General License Class

1

General License Class

Chapter 4
Components & Circuits (Part 2)

2

Active Components

Passive Components

- Passive components.
  - Resistors, capacitors, & inductors.
  - Require no external power to function.
  - Simply react to the applied signal.
- Active components.
  - Semiconductors & vacuum tubes.
  - Usually require an external power source.
  - Can modify the applied signal.

3

Active Components

Semiconductor Components

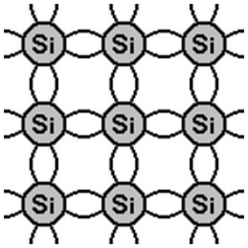
- Semiconductors are materials that do not conduct as well as metals, but better than insulators.
  - Can modify properties by adding controlled amounts of other materials called “dopants”.
- Atomic Structure
  - Nucleus (Protons & Neutrons)
  - Electrons
    - Orbits (Shells)
    - 8 electrons completes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

4

Active Components

Semiconductor Components

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

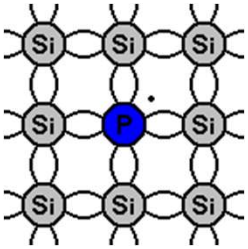


5

Active Components

Semiconductor Components

- N-type Material.
  - Add an element with 5 electrons in the outer shell (donor Impurity).
    - Arsenic.
    - Antimony.
    - Phosphorus.

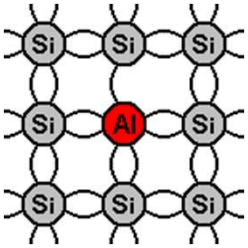


6

Active Components

Semiconductor Components

- P-type material.
  - Add an element with 3 electrons in the outer shell (acceptor Impurity).
    - Aluminum.
    - Gallium.
    - Indium.



7

Active Components

Semiconductor Components

- Majority Charge Carrier.
  - N-type material = electron.
  - P-type material = hole.

8

Active Components

Semiconductor Components

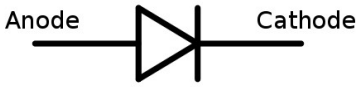
- Other semiconductor materials.
  - Gallium-Arsenide (GaAs).
    - LED's.
    - Microwave frequencies.
  - Gallium-Arsenide-Phosphide (GaAsP).
    - LED's.

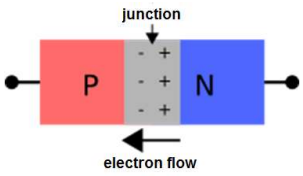
9

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.





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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.

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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 often called “rectifiers”.
    - Maximum reverse voltage as high as 1000 V.
    - Maximum forward current as high as 200 A or more.

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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.

13

Active Components

Semiconductor Components

- Diodes & Rectifiers.
  - Diode Ratings
    - Forward Voltage Drop.
      - Silicon = 0.7 Volts (approx.)
      - Germanium = 0.3 Volts (approx.)
      - GaAs & GaAsP = 1.2 Volts to 1.5 Volts (approx.)

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Active Components

Semiconductor Components

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

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Active Components

Semiconductor Components

- Diodes & Rectifiers.
  - Diode Types.
    - Schottky Diode.
      - Low junction capacitance allows operation at VHF & UHF.
      - Lower forward voltage drop.
        - Used as power supply rectifiers.

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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.

17

Active Components

Semiconductor Components

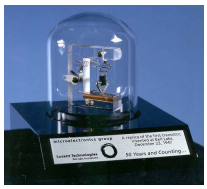
- Diodes & Rectifiers
  - Diode Types
    - Zener diode.
      - Operates with reverse bias at the avalanche (breakdown) voltage.
      - Designed to withstand the avalanche current with a proper heat sink.
      - Used as voltage regulators.
        - A large change in the avalanche current results in only a small change in the voltage.

18

Active Components

Semiconductor Components

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



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Active Components

Semiconductor Components

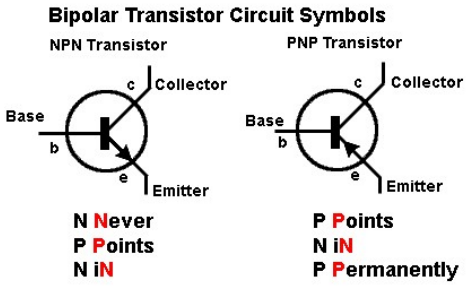
- Bipolar Transistors.
  - Changing the amount of current (small) flowing through the base-emitter junction controls the amount of current (large) flowing from the collector to the emitter.
  - Bipolar transistors exhibit current gain.
    - $\beta = I_C / I_B$
    - $\alpha = I_C / I_E$

20

Active Components

Semiconductor Components

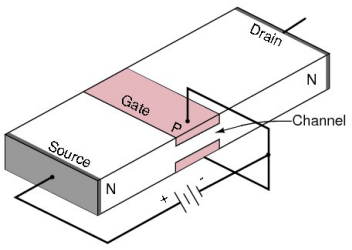
- Bipolar Transistors.



21

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

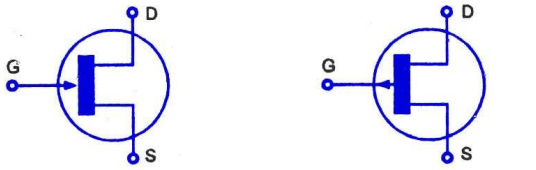


22

Active Components

Semiconductor Components

- Field-Effect Transistors.
  - Junction Field-Effect Transistor (JFET)



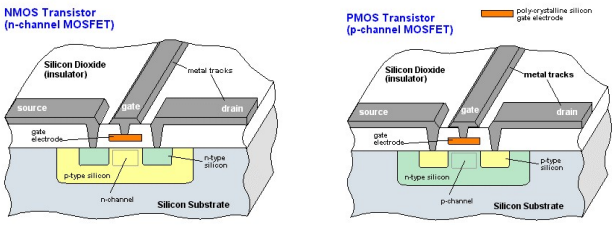
N-Channel JFET *P-Channel JFET*

23

Active Components

Semiconductor Components

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



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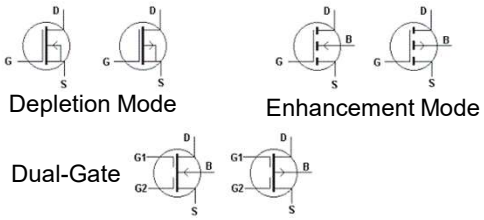
Active Components

Semiconductor Components

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



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Active Components

Semiconductor Components

- Bipolar & Field-Effect Transistors
  - Both bipolar transistors & FET's can be used 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.

Assuming enhancement-mode FET.

26

Active Components

Semiconductor Components

- Bipolar & Field-Effect Transistors.
  - 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.

27

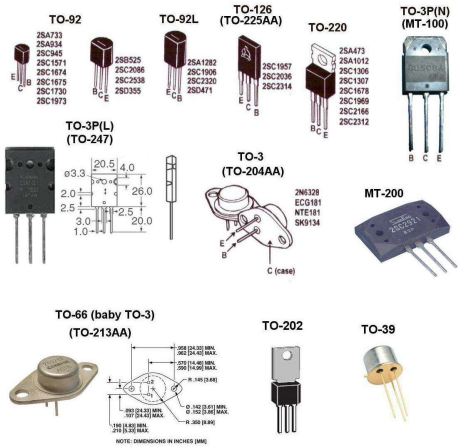
Active Components

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.**

28

Active Components



29

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

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

30

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

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

31

G6A07 -- What are the operating points for a bipolar transistor used as a switch?

A. Saturation and cutoff
B. The active region (between cutoff and saturation)
C. Peak and valley current points
D. Enhancement and depletion modes

32

G6A09 -- Which of the following describes MOSFET construction?

A. The gate is formed by a back-biased junction

B. The gate is separated from the channel by a thin insulating layer

C. The source is separated from the drain by a thin insulating layer

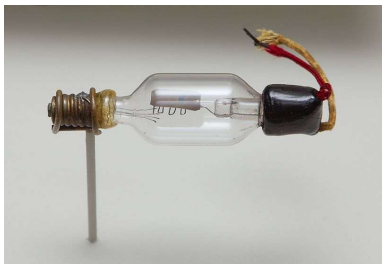
D. The source is formed by depositing metal on silicon

33

Active Components

Vacuum Tubes

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



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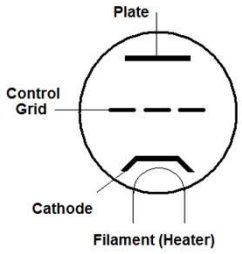
Active Components

Vacuum Tubes

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



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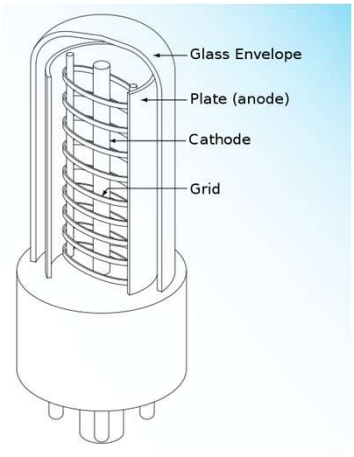
Active Components

Vacuum Tubes

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

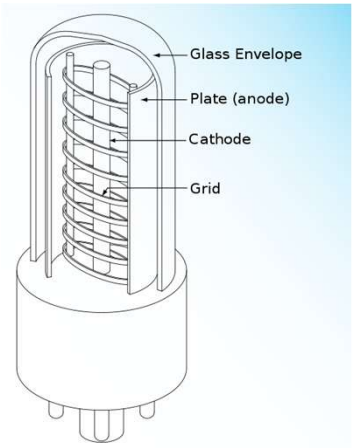


36

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.



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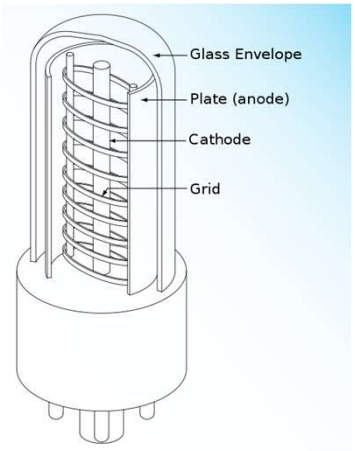
Active Components

Vacuum Tubes

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



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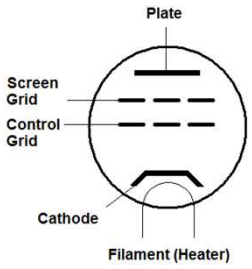
Active Components

Vacuum Tubes

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



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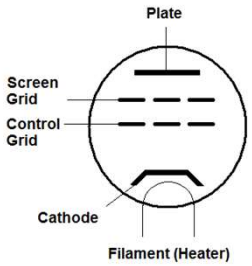
Active Components

Vacuum Tubes

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



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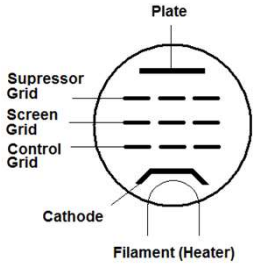
Active Components

Vacuum Tubes

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



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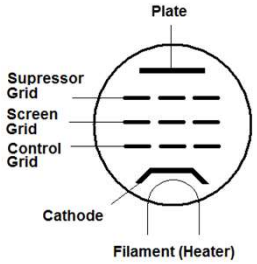
Active Components

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.



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Active Components

Vacuum Tubes






43

G6A10 -- Which element of a vacuum tube regulates the flow of electrons between cathode and plate?

A. Control grid
B. Suppressor grid
C. Screen grid
D. Trigger electrode

44

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

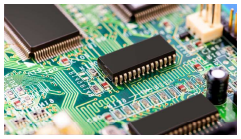
A. To reduce grid-to-plate capacitance
B. To increase efficiency
C. To increase the control grid resistance
D. To decrease plate resistance

45

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” or “IC”.



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Active Components

Analog & Digital Integrated Circuits

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

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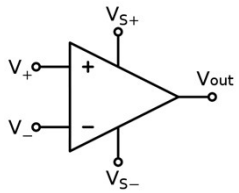
Active Components

Analog & Digital Integrated Circuits

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



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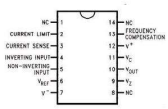
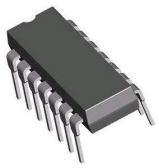
Active Components

Analog & Digital Integrated Circuits

- Analog integrated circuits.
  - Linear Voltage Regulators.
    - LM-723.
      - External Components required.





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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.

50

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.

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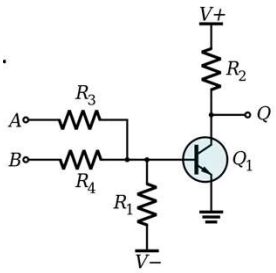
Active Components

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.



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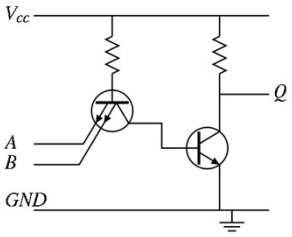
Active Components

Analog & Digital Integrated Circuits

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



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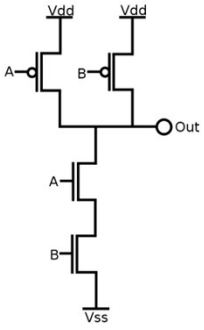
Active Components

Analog & Digital Integrated Circuits

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



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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.

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Active Components

Analog & Digital Integrated Circuits

- Digital Logic Basics.
  - One-input elements.
    - Non-inverting buffer.
    - Inverting buffer or "Not" gate.

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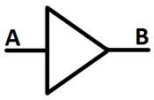
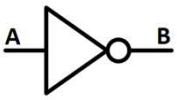
Active Components

Analog & Digital Integrated Circuits

- Buffer & Inverting Buffer (NOT gate).



A	B
0	0
1	1



A	B
0	1
1	0

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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.

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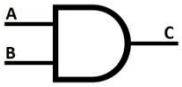
Active Components

Analog & Digital Integrated Circuits

- AND gate and NAND gate.



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

59

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.

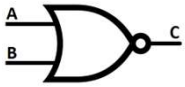
60

Active Components

Analog & Digital Integrated Circuits

- OR gate and NOR gate.

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

61

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.

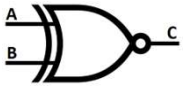
62

Active Components

Analog & Digital Integrated Circuits

- XOR gate and XNOR gate.

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

63

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”.

64

Active Components

Analog & Digital Integrated Circuits

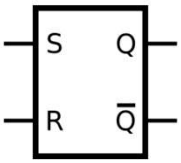
- Digital Logic Basics.
  - Flip-flop
    - a.k.a -- Bi-stable multivibrator, latch.
    - Several different types.
      - S-R, J-K, D, T.
      - Gated, non-gated.
      - Clocked, non-clocked.
    - Can be used as frequency divider.
    - Can be used as frequency counter.

65

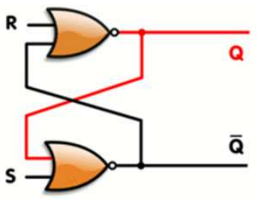
Active Components

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



66

Active Components

Analog & Digital Integrated Circuits

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

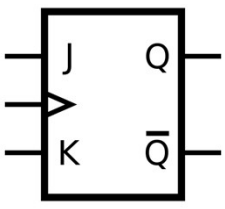
67

Active Components

Analog & Digital Integrated Circuits

- Digital Logic Basics.
  - J-K flip-flop.

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)

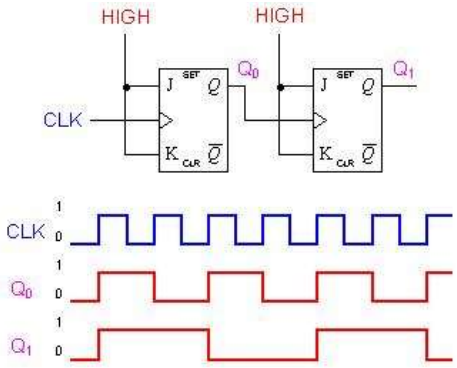


68

Active Components

Analog & Digital Integrated Circuits

- Digital Logic Basics
  - Frequency divider.



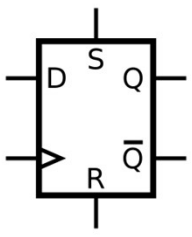
69

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

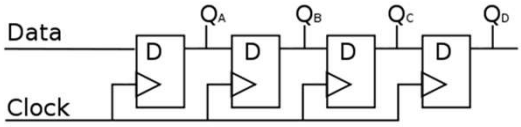


70

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.



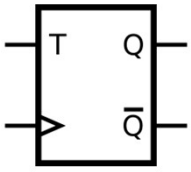
71

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)

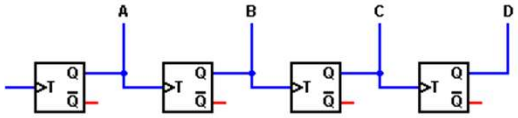


72

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.

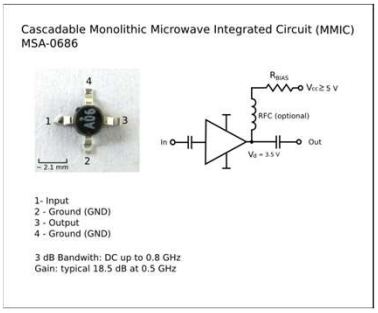


73

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.



74

G6B02 -- What is meant by the term MMIC?

A. Multi-Mode Integrated Circuit
B. Monolithic Microwave Integrated Circuit
C. Metal Monolayer Integrated Circuit
D. Mode Modulated Integrated Circuit

75

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

76

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

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

77

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

78

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

A. 3
B. 6
C. 8
D. 16

79

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

80

Active Components

Microprocessors & Related Components

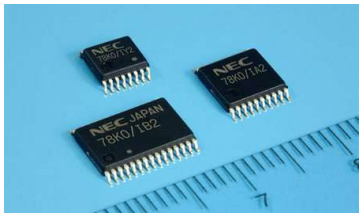
- Microprocessor.
  - A computer on a chip.
    - Thousands of gates.
    - Tens of thousands of transistors & diodes.

81

Active Components

Microprocessors & Related Components

- Microcontroller.
  - Microprocessor with added interfaces to input & output devices.

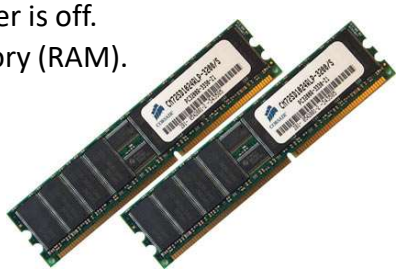


82

Active Components

Microprocessors & Related Components

- Memory.
  - Volatile.
    - Data is lost when power is off.
    - Random Access Memory (RAM).



83

Active Components

Microprocessors & Related Components

- Memory.
  - Non-Volatile.
    - Data is retained when power is off.
    - Read-Only Memory (ROM).
    - Programmable Read-Only Memory (PROM).

84

Active Components

Microprocessors & Related Components

- Memory.
  - Non-Volatile.
    - Erasable Programmable Read-Only Memory (EPROM).
    - Electrically Erasable Programmable Read-Only Memory (EEPROM).

85

Active Components

Microprocessors & Related Components

- Interfaces.
  - Serial interfaces.
    - One bit transferred at a time.
    - RS-232 (COM ports).
      - Commonly used to connect amateur transceivers to personal computers.
      - Becoming obsolete.

86

Active Components

Microprocessors & Related Components

- Interfaces.
  - Serial interfaces.
    - Universal Serial Bus (USB).
      - Replacing RS-232.
      - Commonly used to connect amateur transceivers to personal computers.
    - Ethernet.

87

Active Components

Microprocessors & Related Components

- Data Interfaces.
  - Common serial interfaces.

Interface Type	Maximum Data Transfer Speed
RS-232	115 kilobits/second
USB 1.0	1.5 megabits/second
USB 2.0	480 megabits/second
USB 3.0	5 gigabits/second
Firewire	800 megabits/second

88

Active Components

Microprocessors & Related Components

- Interfaces.
  - Parallel interfaces.
    - 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.

89

Active Components

Microprocessors & Related Components

- Visual Interfaces.
  - Indicator.
    - Displays on/off state of a single item.
    - Incandescent Lamp.
      - Largely replaced by LED's.

90

Active Components

Microprocessors & Related Components

- Visual Interfaces.
  - Indicator.
    - 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.

91

Active Components

Microprocessors & Related Components

- Visual Interfaces.
  - Indicator.
    - Light-Emitting-Diode (LED).

92

Active Components

Visual Interfaces

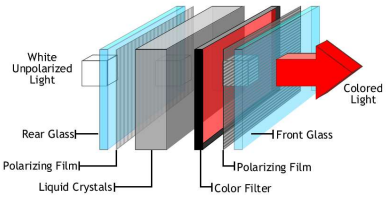
- Display.
  - Displays text or graphical information.
  - Most common type in amateur equipment is the liquid crystal display (LCD).
    - Requires illumination.
      - Ambient light.
      - Back light.

93

Active Components

Visual Interfaces.

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



94

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

A. In the tunnel-effect region
B. At the Zener voltage
C. Reverse biased
D. Forward biased

95

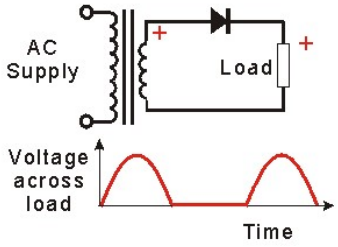
Break

96

Practical Circuits

Rectifiers & Power Supplies

- Rectifier Circuits.
  - Half-Wave Rectifier.
    - Only one-half of the cycle (180°) delivers power to the load.

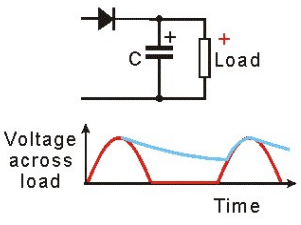


97

Practical Circuits

Rectifiers & Power Supplies

- Rectifier Circuits.
  - Half-Wave Rectifier.
    - 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 $I_{Max} \geq I_{Load}$

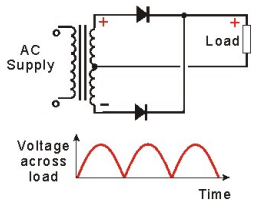


98

Practical Circuits

Rectifiers & Power Supplies

- Rectifier Circuits.
  - Full-Wave Rectifier.
    - The entire cycle (360°) delivers power to the load.

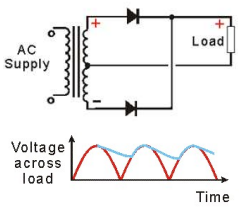


99

Practical Circuits

Rectifiers & Power Supplies

- Rectifier Circuits.
  - Full-Wave Rectifier.
    - 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 $I_{Max} \geq 0.5 \times I_{Load}$

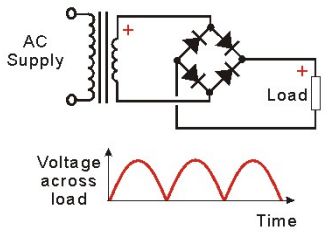


100

Practical Circuits

Rectifiers & Power Supplies

- Rectifier Circuits.
  - Full-Wave Bridge Rectifier.
    - The entire cycle (360°) delivers power to the load.

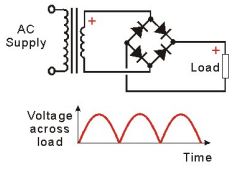


101

Practical Circuits

Rectifiers & Power Supplies

- Rectifier Circuits.
  - Full-Wave Bridge Rectifier.
    - 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 $I_{Max} \geq 0.5 \times I_{Load}$



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Practical Circuits

Rectifiers & Power Supplies

- Rectifier Circuits.

Type of Circuit	Diode PIV Rating	Diode Current Rating
Half-Wave Rectifier	≥ 2 x V_P	≥ I_{Load}
Full-Wave Center-Tapped	≥ 2 x V_P	≥ 0.5 x I_{Load}
Full-Wave Bridge	≥ V_P	≥ 0.5 x I_{Load}

103

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.

104

Practical Circuits

Rectifiers & Power Supplies

- Rectifier Circuits.
  - 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.

105

Practical Circuits

Rectifiers & Power Supplies

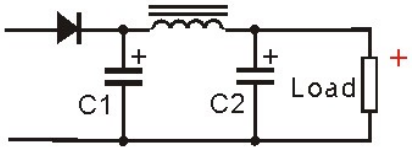
- Power Supply Filter Circuits.
  - The output from a rectifier is a series of pulses unsuitable for operating electronic equipment.
  - Need a filter after the rectifier to smooth pulses into a steady DC voltage.
    - A low-pass filter with a cut-off frequency well below the frequency of the pulses.
      - Half-wave rectifier → 60 Hz pulses.
      - Full-wave rectifier → 120 Hz pulses.

106

Practical Circuits

Rectifiers & Power Supplies

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



107

Practical Circuits

Rectifiers & Power Supplies

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

108

Practical Circuits

Rectifiers & Power Supplies

- Power Supply Filter Circuits.
  - Choosing the inductor.
    - Large inductance.
    - Low series resistance.
    - Not always used.
      - A capacitor alone may provide sufficient filtering, especially if the load is a voltage regulator.

109

Practical Circuits

Rectifiers & Power Supplies

- Power Supply Safety.
  - **EVERY** power supply should have:
    - A fuse in the AC input line.
    - An on/off switch in the AC input line.
    - A bleeder resistor.
      - A high value resistor connected across the output of the power supply.
      - Discharges the filter capacitors when power is removed.

110

Practical Circuits

Rectifiers & Power Supplies

- Switchmode or Switching Power Supplies.
  - The AC input voltage is rectified & fed to a solid-state oscillator.
  - The oscillator generates series of high-frequency pulses.
    - 20 kHz or greater.

111

Practical Circuits

Rectifiers & Power Supplies

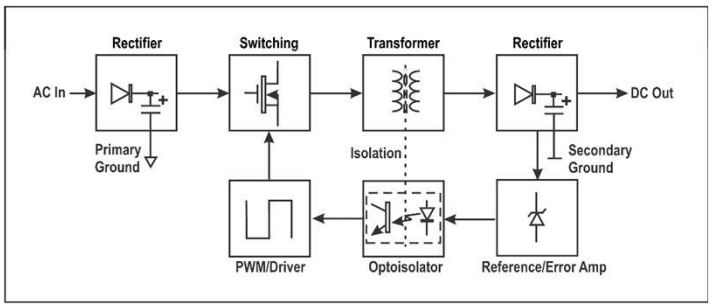
- Switchmode or Switching Power Supplies.
  - The pulses are applied to the primary winding of a transformer.
  - The output from the secondary winding is rectified, filtered, & sent to the load.
  - The output voltage regulated by varying the width of the pulses fed to the transformer.

112

Practical Circuits

Rectifiers & Power Supplies

- Switchmode or Switching Power Supplies.



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Practical Circuits

Rectifiers & Power Supplies

- Switchmode or Switching Power Supplies.
  - The high switching frequency allows:
    - The use of a much smaller transformer.
    - The use of much smaller capacitors.
    - The use of much smaller inductors.
    - A rapid response to load changes.

114

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.

115

G7A01 -- What is the function of a power supply bleeder resistor?

A. It acts as a fuse for excess voltage

B. It discharges the filter capacitors when power is removed

C. It removes shock hazards from the induction coils

D. It eliminates ground loop current

116

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

A. Diodes
B. Transformers and transducers
C. Capacitors and inductors
D. All these choices are correct

117

G7A03 -- Which type of rectifier circuit uses two diodes and a center-tapped transformer?

A. Full-wave
B. Full-wave bridge
C. Half-wave
D. Synchronous

118

G7A04 -- What is characteristic of a half-wave rectifier in a power supply?

A. Only one diode is required
B. The ripple frequency is twice that of a full-wave rectifier
C. More current can be drawn from the half-wave rectifier
D. The output voltage is two times the peak output voltage of the transformer

119

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

120

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

121

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

122

G7A08 -- Which of the following is characteristic of a switchmode power supply as compared to a linear power supply?

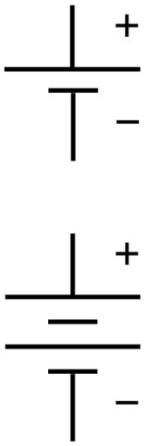
A. Faster switching time makes higher output voltage possible
B. Fewer circuit components are required
C. High-frequency operation allows the use of smaller components
D. Inherently more stable

123

Practical Circuits

Batteries & Chargers

- Batteries.
  - Batteries produce energy by an electrochemical reaction.
  - Batteries are used by amateurs for:
    - Hand-Held operations.
    - Portable operations.
    - Mobile operations.
    - Emergency operations.



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Practical Circuits

Batteries & Chargers

- Batteries.
  - There are two different categories of batteries:
    - Primary.
      - Electrochemical reaction is **not** reversible.
      - Battery **cannot** be recharged.
    - Secondary.
      - Electrochemical reaction **is** reversible.
      - Battery **can** be recharged.

125

Practical Circuits

Batteries & Chargers

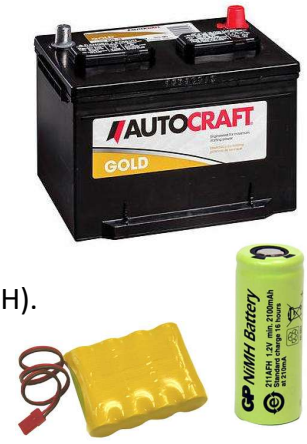
- Batteries.
  - Primary.
    - Examples:
      - Carbon-Zinc
      - Alkaline.
      - Silver-Nickel.
      - Lithium.
      - Silver-Oxide.

126

Practical Circuits

Batteries & Chargers

- Batteries.
  - Secondary.
    - Examples:
      - Lead-Acid.
      - Nickel-Cadmium (NiCad).
      - Nickel-Metal-Hydride (NiMH).
      - Lithium-Ion (Li-Ion).



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Practical Circuits

Batteries & Chargers

- Batteries.
  - Should be discharged at a low rate.
    - Less internal heating.
    - NiCad & NiMH batteries have low internal resistance & are designed for high discharge currents.

128

Practical Circuits

Batteries & Chargers

- Batteries.
  - 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.

129

Practical Circuits

Batteries & Chargers

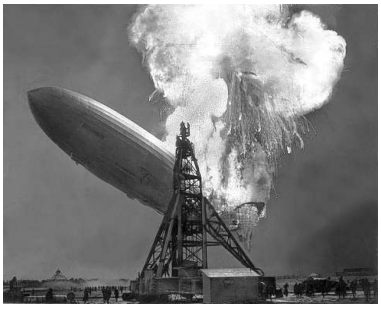
- Charging Batteries.
  - **NEVER** attempt to recharge a primary-cell battery.
  - **ALWAYS** use correct charger.
    - NiCad & NiMH batteries are charged with constant current until voltage rises to specified value.
    - Lead-Acid batteries are charged with constant voltage until current drops to specified value.

130

Practical Circuits

Batteries & Chargers

- Charging Batteries.
  - **ALWAYS** provide proper ventilation.
    - Lead-Acid batteries produce hydrogen gas during charging. **(Remember the Hindenburg!)**



131

Practical Circuits

Alternative Power

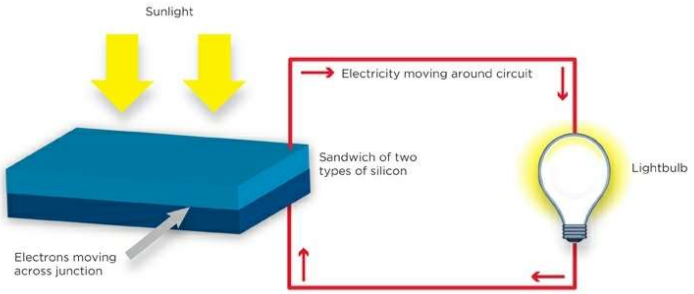
- Solar Power.
  - Photovoltaic conversion.
    - If sufficient light falls on a P-N junction, free electrons in the N-type material will absorb energy & flow across the junction into the P-type material producing an electric current.

132

Practical Circuits

Alternative Power

- Solar Power



133

Practical Circuits

Alternative Power

- Solar Power.
  - Solar cells.
    - The most common material is Silicon.
    - The most efficient material is Gallium-Arsenide.
    - A fully-illuminated junction yields about 0.5 VDC.
    - Solar cell can produce almost 1 kW/m^2.
    - Solar power is rapidly becoming commercially viable for power generation.

134

Practical Circuits

Alternative Power

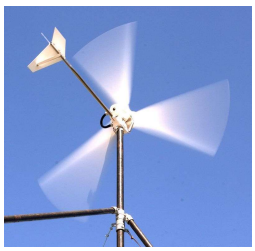
- Solar Power.
  - Solar panels.
    - To create a solar panel, individual cells are connected in series to produce the desired output voltage and then connected in parallel to provide the desired output current.

135

Practical Circuits

Alternative Power

- Wind Power
  - A DC generator attached to a propeller.



136

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.

137

Practical Circuits

Alternative Power

- Energy Storage.
  - Storage batteries are most commonly used.
  - A solar system must have a diode in series between the solar panel & the batteries to prevent discharging batteries back through the panel during low-light conditions.

138

Practical Circuits

Alternative Power

- Energy Storage.
  - A solar system using lithium-ion phosphate batteries for storage must use a charge controller to prevent over-charging the batteries.
    - Over-charging can create a safety hazard.
    - Over-charging can cause battery damage.
    - Over-charging can shorten battery life.

139

G4E08 -- In what configuration are the individual cells in a solar panel connected together?

A. Series-parallel
B. Shunt
C. Bypass
D. Full-wave bridge

140

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

141

G4E10 -- Why should a series diode be connected between a solar panel and a storage battery that is being charged by the panel?

A. To prevent overload by regulating the charging voltage
B. To prevent discharge of the battery through the panel during times of low or no illumination
C. To limit the current flowing from the panel to a safe value
D. To prevent damage to the battery due to excessive voltage at high illumination levels

142

G4E11 -- What precaution should be taken when connecting a solar panel to a lithium iron phosphate battery?

A. Ground the solar panel outer metal framework
B. Ensure the battery is placed terminals-up
C. A series resistor must be in place
D. The solar panel must have a charge controller

143

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

144

G6A02 -- What is an advantage of batteries with low internal resistance?

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

145

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”.

146

Practical Circuits

Connectors

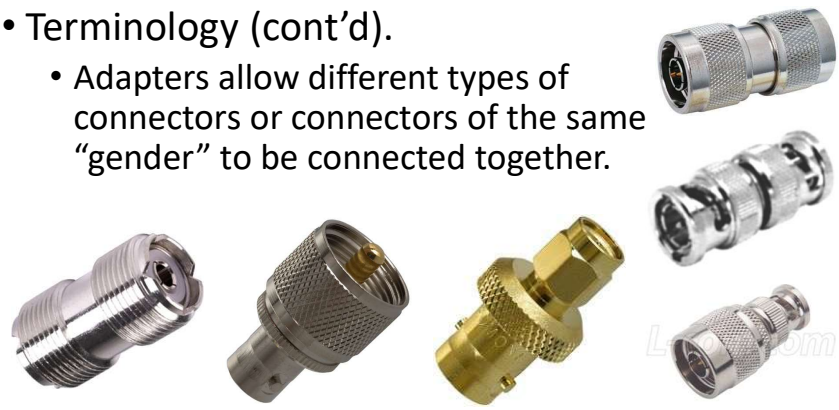
- Terminology (cont'd).
  - Connectors with specially-shaped bodies or pin/socket arrangements are call "keyed connectors".
    - Keyed connectors avoid damage caused by mis-mating connectors.
  - Plugs = Connectors installed on ends of cables.
  - Jacks = Connectors installed on equipment.

147

Practical Circuits

Connectors

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



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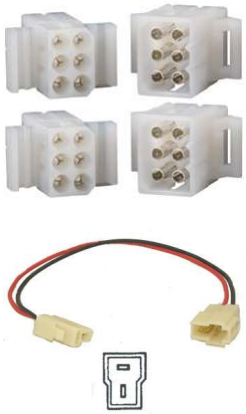
Practical Circuits

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



149

Practical Circuits

Connectors

- Power Connectors.
  - Coaxial Power Connectors.
    - Low current.
    - Commonly used on hand-held transceivers and station accessories.
      - Available with different diameter center pins.

150

Practical Circuits

Connectors

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

151

Practical Circuits

Connectors

- Power Connectors.
  - Terminal Strips.

152

Practical Circuits

Connectors

- Audio and Control Connectors.
  - Phone plugs & jacks (TRS connectors).
    - Audio.
    - Keys.
    - Control signals.

153

Practical Circuits

Connectors

- Audio and Control Connectors.
  - Phone plugs & jacks (TRS connectors).
    - Sizes:
      - Standard -- 1/4 ” (6.35 mm) dia.
      - Aircraft -- 0.206” dia. (Rare).
      - Miniature -- 1/8” (3.5 mm) dia.
      - Sub-miniature -- 3/32” (2.5 mm) dia.

154

Practical Circuits

Connectors

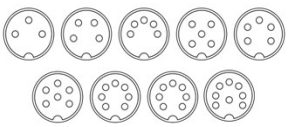
- Audio and Control Connectors.
  - RCA Phono plugs & jacks.
    - Audio.
    - Low-level RF.
    - Control Signals.

155

Practical Circuits

Connectors

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



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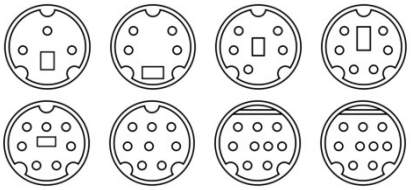
Practical Circuits

Connectors

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



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Practical Circuits

Connectors

- 8-pin round connector.
  - a.k.a. -- Foster connector.
  - Commonly used as a microphone connector.

158

Practical Circuits

Connectors

- RF Connectors.
  - UHF.
    - Plug = PL-259.
    - Socket = SO-239.
    - ≤ 150 MHz.
    - ≥ 1.5 kW.
    - ≤ 500 V_{Peak}.

159

Practical Circuits

Connectors

- RF Connectors.
  - UHF.
    - Non-constant impedance.
    - Not weather resistant.
    - Relatively inexpensive.

160

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.

161

Practical Circuits

Connectors

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

162

Practical Circuits

Connectors

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

163

Practical Circuits

Connectors

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

164

Practical Circuits

Connectors

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

165

G6B04 -- What is a typical upper frequency limit for low SWR operation of 50-ohm BNC connectors?

A. 50 MHz
B. 500 MHz
C. 4 GHz
D. 40 GHz

166

G6B07 -- 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 low noise figure VHF connector
D. A nickel plated version of the PL-259

167

G6B11 -- What is an SMA connector?

A. A type-S to type-M adaptor
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

168

G6B12 -- Which of these connector types is commonly used for low frequency or dc signal connections to a transceiver?

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

169

Basic Test Equipment

Analog & Digital Meters

- Multimeters.
  - a.k.a. – VOM, DVM, DMM, VTVM.
  - Measures:
    - Voltage.
    - Current.
    - Resistance.

170

Basic Test Equipment

Analog & Digital Meters

- Multimeters.
  - 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!**



171

Basic Test Equipment

Analog & Digital Meters

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



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Basic Test Equipment

Analog & Digital Meters

- Multimeters.
  - Analog.
    - D'Arsonval movement.
      - Rotating coil suspended between 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.

173

Basic Test Equipment

Analog & Digital Meters

- Multimeters.
  - Analog.

174

Basic Test Equipment

Analog & Digital Meters

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

175

Basic Test Equipment

Analog & Digital Meters

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

176

Basic Test Equipment

Analog & Digital Meters

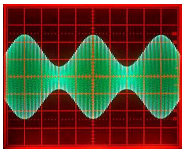
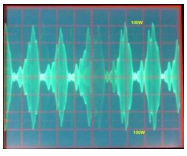
- Analog Meters.
  - Faster response times
  - Easier to use when adjusting a circuit.
    - e.g., Tuning an amplifier.
- Digital Meters.
  - Higher sensitivity.
  - Higher resolution.

177

Basic Test Equipment

Oscilloscope

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

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Basic Test Equipment

Oscilloscope

- Displays voltage versus time.
  - The signal to be displayed is applied to the vertical deflection plates.
  - A sawtooth waveform from a time base is applied to the horizontal deflection plates.

179

Basic Test Equipment

Oscilloscope

- The bandwidth of the vertical amplifier determines the highest frequency signal that can be displayed.
- Sometimes there are 2 or more vertical amplifiers.
  - Allows displaying multiple signals simultaneously.

180

Basic Test Equipment

Impedance & Resonance Measurements

- Antenna analyzer.
  - Measures:
    - Impedance.
      - Resistance.
      - Reactance.
    - Standing-wave-ratio (SWR).

181

Basic Test Equipment

Impedance & Resonance Measurements

- Antenna analyzer.
  - Can also measure:
    - Cable velocity factor.
    - Cable electrical length.
    - Distance to fault.
  - Susceptible to interference from strong nearby transmitters.

182

Basic Test Equipment

Field Strength & RF Power Meters

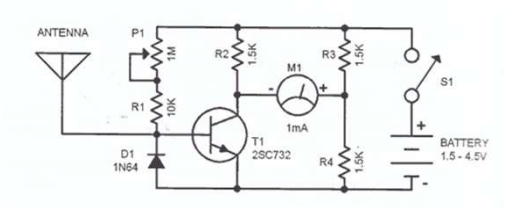
- Field Strength Meters.
  - Measures relative strength of RF field.
  - Determine antenna pattern.
  - Close-in direction finding.

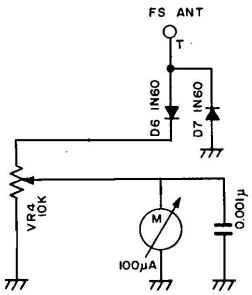
183

Basic Test Equipment

Field Strength & RF Power Meters

- Field Strength Meters.





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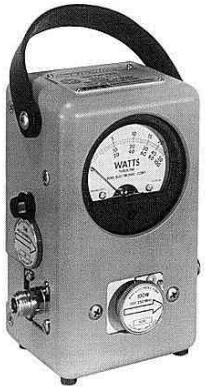
Basic Test Equipment

Field Strength & RF Power Meters

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



185

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

186

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. Greater precision
D. Complex waveforms can be measured

187

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

A. An oscilloscope
B. A field strength meter
C. A sidetone monitor
D. A wavemeter

188

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

189

G4B05 -- Why do voltmeters have high input impedance?

A. It improves the frequency response
B. It allows for higher voltages to be safely measured
C. It improves the resolution of the readings
D. It decreases the loading on circuits being measured

190

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

A. Better for measuring computer circuits
B. Less prone to overload
C. Higher precision
D. Faster response

191

G4B09 -- When is an analog multimeter preferred to a digital multimeter?

A. When testing logic circuits
B. When high precision is desired
C. When measuring the frequency of an oscillator
D. When adjusting circuits for maximum or minimum values

192

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

193

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 these choices are correct

194

G4B12 -- What effect can strong signals from nearby transmitters have on an antenna analyzer?

A. Desensitization which can cause intermodulation products which interfere with impedance readings

B. Received power that interferes with SWR readings

C. Generation of harmonics which interfere with frequency readings

D. All these choices are correct

195

G4B13 -- Which of the following can be measured with an antenna analyzer?

A. Front-to-back ratio of an antenna

B. Power output from a transmitter

C. Impedance of coaxial cable

D. Gain of a directional antenna

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Questions?

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General License Class

Next Week
Chapter 5

Radio Signals & Equipment

198