CHAPTER 6 Radio Circuits and Systems

6.1 AMPLIFIERS (page 6-1)

AMPLIFIER GAIN (page 6-2)

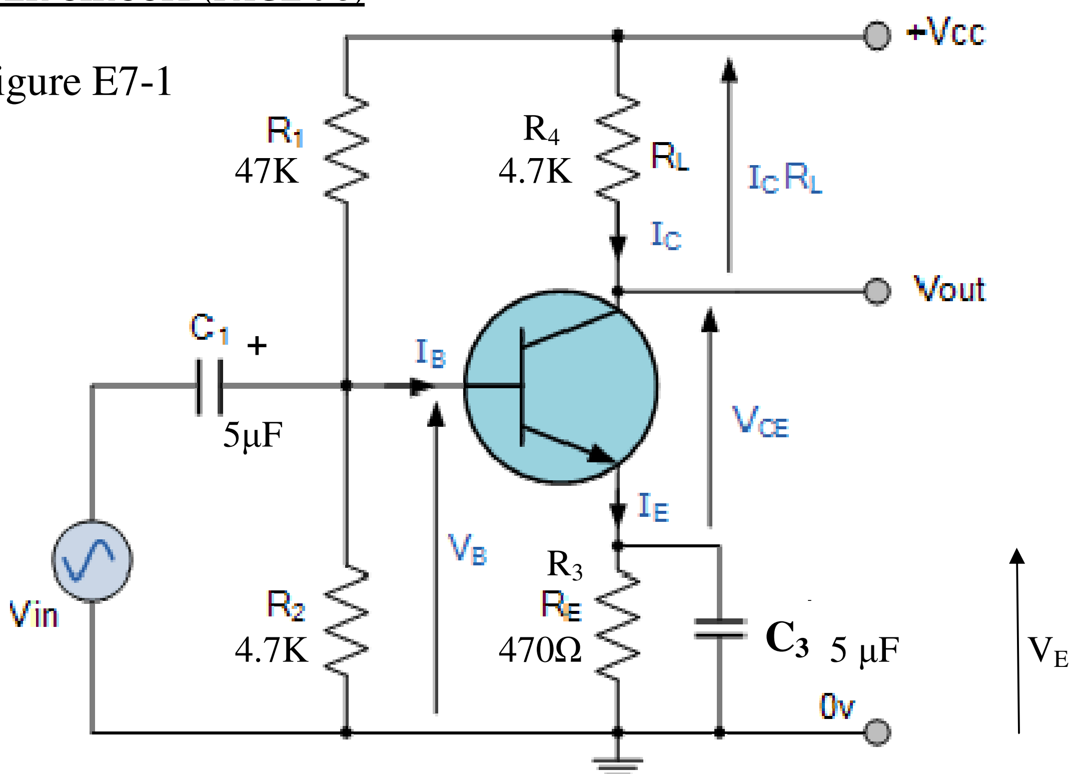
INPUT AND OUTPUT IMPEDANCE (page 6-2)

DISCRETE DEVICE AMPLIFIERS (page 6-2)

BASIC CIRCUITS (page 6-2)

COMMON-EMITTER CIRCUIT (PAGE 6-3)

Equivalent to Figure E7-1



You can recognize the common-emitter amplifier circuit by the value for the resistance in the emitter circuit (R_3 or R_E) being much smaller (or even absent) than that in the collector circuit (R_4 or R_L) or the emitter resistor being bypassed with a capacitor (C_3).

Question E7B12: What type of amplifier circuit is shown in Figure E7-1?
Answer: Common emitter

On a common-emitter amplifier the output signal is 180° out of phase with the input signal.

Resisters R_1 and R_2 form a voltage divider to provide a stable operating point. (This operating point is usually chosen so that the Emitter voltage (V_E) is one volt which means the Base voltage (V_B) is at 1.7 volts on a silicon transistor.)

(The example in the manual has the bias voltage at 0.82 volts which means the emitter is at 0.12 volts.) (A better solution would be to replace R_1 with a 27K ohm resistor.) This is called Fixed Bias.

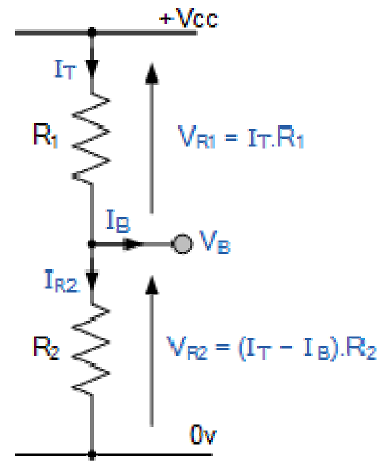
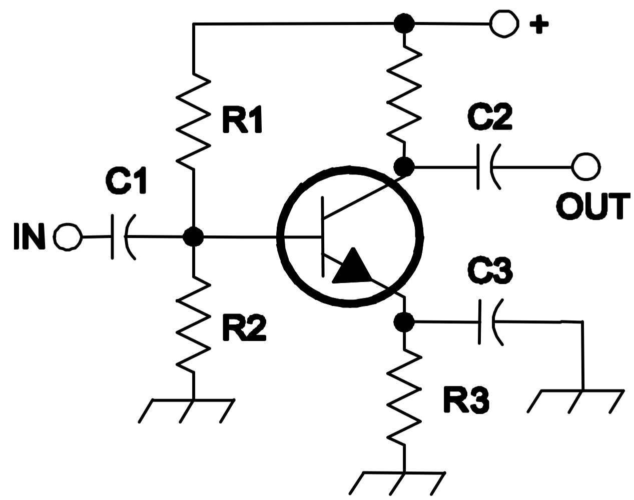


Figure E7-1

Question E7B10: In Figure E7-1, what is the purpose of R1 and R2?
Answer: Fixed bias

Common-emitter circuits are subject to thermal runaway. As forward bias is increased, the collector current and gain are higher, and that makes the temperature of the transistors junctions higher. As temperature increases so does the gain of the transistor, causing collector-emitter current to increase even more. Eventually transistor junctions are overheated and destroyed. Some kind of negative feedback or bias stabilization is required to prevent this from happening.

One solution is to add resistance in the emitter circuit (R_3) to create degenerative emitter feed back or self-bias.



Question E7B11: In Figure E7-1, what is the purpose of R3?
Answer: Self bias

As emitter current increases, so does the DC voltage across R_3. This increasing voltage reduces the base-emitter forward bias established by R_1 and R_2 reducing emitter current. The resulting balancing act stabilizing the transistor's operating point and prevents thermal runaway.

Again, Use a resistor in series with the emitter to prevent thermal runaway in a bipolar transistor amplifier.

Question E7B15: What is one way to prevent thermal runaway in a bipolar transistor amplifier?
Answer: Use a resistor in series with the emitter

[(first paragraph on page 6-4) The first resistance is the parallel combination of an external load R_L, connected between the output terminals and the sum of R_3 and R_4 shown in the numerator of the following question.]

The value $\mathbf{r_e}$ (little r subscript little e) is called dynamic emitter resistance and comes from the specification table for the transistor. It is also called trans-resistance. For this transistor $\mathbf{r_e}$ (emitter resistance) is 26 mV / I_e. This circuit idles, so we are told, at 1.3 mA.

$$\mathbf{r_e} = \frac{26\text{ mV}}{1.3\text{ mA}} = 20\ \Omega$$

$$A_V \text{ (dc gain)} = \frac{-R_4}{R_3 + \mathbf{r_e}} = \frac{-4{,}700\ \Omega}{470\ \Omega + 20\ \Omega} = \frac{-4{,}700\ \Omega}{490\ \Omega} = -\ 9.591836735$$

$$A_V \text{ (ac gain)} = \frac{-R_4}{\mathbf{r_e}} = \frac{-4{,}700\ \Omega}{20\ \Omega} = -\ 235.0$$

(The capacitor C_3 will reduce R_3 to zero ohms.)

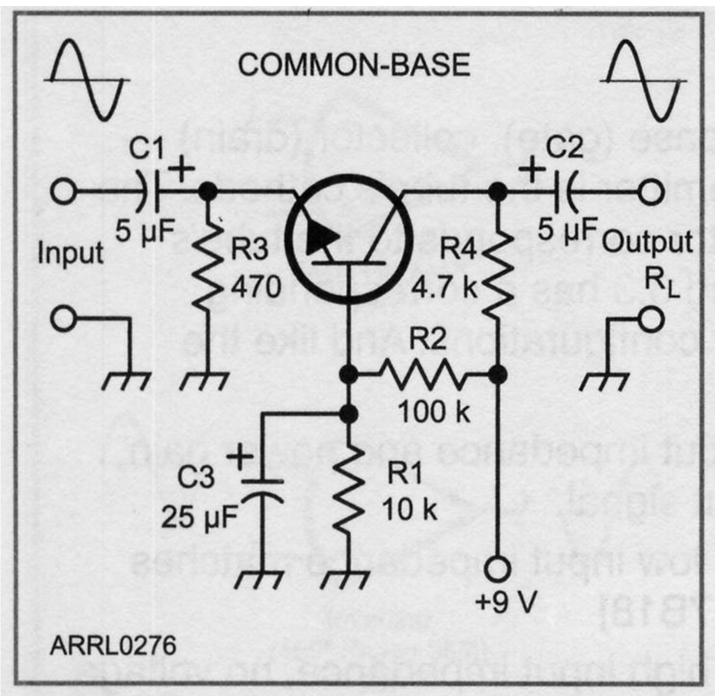
CHAPTER 6 Radio Circuits and Systems

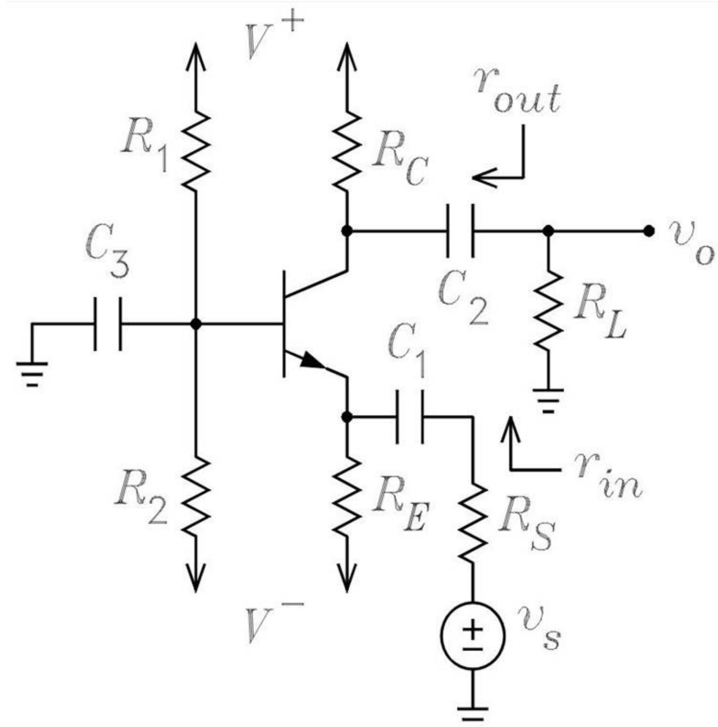
<u>COMMON-BASE CIRCUIT (page 6-5)</u>

The common-base amplifier has the input signal applied to the transistor's emitter and the transistor's base is essentially connected to ground through a capacitor. There may be biasing resistors connect to the transistor's base just like with a common-emitter amplifier. This circuit has no current gain but it may be configured to have a very high voltage gain. The primary use of a common-base amplifier is as an impedance converter when signals from a low impedance source must drive a high impedance load.

On a common-base amplifier the output signal is in phase with the input signal.

Notice, no matter how it is drawn the common-base amplifier has the transistor's BASE grounded and input is to the transistor's emitter.





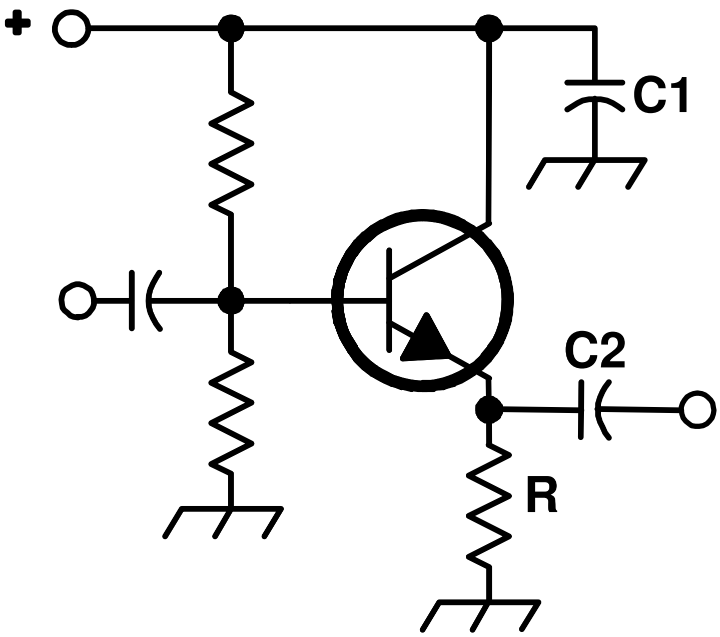
No questions on common-base amplifiers.

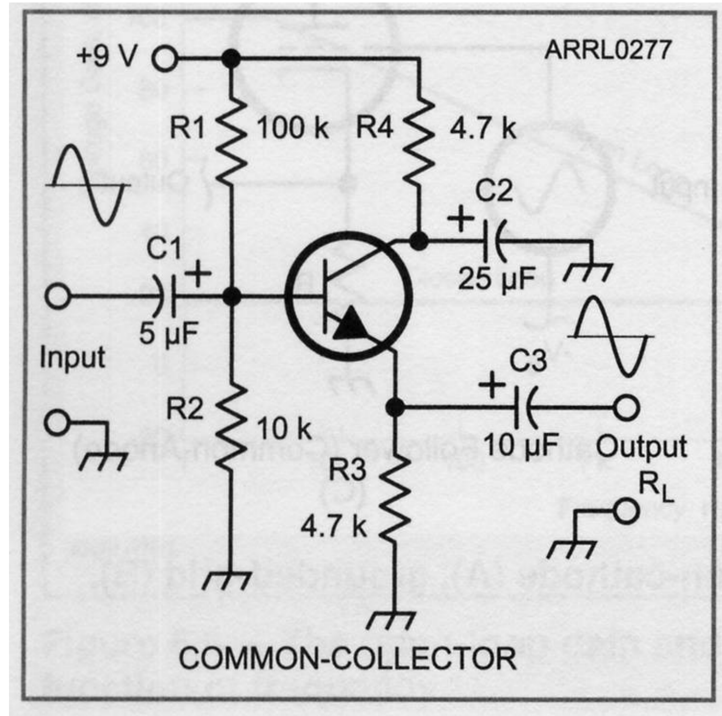
<u>COMMON-COLLECTOR OR EMITTER FOLLOWER CIRCUIT (page 6-5)</u>

The common-collector amplifier is often called an emitter follower amplifier which reminds me of the cathode follower vacuum tube. The common-collector amplifier has the input signal applied to the transistor's base and the transistor's collector is essentially connected to ground through a capacitor. There may be biasing resistors connect to the transistor's base just like with a common-emitter amplifier. This circuit may have a high current gain. The primary use of a common-collector amplifier is as an impedance converter where signals from a high input impedance source must drive a low impedance load.

On a common-base amplifier the output signal is in phase with the input signal.

Figure E7-2





The book says, without an R_L attached, R_3 also acts as the emitter resister or load. In figure E7-2 symbol R is the same as the symbol R_3 in the manual.

Question E7B13: In Figure E7-2, what is the purpose of R?
Answer: Emitter load

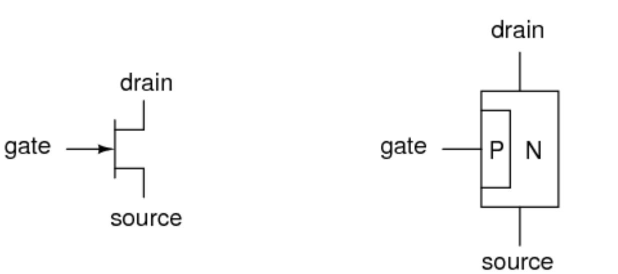
SIMILARITIES OF VACUUM TUBES (page 6-6)

Here are some of the similarities between dipolar transistors, FET transistors, and vacuum tubes.

Common-Emitter	is the same as	Common Source	Common Cathode	High Input Impedance
Common Base	is the same as	Common Gate	Common (grounded) Grid	Low Input Impedance
Common Collector	is the same as	Common Drain	Common Anode or Plate	High Input Impedance

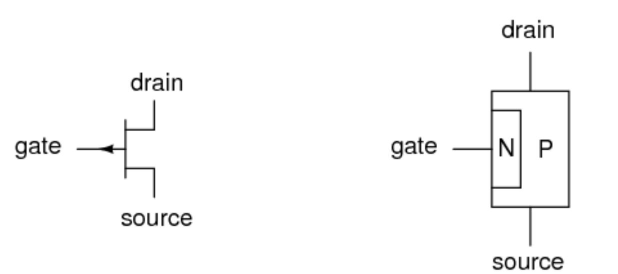
Question E7B18: (C) What is a characteristic of a grounded-grid amplifier?
Answer: C. Low input impedance

***N-channel* JFET**



schematic symbol *physical diagram*

***P-channel* JFET**



schematic symbol *physical diagram*

CHAPTER 6 Radio Circuits and Systems

OP AMP OR OPERATIONAL AMPLIFIERS (page 6-6)

The (integrated circuit) operational amplifier or op amp is a high-gain, direct-coupled, differential amplifier that amplifies dc signals as well as ac signals (and has a very-high input impedance and a very low output impedance.)

Question E7G12: What is an integrated circuit operational amplifier?
Answer: A high-gain, direct-coupled differential amplifier with very high input impedance and very low output impedance

OP AMP CHARACTERISTICS (page 6-7)

A theoretically perfect op amp would have the following characteristics

Zero (very low) output impedance
Infinite (very high) input impedance
Flat (gain does not vary with) frequency response
Infinite voltage gain
Zero output when the input is zero

Question E7G01: What is the typical output impedance of an integrated circuit op-amp?
Answer: Very low

Question E7G03: What is the typical input impedance of an integrated circuit op-amp?
Answer: Very high

Question E7G08: How does the gain of an ideal operational amplifier vary with frequency?
Answer: It does not vary with frequency

If the input terminals of an op amp are shorted together, the output voltage should be zero. With most op amps there will be a small output voltage. This voltage offset results from imbalances between the op amp's input transistors. The op amp's INPUT-OFFSET VOLTAGE specifies the (digital input) voltage between the amplifiers inputs that will produce a zero output voltage, assuming the amplifiers is in a OPEN loop circuit.

(Did you apply the instructions from the manual's ERRATA sheet to the top of page 6-8?)

Question E7G04: What is meant by the term op-amp input offset voltage?
Answer: The differential input voltage needed to bring the OPEN loop output voltage to zero

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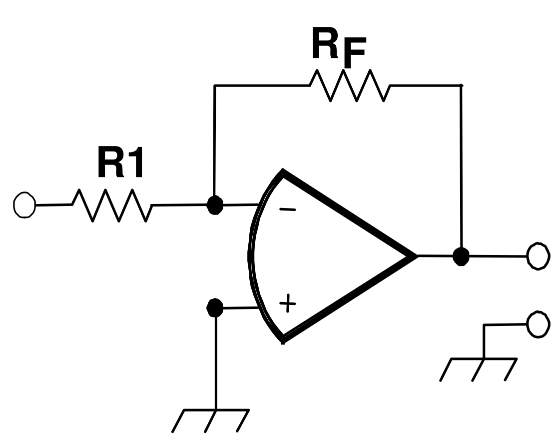
BASIC AMPLIFIER CIRCUITS (page 6-8)

Figure E7-4



Voltage gain for the inverting op amp circuit is determined solely by R_1 (the input resistance) and R_F (the feedback resistor).

If the non-inverting input is grounded then in order to maintain the inverting input at ground, any input current must be balanced by an equal and opposite feedback current from the op amp's output.

$$\text{Voltage Gain} = A_V = \frac{V_{OUT}}{V_{IN}} = \frac{-R_F}{R_1}$$

CHAPTER 6 Radio Circuits and Systems

EXAMPLE 6.1 (page 6-9)

What is the voltage gain of the circuit in Figure 6.7 or Figure E7-4, if $R_1 = 1800\ \Omega$ and $R_F = 68\ k\Omega$?

$$|A_V| = \frac{R_F}{R_1} = \frac{68\ k\Omega}{1{,}800\ \Omega} = \frac{68{,}000\ \Omega}{1{,}800\ \Omega} = 37.777777778$$

Question E7G10: What absolute voltage gain can be expected from the circuit in Figure E7-4 when R1 is 1800 ohms and RF is 68 kilohms?
Answer: 38

EXAMPLE 6.2 (page 6-9)

What is the voltage gain of the circuit in Figure 6.7 or Figure E7-4, if $R_1 = 10\ \Omega$ and $R_F = 470\ \Omega$?

$$|A_V| = \frac{R_F}{R_1} = \frac{470\ \Omega}{10\ \Omega} = 47.0$$

Question E7G07: What magnitude of voltage gain can be expected from the circuit in Figure E7-4 when R1 is 10 ohms and RF is 470 ohms?
Answer: 47

EXAMPLE 6.3 (page 6-9)

What is the voltage gain of the circuit in Figure 6.7 or Figure E7-4, if $R_1 = 3300\ \Omega$ and $R_F = 47\ k\Omega$?

$$|A_V| = \frac{R_F}{R_1} = \frac{47\ k\Omega}{3{,}300\ \Omega} = \frac{47{,}000\ \Omega}{3{,}300\ \Omega} = 14.24242424$$

Question E7G11: What absolute voltage gain can be expected from the circuit in Figure E7-4 when R1 is 3300 ohms and RF is 47 kilohms?
Answer: 14

EXAMPLE 6.4 (page 6-9)

What is the voltage gain of the circuit in Figure 6.7 or Figure E7-4, if $R_1 = 1000\ \Omega$ and $R_F = 10\ k\Omega$ and the input voltage = 0.23 V?

$$|A_V| = \frac{R_F}{R_1} = \frac{10\ k\Omega}{1{,}000\ \Omega} = \frac{10{,}000\ \Omega}{1{,}000\ \Omega} = 10.0 \qquad V_{OUT} = V_{IN} \times -A_V = 0.23\ V \times -10.0 = -2.30\ V$$

Question E7G09: What will be the output voltage of the circuit shown in Figure E7-4 if R1 is 1000 ohms, RF is 10,000 ohms, and 0.23 volts DC is applied to the input?
Answer: -2.3 volts

CHAPTER 6 Radio Circuits and Systems

COMPARATORS (page 6-9)

A comparator circuit compares one or more input signals and produces an output of high or low voltage.

Thus the comparator changes its output state depending on whether the unknown voltage is above or below the threshold voltage.

Question E6C02: What happens when the level of a comparator's input signal crosses the threshold?
Answer: The comparator changes its output state

Hysteresis circuits are added to a comparator circuit to prevent input noise from causing unstable output signals.

Question E6C01: What is the function of hysteresis in a comparator?
Answer: To prevent input noise from causing unstable output signals

CLASSES OF (AMPLIFIER) OPERATION (page 6-10)

Amateur radio amplifiers are generals classified as class A, Class AB, Class B, and Class C.

(AMPLIFIER OPERATION) CLASS A (page 6-10)

The load line of a Class A common emitter amplifier would normally set the bias approximately half-way between saturation and cutoff.

Question E7B04: Where on the load line of a Class A common emitter amplifier would bias normally be set?
Answer: Approximately half-way between saturation and cutoff

(AMPLIFIER OPERATION) CLASS B (page 6-11)

Class B amplifiers operating in Push-pull reduce or eliminates even order harmonics.

Question E7B06: Which of the following amplifier types reduces or eliminates even order harmonics?
Answer: Push-pull

(AMPLIFIER OPERATION) CLASS AB (page 6-11)

Class AB amplifiers operate in the portion of a cycle more than 180 degrees but less than 360 degrees.

Question E7B01: For what portion of a signal cycle does a Class AB amplifier operate?
Answer: More than 180 degrees but less than 360 degrees

(AMPLIFIER OPERATION) CLASS C (page 6-11)

Using a Class C amplifier for SSB or digital signals would result in too much distortion and the output signal would occupy excessive bandwidth.

Question E7B07: Which of the following is a likely result when a Class C amplifier is used to amplify a single-sideband phone signal?
Answer: Signal distortion and excessive bandwidth

CHAPTER 6 Radio Circuits and Systems

(AMPLIFIER OPERATION) SWITCHING OR SWITCH-MODE CLASS (page 6-11)

Switching amplifiers more efficient than linear amplifiers because the power transistor is at saturation or cut off most of the time, resulting in low power dissipation. At cutoff the transistor is not passing any current – high efficiency. At saturation the transistor is passing maximum current just like a closed switch – high efficiency. (If the transistor was just partially turned on then it is acting like a resistor and dissipating heat – low efficiency.)

Question E7B14: Why are switching amplifiers more efficient than linear amplifiers?
Answer: The power transistor is at saturation or cut off most of the time, resulting in low power dissipation

A type of audio amplifier that uses switching technology to achieve high efficiency is called a Class D amplifier.

Question E7B02: What is a Class D amplifier?
Answer: A type of amplifier that uses switching technology to achieve high efficiency

A Class D amplifier usually has a low-pass filter to remove switching signal components.

Question E7B03: Which of the following components form the output of a class D amplifier circuit?
Answer: A low-pass filter to remove switching signal components

DISTORTION AND INTERMODULATION (page 6-12)

Intermodulation products in a linear power amplifier results in the transmission of spurious signals.

Question E7B16: What is the effect of intermodulation products in a linear power amplifier?
Answer: Transmission of spurious signals

Odd-order, especially third-order, rather than even-order intermodulation distortion products are of concern in linear power amplifiers because they are relatively close in frequency to the desired signal.

Question E7B17: Why are odd-order rather than even-order intermodulation distortion products of concern in linear power amplifiers?
Answer: Because they are relatively close in frequency to the desired signal

TUNED AMPLIFIERS (page 6-12)

The tuned circuit will reduce unwanted harmonics generated by a nonlinear amplifier stage.

INSTABILITY AND PARASITIC OSCILLATIONS (page 6-12)

Excessive gain or undesired positive feedback may cause amplifier instability and may over heat the amplifier.

AMPLIFIER STABILITY (page 6-12)

You install parasitic suppressors and/or neutralize the stage to prevent unwanted oscillations in an RF power amplifier.

Question E7B05: What can be done to prevent unwanted oscillations in an RF power amplifier?
Answer: Install parasitic suppressors and/or neutralize the stage

CHAPTER 6 Radio Circuits and Systems

NEUTRALIZATION (page 6-13)

An RF power amplifier can be neutralized by feeding a 180-degree out-of-phase portion of the output back to the input.

Question E7B08: How can an RF power amplifier be neutralized?
Answer: By feeding a 180-degree out-of-phase portion of the output back to the input

PARASITIC OSCILLATIONS (page 6-13)

6.2 SIGNAL PROCESSING (page 6-14)

OSCILLATOR CIRCUITS AND CHARACTERISTICS (page 6-14)

RF OSCILLATORS (page 6-15)

In a Colpitts oscillator positive feedback is supplied through a capacitive divider.

Question E7H04: How is positive feedback supplied in a Colpitts oscillator?
Answer: Through a capacitive divider

In a Hartley oscillator positive feedback is supplied through a tapped coil.

Question E7H03: How is positive feedback supplied in a Hartley oscillator?
Answer: Through a tapped coil

Colpitts, Hartley and Pierce oscillators are three oscillator circuits used in Amateur Radio equipment.

Question E7H01: What are three oscillator circuits used in Amateur Radio equipment?
Answer: Colpitts, Hartley and Pierce

In a Pierce oscillator positive feedback is supplied through a quartz crystal.

Question E7H05: How is positive feedback supplied in a Pierce oscillator?
Answer: Through a quartz crystal

For microwave transmission and reception you may use these techniques for providing highly accurate and stable oscillators needed for microwave transmission and reception:
Use a GPS signal reference
Use a rubidium stabilized reference oscillator
Use a temperature-controlled high Q dielectric resonator

Question E7H13: Which of the following is a technique for providing highly accurate and stable oscillators needed for microwave transmission and reception?
Answer: Use a GPS signal reference
Answer: Use a rubidium stabilized reference oscillator
Answer: Use a temperature-controlled high Q dielectric resonator
Answer: All of these choices are correct

CHAPTER 6 Radio Circuits and Systems

VARIABLE-FREQUENCY OSCILLATORS (page 6-15)

Both Colpitts and Hartley oscillator circuits are commonly used in variable frequency oscillators (VFO).

Question E7H06: Which of the following oscillator circuits are commonly used in VFOs?
Answer: Colpitts and Hartley

IT'S CRYSTAL CLEAR (page 6-16)

For very high accuracy the crystal may be placed in an oven to keep it hot. That way the crystal will be at the same temperature whether the temperature outside the oven (temperature of the room) is 40 degrees below zero or 150 degrees above zero.

The piezoelectric effect is the mechanical deformation of material by the application of a voltage.

Question E6D03: Which of the following is an aspect of the piezoelectric effect?
Answer: Mechanical deformation of material by the application of a voltage

The equivalent circuit, of a quartz crystal, contains motional capacitance, motional inductance, and loss resistance in series, all in parallel with a shunt capacitor representing electrode and stray capacitance.

Question E6D02: What is the equivalent circuit of a quartz crystal?
Answer: Motional capacitance, motional inductance, and loss resistance in series, all in parallel with a shunt capacitor representing electrode and stray capacitance

To insure that a crystal oscillator provides the frequency specified by the crystal manufacturer you must provide the crystal with a specified parallel capacitance.

Question E7H12: Which of the following must be done to insure that a crystal oscillator provides the frequency specified by the crystal manufacturer?
Answer: Provide the crystal with a specified parallel capacitance

MICROPHONICS AND THERMAL DRIFT (page 6-17)

Microphonics is changes in oscillator frequency due to mechanical vibration.

Question E7H02: Which describes a microphonic?
Answer: Changes in oscillator frequency due to mechanical vibration

An oscillator's microphonic responses will be reduced by mechanically isolating the oscillator circuitry from its enclosure.

Question E7H07: How can an oscillator's microphonic responses be reduced?
Answer: Mechanically isolating the oscillator circuitry from its enclosure

You use NP0 (negative-positive-zero temperature coefficient) capacitors to reduce thermal drift in crystal oscillators.

Question E7H08: Which of the following components can be used to reduce thermal drift in crystal oscillators?
Answer: NP0 capacitors

CHAPTER 6 Radio Circuits and Systems

FREQUENCY SYNTHESIS (page 6-17)

DIRECT DIGITAL SYNTHESIZERS (page 6-17)

A direct digital synthesizer circuit uses a phase accumulator, lookup table, digital to analog converter, and a low-pass anti-alias filter.

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

The amplitude values that represent a sine-wave output information is contained in the lookup table of a direct digital frequency synthesizer.

Question E7H10: What information is contained in the lookup table of a direct digital frequency synthesizer?
Answer: The amplitude values that represent a sine-wave output

Spurious signals at discrete frequencies are the major spectral impurity components of direct digital synthesizers.

Question E7H11: What are the major spectral impurity components of direct digital synthesizers?
Answer: Spurious signals at discrete frequencies

PHASE-LOCKED LOOPS (PLL) (page 6-19)

A phase-locked loop circuit is an electronic servo loop consisting of a phase detector, a low-pass filter, a voltage-controlled oscillator, and a stable reference oscillator.

Question E7H14: What is a phase-locked loop circuit?
Answer: An electronic servo loop consisting of a phase detector, a low-pass filter, a voltage-controlled oscillator, and a stable reference oscillator

Phase-locked loop perform the functions of Frequency synthesis and FM demodulation.

Question E7H15: Which of these functions can be performed by a phase-locked loop?
Answer: Frequency synthesis, FM demodulation

MIXERS (page 6-20)

The principal frequencies that appear at the output of a mixer circuit are the two input frequencies along with their sum and difference frequencies.

Question E7E08: What are the principal frequencies that appear at the output of a mixer circuit?
Answer: The two input frequencies along with their sum and difference frequencies

When an excessive amount of signal energy reaches a mixer circuit spurious mixer products are generated.

Question E7E09: What occurs when an excessive amount of signal energy reaches a mixer circuit?
Answer: Spurious mixer products are generated

CHAPTER 6 Radio Circuits and Systems

PASSIVE MIXERS (page 6-20)

ACTIVE MIXERS (page 6-21)

MODULATORS (page 6-22)

The baseband signal contains all of the frequency components present in the modulating signal. This term is used extensively in digital communications.

The term baseband in radio communications is the frequency components present in the modulating signal.

Question E7E07: What is meant by the term baseband in radio communications?
Answer: The frequency components present in the modulating signal

AMPLITUDE MODULATION (6-22)

SSB MODULATION: THE FILTER METHOD (page 6-23)

One uses a balanced modulator followed by a filter to generate a single-sideband phone signal.

Question E7E04: What is one way a single-sideband phone signal can be generated?
Answer: By using a balanced modulator followed by a filter

SSB MODULATION: THE QUADRATURE METHOD (page 6-23)

FREQUENCY AND PHASE MODULATION (page 6-24)

DIRECT (FM) FREQUENCY MODULATION (6-24)

A reactance modulator on the oscillator can be used to generate FM phone emissions.

Question E7E01: Which of the following can be used to generate FM phone emissions?
Answer: A reactance modulator on the oscillator

INDIRECT FREQUENCY MODULATION AND PHASE MODULATION (page 6-25)

A reactance modulator produces PM signals by using an electrically variable inductance or capacitance.

Question E7E02: What is the function of a reactance modulator?
Answer: To produce PM signals by using an electrically variable inductance or capacitance

An analog phase modulator varies the tuning of an amplifier tank circuit to produce PM signals.

Question E7E03: How does an analog phase modulator function?
Answer: By varying the tuning of an amplifier tank circuit to produce PM signals

CHAPTER 6 Radio Circuits and Systems

PRE-EMPHASIS AND DE-EMPHASIS (page 6-26)

In an FM transmitter, pre-emphasis is used to boost the amplitude of higher audio frequencies. In an FM receiver de-emphasis is used to reduce the amplitude of higher audio frequencies.

A pre-emphasis network circuit is added to an FM transmitter to boost the amplitude of the higher audio frequencies.

Question E7E05: What circuit is added to an FM transmitter to boost the higher audio frequencies?
Answer: A pre-emphasis network

De-emphasis circuits are commonly used in FM communications receivers for compatibility with transmitters using phase modulation. The de-emphasis works for both FM and PM systems but is not need for PM systems.

Question E7E06: Why is de-emphasis commonly used in FM communications receivers?
Answer: For compatibility with transmitters using phase modulation

DETECTORS AND DEMODULATORS (page 6-26)

DETECTORS (page 6-26)

A diode detector functions by rectification and filtering of RF signals.

Question E7E10: How does a diode detector function?
Answer: By rectification and filtering of RF signals

PRODUCT DETECTORS (page 6-27)

A product detector is used for demodulating SSB signals.

Question E7E11: Which type of detector is used for demodulating SSB signals?
Answer: Product detector

DETECTING FM SIGNALS (page 6-27)

A frequency discriminator stage in a FM receiver is a circuit for detecting FM signals.

Question E7E12: What is a frequency discriminator stage in a FM receiver?
Answer: A circuit for detecting FM signals

6.3 DIGITAL SIGNAL PROCESSING (DSP) AND SOFTWARE DEFINED RADIO (SDR) (page 6-28)

Human speech, Video signals, and Data information can be conveyed using digital waveforms.

Question E8A11: What type of information can be conveyed using digital waveforms?
Answer: Human speech
Answer: Video signals
Answer: Data
Answer: All of these choices are correct

An advantage of using digital signals instead of analog signals to convey the same information is because digital signals can be regenerated multiple times without error.

Question E8A12: What is an advantage of using digital signals instead of analog signals to convey the same information?
Answer: Digital signals can be regenerated multiple times without error

DIGITAL SIGNAL PROCESSING (DSP) (page 6-28)

SEQUENTIAL SAMPLING (page 6-28)

Remember the old sample-and-hold circuits? May be not. But, when signaled, a sample-and-hold circuit, will output, for a long time, a voltage that matched the input signal at the sample time. In digital signal processing that output signal is fed into an Analog-to-Digital converter (ADC). When we are doing sequential sampling, a sequential signal activates the sample-and-hold circuit and activates the analog-to-digital conversion and activates the transfer of the digital output of the analog-to-digital converter to a shift register or similar digital storage device. This is sequential sampling and is accomplished at high speeds for radio operations.

Sequential sampling is the best method commonly used to convert analog signals to digital signals.

Question E8A13: Which of these methods is commonly used to convert analog signals to digital signals?
Answer: Sequential sampling

SINE WAVE, ALIAS SINE WAVE (page 6-29)

If the signal being processed is faster than the sequential sampling rate the sample being produced is called an Alias and it is not an accurate representation of the signal we are interested in. Think of watching the spokes on a wagon wheel on television. If the spokes are moving faster than the television frame rate the spokes will appear to turn backwards. For the spokes to appear to turn forward they should spin at ½ the frame rate. To say that another way, the frame rate should be twice the spoke rate.

To stop aliasing from occurring, the sampling rate should be higher than the signal being processed. This can be accomplished by passing the signal being processed through at low-pass filter. The low pass filter can operate at VHF frequencies as long as it stops signal at ½ the sampling rate and higher.

CHAPTER 6 Radio Circuits and Systems

To prevent "Aliasing" of an analog signal and so the signal can be accurately reproduced, it must be sampled by an analog-to-digital converter at TWICE the rate of the highest frequency component of the signal.

Question E7F05: How frequently must an analog signal be sampled by an analog-to-digital converter so that the signal can be accurately reproduced?
Answer: At twice the rate of the highest frequency component of the signal

DATA CONVERTERS (page 6-30)

The device used to perform sampling is called an analog-to-digital converter (ADC). For each sample, an ADC produces a binary number that is directly proportional to the input voltage. The number of bits in the binary number limits the number of discrete voltage levels that can be represented. An 8-bit ADC can only produce one of 2^8 or 256 values.

An analog-to-digital converter with 8 bit resolution encode can encode 256 levels.

Question E8A09: How many levels can an analog-to-digital converter with 8 bit resolution encode?
Answer: 256

With respect to analog to digital converters, a small amount of noise is added to the input signal to allow for more precise representation of a signal over time. This noise is called "dither". This causes the ADC's average output value to be more precise over time.

Question E8A04: What is "dither" with respect to analog to digital converters?
Answer: A small amount of noise added to the input signal to allow more precise representation of a signal over time

The resolution of the ADC is determined by the reference voltage corresponding to the maximum digitized value and the number of bits representing each sample.

If a 10-bit ADC has a reference voltage of 1 volt, the resolution is:

$$1 \text{ volt}/2^{10} = 1 \text{ volt}/1024 = 0.000976563 = 1 \text{ millivolt.}$$

10 bits is the minimum number of bits required for an analog-to-digital converter to sample a signal with a range of 1 volt at a resolution of 1 millivolt.

Question E7F06: What is the minimum number of bits required for an analog-to-digital converter to sample a signal with a range of 1 volt at a resolution of 1 millivolt?
Answer: 10 bits

The Reference voltage level and sample width in bits are used to set the minimum detectable signal level for an SDR in the absence of atmospheric or thermal noise,

Question E7F11: What sets the minimum detectable signal level for an SDR in the absence of atmospheric or thermal noise?
Answer: Reference voltage level and sample width in bits

A digital-to-analog converter (DAC) performs the conversion of binary numbers back into analog voltages – the reverse operation of an ADC. The structure of a DAC allows it to operate at a very high speed. If a sign wave is created by a DAC, it will have a “stair step” appearance as each successive voltage level is created. A low pass filter is used in conjunction with a digital-to-analog converter to remove harmonics from the output caused by the discrete analog levels generated.

Question E8A10: What is the purpose of a low pass filter used in conjunction with a digital-to-analog converter?
Answer: Remove harmonics from the output caused by the discrete analog levels generated

REPRESENTATION OF NUMBERS: FIXED-POINT VERSUS FLOATING-POINT (page 6-30)

Much to talk about but no time.

FOURIER ANALYSIS AND FAST FOURIER TRANSFORMS (FFT) (page 6-31)

Fourier analysis is the mathematical method that shows how any time-varying signal is made up of sine and cosine waves of a fundamental frequency and harmonic frequencies.

A Fourier analysis is the name of the process that shows that a square wave is made up of a sine wave plus all of its odd harmonics.

Question E8A01: What is the name of the process that shows that a square wave is made up of a sine wave plus all of its odd harmonics?
Answer: Fourier analysis

The Fast-Fourier Transform (FFT), reduces the number of calculations for a 1024-sample data set by a factor of more than 100. FFT calculations can be used to convert oscilloscope displays to spectrum displays.

Fast Fourier Transform performs the function of converting digital signals from the time domain to the frequency domain.

Question E7F07: What function can a Fast Fourier Transform perform?
Answer: Converting digital signals from the time domain to the frequency domain

DECIMATION AND INTERPOLATION (page 6-31)

Decimation with regard to digital filters is the function of reducing the effective sample rate by removing samples.

Question E7F08: What is the function of decimation with regard to digital filters?
Answer: Reducing the effective sample rate by removing samples

In order to prevent generating aliases due to the new lower sample rate, a digital low-pass anti-aliasing filter must be applied before decimation. This anti-aliasing digital filter (low-pass) removes high-frequency signal components which would otherwise be reported as lower frequency components, that is aliases.

Question E7F09: Why is an anti-aliasing digital filter required in a digital decimator?
Answer: It removes high-frequency signal components which would otherwise be reproduced as lower frequency components

CHAPTER 6 Radio Circuits and Systems

If you wish to change the sampling rate of an existing digital signal by a factor of ¾, you must first Interpolate by a factor of three (increase the sample rate), then decimate by a factor of four (decrease the sample rate).

Question E7F16: How might the sampling rate of an existing digital signal be adjusted by a factor of 3/4?
Answer: Interpolate by a factor of three, then decimate by a factor of four

SOFTWARE-DEFINED RADIO (SDR) SYSTEMS (page 6-32)

What is important to understand about Software Defined Radio systems is that they can perform any mathematically defined signal processing function if hardware is available to adequately sample the signal and perform the required math operations quickly enough. That includes modulation, demodulation, filtering, and speech processing and so on.

SDR (SOFTWARE-DEFINED RADIO) HARDWARE (page 6-32)

The transition between analog RF and digital signals can occur at any of several places in the signal chain between the antenna and the human interface. The technique used today to implement many digital modulation modes uses the sound card of a PC connected to the audio input and output of a conventional transceiver. [Most] Other systems pick up signals at the IF or at the RF signals of a radio.

When a software defined radio functions by direct digital conversion the incoming RF is digitized by an analog-to-digital converter without being mixed with a local oscillator signal.

Question E7F01: What is meant by direct digital conversion as applied to software defined radios?
Answer: Incoming RF is digitized by an analog-to-digital converter without being mixed with a local oscillator signal

A direct or flash conversion analog-to-digital converter is useful for a software defined radio because they operate at a very high speed allowing digitizing of high frequencies.

Question E8A08: Why would a direct or flash conversion analog-to-digital converter be useful for a software defined radio?
Answer: Very high speed allows digitizing high frequencies

The Sample rate aspect of receiver analog-to-digital conversion determines the maximum receive bandwidth of a Direct Digital Conversion Software Defined Radio (SDR).

Question E7F10: What aspect of receiver analog-to-digital conversion determines the maximum receive bandwidth of a Direct Digital Conversion SDR?
Answer: Sample rate

DSP (DIGITAL SIGNAL PROCESSING) MODULATION (page 6-33)

A sinusoidal wave of any arbitrary amplitude and phase may be represented by the weighted sum of a sine and cosine wave. These are the I and Q signals used in Digital Signal Processing.

The letters I and Q in I/Q Modulation represent the signals In-phase and Quadrature.

Question E7F17: What do the letters I and Q in I/Q Modulation represent?
Answer: In-phase and Quadrature

CHAPTER 6 Radio Circuits and Systems

I/Q MODULATION AND DEMODULATION (page 6-34)

A. Fast Fourier Transform digital process is applied to I and Q signals in order to recover the baseband modulation information.

Question E7F12: What digital process is applied to I and Q signals in order to recover the baseband modulation information?
Answer: Fast Fourier Transform

A Hilbert-transform filter digital signal processing filter is used to generate an SSB signal.

Question E7F03: What type of digital signal processing filter is used to generate an SSB signal?
Answer: A Hilbert-transform filter

Combining signals with a Quadrature phase relationship is a common method of generating an SSB signal using digital signal processing.

Question E7F04: What is a common method of generating an SSB signal using digital signal processing?
Answer: Combine signals with a quadrature phase relationship

Figure 6.33A shows I and Q signals being processed but where do they come from? That is very hard information to obtain.

If it is the audio signal from a microphone, there is simply a circuit that produces a 90° phase shift in the audio signal. This circuit must have a bandwidth to cover the 20 KHz audio spectrum. The audio or I signal is input to this circuit and the 90° phase shift output is the Q signal.

For binary signals the signal is usually one frequency so the phase shift is simply a shift register.

CHAPTER 6 Radio Circuits and Systems

6.4 FILTERS AND IMPEDANCE MATCHING (page 6-35)

FILTER FAMILIES AND RESPONSE TYPES (page 6-35)

Passive filters are made with un-powered components (R-resistors, C-capacitors, L-inductors) and always results in some loss of signal strength called insertion loss.

Active filters include a powered amplifying device to overcome the filter insertion loss and sometimes even provide signal gain.

Mechanical filters are a class of passive filter that use internal elements such as disk and rods that vibrate at the frequencies of interest.

Cavity filters are also a class of passive filter that uses the resonant characteristics of a conducting tube or box to act as a filter and are used in repeater duplexes because of their extremely low loss and sharp tuning characteristics.

A cavity filter would be the best choice for use in a 2 meter repeater duplexer.

Question E7C10: Which of the following filters would be the best choice for use in a 2 meter repeater duplexer?
Answer: A cavity filter

FILTER CLASSIFICATION (page 6-35)

The "Cutoff-frequency" is the frequency at which the output signal power is one-half that of the input signal power.

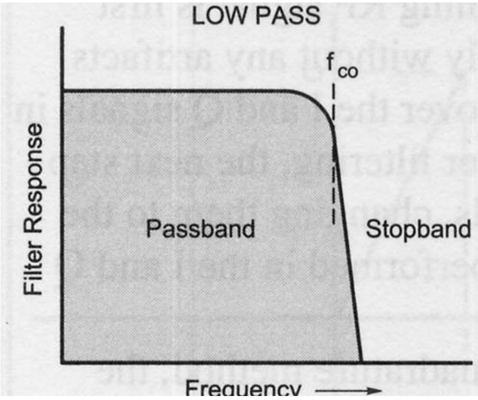
A "Low-pass filter" is one in which all frequencies below the cutoff-frequency are passed with little or no attenuation.

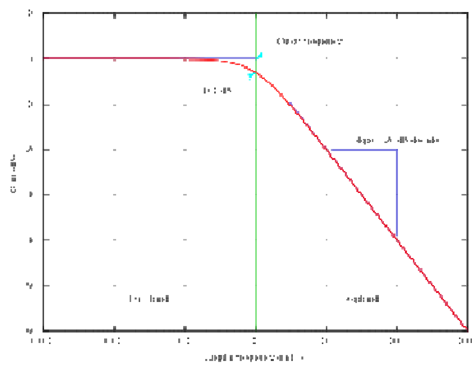
A "High-pass filter" is one in which all frequencies above the cutoff-frequency are passed with little or no attenuation.

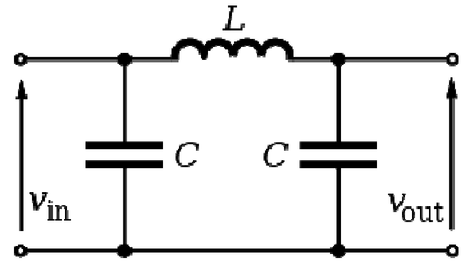
A "Band-pass filter" has both an upper and lower cutoff frequency. Signals between the cutoff frequencies are passed, while those outside the passband are attenuated.

A "Band-stop filter" has both an upper and lower cutoff frequency. Signals between the cutoff frequencies are attenuated, while those outside the cutoff frequencies are passed. This opposite reaction to the band-pass filter

A "Notch filter" is a band-stop filter that has a very narrow frequency response.


LOW PASS
f co
Passband
Stopband
Filter Response
Frequency




L
C
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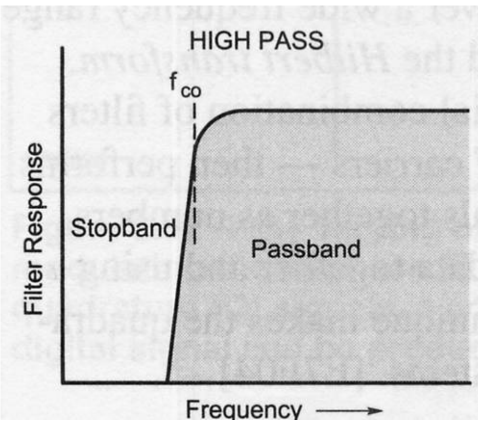
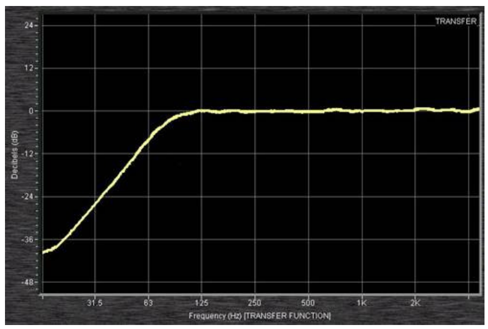
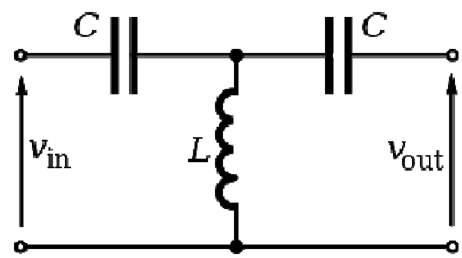
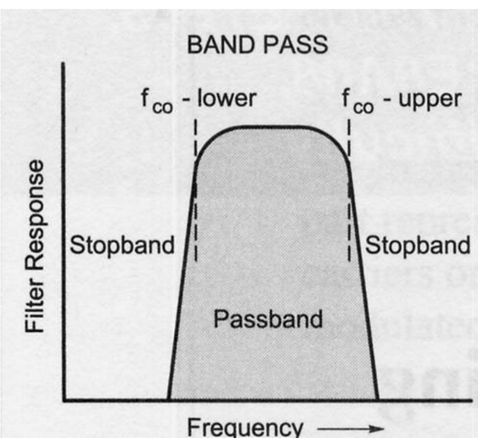
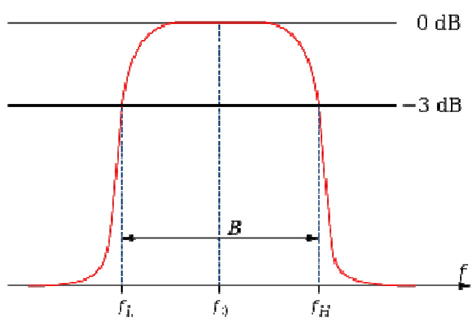
vin
vout

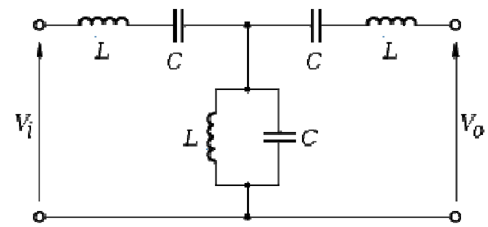

HIGH PASS
f co
Stopband
Passband
Filter Response
Frequency


TRANSFER
Frequency (Hz) [TRANSFER FUNCTION]


C
C
L
vin
vout


BAND PASS
f co - lower
f co - upper
Stopband
Stopband
Passband
Filter Response
Frequency


0 dB
−3 dB
B
f
fL
fH


L
C
C
L
L
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Vi
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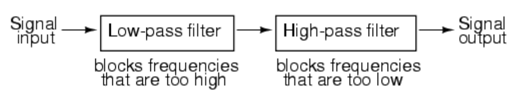
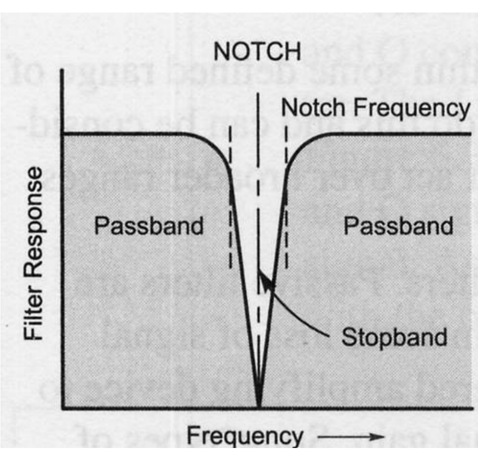
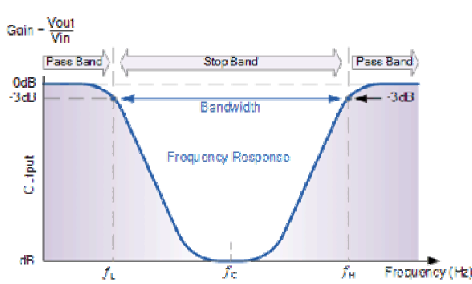
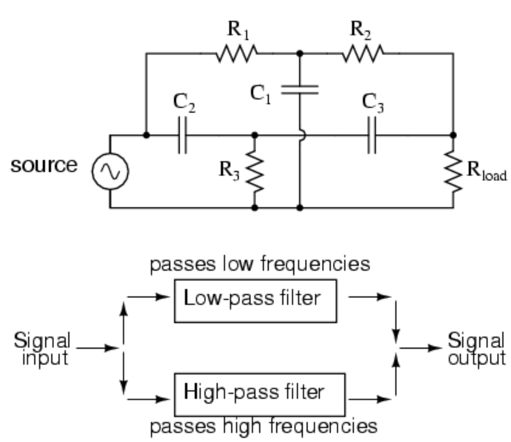

Signal input
Low-pass filter
High-pass filter
Signal output
blocks frequencies that are too high
blocks frequencies that are too low


NOTCH
Notch Frequency
Passband
Passband
Stopband
Filter Response
Frequency

BAND STOP


Pass Band
Stop Band
Pass Band
0dB
-3dB
Bandwidth
-3dB
Frequency Response
Frequency (Hz)


R1
R2
C2
C1
C3
source
R3
Rload
passes low frequencies
Low-pass filter
Signal input
Signal output
High-pass filter
passes high frequencies

CHAPTER 6 Radio Circuits and Systems

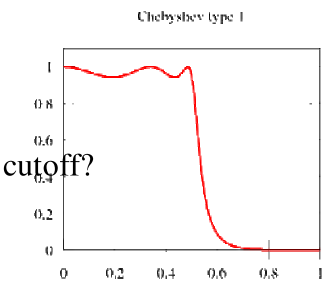
FILTER DESIGN (page 6-35)

Ringing in a filter causes undesired oscillations added to the desired signal.

Question E7G02: What is the effect of ringing in a filter?
Answer: Undesired oscillations added to the desired signal

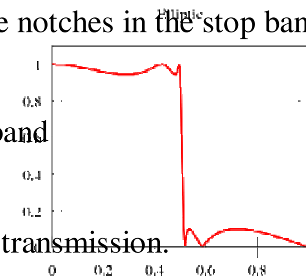
Digital mode is most affected by non-linear phase response in a receiver IF filter.

Question E7C14: Which mode is most affected by non-linear phase response in a receiver IF filter?
Answer: Digital



A Chebyshev filter is described as having ripple in the passband and a sharp cutoff.

Question E7C05: Which filter type is described as having ripple in the passband and a sharp cutoff?
Answer: A Chebyshev filter



The distinguishing features of an elliptical filter is an extremely sharp cutoff with one or more notches in the stop band.

Question E7C06: What are the distinguishing features of an elliptical filter?
Answer: Extremely sharp cutoff with one or more notches in the stop band

A notch filter would be used to attenuate an interfering carrier signal while receiving an SSB transmission.

Question E7C07: What kind of filter would you use to attenuate an interfering carrier signal while receiving an SSB transmission?
Answer: A notch filter

CRYSTAL FILTERS (page 6-37)

A crystal lattice filter is a filter with narrow bandwidth and steep skirts made using quartz crystals.

Question E7C15: What is a crystal lattice filter?
Answer: A filter with narrow bandwidth and steep skirts made using quartz crystals

When building a crystal ladder filter remember that the relative frequencies of the individual crystals has the greatest effect in helping determine the bandwidth and response shape of a crystal ladder filter.

Question E7C08: Which of the following factors has the greatest effect in helping determine the bandwidth and response shape of a crystal ladder filter?
Answer: The relative frequencies of the individual crystals

A Jones filter, as used as part of an HF receiver IF stage, is a variable bandwidth crystal lattice filter.

Question E7C09: What is a Jones filter as used as part of an HF receiver IF stage?
Answer: A variable bandwidth crystal lattice filter

CHAPTER 6 Radio Circuits and Systems

ACTIVE FILTERS (page 6-38)

ACTIVE AUDIO FILTERS (page 6-39)

An audio filter in a receiver is the most appropriate use of an op-amp active filter.

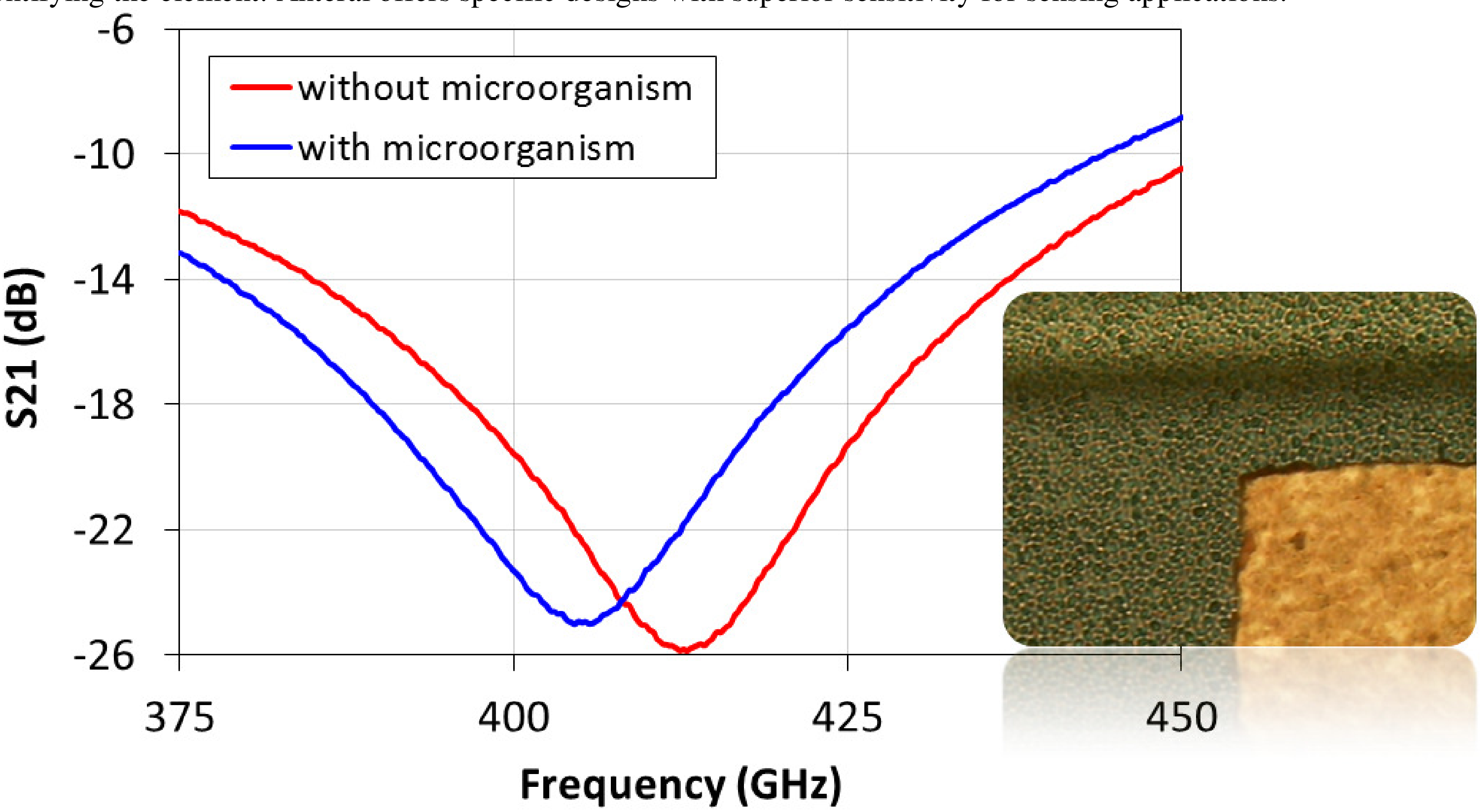
Question E7G06: Which of the following is the most appropriate use of an op-amp active filter?
Answer: As an audio filter in a receiver

By restricting both gain and Q we can eliminate unwanted ringing and audio instability in a multi-section op-amp RC audio filter circuit.

Question E7G05: How can unwanted ringing and audio instability be prevented in a multi-section op-amp RC audio filter circuit?
Answer: Restrict both gain and Q

Shades of Star Trek. They are now making filters with biological products.

Aplications:
The Field Filters can be used in MmW and THz systems for filtering signal in transmission or reception. They are suitable for radio-communication, astronomy, material research or imaging applications.
One of the most cutting-edge applications of Anteral's THz Filed Filters is biological and chemical sensing. Since the filters provide sharp peaks with high rejection at the resonant frequency, they can be used as sensing or detecting devices. By placing the element to be sensed on the surface, a redshift in the resonant frequency occurs which allows identifying the element. Anteral offers specific designs with superior sensitivity for sensing applications.



CHAPTER 6 Radio Circuits and Systems

DIGITAL SIGNAL PROCESSING (DSP) filters (page 6-39)

An Adaptive filter is used with a digital signal processing audio filter to remove unwanted noise from a received SSB signal.

Question E7F02: What kind of digital signal processing audio filter is used to remove unwanted noise from a received SSB signal?
Answer: An adaptive filter

FINITE IMPULSE RESPONSE (FIR) FILTERS (page 6-40)

The function of taps in a digital signal processing filter is that they Provide incremental signal delays for filter algorithms.

Question E7F13: What is the function of taps in a digital signal processing filter?
Answer: Provide incremental signal delays for filter algorithms

More taps would allow a digital signal processing filter to create a sharper filter response.

Question E7F14: Which of the following would allow a digital signal processing filter to create a sharper filter response?
Answer: More taps

INFINITE IMPULSE RESPONSE (IIR) FILTERS (page 6-41)

(ERRATA: CORRECTION NEAR THE TOP OF PAGE 6-41)

Unlike a symmetrical FIR filter, all frequency components of the input signal (in an IIR filter) are delayed by ~~the same~~ a different amount. So a FIR filters delay all frequency components of the signal by the same amount.

Question E7F15: Which of the following is an advantage of a Finite Impulse Response (FIR) filter vs an Infinite Impulse Response (IIR) digital filter?
Answer: FIR filters delay all frequency components of the signal by the same amount

IMPEDANCE MATCHING (page 6-41)

To perform the task of converting a complex impedance to a resistive impedance an impedance-matching circuit cancels the reactive part of the impedance and changes the resistive part to a desired value.

Question E7C04: How does an impedance-matching circuit transform a complex impedance to a resistive impedance?
Answer: It cancels the reactive part of the impedance and changes the resistive part to a desired value

L-NETWORKS (page 6-42)

CHAPTER 6 Radio Circuits and Systems

PI AND PI-L NETWORKS (page 6-42)

The capacitors and inductors of a low-pass filter Pi-network are arranged between the network's input and output and ground to form a figure Pi. A capacitor is connected between the input and ground, another capacitor is connected between the output and ground, and an inductor is connected between input and output.

Question E7C01: How are the capacitors and inductors of a low-pass filter Pi-network arranged between the network's input and output?
Answer: A capacitor is connected between the input and ground, another capacitor is connected between the output and ground, and an inductor is connected between input and output

The tuning capacitor is adjusted for minimum plate current, and the loading capacitor is adjusted for maximum permissible plate current. That is how the loading and tuning capacitors are to be adjusted when tuning a vacuum tube RF power amplifier that employs a Pi-network output circuit.

Question E7B09: Which of the following describes how the loading and tuning capacitors are to be adjusted when tuning a vacuum tube RF power amplifier that employs a Pi-network output circuit?
Answer: The tuning capacitor is adjusted for minimum plate current, and the loading capacitor is adjusted for maximum permissible plate current

A Pi filter network is the common name for a filter network which is equivalent to two L-networks connected back-to-back with the two inductors in series and the capacitors in shunt at the input and output.

Question E7C11: Which of the following is the common name for a filter network which is equivalent to two L-networks connected back-to-back with the two inductors in series and the capacitors in shunt at the input and output?
Answer: Pi

One advantage of a Pi-matching network over an L-matching network consisting of a single inductor and a single capacitor is the Q of Pi-networks can be varied depending on the component values chosen.

Question E7C13: What is one advantage of a Pi-matching network over an L-matching network consisting of a single inductor and a single capacitor?
Answer: The Q of Pi-networks can be varied depending on the component values chosen

A Pi-network with an additional series inductor on the output, which describes a Pi-L-network, is used for matching a vacuum tube final amplifier to a 50 ohm unbalanced output.

Question E7C12: Which describes a Pi-L-network used for matching a vacuum tube final amplifier to a 50 ohm unbalanced output?
Answer: A Pi-network with an additional series inductor on the output

You get Greater harmonic suppression with a Pi-L-network over a regular Pi-network for impedance matching between the final amplifier of a vacuum-tube transmitter and an antenna.

Question E7C03: What advantage does a Pi-L-network have over a regular Pi-network for impedance matching between the final amplifier of a vacuum-tube transmitter and an antenna?
Answer: Greater harmonic suppression

CHAPTER 6 Radio Circuits and Systems

T-NETWORKS (page 6-43)

A T-network with series capacitors and a parallel shunt inductor makes a high-pass filter.

Question E7C02: Which of the following is a property of a T-network with series capacitors and a parallel shunt inductor?
Answer: It is a high-pass filter

6.5 POWER SUPPLIES (page 6-44)

LINEAR VOLTAGE REGULATORS (page 6-44)

One characteristic of a linear electronic voltage regulator is the conduction of a control element is varied to maintain a constant output voltage.

Question E7D01: What is one characteristic of a linear electronic voltage regulator?
Answer: The conduction of a control element is varied to maintain a constant output voltage

SHUNT AND SERIES REGULATORS (page 6-44)

A shunt regulator is a type of linear voltage regulator that places a constant load on the unregulated voltage source.

Question E7D05: Which of the following types of linear voltage regulator places a constant load on the unregulated voltage source?
Answer: A shunt regulator

The pass transistor circuit element is controlled by a series analog voltage regulator to maintain a constant output voltage.

Question E7D11: What circuit element is controlled by a series analog voltage regulator to maintain a constant output voltage?
Answer: Pass transistor

Figure E7-3 is a Linear voltage regulator.

Question E7D08: What type of circuit is shown in Figure E7-3?
Answer: Linear voltage regulator

A Zener diode is typically used as a stable reference voltage in a linear voltage regulator.

Question E7D03: What device is typically used as a stable reference voltage in a linear voltage regulator?
Answer: A Zener diode

Figure E7- 3

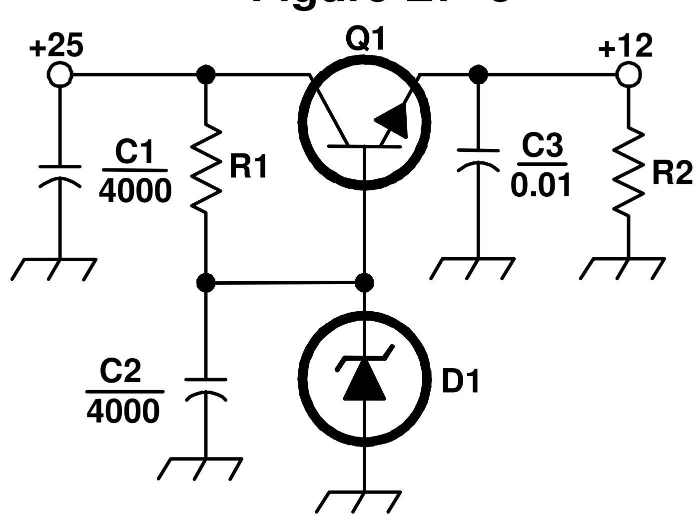
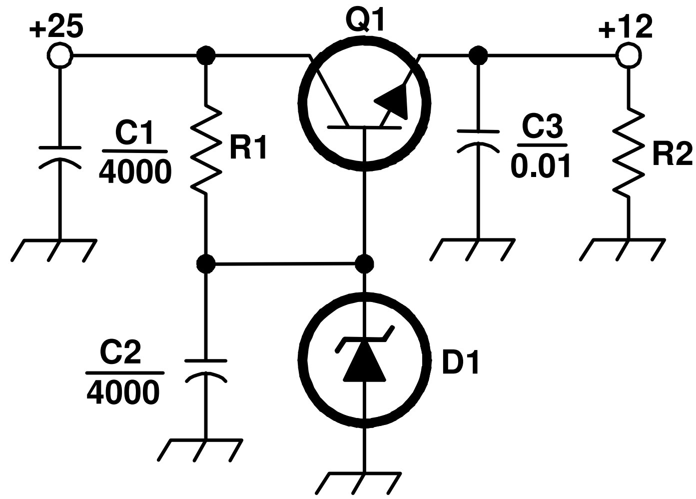


Figure E7- 3



The purpose of C2 in the circuit shown in Figure E7-3 is to bypasses hum around D1.

Question E7D07: What is the purpose of C2 in the circuit shown in Figure E7-3?
Answer: It bypasses hum around D1

The purpose of Q1 in the circuit shown in Figure E7-3 is to increases the current-handling capability of the regulator.

Question E7D06: What is the purpose of Q1 in the circuit shown in Figure E7-3?
Answer: It increases the current-handling capability of the regulator

IC "THREE TERMINAL" REGULATORS (page 6-45)

EFFICIENCY AND POWER DISSIPATION (page 6-45)

$$P_{DISS} = (V_{IN} - V_{OUT}) \times I_{OUT}$$

Question E7D13: What is the equation for calculating power dissipation by a series connected linear voltage regulator?
Answer: Voltage difference from input to output multiplied by output current

A series (linear voltage) regulator usually makes the most efficient use of the primary power source.

Question E7D04: Which of the following types of linear voltage regulator usually make the most efficient use of the primary power source?
Answer: A series regulator

The drop-out voltage of an analog voltage regulator is the minimum input-to-output voltage required to maintain regulation.

Question E7D12: What is the drop-out voltage of an analog voltage regulator?
Answer: Minimum input-to-output voltage required to maintain regulation

BATTERY CHARGING REGULATORS (page 6-46)

Prevention of battery damage due to overcharge is the main reason to use a charge controller with a solar power system.

Question E7D09: What is the main reason to use a charge controller with a solar power system?
Answer: Prevention of battery damage due to overcharge

CHAPTER 6 Radio Circuits and Systems

SWITCHING REGULATORS (page 6-46)

One characteristic of a switching electronic voltage regulator is that the controlled device's duty cycle is changed to produce a constant average output voltage.

Question E7D02: What is one characteristic of a switching electronic voltage regulator?
Answer: The controlled device's duty cycle is changed to produce a constant average output voltage

The high frequency inverter design uses much smaller transformers and filter components for an equivalent power output and that is the primary reason that a high-frequency switching type high voltage power supply can be both less expensive and lighter in weight than a conventional power supply.

Question E7D10: What is the primary reason that a high-frequency switching type high voltage power supply can be both less expensive and lighter in weight than a conventional power supply?
Answer: The high frequency inverter design uses much smaller transformers and filter components for an equivalent power output

HIGH VOLTAGE TECHNIQUES (page 6-46)

CAPACITORS (page 6-46)

When several electrolytic filter capacitors are connected in series to increase the operating voltage of a power supply filter circuit, resistors should be connected across each capacitor:
To equalize, as much as possible, the voltage drop across each capacitor
To provide a safety bleeder to discharge the capacitors when the supply is off
To provide a minimum load current to reduce voltage excursions at light loads

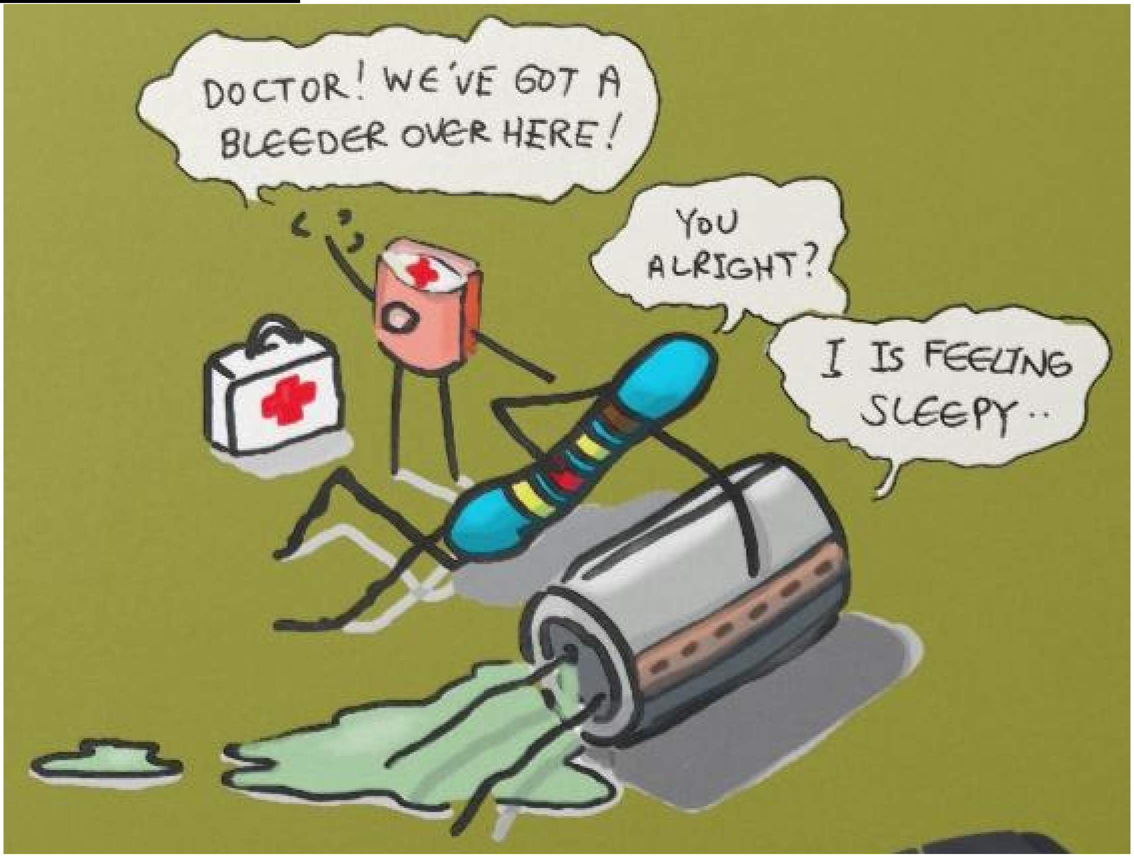
Question E7D16: When several electrolytic filter capacitors are connected in series to increase the operating voltage of a power supply filter circuit, why should resistors be connected across each capacitor?
Answer: To equalize, as much as possible, the voltage drop across each capacitor
Answer: To provide a safety bleeder to discharge the capacitors when the supply is off
Answer: To provide a minimum load current to reduce voltage excursions at light loads
Answer: All of these choices are correct

The purpose of a "step-start" circuit in a high voltage power supply is to allow the filter capacitors to charge gradually.

Question E7D15: What is the purpose of a "step-start" circuit in a high voltage power supply?
Answer: To allow the filter capacitors to charge gradually

CHAPTER 6 Radio Circuits and Systems

BLEEDER RESISTORS (page 6-47)



Bleeder resistors provide protection against shock when the power supply is turned off and dangerous wiring is exposed because the "bleed off": the stored charge in the filter capacitors.

Bleed resistors are not only used in electronic equipment. Here is a picture of a bleed resistor in a motor start capacitor.

A general rule is that the bleeder resistor should be designed to reduce the output voltage to 30 volts or less within 2 second of turning off the power supply.

One purpose of a "bleeder" resistor in a conventional unregulated power supply is to improve output voltage regulation.

Question E7D14: What is one purpose of a "bleeder" resistor in a conventional unregulated power supply?
Answer: To improve output voltage regulation