Electronic Circuits

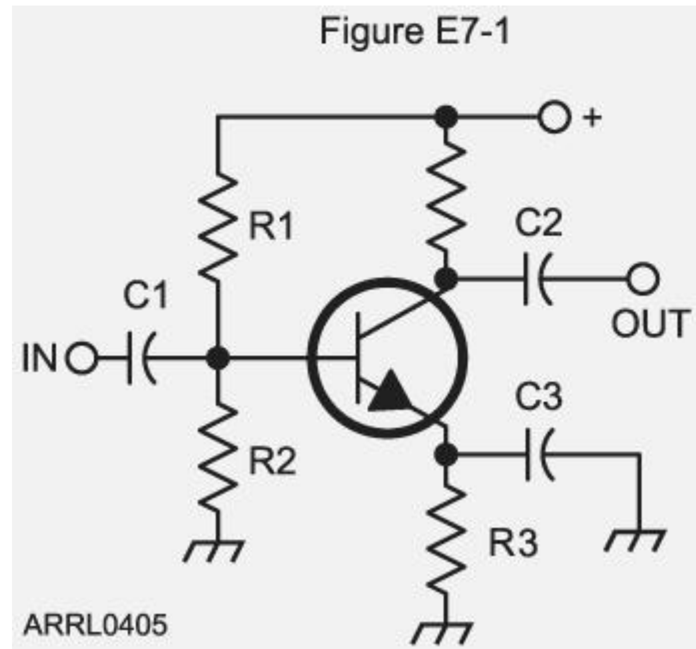
Chapter - 6

Amplifiers

- RF, IF, Audio
- High Power Low Power
- Gain
  - Ratio of output to input Voltage, Current, or Power
- Input & output impedance
- Main Component
  - Transistors, Tubes, or ICs

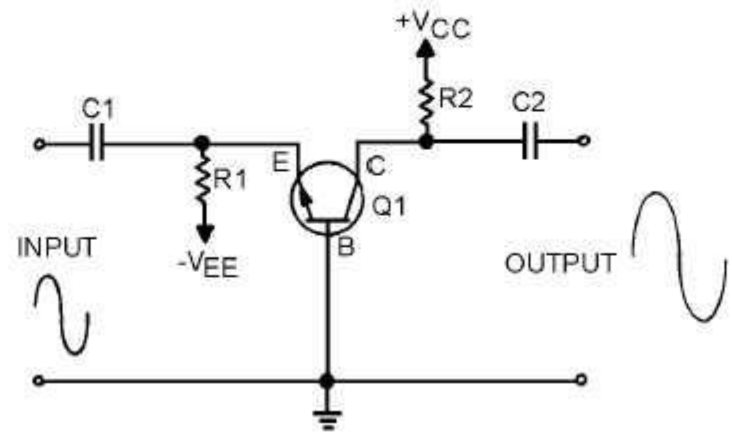
Common-Emitter Circuit

- Most often used
- Input to base Output from collector
- R1 & R2 form a voltage divider for fixed bias
- R3 is used for self bias to prevent thermal runaway
- Provides the highest gain



Common Base Circuit

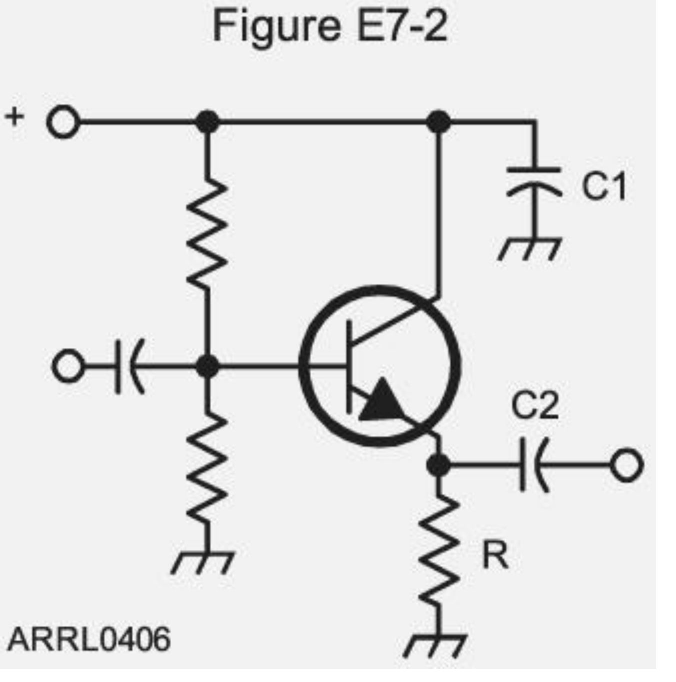
- Input on Emitter output on collector
- Low impedance input
- High impedance output
- Primarily used as an impedance converter



(B)

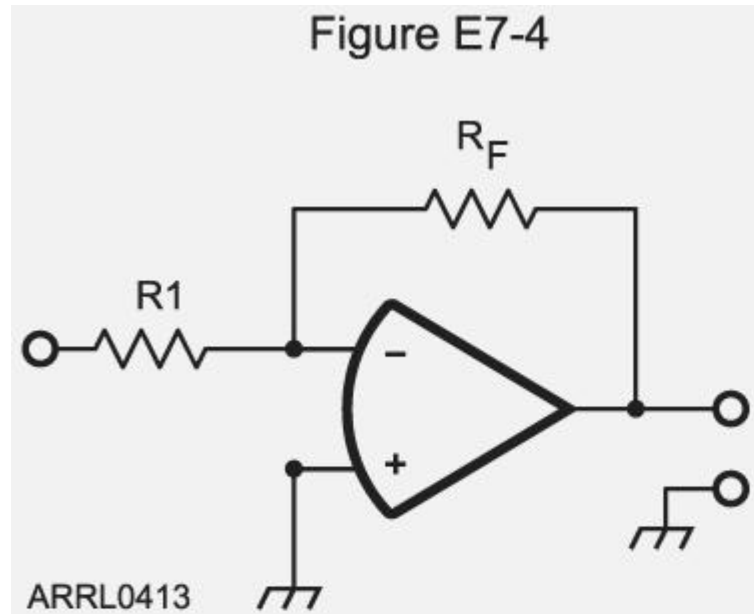
Common Collector

- Also, Emitter Follower
- High input and low output impedance
- <u>Output coupling capacitor C2</u>
- <u>R is the Emitter load resistor</u>
- Often used as buffer amplifiers



Op Amp Amplifiers

- Amplifies DC as well as AC signals
- Direct coupled, with High input and low output impedance
- Have two inputs
  - Inverting (-)
  - Non-inverting (+)
- Amplifies the difference between the two inputs



OP Amp Characteristics

Ideal Op Amp

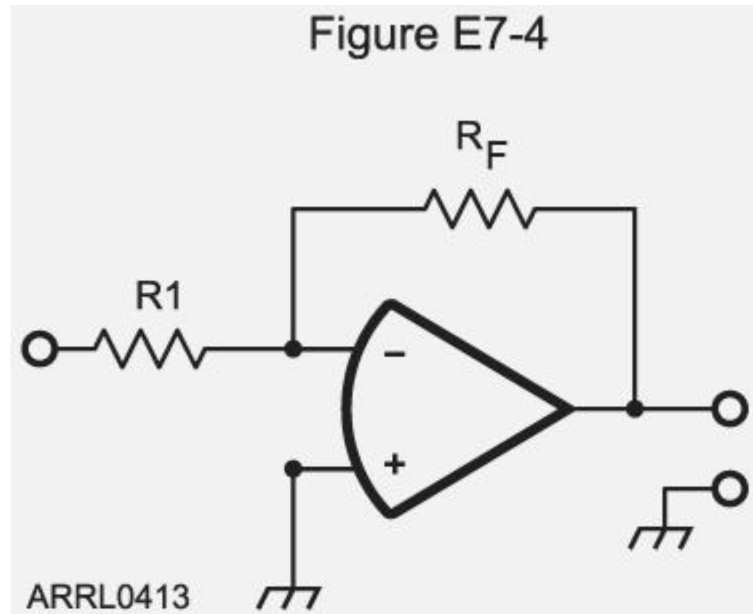
- Infinite input impedance
- Zero output impedance
- Infinite voltage gain
- Flat frequency response
- Zero output when the input is zero

Practical Op Amp

- Very high input impedance
- Very low output impedance
- As high as 120 DB (open loop) gain
- Gain decreases with frequency in an open loop circuit
- Small output with zero input

Op Amp Basic Circuit

- Gain and frequency response determined by feedback components
- <u>Voltage gain is determined by the values of R1 and R_F</u>
  - $|A_V| = R_F / R1$
- As this example circuit is using the inverting input the result will be negative



Vacuum Tubes

- Compared to Transistors
  - Grid - Base
  - Cathode - Emitter
  - Plate – Collector
- Circuits
  - Common Cathode
    - High input impedance, Power Gain
  - Grounded Grid
    - <u>Low input impedance, matches well to 50 ohms</u>

Amplifier Classes

- Class A
  - Bias is set at about halfway on the Load Line
- Class B
  - Bias is set at cutoff level
- Class AB
  - Operates between the 180° and 360° points of the signal cycle
- Class C
  - Bias is set well into the cutoff region
- Class D
  - Uses switching technology to achieve high efficiency
  - Requires low pass filter on output to remove harmonics

Distortion and Intermodulation

- Distortion
  - Nonlinearity produces distortion
  - Distortion results in harmonics
  - You can have low distortion or high efficiency, but not both
- Intermodulation
  - 2 or more signals mixed to produce other signals
  - <u>Even order products result in spurious signals</u>
  - <u>Third order products are close to the desired frequency</u>

Selecting Operating Class

- For Audio, AM & SSB Linear amp is required
- For CW or FM a nonlinear amp will work
- Using a Class C amp for AM or SSB will result in distortion and excessive bandwidth
- Class B amplifiers can be used for audio by connecting two of them in push-pull to eliminate even order harmonics

Instability and Parasitic Oscillation

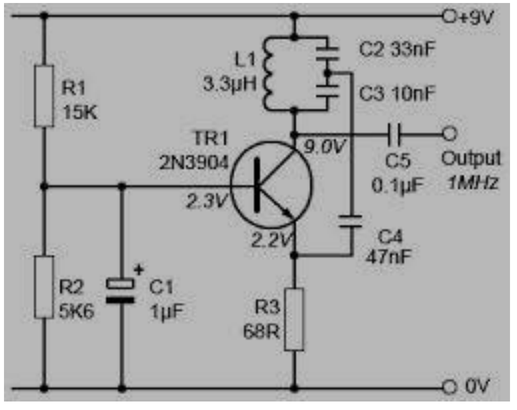
- Excessive gain or positive feedback may case amplifier instability
- Oscillation can be prevented by neutralizing the stage or parasitic suppression
- One way to neutralize an RF power amplifier is by feeding a 180 degree out of phase portion of the output back to the input
- Parasitics are oscillations that are not related to the operating frequency of an amplifier

VHF, UHF & Microwave Amplifiers

- Klystrons
  - Uses Velocity Modulation
- Parametric Amplifiers
  - Uses a varactor diode and separate oscillator
  - Uses varying reactance for amplification
  - Low noise on the output
- Microwave Semiconductor Amplifiers
  - Geometry of junction transistors limits upper frequency limit to a few GHz
  - Gallium-Arsenide FET's can operate up to 20-30 GHz

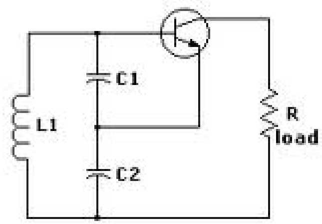
Oscillator Circuits and Characteristics

- Amplifier with positive feedback
  - A_V = Amplifier gain
  - β = Feedback ratio
  - Loop Gain = AV x β
  - <u>If positive loop gain > 1 and in phase, circuit will oscillate</u>

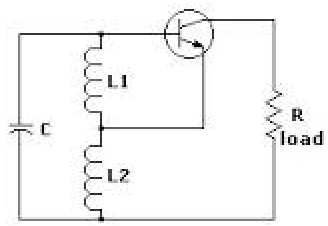


RF Oscillators

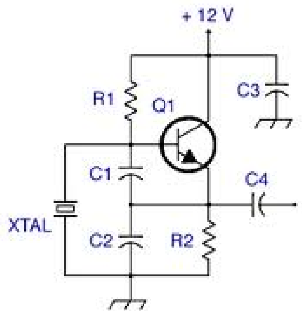
- Colpitts
  - <u>Tapped capacitance</u>
  - “C” for capacitance & Colpitts



- Hartley
  - <u>Tapped Inductance</u>
  - “H” for henry and Hartley



- Pierce
  - <u>Colpitts with a crystal</u>
  - Most stable of three



Crystals

- Usually a small wafer of quartz with precise dimensions
- Piezoelectric effect
  - Crystal deforms physicaly when voltage applied
  - Voltage generated when crystal deformed
- High Q
  - Very stable and precise
- Use parallel external capacitance to insure the proper frequency

Variable Frequency Oscillator (VFO)

- Used to allow an oscillator to tune over a frequency range
  - Like in the tuning circuit on a radio
- Either the capacitance or inductance must be variable
  - Variable capacitance is the most common
- Not as stable as a crystal oscillator

Microwave Oscillators

- Magnetron
  - A diode vacuum tube with a specially shaped anode surrounded by a magnet
  - Used for UHF and Microwave frequencies
  - Used in microwave ovens
- Gunn Diode
  - Use a resonant cavity to control frequency
  - Uses negative resistive properties of properly doped semiconductors
  - Used in traffic radar guns

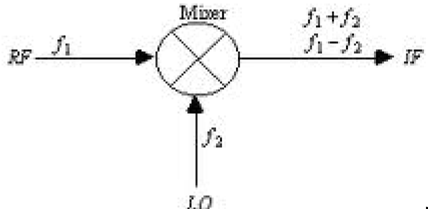
Digital Signal Processing (DSP)

- Sequential Sampling
    - Commonly used to convert analog signals to digital signals
- Data Converters
    - ADC – converts analog signals to digital
    - DAC – converts digital signals to analog
- Software Defined Radios (SDR)
    - A radio whose functionality can be altered by software
    - Replaces traditional analog circuits with DSP

Mixers

- Are used to change the frequency of a signal
- In a receiver converts to the IF frequency
- Can also be used to change frequencies in a transmitter
- <u>Excessive signals can cause spurious signals to be generated from a mixer</u>

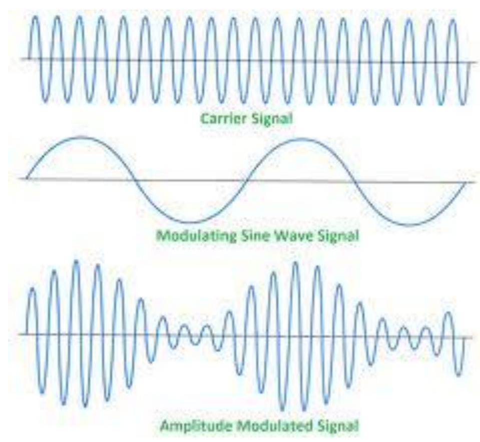
- <u>Mixer output contains Input Signal, Oscillator Signal, the sum of the two and the difference of the two</u>



- Use a filter to select the proper frequency

Modulators

- Process of adding information to an RF carrier
  - The frequency components (voice or data) in the modulating signal make up the baseband
- Amplitude Modulation
  - Contains a carrier and two sidebands
  - Amplitude of the signal depends on the amplitude audio signal



Single Sideband (SSB)

- Starts with an AM signal
- Filter method
  - Use balance modulator to remove carrier
  - Use a bandpass filter to remove one of the sidebands
- The Quadrature method
  - Uses 90° phase shift to cancel the carrier and one sideband
    - Hard to do with analog circuit
    - Can do with DSP circuit – Hilbert transformer
    - Preferred method in radios using DSP

Frequency Modulation (FM)

- Direct FM
  - Can be produced with a *reactance modulator* on the oscillator
  - Gives true F3E emission
- Indirect FM (*Phase Modulator*)
  - PM signals can be produced by electrically variable capacitance or inductance
  - Uses a *reactance modulator* to vary tuning on an RF amplifier tank circuit

Pre-emphasis & De-emphasis

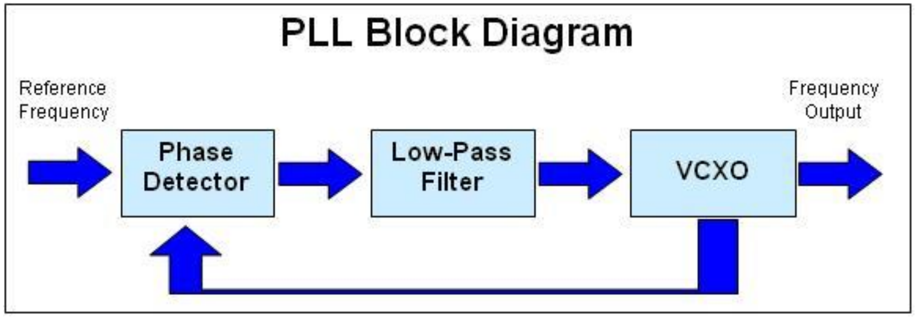
- Pre-emphasis is used on FM transmitters
  - Boosts the higher audio frequency
  - Not needed in Phase Modulated transmitters
- De-emphasis is used on FM receivers
  - The opposite of De-emphasis
  - Used to restore the audio back to its original form
- This process is used to reduce high frequency noise

Detectors & Demodulators

- Used to recover information from modulated signal
- Diode Detector
  - Works by rectifying and filtering modulated signal
- Product Detectors
  - Uses locally generated carrier (BFO)
  - Used for SSB, CW, & RTTY
- Direct Conversion
  - Incoming RF signal is mixed to baseband for ADC conversion
- Detecting FM signals
  - A common way is to use a Frequency-discriminator

Phased-Locked Loops

- An electronic servo loop
  - Reference Oscillator, Phase Detector, Low-Pass Filter, and Voltage Controlled Oscillator
- This allows a radios VFO to have the stability of a crystal oscillator
- The capture range is the frequency range over which the circuit can lock

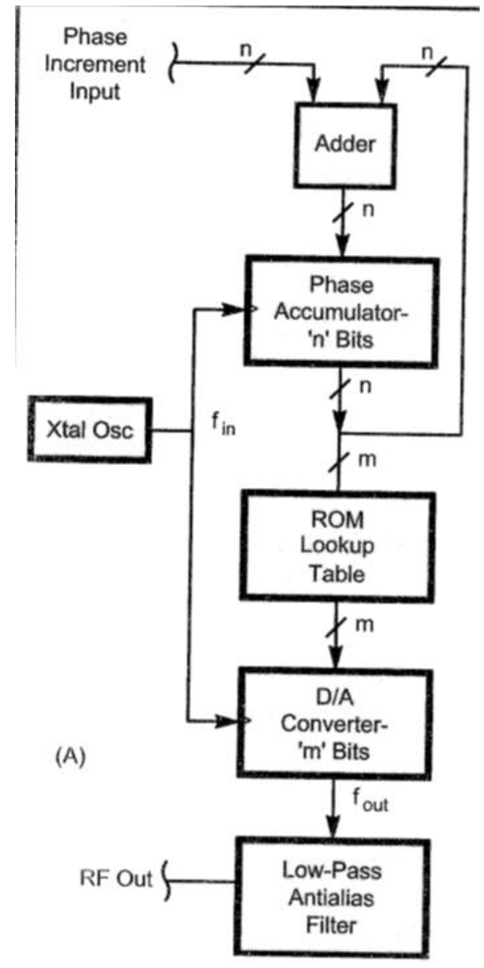


Phase-Locked Loops

- Unwanted variations Any short term variation in the phase of the output signal will *Phase Noise*
  - Major spectral impurity component of PLL synthesizer
- Phase-Locked Loops can also be used for FM Modulation and Demodulation

Direct Digital Synthesizers (DDS)

- <u>Phase Accumulator</u>
  - Reads data from the adder
- <u>Lookup Table</u>
  - <u>Contains amplitude values to create sine wave</u>
- <u>Digital to Analog Converter</u>
- <u>Low-pass alias filter</u>
  - Smooth's sine wave output
- No phase noise, but spurs at discrete frequencies



Passive Filters

- Passive Filters
  - Constructed using passive components
    - Capacitors, Inductors, Resisters
  - Crystal
  - Mechanical (Collins)
  - Cavity (Used for Repeater Duplexers)
  - Always have insertion loss
- Active Filters
  - Include an amplifying device
    - No insertion loss, may have gain

Filter Classification

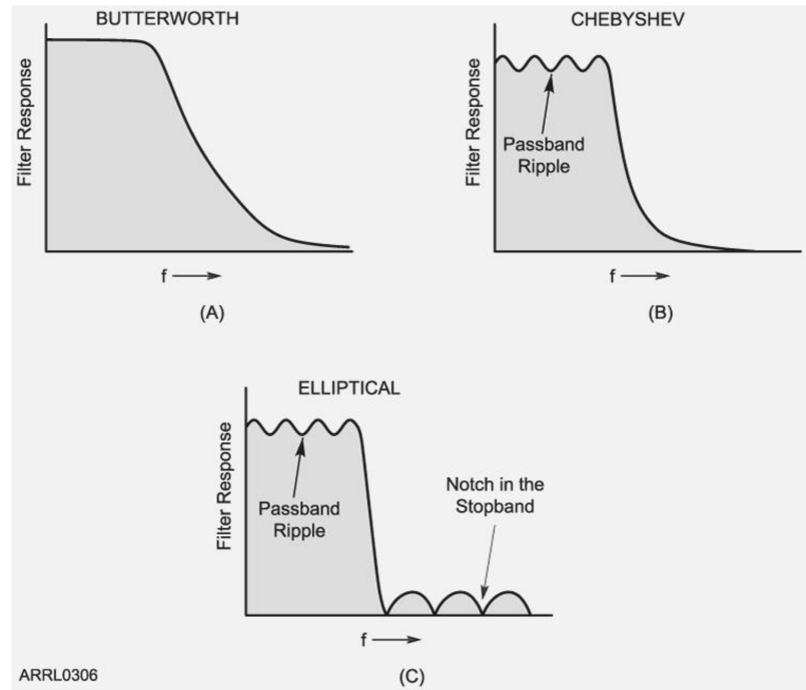
- Low-pass
  - Passes frequencies below the cut off frequency
- High-pass
  - Passes frequencies above the cutoff frequency
- Band-pass
  - Passes signal between upper and lower cutoff frequency
- Band Stop or Notch
  - Rejects signals between upper and lower cutoff frequency
    - Used to attenuate interfering signals
- Cutoff frequencies are at 3db below the maximum

Filter Design Definitions

- Phase Response
  - Shift of signal phase vs, frequency between input and output
  - Linear response indicates smooth no ripple as frequency changes
  - <u>Non-linear response can result in distortion of complex digital signals</u>
- Ringing
  - <u>Oscillations continue after signal is removed</u>

Filter Types

- Butterworth
  - Passband and stopband are flat
- Chebyshev
  - Ripple in the passband
  - Sharper cutoff transition
- Elliptical
  - Notches in passband and stopband
  - Sharpest cutoff



Crystal Filters

- Used in receiver IF stages to obtain narrow bandwidth to filter out adjacent signals
  - Normally a Crystal Lattice filter is made from quartz crystals and has narrow bandwidth and steep response curves
  - <u>The bandwidth and response curve are determined by the crystal frequencies</u>
  - <u>A Jones filter is a special type of Crystal Lattice filter with a variable bandwidth</u>
- Crystal Lattice filter are used in SSB transmitters to filter out unwanted sideband

Active Filters

- Can be built without inductors
- No insertion loss & can have gain
- Normally built with Op-amps
  - Gain and frequency determined by external capacitance and resistance values
  - Use polystyrene capacitors to improve stability
- Best suited for audio filtering in receivers
- Easily available low cost parts
- May have ringing and audio instability
  - Restrict gain and Q to reduce this problem

Digital Signal Processing (DSP)

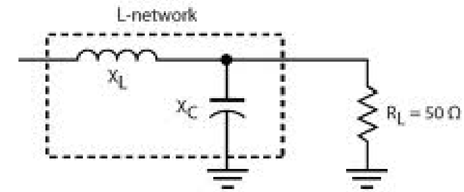
- Adaptive processing
  - Software can recognize and adopt to different signals and conditions
  - No tuning required
  - <u>Can be used to remove unwanted noise from a received SSB signal</u>
- Can build filters that are impossible with hardware
  - "Brick Wall" filters approach shape factor of 1.0

Impedance Matching

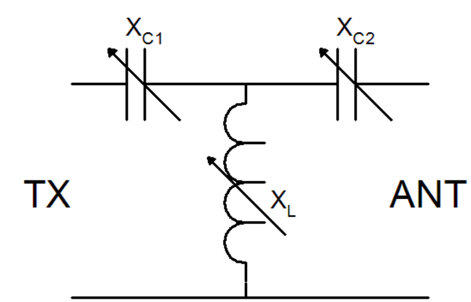
- If load and source impedances are not equal, an impedance matching network is needed
- Assuming a source impedance of 50Ω, the matching network must:
  - <u>Cancel the reactive portion of the load impedance</u>
  - <u>Transform the resistive component to 50Ω</u>

Impedance Matching Networks

- L-Networks
  - Can match virtually any 2 impedances
  - Q is fixed
  - Usually can only operate on one frequency band

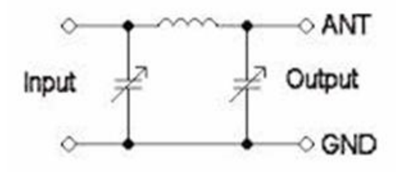


- T-Networks
  - Commonly used in antenna coupling equipment
  - Can match wide range of impedances
  - It also acts as a band-pass filter



Pi Impedance Matching

- Pi and Pi-L Networks
  - An inductor is between the input and output with capacitors on each side going to ground
  - Equivalent to two L-networks connected back-to-back
  - The Q can be varied compared to a fixed Q for L-networks
  - A Pi-L network has an additional series inductor on the output and greater harmonic suppression
  - On a power amplifier the tuning capacitor is adusted for minimum plate current and the load capacitor is adjusted for maximum permissible plate current

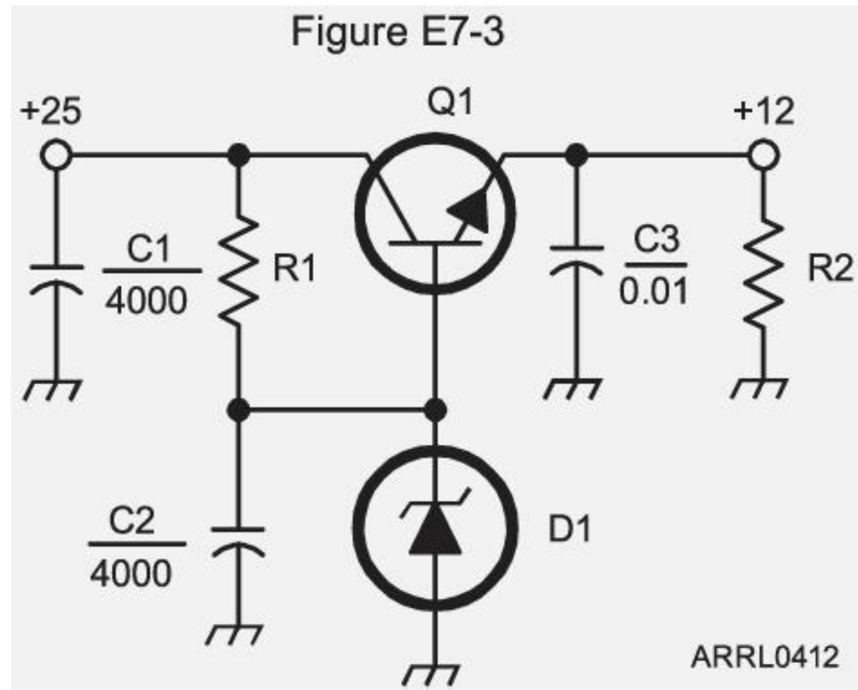


Linear Voltage Regulators

- The conduction is of a control element is varied to maintain a constant output voltage
- Shunt Regulators
  - Maximum current flows all of the time
  - <u>Has a constant load on the unregulated power source</u>
- Series Regulator
  - <u>Good efficiency compared to shunt regulator</u>
  - Only the current required by the load flows

Linear Regulator Circuit

- Q1 increases the current handling capability
- C1 is a filter capacitor
- C2 bypasses hum around D1
- C3 prevents self oscillation
- R1 supplies current to D1
- R2 provides a constant minimum load to Q1
- D1 is a Zener diode which provides a voltage reference
  - Zener diodes provide a stable reference voltage



Other Power Supplies

- Switching Regulators
  - The control device's duty cycle is controlled to produce a constant average voltage
  - By using a high frequency inverter design the transformers and filter components are smaller and lighter
- High Voltage supply capacitors
  - Connecting series to increase voltage handling
    - To equalize the voltage drop across each capacitor
    - To provide a safety bleeder
    - To provide a minimum load current
  - Step-start Circuit
    - Allows filter capacitors to charge gradually
- A bleeder resistor is used improve output regulation on Unregulated power supplies