



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 any 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.

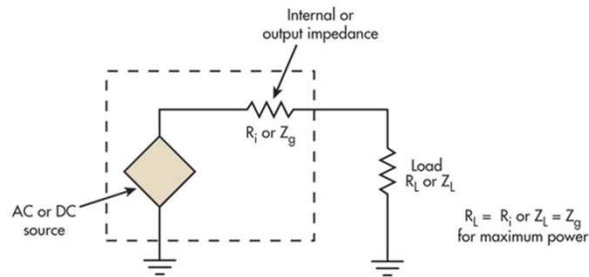
- The input impedance of an amplifier is the load seen by driver.
- The output impedance is the source impedance of the amplifier.
- Maximum power transfer occurs when the source impedance of the amplifier equals the input impedance of the following circuit.

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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.

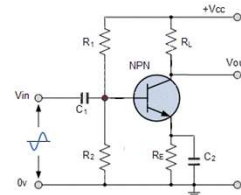
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Amplifiers

Common Emitter and Common Collector Circuits

- Common emitter.
 - The most common amplifier type.
 - Provides both voltage gain and current gain.
 - Input & output voltages 180° out of phase.
 - Fairly high input impedance.
 - Output impedance depends on R_L .



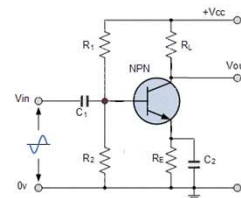
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Amplifiers

Common Emitter and Common Collector Circuits

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



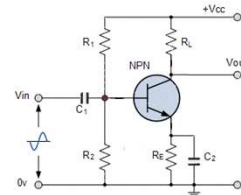
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Amplifiers

Common Emitter and Common Collector Circuits

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



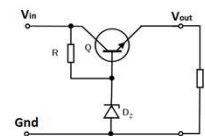
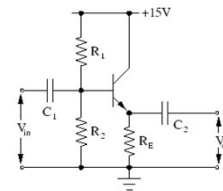
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Amplifiers

Discrete Device Amplifiers

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



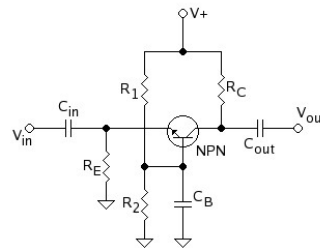
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Amplifiers

Discrete Device Amplifiers

- Common base.
 - Provides voltage gain.
 - Current gain < 1 .
 - Input & output voltages 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 \leftrightarrow Common-Cathode.
 - Common-Base \leftrightarrow Grounded-Grid.
 - Common-Collector \leftrightarrow Common-Anode.
 - Emitter Follower \leftrightarrow Cathode Follower.

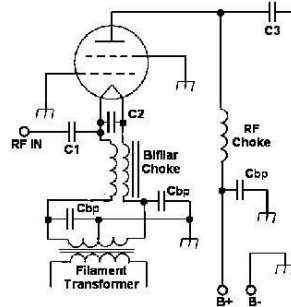
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Amplifiers

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.

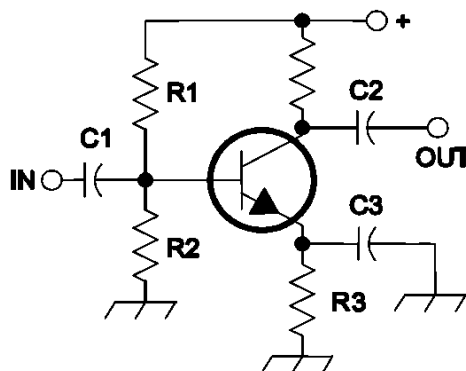


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E7B10 -- In Figure E7-1, what is the purpose of R1 and R2?

- A. Load resistors
- B. Fixed bias
- C. Self bias
- D. Feedback

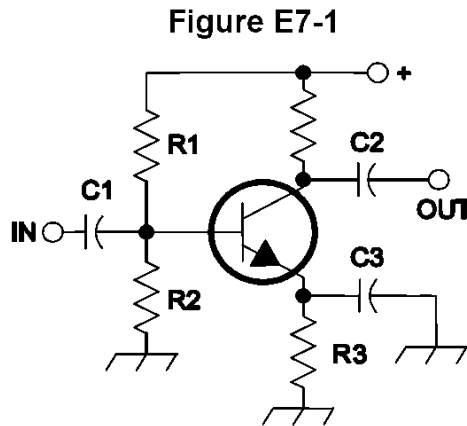
Figure E7-1



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

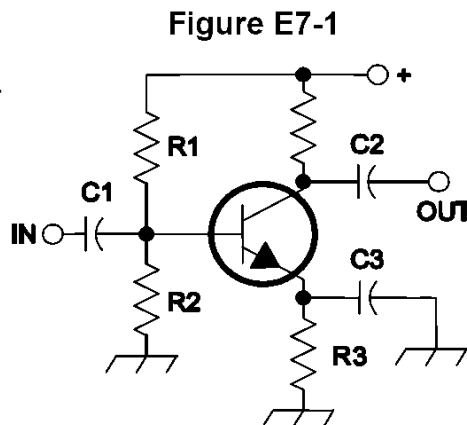
- A. Fixed bias
- B. Emitter bypass
- C. Output load resistor
- D. Self bias



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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



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E7B13 -- Which of the following describes an emitter follower (or common collector) amplifier?

- A. A two-transistor amplifier with the emitters sharing a common bias resistor
- B. A differential amplifier with both inputs fed to the emitter of the input transistor
- C. An OR circuit with only one emitter used for output
- D. An amplifier with a low impedance output that follows the base input voltage

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E7B15 -- What is one way to prevent thermal runaway in a bipolar transistor amplifier?

- A. Neutralization
- B. Select transistors with high beta
- C. Use a resistor in series with the emitter
- D. All of these choices are correct

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E7B18 -- Which of the following is a characteristic of a grounded-grid amplifier?

- A. High power gain
- B. High filament voltage
- C. Low input impedance
- D. Low bandwidth

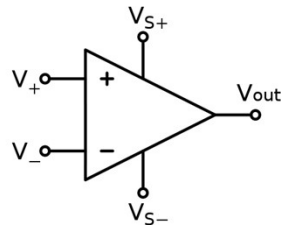
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Amplifiers

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.



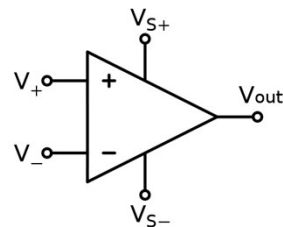
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Amplifiers

Op Amp Amplifiers

- Op Amp Characteristics
 - The ideal operational amplifier has:
 - Infinite input impedance.
 - Zero output impedance.
 - Infinite gain.
 - Flat frequency response.
 - Zero offset voltage.
 - $0 V_{IN} \rightarrow 0 V_{OUT}$



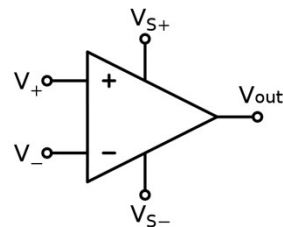
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Amplifiers

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.
 - 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.



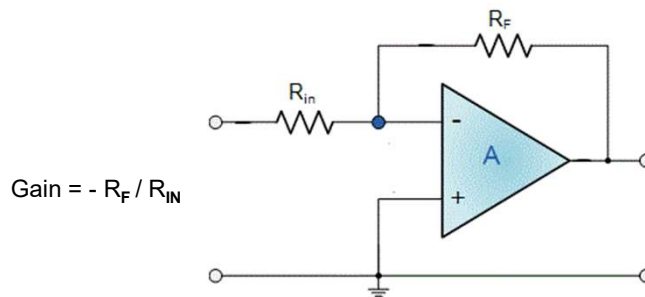
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Amplifiers

Op Amp Amplifiers

- Basic Amplifier Circuits.
 - Inverting Amplifier.



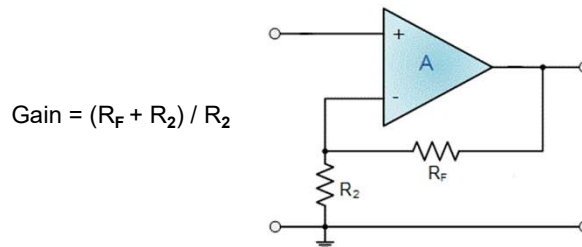
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Amplifiers

Op Amp Amplifiers

- Basic Amplifier Circuits.
 - Non-inverting Amplifier.



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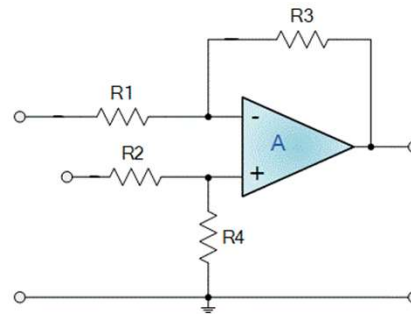


Amplifiers

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 $R_3 = R_4$



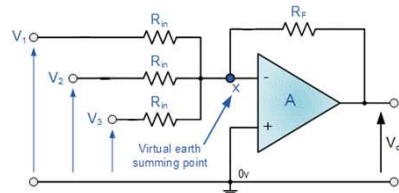
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Amplifiers

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

- A. Very low
- B. Very high
- C. 100 ohms
- D. 1000 ohms

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

- A. 100 ohms
- B. 1000 ohms
- C. Very low
- D. Very high

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E7G04 -- What is meant by the “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?

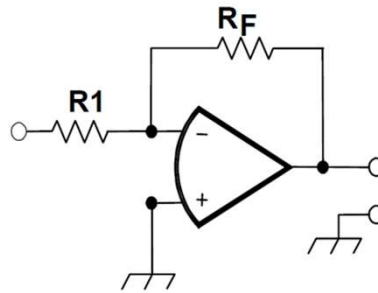
- A. The maximum frequency for a filter circuit using that type of amplifier
- B. The frequency at which the open-loop gain of the amplifier equals one
- C. The gain of the amplifier at a filter's cutoff frequency
- D. The frequency at which the amplifier's offset voltage is zero

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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. 94
- C. 47
- D. 24

Figure E7-3



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

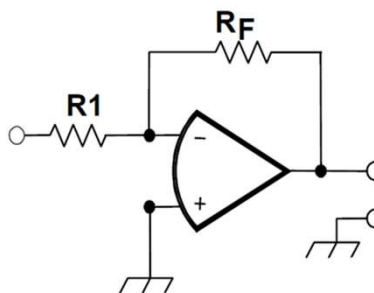
- A. It increases linearly with increasing frequency
- B. It decreases linearly with increasing frequency
- C. It decreases logarithmically with increasing frequency
- D. It does not vary with frequency

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E7G09 -- What will be the output voltage of the circuit shown in Figure E7-3 if R1 is 1000 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

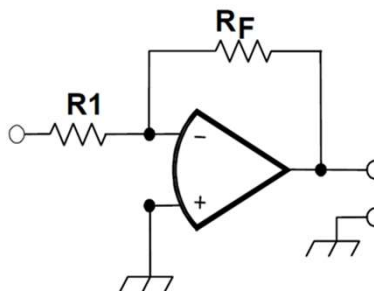


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E7G10 -- What absolute voltage gain can be expected from the circuit in Figure E7-3 when R1 is 1800 ohms and RF is 68 kilohms?

- A. 1
- B. 0.03
- C. 38
- D. 76

Figure E7-3

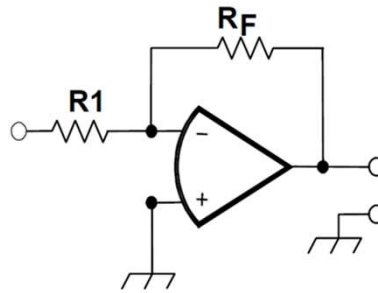


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E7G11 -- What absolute voltage gain can be expected from the circuit in Figure E7-3 when R1 is 3300 ohms and RF is 47 kilohms?

- 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

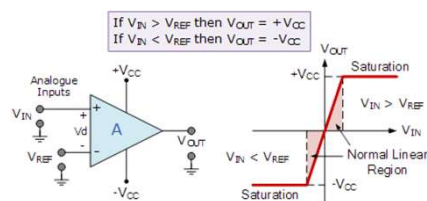
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Amplifiers

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 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.
 - Output changes state slightly above the threshold on the way up & slightly below the threshold on the way down.

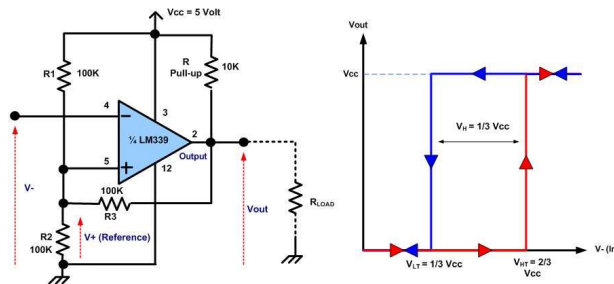
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Amplifiers

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 signal
- C. To cause the output to change states continually
- 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 comparator enters latch-up
- D. The feedback loop becomes unstable

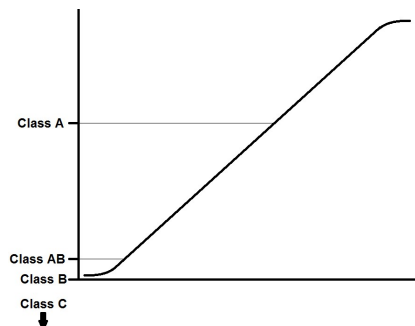
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Amplifiers

Classes of Operation

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



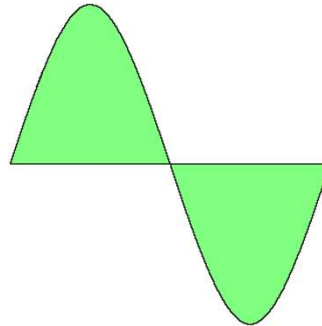
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Amplifiers

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%)



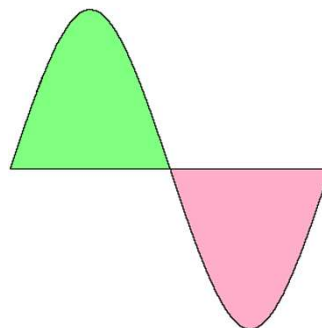
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Amplifiers

Classes of Operation

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



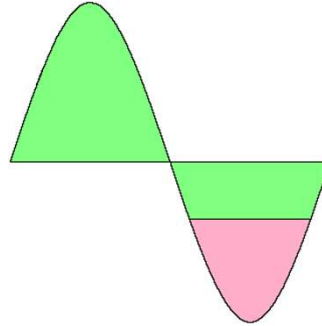
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Amplifiers

Classes of Operation

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



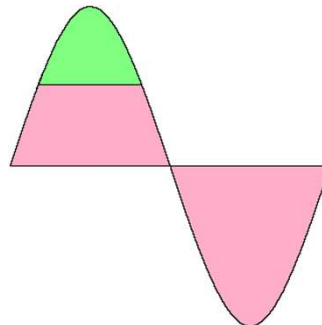
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Amplifiers

Classes of Operation

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



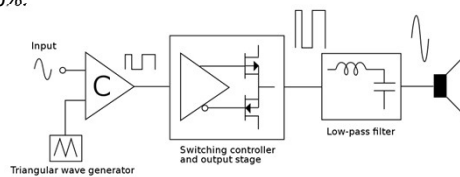
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Amplifiers

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 either cut off or saturated most of the time.
 - Efficiency >90%.



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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

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E7B02 -- What is a Class D amplifier?

- A. A type of amplifier that uses switching technology to achieve high efficiency
- B. A low power amplifier using a differential amplifier for improved linearity
- C. An amplifier using drift-mode FETs for high efficiency
- D. A frequency doubling amplifier

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E7B03 -- Which of the following components form the output of a class D amplifier circuit?

- A. A low-pass filter to remove switching signal components
- 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

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E7B04 -- Where on the load line of a Class A common emitter amplifier would bias normally be set?

- A. Approximately half-way between saturation and cutoff
- B. Where the load line intersects the voltage axis
- 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

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E7B06 -- Which of the following amplifier types reduces even-order harmonics?

- A. Push-push
- B. Push-pull
- C. Class C
- D. Class AB

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

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

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E7B14 -- Why are switching amplifiers more efficient than linear amplifiers?

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

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Amplifiers

Distortion and Intermodulation

- 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

Distortion and Intermodulation

- 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

Distortion and Intermodulation

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

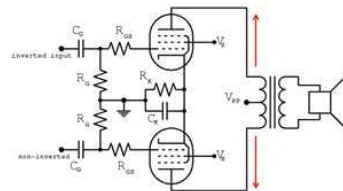
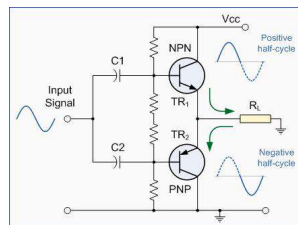
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Amplifiers

Distortion and Intermodulation

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



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Amplifiers

Distortion and Intermodulation

- Distortion
 - Non-linearity results in distortion.
 - **ALL** physical components have non-linearity.
 - Distortion results in harmonics.
 - 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.
 - 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 .

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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.

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E7B16 -- What is the effect of intermodulation products in a linear power amplifier?

- A. Transmission of spurious signals
- B. Creation of parasitic oscillations
- C. Low efficiency
- D. All of these choices are correct

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E7B17 -- Why are odd-order rather than even-order intermodulation distortion products of concern in linear power amplifiers?

- A. Because they are relatively close in frequency to the desired signal
- B. Because they are relatively far in frequency from the desired signal
- C. Because they invert the sidebands causing distortion
- D. Because they maintain the sidebands, thus causing multiple duplicate signals

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Signal Processing

Oscillator Circuits and Characteristics

- Oscillator circuits are used to generate 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.

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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 acts as a filter to restrict the feedback to the resonant frequency.

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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.

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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.

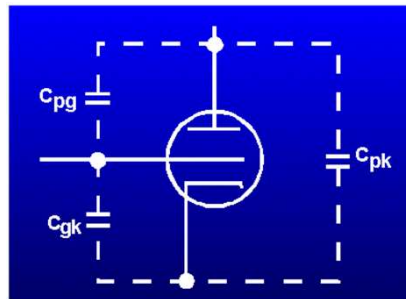
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Signal Processing

Instability and Parasitic Oscillation

- Neutralization.



73



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.

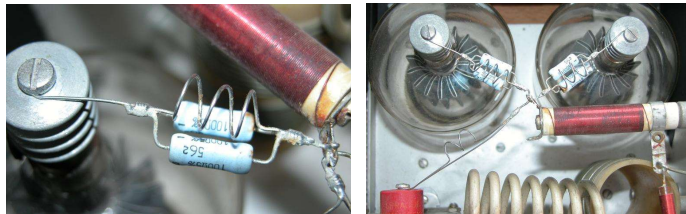
74



Signal Processing

Instability and Parasitic Oscillation

- Parasitic suppressor.



75



Signal Processing

Instability and Parasitic Oscillation

- Parasitic suppressor.



76

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

- A. Tune the stage for maximum SWR
- 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

E7B08 -- How can an RF power amplifier be neutralized?

- A. By increasing the driving power
- B. By reducing the driving power
- C. By feeding a 180-degree out-of-phase portion of the output back to the input
- D. By feeding an in-phase component of the output back to the input

78



Break



79



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.

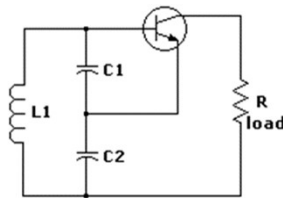
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Signal Processing

RF Oscillators

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



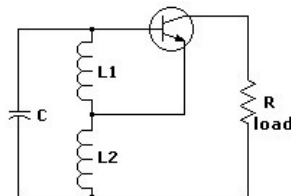
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Signal Processing

RF Oscillators

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



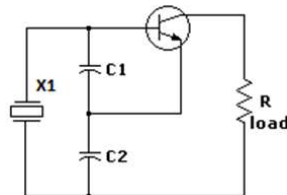
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Signal Processing

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.



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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.

84



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.

85

E7H01 -- What are three oscillator circuits used in Amateur Radio equipment?

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

86

E7H03 -- How is positive feedback supplied in a Hartley oscillator?

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


87

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


88

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

89

E7H06 -- Which of the following oscillator circuits are commonly used in VFOs?

- A. Pierce and Zener
-  B. Colpitts and Hartley
- C. Armstrong and deForest
- D. Negative feedback and balanced feedback

90

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

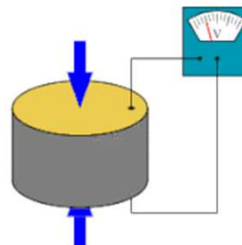
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Signal Processing

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.



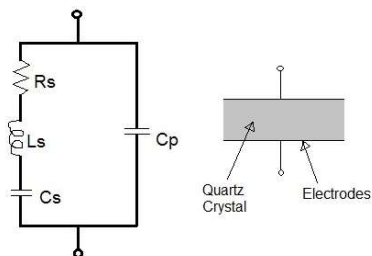
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Signal Processing

Crystals for Oscillators

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



94



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.

95

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

- A. Motional capacitance, motional inductance, and loss resistance in series, all in parallel with a shunt capacitor representing electrode and stray capacitance
- B. Motional capacitance, motional inductance, loss resistance, and a capacitor representing electrode and stray capacitance all in parallel
- C. Motional capacitance, motional inductance, loss resistance, and a capacitor representing electrode and stray capacitance all in series
- D. Motional inductance and loss resistance in series, paralleled with motional capacitance and a capacitor representing electrode and stray capacitance

96

E6E03 -- 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

97

E7H12 -- Which of the following must be done to ensure that a crystal oscillator provides 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

98



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.

99



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.

100

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

101

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

- A. Use NPO capacitors
- B. Reduce noise on the oscillator's power supply
- C. Increase the bias voltage
- D. Mechanically isolate the oscillator circuitry from its enclosure

102

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

- A. NPO capacitors
- B. Toroidal inductors
- C. Wirewound resistors
- D. Non-inductive resistors

103



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).

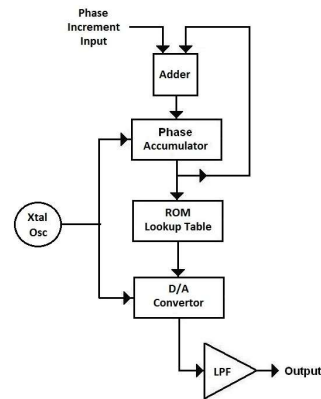
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Signal Processing

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.



105

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

106

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

107

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

108



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.

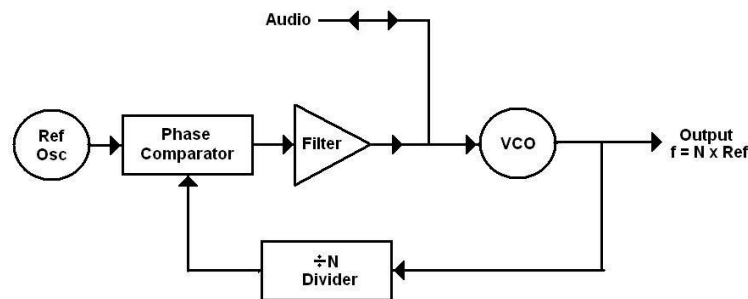
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Signal Processing

Frequency Synthesis

- Phase-Locked Loop (PLL).



110

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

111

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

112



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.
 - $f_{RF} \times f_{LO} \rightarrow f_{LO} - f_{RF} = f_{IF}$

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Signal Processing

Mixers

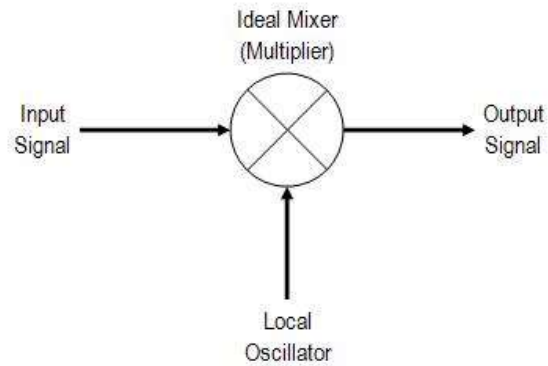
- Only enough pre-amp gain should be used to overcome mixer losses.
- Excessive input signal can:
 - Overload mixer circuit.
 - Distort signal.
 - Generate spurious mixer products.
- Operation of a mixer is similar to operation of product detectors & modulators.

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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.

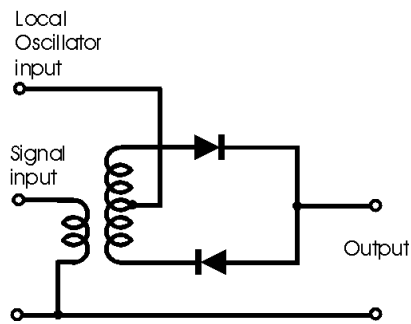
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Signal Processing

Mixers

- Single-balanced mixer.



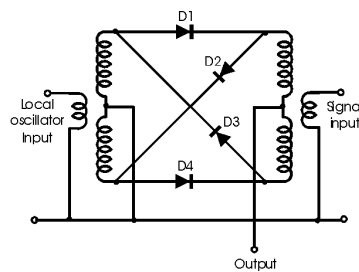
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Signal Processing

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 LO signal needed.
 - Generate less noise.
 - Strong signal handling capability not as good as passive mixers.

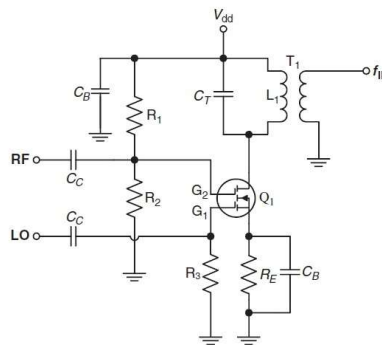
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Signal Processing

Mixers

- Dual-gate MOSFET mixer.



120

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

121

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

122



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.

123



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)*.

124

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

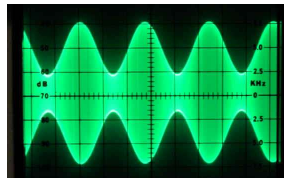
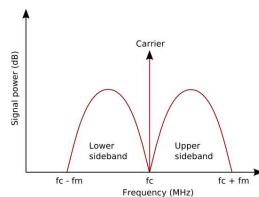
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Signal Processing

Modulators

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



126



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.

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Signal Processing

Modulators

- Single-sideband modulation (SSB).
 - If we eliminate the carrier and one of the sidebands:
 - We can transmit a signal that occupies $\frac{1}{2}$ 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.

128



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).

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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.

130



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 & result is that the carrier & one sideband are canceled out leaving only one sideband.

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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.

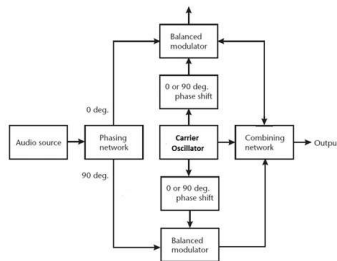
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Signal Processing

Modulators

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



133

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

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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).

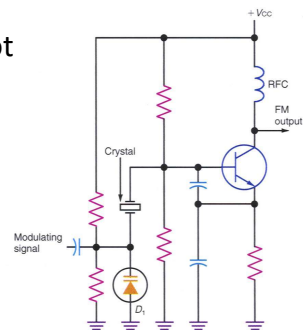
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Signal Processing

Frequency and phase modulation.

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



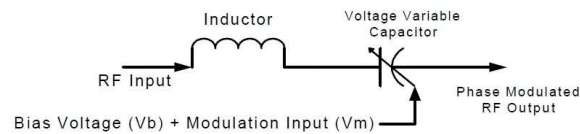
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Signal Processing

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.

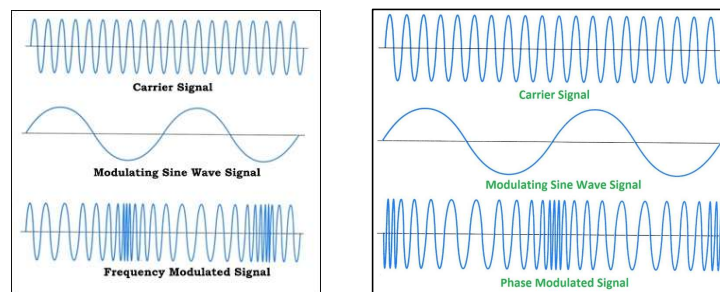


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Signal Processing

Frequency and phase modulation.



138

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

139

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.

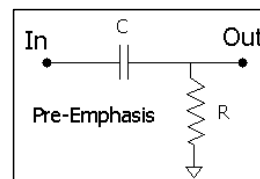
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Signal Processing

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*.



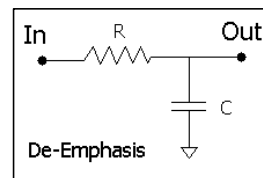
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Signal Processing

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.

144

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

145

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*.

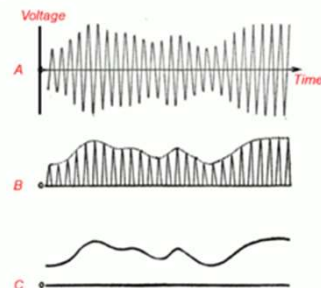
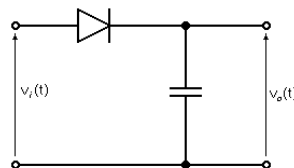
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Signal Processing

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.



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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.
 - $f_{RF} \times f_{LO} \rightarrow f_{RF} - f_{LO} \rightarrow f_{AF}$
 - 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.

150



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 software-defined radios (SDR) 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.

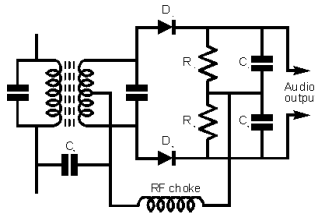
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Signal Processing

Detectors and Demodulators

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



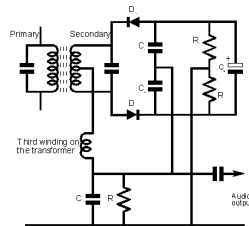
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Signal Processing

Detectors and Demodulators

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



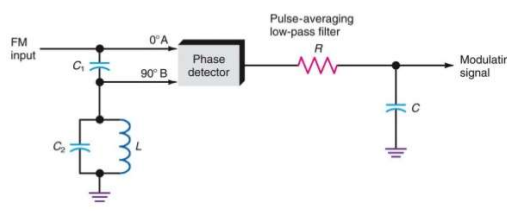
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Signal Processing

Detectors and Demodulators

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



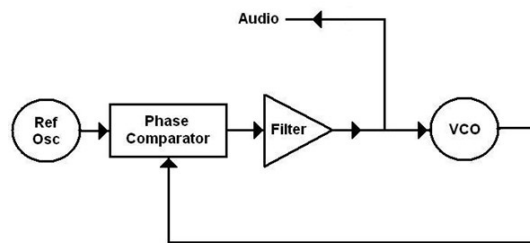
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Signal Processing

Detectors and Demodulators

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



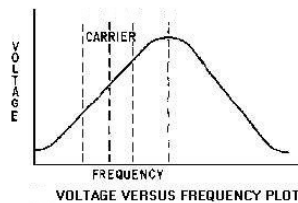
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Signal Processing

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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