.
    - Use components that are not susceptible to value changes with changes in temperature.
      - NPO capacitors, etc.
    - Provide oscillator (or crystal) with a non-changing temperature.
      - Crystal ovens.

98

E7H02 -- Which is a microphonic?

A. An IC used for amplifying microphone signals
B. Distortion caused by RF pickup on the microphone cable
➡ C. Changes in oscillator frequency due to mechanical vibration
D. Excess loading of the microphone by an oscillator

99

E7H07 -- How can an oscillator's microphonic responses be reduced?

A. Use NP0 capacitors
B. Reduce noise on the oscillator's power supply
C. Increase the gain
➡ D. Mechanically isolate the oscillator circuitry from its enclosure

100

E7H08 -- Which of the following components can be used to reduce thermal drift in crystal oscillators?

A. NP0 capacitors

B. Toroidal inductors

C. Wirewound resistors

D. Non-inductive resistors

101

Signal Processing

Frequency Synthesis

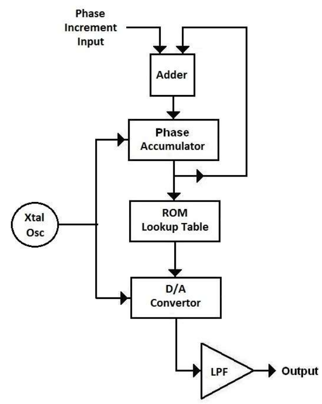
- The use of frequency synthesis provides the capabilities of a variable frequency oscillator (VFO) but with the stability of a crystal oscillator (XO).
  - Virtually **ALL** modern equipment uses frequency synthesizers rather than VFO's to determine operating frequency.
- There are 2 primary types of frequency synthesizers:
  - Phase-locked loop (PLL).
  - Direct digital synthesis (DDS).

102

Signal Processing

Frequency Synthesis

- Direct Digital Synthesis (DDS).
  - Generates a sine wave by looking up values in a table.
  - Changing the phase increment changes the frequency.
  - Increase the tuning range by adding a PLL.
  - No phase noise, but has spurs at discrete frequencies.



103

E7H09 -- What type of frequency synthesizer circuit uses a phase accumulator, lookup table, digital to analog converter and a low-pass anti-alias filter?

➡ A. A direct digital synthesizer

B. A hybrid synthesizer

C. A phase locked loop synthesizer

D. A diode-switching matrix synthesizer

104

E7H10 -- What information is contained in the lookup table of a direct digital frequency synthesizer (DDS)?

A. The phase relationship between a reference oscillator and the output waveform
B. Amplitude values that represent the desired waveform
C. The phase relationship between a voltage-controlled oscillator and the output waveform
D. Frequently used receiver and transmitter frequencies

105

E7H11 -- What are the major spectral impurity components of direct digital synthesizers?

A. Broadband noise
B. Digital conversion noise
C. Spurious signals at discrete frequencies
D. Nyquist limit noise

106

Signal Processing

Frequency Synthesis

- Phase-Locked Loop (PLL).
  - A servo loop with an error-detecting circuit with negative feedback.
  - Can do FM modulation & demodulation.
  - Capture range – Range of frequencies over which PLL can achieve lock.
  - Spectral impurities are mainly broadband phase noise.
  - PLL has been replaced in modern designs by direct digital synthesis.

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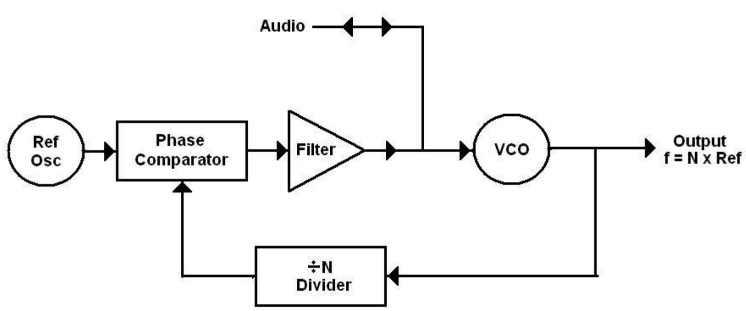
Signal Processing

Frequency Synthesis

- Phase-Locked Loop (PLL).



108

E7H14 -- What is a phase-locked loop circuit?

A. An electronic servo loop consisting of a ratio detector, reactance modulator, and voltage-controlled oscillator
B. An electronic circuit also known as a monostable multivibrator
C. An electronic servo loop consisting of a phase detector, a low-pass filter, a voltage-controlled oscillator, and a stable reference oscillator
D. An electronic circuit consisting of a precision push-pull amplifier with a differential input

109

E7H15 -- Which of these functions can be performed by a phase-locked loop?

A. Wide-band AF and RF power amplification
B. Comparison of two digital input signals, digital pulse counter
C. Photovoltaic conversion, optical coupling
D. Frequency synthesis, FM demodulation

110

Signal Processing

Mixers

- Used to change the frequency of a signal.
- Mathematically multiplies 2 frequencies together, generating 4 output frequencies.
  - $f_1 \times f_2 \rightarrow f_1,\ f_2,\ f_1+f_2,\ f_1-f_2$
- Superheterodyne receiver.
  - $f_{RF} \times f_{LO} \rightarrow f_{LO} - f_{RF} = f_{IF}$

111

Signal Processing

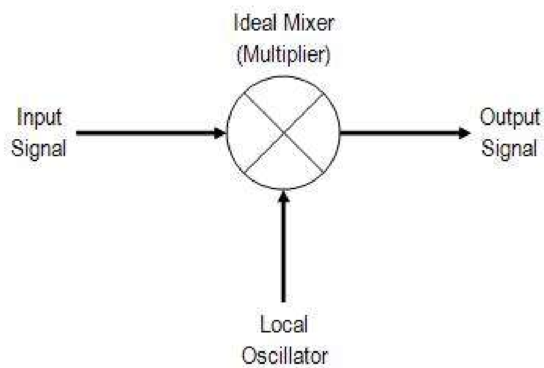
Mixers

- Only enough pre-amp gain should be used to overcome mixer losses.
- Excessive input signal can:
  - Overload mixer circuit.
  - Distort signal.
  - Generate spurious mixer products.
- Operation of a mixer is similar to operation of product detectors & modulators.

112

Signal Processing

Mixers



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Signal Processing

Mixers

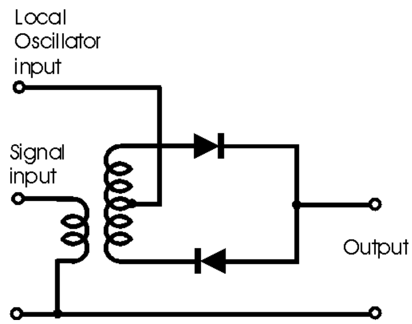
- Passive mixers.
  - Uses passive components such as diodes.
  - No amplification.
  - Some conversion loss.
  - Require strong LO signal.
  - Generate noise.

114

Signal Processing

Mixers

- Single-balanced mixer.



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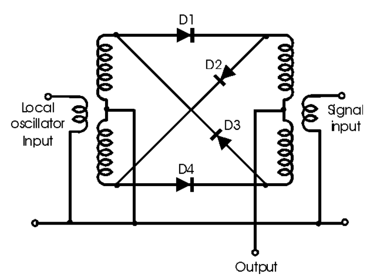
Signal Processing

Mixers

- Double-balanced mixer.
  - f_{RF} & f_{LO} are suppressed leaving only sum & difference frequencies.



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Signal Processing

Mixers

- Active mixers.
  - Use active components such as transistors or FET's.
  - Amplification possible.
  - No conversion loss.
  - Less local oscillator signal needed.
  - Generate less noise.
  - Strong signal handling capability is not as good as passive mixers.

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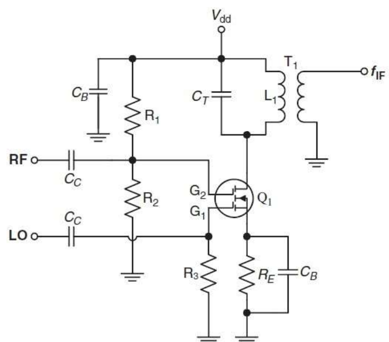
Signal Processing

Mixers

- Dual-gate MOSFET mixer.



118

E7E08 -- What are the principal frequencies that appear at the output of a mixer circuit?

A. Two and four times the original frequency
B. The square root of the product of input frequencies
➡ C. The two input frequencies along with their sum and difference frequencies
D. 1.414 and 0.707 times the input frequency

119

E7E09 -- What occurs when an excessive amount of signal energy reaches a mixer circuit?

➡ A. Spurious mixer products are generated
B. Mixer blanking occurs
C. Automatic limiting occurs
D. A beat frequency is generated

120

Signal Processing

Modulators

- Combining information with an RF signal resulting in a signal that can be transmitted is called *modulation*.
- The information is called:
  - The *modulating signal*, or
  - The *baseband* signal.

121

Signal Processing

Modulators

- Varying the strength (amplitude) of the signal is called *amplitude modulation (AM)*.
- Varying the frequency or phase of the signal is called *angle modulation*.
  - Changing the frequency of the carrier is called *frequency modulation (FM)*.
  - Shifting the phase of the carrier is called *phase modulation (PM)*.

122

E7E07 -- What is meant by the term "baseband" in radio communications?

A. The lowest frequency band that the transmitter or receiver covers

➡ B. The frequency range occupied by a message signal prior to modulation

C. The unmodulated bandwidth of the transmitted signal

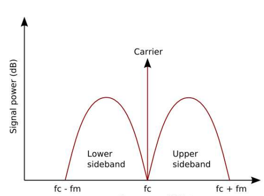
D. The basic oscillator frequency in an FM transmitter that is multiplied to increase the deviation and carrier frequency

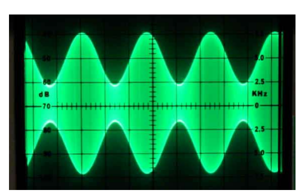
123

Signal Processing

Modulators

- Amplitude Modulation and Single Sideband.
  - Amplitude modulation (AM).
    - Multiplying (mixing) an AF signal with a carrier produces an amplitude modulated (AM) signal.





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Signal Processing

Modulators

- Amplitude Modulation and Single Sideband.
  - Amplitude modulation (AM).
    - An AM signal consists of 3 components.
      - **Carrier** -- 50% of the power and carries no information.
      - **Lower sideband** -- 25% of the power and carries the same information as the upper sideband.
      - **Upper sideband** -- 25% of the power and carries the same information as the lower sideband.
    - The bandwidth occupied by an AM signal is twice the bandwidth of the modulating signal.

125

Signal Processing

Modulators

- Single-sideband modulation (SSB).
  - If we eliminate the carrier and one of the sidebands:
    - We can transmit a signal that occupies ½ the bandwidth of an AM signal.
      - Narrower bandwidth = less noise power in the receiver.
    - We can increase the power of the information being transmitted by a factor of 4 without increasing the transmitter power.

126

Signal Processing

Modulators

- Single-sideband modulation (SSB).
  - There are 2 methods used to generate SSB signals:
    - Filter method.
      - Used in traditional (non-SDR) transmitters.
    - Phasing or quadrature method.
      - Used in software-defined radios (SDR).

127

Signal Processing

Modulators

- Single-sideband modulation (SSB).
  - Filter method.
    - Start with an AM double-sideband signal & use filters to remove one sideband & the carrier.
    - Better idea – use a balanced modulator (double-balanced mixer) to generate a double-sideband suppressed carrier signal. Then all you have to filter out is the unwanted sideband.

128

Signal Processing

Modulators

- Single-sideband modulation.
  - Phasing (quadrature) method.
    - Generate 2 identical carrier signals, 90° out of phase.
    - Generate 2 identical audio signals, 90° out of phase.
    - Mix these together in a pair of balanced modulators & the result is the carrier & one sideband being canceled out, leaving only one sideband.

129

Signal Processing

Modulators

- Single-sideband modulation.
  - Phasing (quadrature) method.
    - Creating a 90° phase shift of a band of audio frequencies is difficult to accomplish in hardware, but relatively easy in software.
      - Hilbert-transform filters.
    - Most SDR transmitters use the phasing or quadrature method to generate SSB mathematically.

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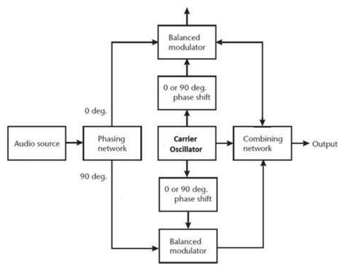
Signal Processing

Modulators

- Single-sideband modulation.
  - Phasing (quadrature) method.



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E7E04 -- What is one way a single-sideband phone signal can be generated?

A. By using a balanced modulator followed by a filter

B. By using a reactance modulator followed by a mixer

C. By using a loop modulator followed by a mixer

D. By driving a product detector with a DSB signal

132

Signal Processing

Frequency and Phase Modulation

- Reactance Modulator.
  - A reactance modulator modulates a signal by varying the reactance of a circuit.
    - Usually by varying the bias voltage of a variable-capacitance diode (varicap).
    - Varying the reactance in the oscillator circuit results in frequency modulation (FM).
    - Varying the reactance in any stage other than the oscillator circuit results in phase modulation (PM).

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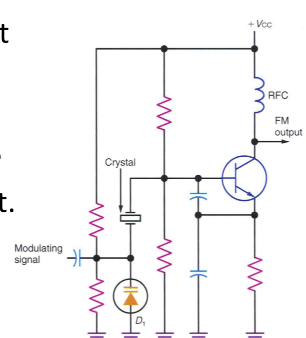
Signal Processing

Frequency and phase modulation.

- Direct FM.
  - The frequency deviation does not change with the modulating frequency.
  - Generated by adding a reactance modulator to the oscillator circuit.



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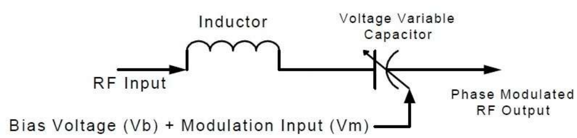
Signal Processing

Frequency and phase modulation.

- Indirect FM (phase modulation).
  - The frequency deviation increases with an increase in the modulating frequency.
  - PM is generated by adding a reactance modulator to any stage other than the oscillator.



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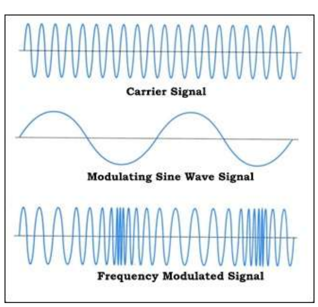
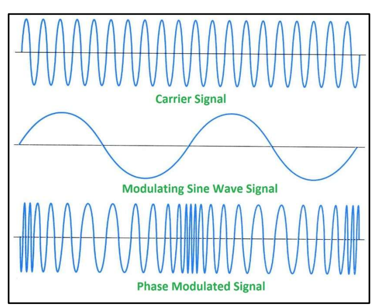
Signal Processing

Frequency and phase modulation.





136

E7E01 -- Which of the following can be used to generate FM phone emissions?

A. A balanced modulator on the audio amplifier
B. A reactance modulator on the oscillator
C. A reactance modulator on the final amplifier
D. A balanced modulator on the oscillator

137

E7E02 -- What is the function of a reactance modulator?

A. To produce PM signals by using an electrically variable resistance
B. To produce AM signals by using an electrically variable inductance or capacitance
C. To produce AM signals by using an electrically variable resistance
D. To produce PM or FM signals by using an electrically variable inductance or capacitance

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Signal Processing

Pre-Emphasis and De-Emphasis

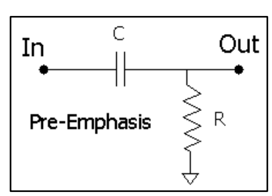
- Deviation is the amount that the frequency of a modulated signal changes from the frequency with no modulation.
- With FM, the deviation is constant regardless of the modulating frequency.
- With PM, the deviation increases as the modulating frequency increases.

139

Signal Processing

Pre-Emphasis and De-Emphasis

- In a transmitter, if we amplify the higher frequencies in the modulating signal more than the lower frequencies, we can make an FM signal “look like” a PM signal.
- This is called *pre-emphasis*.



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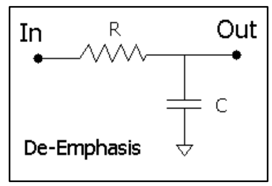
Signal Processing

Pre-Emphasis and De-Emphasis

- In a receiver, if we attenuate the higher frequencies in the de-modulated signal with respect to the lower frequencies, we can make a received PM signal "look like" an FM signal.
- This is called *de-emphasis*.



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Signal Processing

Modulators

- Pre-Emphasis and De-Emphasis.
  - Using pre-emphasis & de-emphasis yields a better signal-to-noise ratio.
  - A PM transmitter does not need pre-emphasis.
  - An FM receiver with de-emphasis can receive both FM & PM signals.

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E7E05 -- What circuit is added to an FM transmitter to boost the higher audio frequencies?

A. A de-emphasis network

B. A heterodyne suppressor

C. A heterodyne enhancer

➡ D. A pre-emphasis network

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E7E06 -- Why is de-emphasis commonly used in FM communications receivers?

➡ A. For compatibility with transmitters using phase modulation

B. To reduce impulse noise reception

C. For higher efficiency

D. To remove third-order distortion products

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Signal Processing

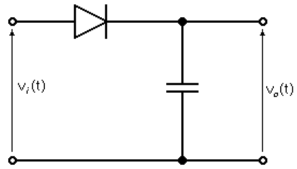
Detectors and Demodulation

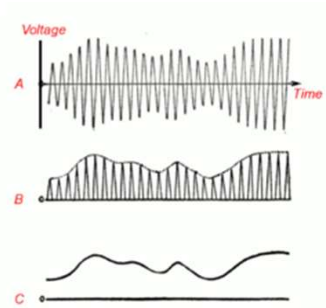
- The process of extracting the information from a modulated signal is called *detection* or *demodulation*.
- The circuit that extracts the information is called a *detector* or a *demodulator*.

Signal Processing

Detectors and Demodulation

- Detectors.
  - The simplest detector is the diode detector.
    - a.k.a. – Envelope detector.
    - Rectifies & filters the RF signal.
    - Can demodulate AM signals.





Signal Processing

Detectors and Demodulators

- Product Detectors.
  - A product detector is actually a mixer circuit which multiplies the received signal with a frequency from a local oscillator to retrieve the modulating signal.
    - $f_{RF} \times f_{LO}$ ➔ $f_{RF} - f_{LO}$ ➔ f_{AF}
  - The local oscillator is sometimes called a *beat frequency oscillator (BFO)*.
    - A BFO simulates the original carrier.

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Signal Processing

Detectors and Demodulators

- Product Detectors.
  - A product detector provides a better signal-to-noise ratio than an envelope detector.
  - A product detector can demodulate AM, SSB, & CW signals.
    - To detect AM or SSB, the local oscillator frequency must precisely match the AM signal carrier.
    - To detect CW, the local oscillator frequency is offset from the signal frequency to produce a sidetone.

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Signal Processing

Detectors and Demodulators

- Direct Conversion.
  - The local oscillator is at the frequency of the received signal.
  - Direct conversion requires a very stable local oscillator.
  - Some older software-defined radio (SDR) designs use a modified direct-conversion technique.
    - The RF signal is converted to a baseband AF signal for A-to-D conversion & processing.

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Signal Processing

Detectors and Demodulators

- Detecting FM signals.
  - There are 4 methods commonly used to demodulate FM or PM signals & 1 not-so-common method.
    - Frequency discriminator.
    - Ratio detector.
    - Quadrature detector.
    - Phase-locked loop detector.
    - Slope detection.

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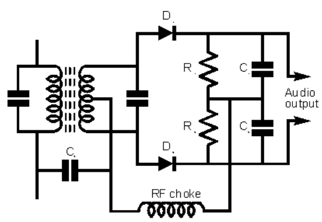
Signal Processing

Detectors and Demodulators

- Detecting FM signals.
  - Frequency discriminator.
    - a.k.a. – Foster-Seeley Detector.



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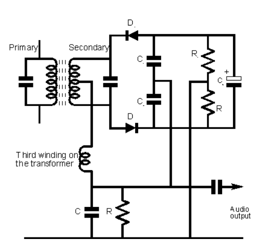
Signal Processing

Detectors and Demodulators

- Detecting FM signals.
  - Ratio detector.
    - A variation of the Foster-Seely discriminator.



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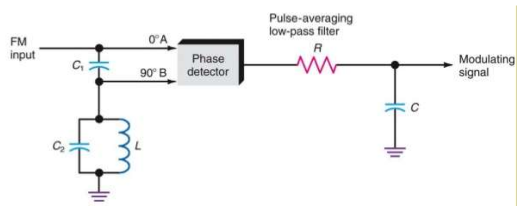
Signal Processing

Detectors and Demodulators

- Detecting FM signals.
  - Quadrature detector.
    - Often implemented on a single integrated circuit.



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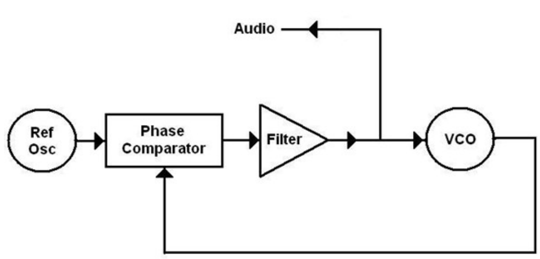
Signal Processing

Detectors and Demodulators

- Detecting FM signals.
  - Phase-locked loop (PLL) detector.



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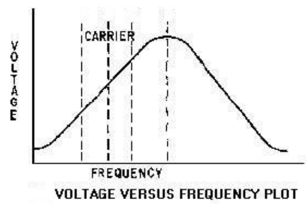
Signal Processing

Detectors and Demodulators

- Detecting FM signals.
  - Slope detector.
    - If you do not have an FM receiver, you can use an AM receiver's selectivity curve to detect FM.



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E7E03 -- What is a frequency discriminator stage in a FM receiver?

A. An FM generator circuit

B. A circuit for filtering two closely adjacent signals

C. An automatic band-switching circuit

D. A circuit for detecting FM signals

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E7E10 -- How does a diode envelope detector function?

A. By rectification and filtering of RF signals
B. By breakdown of the Zener voltage
C. By mixing signals with noise in the transition region of the diode
D. By sensing the change of reactance in the diode with respect to frequency

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E7E11 -- Which type of detector circuit is used for demodulating SSB signals?

A. Discriminator
B. Phase detector
C. Product detector
D. Phase comparator

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Questions?

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Amateur Extra Class

Next Week

Chapter 6 (Part 2)

Electronic Circuits

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