General License Class

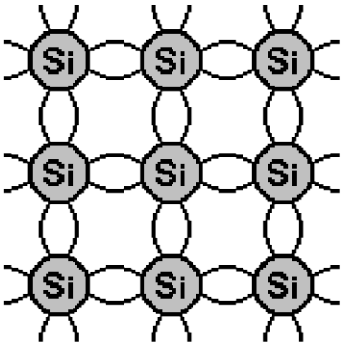
Chapter 4
Components & Circuits
(Part 2)

Active Components

- Semiconductor Components
  - Semiconductors are materials that do not conduct as well as metals, but better than insulators.
    - Can modify properties by adding controlled amounts of other materials called “dopants”.
  - Atomic Structure
    - Nucleus (Protons & Neutrons)
    - Electrons
      - Orbits (Shells)
      - 8 electrons completes a shell

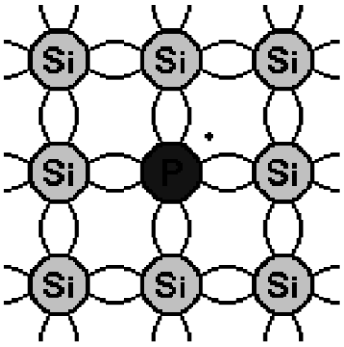
Active Components

- Semiconductor Components
  - 4 electrons in outer shell.
    - Silicon.
    - Germanium.



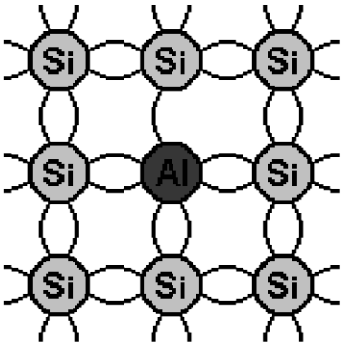
Active Components

- Semiconductor Components
  - "N" Material
    - Add element with 5 electrons in outer shell (donor Impurity).
      - Arsenic.
      - Antimony.
      - Phosphorus.



Active Components

- Semiconductor Components
  - "P" Material
    - Add element with 3 electrons in outer shell (acceptor Impurity).
      - Aluminum.
      - Gallium.
      - Indium.

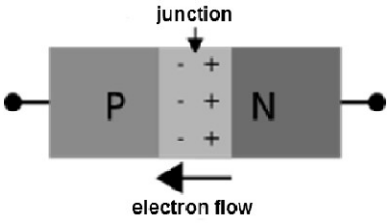


Active Components

- Semiconductor Components
  - Majority Charge Carrier
    - N-Type Material = Electron
    - P-Type Material = Hole
  - Other semiconductor materials
    - Gallium-Arsenide (GaAs)
      - LED's
      - Microwave frequencies.
    - Gallium-Arsenide-Phosphide (GaAsP)
      - LED's

Active Components

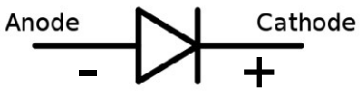
- Semiconductor Components
  - Diodes & Rectifiers
    - Junction diodes.
      - A P-N junction blocks current flow in one direction & allows current to flow in the other direction.



Active Components

- Semiconductor Components
  - Diodes & Rectifiers
    - Junction diodes.
      - Voltage applied in the forward direction is called “forward bias”.
        - Large current flow.

      - Voltage applied in the reverse direction is called “reverse bias”.
        - Minimal current flow.



Active Components

- Semiconductor Components
  - Diodes & Rectifiers
    - Diodes designed for low-power signals are called "signal" or "switching" diodes.
    - Diodes designed for high power circuits are called "rectifiers".
      - Maximum reverse voltage as high as 1000 Volts.
      - Maximum forward current as high as 200 Amp.

Active Components

- Semiconductor Components
  - Diodes & Rectifiers
    - Diode Ratings
      - Peak Inverse Voltage (PIV).
        - Maximum voltage in reverse direction (reverse bias).
      - Maximum Average Forward Current.
        - Maximum Allowable Junction Temperature.
      - Forward Voltage Drop.
        - Silicon = 0.7 Volts (approx.)
        - Germanium = 0.3 Volts (approx.)
        - GaAs & GaAsP = 1.2 Volts to 1.5 Volts (approx.)

Active Components

- Semiconductor Components
  - Diodes & Rectifiers
    - Diode Types
      - PIN diode.
        - Low forward voltage drop.
        - RF switching & control.

Active Components

- Semiconductor Components
  - Diodes & Rectifiers
    - Diode Types
      - Schottky Diode.
        - Low junction capacitance allows operation at VHF & UHF.
        - Lower forward voltage drop.

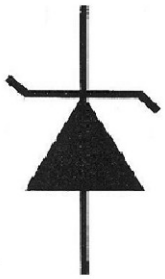
          Power supply rectifiers.

Active Components

- Semiconductor Components
  - Diodes & Rectifiers
    - Diode Types
      - Varactor Diodes (VariCap).
        - Operates with reverse bias.
        - Varying voltage varies junction capacitance.
        - Used for variable-frequency oscillators & for FM modulators.

Active Components

- Semiconductor Components
  - Diodes & Rectifiers
    - Diode Types
      - Zener diode.
        - Operates with reverse bias.
        - Operates at avalanche (breakdown) voltage.
        - Designed to withstand avalanche current with proper heat sink.
        - Large change in avalanche current results in small change in voltage.



Active Components

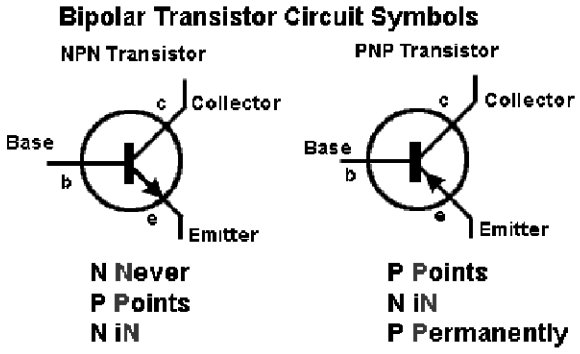
- Semiconductor Components
  - Bipolar & Field-Effect Transistors
    - Adding another layer to a diode creates a device capable of amplifying a signal.
      - 1st Transistor was created at Bell Labs in late 1947.

Active Components

- Semiconductor Components
  - Bipolar Transistors
    - Changing the amount of current (small) flowing through the base-emitter junction controls the amount of current (large) flowing from the collector to the emitter.
    - Bipolar transistors exhibit current gain.
      - $\beta = I_C / I_B$
      - $\alpha = I_C / I_E$

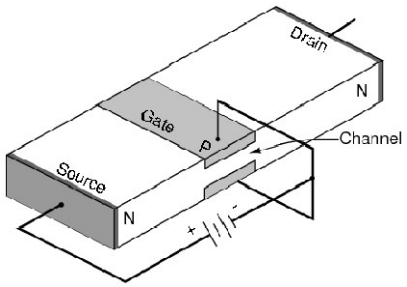
Active Components

- Semiconductor Components
  - Bipolar Transistors



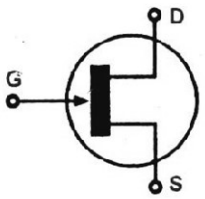
Active Components

- Semiconductor Components
  - Field-Effect Transistors (FET)
    - Gate voltage controls channel current.
    - Gain measured in Transconductance
      - Siemens
    - High input impedance.
    - Enhancement Mode
    - Depletion Mode

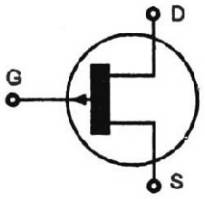


Active Components

- Semiconductor Components
  - Field-Effect Transistors
    - Junction Field-Effect Transistor (JFET)



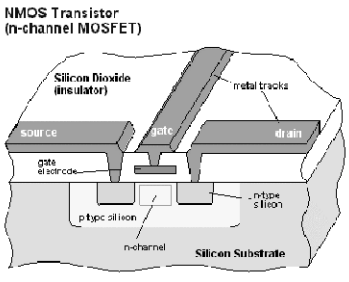
N-Channel JFET

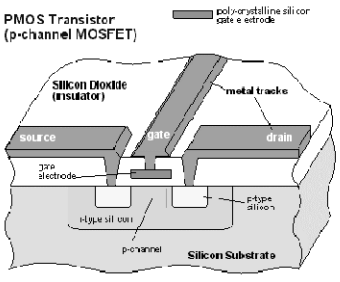


P-Channel JFET

Active Components

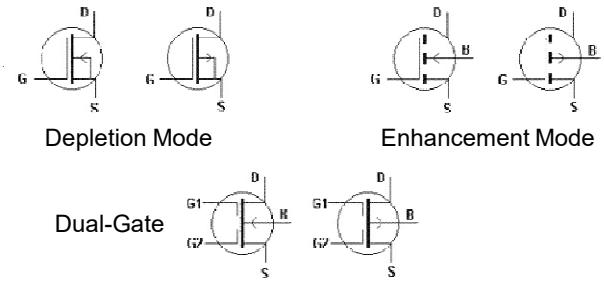
- Semiconductor Components
  - Field-Effect Transistors
    - Metal Oxide Semiconductor Field-Effect Transistor (MOSFET)





Active Components

- Semiconductor Components
  - Field-Effect Transistors
    - Metal Oxide Semiconductor Field-Effect Transistor (MOSFET)



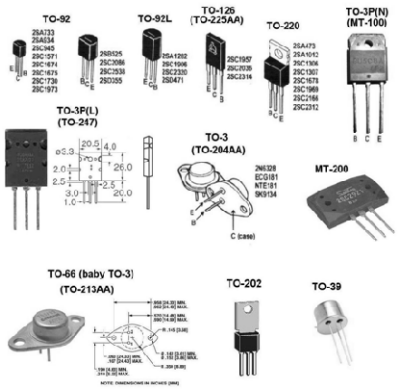
Active Components

- Semiconductor Components
  - Bipolar & Field-Effect Transistors
    - High gain makes both bipolar transistors & FET's useful as switches.
      - Low base current or low gate voltage* puts transistor into "cutoff" -- little or no current flow.
        - Additional reduction of base current or gate voltage does not result in any further reduction in current flow.
      - High base current or high gate voltage* puts transistor into "saturation" – maximum current flow.
        - Additional increase of base current or gate voltage does not result in any further increase in current flow.

**Assuming enhancement-mode FET.*

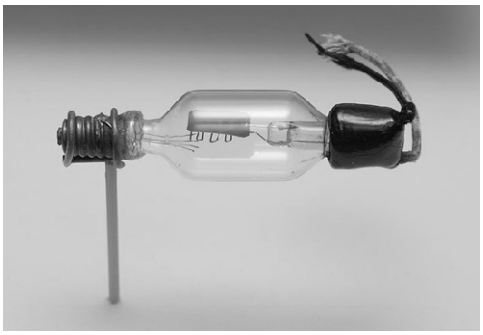
Active Components

- Semiconductor Components
  - Bipolar & Field-Effect Transistors
    - Transistors come in wide variety of packages.
    - Some high-power cases have collector or source directly connected to case.
      - Better heat transfer.
      - **Must be insulated from heat sink or chassis.**



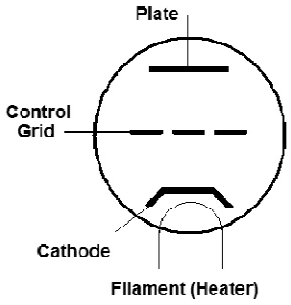
Active Components

- Vacuum Tubes
  - Oldest amplification device.
    - Invented by Lee De Forest in 1906.



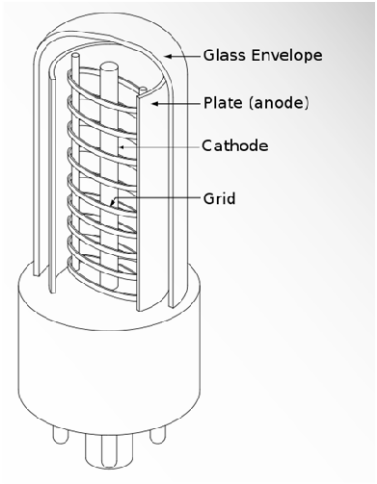
Active Components

- Vacuum Tubes
  - Triode
    - Simplest tube capable of amplification.
    - 3 Elements
      - Cathode.
      - Control Grid (Grid).
      - Plate (Anode).



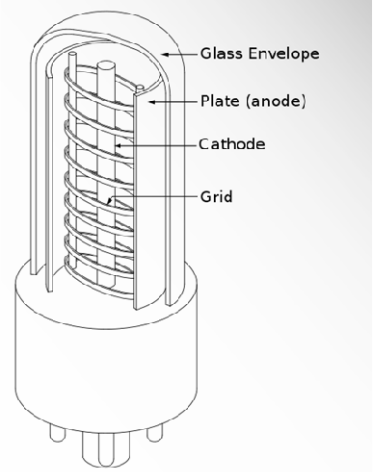
Active Components

- Vacuum Tubes
  - Cathode.
    - Source of electrons.
      - Directly heated.
      - Indirectly heated.
    - At or near ground potential.
    - High current.



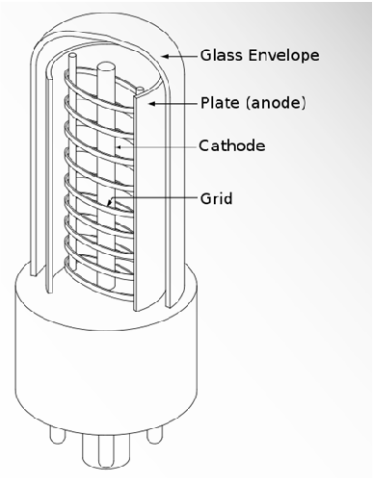
Active Components

- Vacuum Tubes
  - Control Grid (Grid).
    - Fine wire mesh.
    - Controls flow of electrons from cathode to plate.
    - Small negative voltage.
      - Tens of volts.
    - Low current.



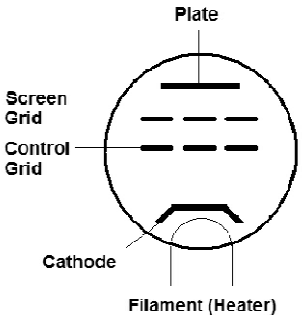
Active Components

- Vacuum Tubes
  - Plate (Anode).
    - Collects electrons emitted by cathode.
    - High positive voltage.
      - Hundreds or thousands of volts.
    - High current.



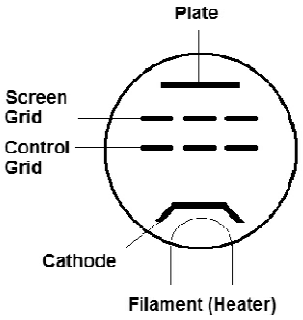
Active Components

- Vacuum Tubes
  - Tetrode
    - 4 Elements
      - Cathode.
      - Control Grid.
      - Screen Grid.
      - Plate .



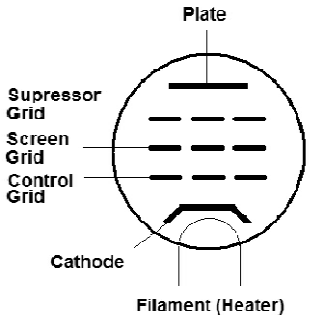
Active Components

- Vacuum Tubes
  - Tetrode
    - Screen Grid.
      - Reduces capacitance between plate & control grid, preventing self-oscillation.
      - Medium positive voltage.
        - 150-200 Volts.
      - Low Current.



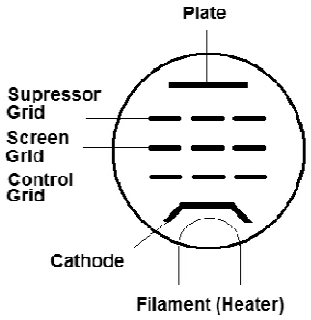
Active Components

- Vacuum Tubes
  - Pentode
    - 5 Elements
      - Cathode.
      - Control Grid.
      - Screen Grid.
      - Suppressor Grid.
      - Plate .



Active Components

- Vacuum Tubes
  - Pentode
    - Suppressor Grid.
      - Reduces “splashback” of electrons from plate to screen grid.
      - At or near cathode potential.
        - Often directly connected to cathode.
      - Low current.



Active Components

- Vacuum Tubes






Active Components

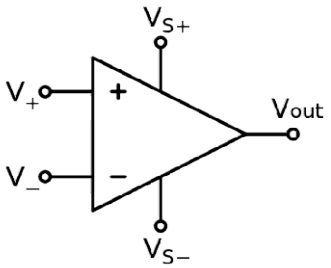
- Analog & Digital Integrated Circuits
  - Many transistors, diodes, & interconnections can be made on a single silicon wafer almost as easily as a single transistor. The result is called an integrated circuit.

Active Components

- Analog & Digital Integrated Circuits
  - Analog integrated circuits.
    - Used for amplification, filtering, voltage regulation, and many other applications.
      - Operational Amplifier.
      - Linear Voltage Regulator.

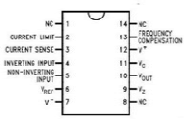
Active Components

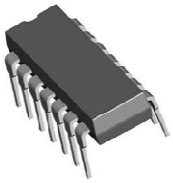
- Analog & Digital Integrated Circuits
  - Analog integrated circuits.
    - Operational Amplifier.
      - Circuit characteristics totally controlled by external components.
      - Amplifiers.
      - Active filters.
      - Adding signals.



Active Components

- Analog & Digital Integrated Circuits
  - Analog integrated circuits.
    - Linear Voltage Regulators.
      - LM-723.
        - External Components required.





Active Components

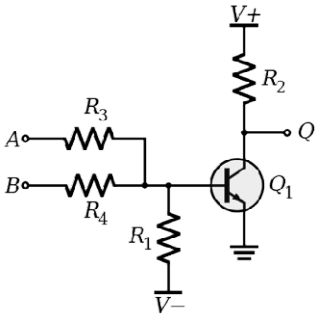
- Analog & Digital Integrated Circuits
  - Analog integrated circuits.
    - Linear Voltage Regulators.
      - IC 3-Terminal Regulators.
        - Thermal shutdown.
        - Overvoltage protection.
        - Foldback current limiting.
        - LM78Lxx -- 100 mA.
        - LM78xx -- 1 Amp.
        - LM78Hxx -- 3 Amps.

Active Components

- Analog & Digital Integrated Circuits
  - Digital integrated circuits.
    - Binary (base2) number system used for digital processing.
      - Only digits 0 & 1 are used.
      - Any number can be represented by a string of 0's & 1's.
        - 0 = 000, 1 = 001, 2 = 010, 3 = 011, 4 = 100, etc.
      - "0" & "1' can be easily represented by the "off" & "on" states of a transistor or similar device.

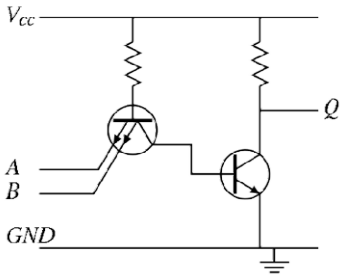
Active Components

- Analog & Digital Integrated Circuits
  - Digital integrated circuits.
    - Logic Families.
      - Resistor-Transistor-Logic (RTL).
        - 1st digital logic family (1961).
        - High power consumption.
        - No longer used.
          - Replaced by DTL.



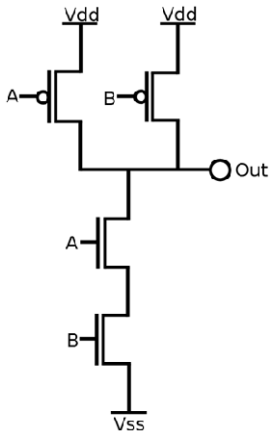
Active Components

- Analog & Digital Integrated Circuits
  - Digital integrated circuits.
    - Logic Families.
      - Transistor-Transistor-Logic (TTL).
        - Replaced RTL & DTL.
        - +5V supply voltage.
        - Low noise immunity.



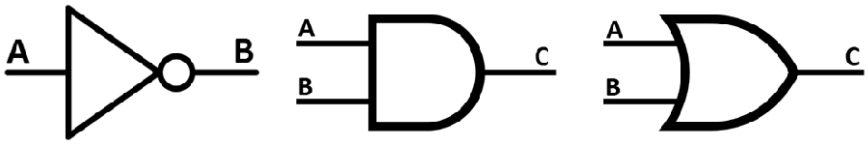
Active Components

- Analog & Digital Integrated Circuits
  - Digital integrated circuits.
    - Logic Families.
      - Complimentary Metal-Oxide Semiconductor (CMOS).
        - Replacing TTL.
        - +5V - 15V supply voltage.
        - High noise immunity.



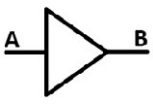
Active Components

- Analog & Digital Integrated Circuits
  - Digital Logic Basics.
    - Basic building block of a digital circuit is called a “gate”.
      - NOT (inverting) gate.
      - AND gate.
      - OR gate.

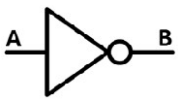


Active Components

- Analog & Digital Integrated Circuits
  - Digital Logic Basics.
    - One-input elements.
      - Non-inverting buffer.
      - Inverting buffer or “Not” gate.



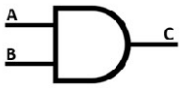
A	B
0	0
1	1



A	B
0	1
1	0

Active Components

- Analog & Digital Integrated Circuits
  - Digital Logic Basics.
    - AND gate.
      - Output true only if ALL inputs are true
    - NAND (Not-AND) gate.
      - Output false only if ALL inputs are true.



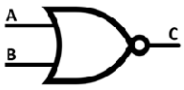
A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

A	B	C
0	0	1
1	0	1
0	1	1
1	1	0

Active Components

- Analog & Digital Integrated Circuits
  - Digital Logic Basics.
    - OR gate.
      - Output true if one or more of the inputs are true.
    - NOR (Not-OR) gate.
      - Output false if one or more of the inputs are true.

A	B	C
0	0	0
0	1	1
1	0	1
1	1	1



A	B	C
0	0	1
1	0	0
0	1	0
1	1	0

Active Components

- Analog & Digital Integrated Circuits
  - Digital Logic Basics.
    - XOR (Exclusive-OR) gate.
      - Output true if one and only one of the inputs is true.
    - XNOR (Exclusive-NOR) gate.
      - Output false if one and only one of the inputs is true.

A	B	C
0	0	0
0	1	1
1	0	1
1	1	0

A	B	C
0	0	1
1	0	0
0	1	0
1	1	1

Active Components

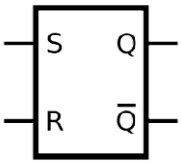
- Analog & Digital Integrated Circuits
  - Digital Logic Basics.
    - Sequential logic
      - Current state dependent on both current inputs and previous state.
      - Must include some form of “memory”.

Active Components

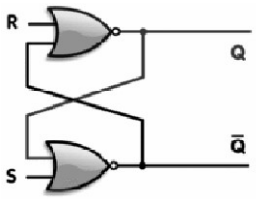
- Analog & Digital Integrated Circuits
  - Digital Logic Basics.
    - Flip-flop
      - a.k.a -- Bi-stable multivibrator, latch.
      - Several different types.
        - S-R, J-K, D, T.
        - Gated, non-gated.
        - Clocked, non-clocked.
      - Can be used as frequency divider.
      - Can be used as frequency counter.

Active Components

- Analog & Digital Integrated Circuits
  - Digital Logic Basics.
    - Set-Reset (SR) Latch
      - Most basic latch type.



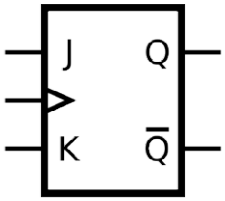
S	R	Action
0	0	No change
0	1	Q = 0
1	0	Q = 1
1	1	Forbidden



Active Components

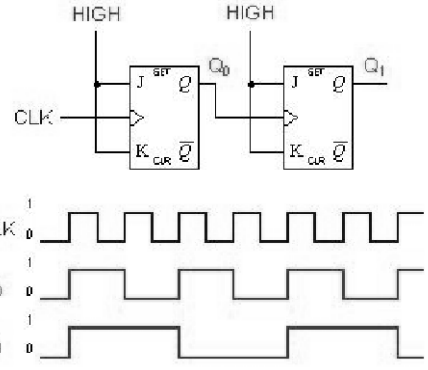
- Analog & Digital Integrated Circuits
  - Digital Logic Basics.
    - J-K flip-flop
      - Adds toggle function to SR latch.
      - Must be clocked.

Clock (>)	J	K	Action
0	--	--	No change
1	0	0	No change
1	0	1	Q = 0
1	1	0	Q = 1
1	1	1	Toggle (Q = not Q)



Active Components

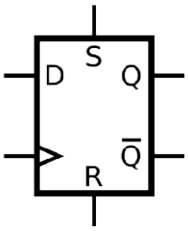
- Analog & Digital Integrated Circuits
  - Digital Logic Basics.
    - Frequency divider.



Active Components

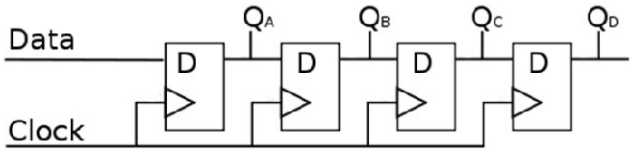
- Analog & Digital Integrated Circuits
  - Digital Logic Basics.
    - D flip-flop
      - Most common type.
      - Computer RAM.
      - Must be clocked.

Clock (>)	D	Action
0	--	No change
1	0	Q = 0
1	1	Q = 1



Active Components

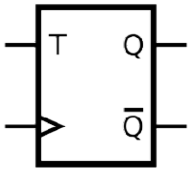
- Analog & Digital Integrated Circuits
  - Digital Logic Basics.
    - Shift Register
      - Cascaded D flip-flops.
      - Shifts data from stage to stage.
      - Converts serial data to parallel data.
      - Converts parallel data to serial data.



Active Components

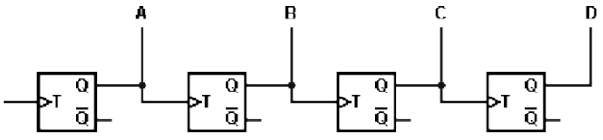
- Analog & Digital Integrated Circuits
  - Digital Logic Basics.
    - T flip-flop
      - Toggles state with each clock pulse.
      - D flip-flop with Q output connected to D input.

Clock (>)	T	Action
0	--	No change
1	0	No change
1	1	Toggle (Q = not Q)



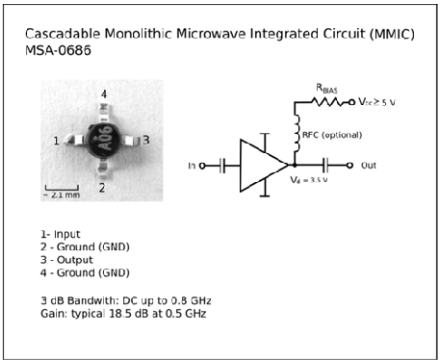
Active Components

- Analog & Digital Integrated Circuits
  - Digital Logic Basics.
    - Digital Counter
      - Cascaded T flip-flops.
      - Counts number of input pulses.
      - Number of states = 2^N where N = number of stages.
        - For example: 3-stage counter has 8 states.



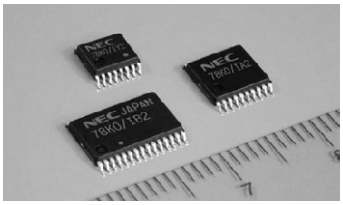
Active Components

- RF Integrated Circuits.
  - Monolithic Microwave Integrated Circuit (MMIC)
    - VHF, UHF, microwaves.
    - Typically 50Ω
    - Low Noise Figure
      - 3.5 dB to 6.0 dB
    - Microstrip construction



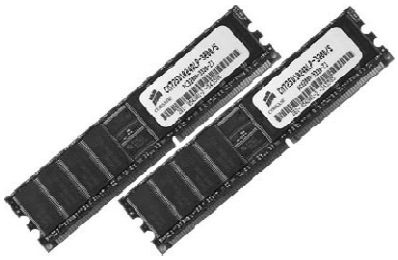
Active Components

- Microprocessors & Related Components.
  - Microprocessor.
    - A computer on a chip.
      - Thousands of gates.
      - Tens of thousands of transistors & diodes.
  - Microcontroller.
    - Microprocessor with added interfaces to input & output devices.



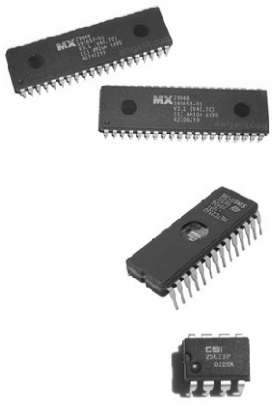
Active Components

- Microprocessors & Related Components.
  - Memory
    - Volatile
      - Data is lost when power is off.
      - Random Access Memory (RAM)



Active Components

- Microprocessors & Related Components.
  - Memory
    - Non-Volatile
      - Data is retained when power is off.
      - Read-Only Memory (ROM)
      - Programmable Read-Only Memory (PROM)
      - Erasable Programmable Read-Only Memory (EPROM)
      - Electrically Erasable Programmable Read-Only Memory (EEPROM)



Active Components

- Microprocessors & Related Components.
  - Interfaces.
    - Serial
      - One bit transferred at a time.
    - Parallel
      - Multiple bits transferred at a time.

Active Components

- Microprocessors & Related Components.
  - Interfaces.
    - Serial
      - One bit transferred at a time.
      - RS-232 (COM ports).
        - Commonly used to connect amateur transceivers to personal computers.
      - Universal Serial Bus (USB).
        - Replacing RS-232.
        - Commonly used to connect amateur transceivers to personal computers.
      - Ethernet.

Active Components

- Microprocessors & Related Components.
  - Interfaces.
    - Parallel
      - Multiple bits transferred at a time.
      - Used for connections to mass storage devises.
        - Integrated Drive Electronics (IDE)
        - Small Computer System Interface (SCSI)
      - Centronics® Parallel Printer Port.
      - Being replaced by high-speed serial interfaces.

Active Components

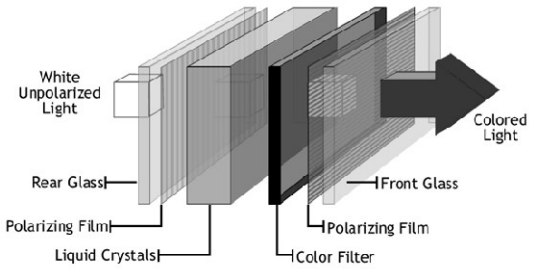
- Visual Interfaces.
  - Indicator
    - Displays on/off state of a single item.
    - Incandescent Lamp
      - Largely replaced by LED's.
    - Light-Emitting-Diode (LED)
      - Emits light when forward biased.
      - Faster than incandescent lamp.
      - Less power than incandescent lamp.
      - Less heat than incandescent lamp.
      - Longer life than incandescent lamp.

Active Components

- Visual Interfaces.
  - Display
    - Displays text or graphical information.
    - Most common type in amateur equipment is the liquid crystal display (LCD).
      - Requires illumination.
        - Ambient light.
        - Back light.

Active Components

- Visual Interfaces.
  - Liquid-Crystal Displays
    - Rotates polarization of light passing through it.
    - Applying voltage across crystal changes polarization.



G6A03 -- What is the approximate junction threshold voltage of a germanium diode?

A. 0.1 volt
B. 0.3 volts
C. 0.7 volts
D. 1.0 volts

G6A05 -- What is the approximate junction threshold voltage of a conventional silicon diode?

A. 0.1 volt
B. 0.3 volts
C. 0.7 volts
D. 1.0 volts

G6A06 -- Which of the following is an advantage of using a Schottky diode in an RF switching circuit rather than a standard silicon diode?

➡ A. Lower capacitance

B. Lower inductance

C. Longer switching times

D. Higher breakdown voltage

G6A07 -- What are the stable operating points for a bipolar transistor used as a switch in a logic circuit?

➡ A. Its saturation and cutoff regions

B. Its active region (between the cutoff and saturation regions)

C. Its peak and valley current points

D. Its enhancement and depletion modes

G6A08 -- Why must the cases of some large power transistors be insulated from ground?

A. To increase the beta of the transistor
B. To improve the power dissipation capability
C. To reduce stray capacitance
➡ D. To avoid shorting the collector or drain voltage to ground

G6A09 -- Which of the following describes the construction of a MOSFET?

A. The gate is formed by a back-biased junction
➡ B. The gate is separated from the channel with a thin insulating layer
C. The source is separated from the drain by a thin insulating layer
D. The source is formed by depositing metal on silicon

G6A10 -- Which element of a triode vacuum tube is used to regulate the flow of electrons between cathode and plate?

➡ A. Control grid
B. Heater
C. Screen grid
D. Trigger electrode

G6A11 -- Which of the following solid state devices is most like a vacuum tube in its general operating characteristics?

A. A bipolar transistor
➡ B. A field effect transistor
C. A tunnel diode
D. A varistor

G6A12 -- What is the primary purpose of a screen grid in a vacuum tube?

➡ A. To reduce grid-to-plate capacitance

B. To increase efficiency

C. To increase the control grid resistance

D. To decrease plate resistance

G6B01 -- Which of the following is an analog integrated circuit?

A. NAND Gate

B. Microprocessor

C. Frequency Counter

➡ D. Linear voltage regulator

G6B02 -- What is meant by the term MMIC?

A. Multi Megabyte Integrated Circuit
B. Monolithic Microwave Integrated Circuit
C. Military Manufactured Integrated Circuit
D. Mode Modulated Integrated Circuit

G6B03 -- Which of the following is an advantage of CMOS integrated circuits compared to TTL integrated circuits?

A. Low power consumption
B. High power handling capability
C. Better suited for RF amplification
D. Better suited for power supply regulation

G6B04 -- What is meant by the term ROM?

A. Resistor Operated Memory
B. Read Only Memory
C. Random Operational Memory
D. Resistant to Overload Memory

G6B05 -- What is meant when memory is characterized as non-volatile?

A. It is resistant to radiation damage
B. It is resistant to high temperatures
C. The stored information is maintained even if power is removed
D. The stored information cannot be changed once written

G6B06 -- What kind of device is an integrated circuit operational amplifier?

A. Digital
B. MMIC
C. Programmable Logic
➡ D. Analog

G6B07 -- Which of the following is an advantage of an LED indicator compared to an incandescent indicator?

A. Lower power consumption
B. Faster response time
C. Longer life
➡ D. All of these choices are correct

G6B08 -- How is an LED biased when emitting light?

A. Beyond cutoff
B. At the Zener voltage
C. Reverse Biased
➡ D. Forward Biased

G6B09 -- Which of the following is a characteristic of a liquid crystal display?

➡ A. It requires ambient or back lighting
B. It offers a wide dynamic range
C. It has a wide viewing angle
D. All of these choices are correct

G6B10 -- What two devices in an Amateur Radio station might be connected using a USB interface?

➡ A. Computer and transceiver
B. Microphone and transceiver
C. Amplifier and antenna
D. Power supply and amplifier

G6B11 -- What is a microprocessor?

➡ A. A low power analog signal processor used as a microwave detector
B. A computer on a single integrated circuit
C. A microwave detector, amplifier, and local oscillator on a single integrated circuit
D. A low voltage amplifier used in a microwave transmitter modulator stage

G7B01 -- Complex digital circuitry can often be replaced by what type of integrated circuit?

➡ A. Microcontroller
B. Charge-coupled device
C. Phase detector
D. Window comparator

G7B02 -- Which of the following is an advantage of using the binary system when processing digital signals?

➡ A. Binary "ones" and "zeros" are easy to represent with an "on" or "off" state
B. The binary number system is most accurate
C. Binary numbers are more compatible with analog circuitry
D. All of these choices are correct

G7B03 -- Which of the following describes the function of a two input AND gate?

A. Output is high when either or both inputs are low

➡ B. Output is high only when both inputs are high

C. Output is low when either or both inputs are high

D. Output is low only when both inputs are high

G7B04 -- Which of the following describes the function of a two input NOR gate?

A. Output is high when either or both inputs are low

B. Output is high only when both inputs are high

➡ C. Output is low when either or both inputs are high

D. Output is low only when both inputs are high

G7B05 -- How many states does a 3-bit binary counter have?

A. 3
B. 6
➡ C. 8
D. 16

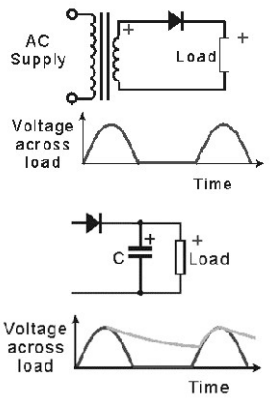
G7B06 -- What is a shift register?

➡ A. A clocked array of circuits that passes data in steps along the array
B. An array of operational amplifiers used for tri state arithmetic operations
C. A digital mixer
D. An analog mixer

Break

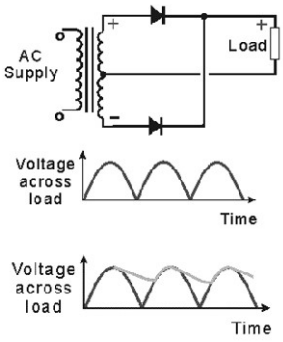
Practical Circuits

- Rectifiers & Power Supplies
  - Rectifier Circuits.
    - Half-Wave Rectifier.
      - Only one-half of the cycle (180°) delivers power to the load.
      - Creates a series of widely-spaced pulses at the frequency of the input voltage.
      - Very difficult to filter.
      - $V_{Avg} = 0.45 \times V_{AC}$
      - Diode PIV $\geq 2 \times V_P$
      - Diode $I_{Max} \geq I_{Load}$



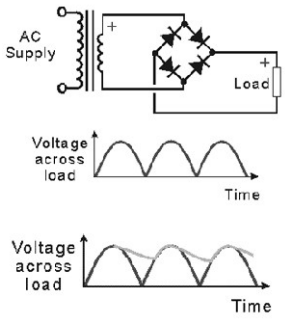
Practical Circuits

- Rectifiers & Power Supplies
  - Rectifier Circuits.
    - Full-Wave Rectifier.
      - All of the cycle (360°) is used to deliver power to the load.
      - Creates a series of closely-spaced pulses at twice the frequency of the input voltage.
      - Easier to filter.
      - $V_{Avg} = 0.9 \times V_{AC}$
      - Diode PIV $\geq 2 \times V_P$
      - Diode $I_{Max} \geq 0.5 \times I_{Load}$



Practical Circuits

- Rectifiers & Power Supplies
  - Rectifier Circuits.
    - Full-Wave Bridge Rectifier.
      - All of the cycle (360°) is used to deliver power to the load.
      - Creates a series of closely-spaced pulses at twice the frequency of the input voltage.
      - Easier to filter.
      - $V_{Avg} = 0.9 \times V_{AC}$
      - Diode PIV $\geq V_P$
      - Diode $I_{Max} \geq 0.5 \times I_{Load}$



Practical Circuits

- Rectifiers & Power Supplies
  - Rectifier Circuits.

Type of Circuit	Diode PIV Rating	Diode Current Rating
Half-Wave Rectifier	$\geq 2 \times V_P$	$\geq I_{Load}$
Full-Wave Center-Tapped	$\geq 2 \times V_P$	$\geq 0.5 \times I_{Load}$
Full-Wave Bridge	$\geq V_P$	$\geq 0.5 \times I_{Load}$

Practical Circuits

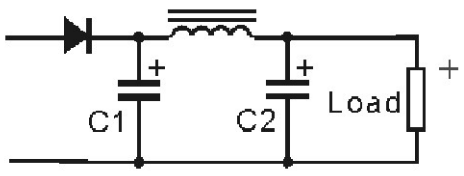
- Rectifiers & Power Supplies
  - Rectifier Circuits.
    - Diodes in parallel.
      - Diodes can be connected in parallel to increase current capacity, **ONLY** if you put a small-value resistor in series with each diode to equalize the currents between each diode.
    - Diodes in series.
      - Diodes can be connected in series to increase voltage capacity, **ONLY** if you put a large-value resistor in parallel with each diode to equalize the voltage across each diode.

Practical Circuits

- Rectifiers & Power Supplies
  - Raw output from rectifier is a series of pulses unsuitable for operating electronic equipment.
  - Need filter after rectifier to smooth pulses into a steady DC voltage.
    - Low-pass filter with cut-off frequency well below frequency of pulses.
      - Half-wave rectifier → 60 Hz pulses.
      - Full-wave rectifier → 120 Hz pulses.

Practical Circuits

- Rectifiers & Power Supplies
  - Filter Circuits.
    - R-C or L-C network after rectifier to reduce variations in the DC output voltage.
      - Variations are called “ripple”.
      - Ripple = 100 x $V_{AC(P-P)}$ / V_{DC}



Practical Circuits

- Rectifiers & Power Supplies
  - Filter Circuits.
    - Choosing the capacitors.
      - Large capacitance.
      - Low effective series resistance (ESR).
      - Computer-grade aluminum electrolytic.
        - Large capacitances & low ESR in smaller case sizes.

Practical Circuits

- Rectifiers & Power Supplies
  - Filter Circuits.
    - Choosing the inductor.
      - Large inductance.
      - Low series resistance.
      - Not always used.
        - Capacitor may provide sufficient filtering, especially if load is a voltage regulator.

Practical Circuits

- Rectifiers & Power Supplies
  - Power Supply Safety.
    - **EVERY** power supply should have:
      - Fuse in AC input line.
      - On/off switch in AC input line.
      - Bleeder resistor.
        - High value resistor across output of power supply.
        - Discharges filter capacitors.

Practical Circuits

- Rectifiers & Power Supplies
  - Switchmode or Switching Power Supplies.
    - AC input voltage is rectified & fed to a solid-state oscillator.
    - Oscillator generates series of high-frequency pulses.
      - 20 kHz or greater.
    - Pulses are applied to the primary of a transformer.
    - Output of secondary is filtered & sent to load.
    - Voltage regulated by varying width of pulses fed to transformer.

Practical Circuits

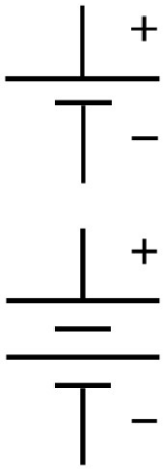
- Rectifiers & Power Supplies
  - Switchmode or Switching Power Supplies.
    - High frequency allows use of much smaller transformer.
    - High frequency allows use of much smaller capacitors.
      - Low effective series inductance (ESL).
    - High frequency allows use of much smaller inductors.
    - High frequency allows rapid response to load changes.

Practical Circuits

- Rectifiers & Power Supplies
  - Switchmode or Switching Power Supplies.
    - Advantages over linear power supplies.
      - Smaller size.
      - Less weight.
      - Higher efficiency.
    - Disadvantages over linear power supplies.
      - RF noise generation.
      - Higher cost.

Practical Circuits

- Batteries & Chargers
  - Batteries.
    - Produce energy by electrochemical reaction.
    - Used by amateurs for:
      - Hand-Held operations.
      - Portable operations.
      - Mobile operations.
      - Emergency operations.



Practical Circuits

- Batteries & Chargers
  - Batteries.
    - Primary.
      - Electrochemical reaction is not reversible.
      - Battery cannot be recharged.
      - Examples:
        - Carbon-Zinc
        - Alkaline.
        - Silver-Nickel.
        - Lithium.
        - Mercury.
        - Silver-Oxide.

Practical Circuits

- Batteries & Chargers
  - Batteries.
    - Secondary.
      - Electrochemical reaction is reversible.
      - Battery can be recharged.
      - Examples:
        - Lead-Acid.
        - Nickel-Cadmium (NiCad).
        - Nickel-Metal-Hydride (NiMH).
        - Lithium-Ion (Li-Ion).

Practical Circuits

- Batteries & Chargers
  - Batteries.
    - Discharge at low rate.
      - Less internal heating.
      - NiCad & NiMH batteries have low internal resistance & are designed for high discharge currents.
    - All batteries have some leakage.
      - Self-discharge.
        - Store in cool, dry location.
    - 12-volt lead-acid batteries should not be discharged below 10.5 volts.

Practical Circuits

- Batteries & Chargers
  - Charging Batteries.
    - **NEVER** attempt to recharge a primary-cell battery.
    - **ALWAYS** use proper charger.
      - NiCad & NiMH batteries are charged with constant current until voltage rises to specified value.
      - Lead-Acid batteries are charged with constant voltage until current drops to specified value.
    - **ALWAYS** provide proper ventilation.
      - Lead-Acid batteries give off hydrogen gas during charging. **(Remember the Hindenburg!)**

Practical Circuits

- Alternative Power
  - Generators
    - Gasoline or Diesel Powered.
    - <1kW to >10kW.

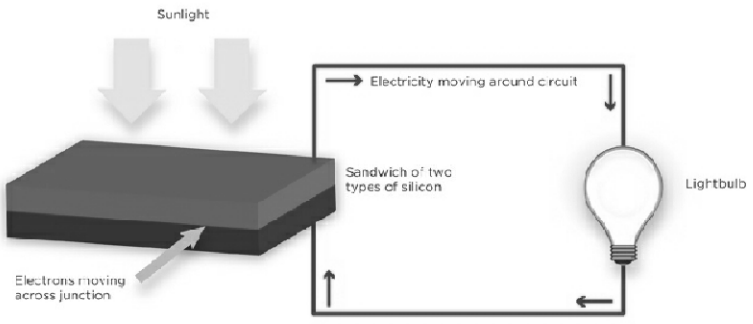


Practical Circuits

- Alternative Power
  - Solar Power
    - If sufficient light falls on a P-N junction, free electrons in the N-type material will absorb energy & flow across the junction into the P-type material.
      - Most common material is Silicon.
      - Most efficient material is Gallium-Arsenide.
      - Fully-illuminated junction yields about 0.5 VDC.
      - Almost 1 kW/m^2.
      - Rapidly becoming commercially viable for power generation.

Practical Circuits

- Alternative Power
  - Solar Power



Practical Circuits

- Alternative Power
  - Wind Power
    - DC generator attached to propeller.



Practical Circuits

- Alternative Power
  - Energy Storage.
    - Solar power & wind power are not continuously available.
    - Must store energy during periods of daylight or when the wind is blowing to save up for nighttime or when the wind is calm.
      - Storage batteries most commonly used.
      - Solar system have diode in series between solar panel & batteries to prevent discharging batteries back through the panel during low-light conditions.

Practical Circuits

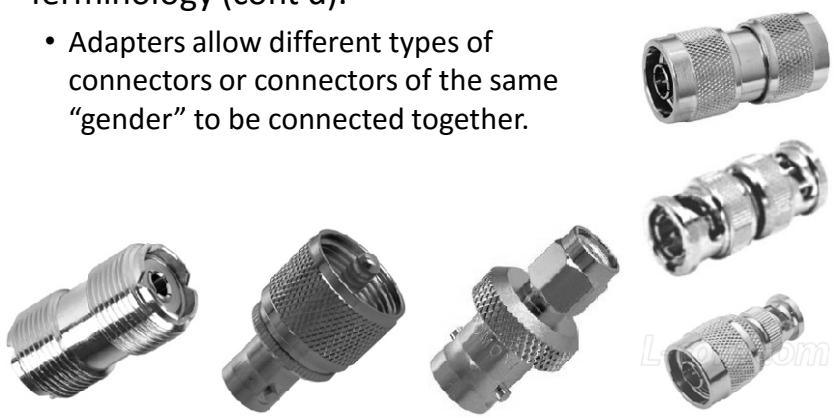
- Connectors
  - Convenient way to make electrical connections.
  - Terminology.
    - Pins = Contacts that extend out of connector body.
    - Sockets = Hollow, recessed contacts.
    - Connectors with pins are “male”.
    - Connectors with sockets are “female”.

Practical Circuits

- Connectors
  - Terminology (cont’d).
    - Connectors with specially-shaped bodies or pin/socket arrangements are call “keyed connectors”.
      - Keyed connectors avoid damage caused by mis-mating connectors.
    - Plugs = Connectors installed on ends of cables.
    - Jacks = Connectors installed on equipment.

Practical Circuits

- Connectors
  - Terminology (cont'd).
    - Adapters allow different types of connectors or connectors of the same "gender" to be connected together.



Practical Circuits

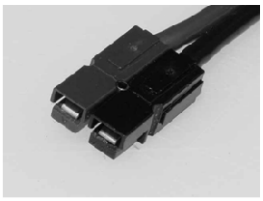
- Connectors
  - Power Connectors.
    - Coaxial Power Connectors.
      - Low current.
      - Commonly used on hand-held transceivers and station accessories.

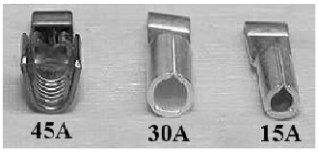
Practical Circuits

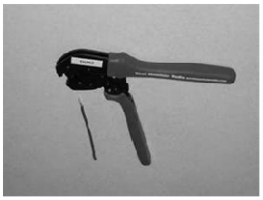
- Connectors
  - Power Connectors.
    - Molex® Connectors.
      - Many HF transceivers use the 6-pin connector.
        - Pins paralleled to increase current capacity.
      - Many VHF/UHF transceivers use the 2-pin connector.

Practical Circuits

- Connectors
  - Power Connectors.
    - Anderson PowerPole® Connectors.
      - Becoming increasingly popular for station interconnections.
      - Easy to install with proper crimp tool.

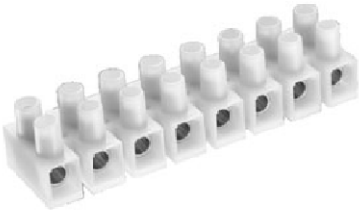






Practical Circuits

- Connectors
  - Power Connectors.
    - Terminal Strips.



Practical Circuits

- Connectors
  - Audio and Control Connectors.
    - Phone plugs & jacks (TRS connectors).
      - Audio.
      - Keys.
      - Control signals.
      - Sizes:
        - Standard -- 1/4” dia.
        - Aircraft -- 0.206” dia. (Rare)
        - Miniature -- 1/8” (3.5 mm) dia.
        - Sub-miniature -- 3/32” (2.5 mm) dia.

Practical Circuits

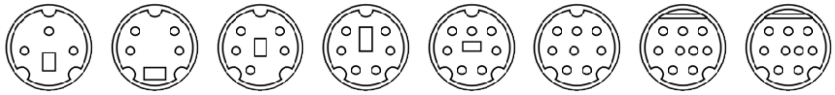
- Connectors
  - Audio and Control Connectors.
    - RCA Phono plugs & jacks.
      - Audio.
      - Low-level RF.
      - Control Signals.

Practical Circuits

- Connectors
  - Audio and Control Connectors.
    - DIN connectors.
      - *Deutsches Institut für Normung*
        - German national standards organization.
      - Audio.
      - Control Signals.

Practical Circuits

- Connectors
  - Audio and Control Connectors.
    - Mini-DIN connectors.
      - Audio.
      - Control Signals.



Practical Circuits

- Connectors
  - RF Connectors.
    - UHF.
      - Plug = PL-259.
      - Socket = SO-239.
      - ≤ 150 MHz.
      - ≥ 1.5 kW.
      - ≤ 500 V_{Peak}
      - Non-constant impedance.
      - Not weather resistant.
      - Inexpensive.

Practical Circuits

- Connectors
  - RF Connectors.
    - N.
      - ≤ 10 GHz.
      - ≥ 1.5 kW.
      - ≤ 1500 V_{Peak}
      - Constant impedance.
        - 50 Ω or 75 Ω versions available.
      - Weather-resistant.
      - More expensive than UHF connectors.

Practical Circuits

- Connectors
  - RF Connectors.
    - BNC.
      - ≤ 4 GHz.
      - Low power.
      - ≤ 500 V_{Peak}
      - Constant impedance.
        - 50 Ω or 75 Ω versions available.

Practical Circuits

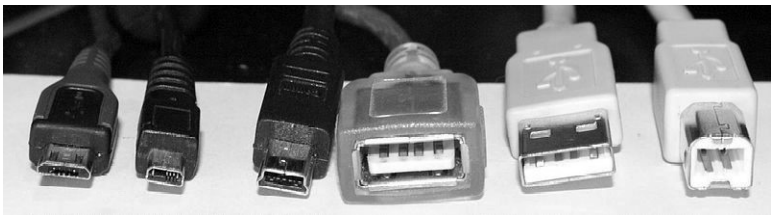
- Connectors
  - RF Connectors.
    - SMA.
      - ≤ 18 GHz.
      - Low Power
      - ≤ 250 V_{RMS}
      - Constant impedance.
        - 50 Ω.

Practical Circuits

- Connectors
  - Data Connectors.
    - D-Subminiature Connectors.
      - DB-25
        - Serial (COM) ports.
        - Parallel printer ports.
      - DE-9
        - Incorrectly known as DB-9.
        - Serial (COM) ports.

Practical Circuits

- Connectors
  - Data Connectors.
    - USB Connectors.
      - USB replacing RS-232.
      - Many manufacturers making devices to interconnect transceivers & other station equipment using USB.



G4E08 -- What is the name of the process by which sunlight is changed directly into electricity?

➡ A. Photovoltaic conversion

B. Photon emission

C. Photosynthesis

D. Photon decomposition

G4E09 -- What is the approximate open-circuit voltage from a fully illuminated silicon photovoltaic cell?

A. 0.02 VDC

➡ B. 0.5 VDC

C. 0.2 VDC

D. 1.38 VDC

G4E10 -- What is the reason that a series diode is connected between a solar panel and a storage battery that is being charged by the panel?

A. The diode serves to regulate the charging voltage to prevent overcharge

➡ B. The diode prevents self discharge of the battery though the panel during times of low or no illumination

C. The diode limits the current flowing from the panel to a safe value

D. The diode greatly increases the efficiency during times of high illumination

G4E11 -- Which of the following is a disadvantage of using wind as the primary source of power for an emergency station?

A. The conversion efficiency from mechanical energy to electrical energy is less than 2 percent
B. The voltage and current ratings of such systems are not compatible with amateur equipment
➡ C. A large energy storage system is needed to supply power when the wind is not blowing
D. All of these choices are correct

G6A01 -- What is the minimum allowable discharge voltage for maximum life of a standard 12 volt lead acid battery?

A. 6 volts
B. 8.5 volts
➡ C. 10.5 volts
D. 12 volts

G6A02 -- What is an advantage of the low internal resistance of nickel-cadmium batteries?

A. Long life
➡ B. High discharge current
C. High voltage
D. Rapid recharge

G6B04 -- When is it acceptable to recharge a carbon-zinc primary cell?

A. As long as the voltage has not been allowed to drop below 1.0 volt
B. When the cell is kept warm during the recharging period
C. When a constant current charger is used
➡ D. Never

G6B12 -- Which of the following connectors would be a good choice for a serial data port?

A. PL-259
B. Type N
C. Type SMA
➡ D. DE-9

G6B13 -- Which of these connector types is commonly used for RF connections at frequencies up to 150 MHz?

A. Octal
B. RJ-11
➡ C. PL-259
D. DB-25

G6B14 -- Which of these connector types is commonly used for audio signals in Amateur Radio stations?

A. PL-259
B. BNC
➡ C. RCA Phono
D. Type N

G6B15 -- What is the main reason to use keyed connectors instead of non-keyed types?

A. Prevention of use by unauthorized persons
➡ B. Reduced chance of incorrect mating
C. Higher current carrying capacity
D. All of these choices are correct

G6B16 -- Which of the following describes a type-N connector?

- A. A moisture-resistant RF connector useful to 10 GHz
- B. A small bayonet connector used for data circuits
- C. A threaded connector used for hydraulic systems
- D. An audio connector used in surround-sound installations

G6B17 -- What is the general description of a DIN type connector?

- A. A special connector for microwave interfacing
- B. A DC power connector rated for currents between 30 and 50 amperes
- C. A family of multiple circuit connectors suitable for audio and control signals
- D. A special watertight connector for use in marine applications

G6B18 -- What is a type SMA connector?

A. A large bayonet-type connector usable at power levels in excess of 1 KW

➡ B. A small threaded connector suitable for signals up to several GHz

C. A connector designed for serial multiple access signals

D. A type of push-on connector intended for high-voltage applications

G7A01 -- What safety feature does a power-supply bleeder resistor provide?

A. It acts as a fuse for excess voltage

➡ B. It ensures that the filter capacitors are discharged when power is removed

C. It removes shock hazards from the induction coils

D. It eliminates ground-loop current

G7A02 -- Which of the following components are used in a power-supply filter network?

A. Diodes
B. Transformers and transducers
C. Quartz crystals
➡ D. Capacitors and inductors

G7A03 -- What is the peak-inverse-voltage across the rectifiers in a full-wave bridge power supply?

A. One-quarter the normal output voltage of the power supply
B. Half the normal output voltage of the power supply
C. Double the normal peak output voltage of the power supply
➡ D. Equal to the normal peak output voltage of the power supply

G7A04 -- What is the peak-inverse-voltage across the rectifier in a half-wave power supply?

A. One-half the normal peak output voltage of the power supply

B. One-half the normal output voltage of the power supply

C. Equal to the normal output voltage of the power supply

➡ D. Two times the normal peak output voltage of the power supply

G7A05 -- What portion of the AC cycle is converted to DC by a half-wave rectifier?

A. 90 degrees

➡ B. 180 degrees

C. 270 degrees

D. 360 degrees

G7A06 -- What portion of the AC cycle is converted to DC by a full-wave rectifier?

A. 90 degrees
B. 180 degrees
C. 270 degrees
➡ D. 360 degrees

G7A07 -- What is the output waveform of an unfiltered full-wave rectifier connected to a resistive load?

➡ A. A series of DC pulses at twice the frequency of the AC input
B. A series of DC pulses at the same frequency as the AC input
C. A sine wave at half the frequency of the AC input
D. A steady DC voltage

G7A08 -- Which of the following is an advantage of a switch-mode power supply as compared to a linear power supply?

A. Faster switching time makes higher output voltage possible

B. Fewer circuit components are required

➡ C. High frequency operation allows the use of smaller components

D. All of these choices are correct

Basic Test Equipment

- Analog & Digital Meters
  - Multimeters.
    - a.k.a. – VOM, DVM, VTVM.
    - Accuracy expressed in % of full scale.
      - If accuracy is 2% of full scale on 100 mA scale, then accuracy is ±2 mA.
    - Resolution expressed in digits.
      - Typically 3½ digits (0.000 to 1.999)
      - 3½ digit → 0.05% resolution.
    - **DO NOT CONFUSE RESOLUTION WITH ACCURACY!**

Basic Test Equipment

- Analog & Digital Meters
  - For most accurate results, meters should have little or no effect on the value being measured.
    - A voltmeter should have the highest input impedance as possible.
    - An ammeter should have the lowest series resistance as possible.

Basic Test Equipment

- Analog & Digital Meters
  - Multimeters.
    - Analog.
      - D'Arsonval movement.
        - Rotating coil suspended between permanent magnets.
        - When current flows in coil, coil rotates moving needle across scale.
        - Coil impedance affects accuracy.
      - Sensitivity expressed in Ohms/Volt.
        - 20,000 Ω/V = very good analog voltmeter.

Basic Test Equipment

- Analog & Digital Meters
  - Multimeters
    - Vacuum Tube Voltmeters.
      - D'Arsonval movement.
      - Used vacuum tube amplifier to improve sensitivity.
        - Typically 10 megΩ/V or greater.

Basic Test Equipment

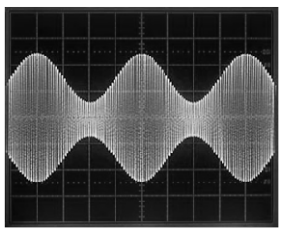
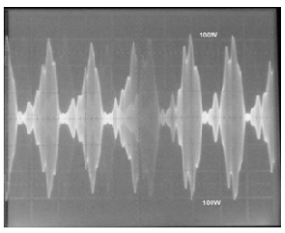
- Analog & Digital Meters
  - Multimeters
    - Digital Meters.
      - Uses high input impedance FET amplifier to improve sensitivity.
        - Typically 10 MΩ/V or greater.
      - Uses internal microprocessor to perform measurement calculations.

Basic Test Equipment

- Analog & Digital Meters
  - Analog Meters.
    - Faster response times
    - Easier to use when adjusting a circuit.
      - e.g., Tuning an amplifier.
  - Digital Meters.
    - Higher sensitivity.
    - Higher resolution.

Basic Test Equipment

- The Oscilloscope
  - Real-time display of rapidly-changing audio or RF signals.
    - Keying waveform of CW signal.
  - Voltage measurements of complex waveforms.

Basic Test Equipment

- The Oscilloscope
  - Displays voltage versus time.
    - Signal applied to vertical deflection plates.
    - Sawtooth waveform from a time base applied to horizontal deflection plates.
  - Bandwidth of vertical amplifier determines highest frequency signal that can be displayed.
  - Sometimes 2 or more vertical amplifiers.
    - Allows displaying multiple signals simultaneously.

Basic Test Equipment

- Signal Generators
  - Generate accurate signals.
    - Precise amplitude.
    - Different waveforms.
      - Sine wave.
      - Square wave.
      - Sawtooth wave.
      - Pulse train.

Basic Test Equipment

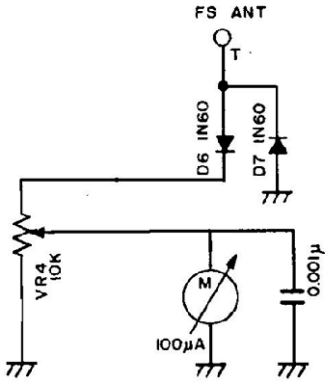
- Signal Generators
  - Service Monitors
    - Equipment designed for testing communications equipment.
      - Signal generator.
        - Precise voltage.
        - Precise frequency.
        - AM modulation.
        - FM modulation.
      - Frequency counter.
      - Power meter.
      - Dummy load.

Basic Test Equipment

- Impedance & Resonance Measurements
  - Antenna Analyzer.
    - Impedance.
      - Resistance.
      - Reactance.
    - Standing-wave-ratio (SWR).
    - Cable velocity factor.
    - Cable electrical length.
    - Distance to fault.
    - Susceptible to interference from strong nearby transmitters.

Basic Test Equipment

- Field Strength & RF Power Meters
  - Field Strength Meters.
    - Measures relative strength of RF field.
    - Determine antenna pattern.
    - Close-in direction finding.



Basic Test Equipment

- Field Strength & RF Power Meters
  - RF Power Meters.
    - Directional Wattmeter.
      - Measure forward power.
      - Measure reflected power.
      - Calculate SWR.

G4B01 -- What item of test equipment contains horizontal and vertical channel amplifiers?

A. An ohmmeter
B. A signal generator
C. An ammeter
➡ D. An oscilloscope

G4B02 -- Which of the following is an advantage of an oscilloscope versus a digital voltmeter?

A. An oscilloscope uses less power
B. Complex impedances can be easily measured
C. Input impedance is much lower
➡ D. Complex waveforms can be measured

G4B03 -- Which of the following is the best instrument to use when checking the keying waveform of a CW transmitter?

➡ A. An oscilloscope

B. A field-strength meter

C. A sidetone monitor

D. A wavemeter

G4B04 -- What signal source is connected to the vertical input of an oscilloscope when checking the RF envelope pattern of a transmitted signal?

A. The local oscillator of the transmitter

B. An external RF oscillator

C. The transmitter balanced mixer output

➡ D. The attenuated RF output of the transmitter

G4B05 -- Why is high input impedance desirable for a voltmeter?

A. It improves the frequency response
B. It decreases battery consumption in the meter
C. It improves the resolution of the readings
➡ D. It decreases the loading on circuits being measured

G4B06 -- What is an advantage of a digital voltmeter as compared to an analog voltmeter?

A. Better for measuring computer circuits
B. Better for RF measurements
➡ C. Better precision for most uses
D. Faster response

G4B08 -- Which of the following instruments may be used to monitor relative RF output when making antenna and transmitter adjustments?

➡ A. A field-strength meter

B. An antenna noise bridge

C. A multimeter

D. A Q meter

G4B09 -- Which of the following can be determined with a field strength meter?

A. The radiation resistance of an antenna

➡ B. The radiation pattern of an antenna

C. The presence and amount of phase distortion of a transmitter

D. The presence and amount of amplitude distortion of a transmitter

G4B10 -- Which of the following can be determined with a directional wattmeter?

➡ A. Standing wave ratio

B. Antenna front-to-back ratio

C. RF interference

D. Radio wave propagation

G4B11 -- Which of the following must be connected to an antenna analyzer when it is being used for SWR measurements?

A. Receiver

B. Transmitter

➡ C. Antenna and feed line

D. All of these choices are correct

G4B12 -- What problem can occur when making measurements on an antenna system with an antenna analyzer?

A. Permanent damage to the analyzer may occur if it is operated into a high SWR

➡ B. Strong signals from nearby transmitters can affect the accuracy of measurements

C. The analyzer can be damaged if measurements outside the ham bands are attempted

D. Connecting the analyzer to an antenna can cause it to absorb harmonics

G4B13 -- What is a use for an antenna analyzer other than measuring the SWR of an antenna system?

A. Measuring the front to back ratio of an antenna

B. Measuring the turns ratio of a power transformer

➡ C. Determining the impedance of an unknown or unmarked coaxial cable

D. Determining the gain of a directional antenna

G4B14 -- What is an instance in which the use of an instrument with analog readout may be preferred over an instrument with a numerical digital readout?

A. When testing logic circuits
B. When high precision is desired
C. When measuring the frequency of an oscillator
➡ D. When adjusting tuned circuits

Questions?

Next Week

Chapter 5

Radio Signals & Equipment