Electronics 101

NANT

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Electricity is intimidating because…

- Human aren’t equipped to detect it …until it’s to late !
- You have five senses:
  - See (10,000 volts)
  - Hear (5,000 volts)
  - Taste (???)
  - Smell (ozone from movement in air)
  - Feel (a/c > 20 volts, static > 3,000 volts)
- Skin is your best protection if it’s dry.
- Electricity tends to flow on the outside of the body. The heart is mid-torso.

Basic Electron Characteristics

- The electron was "discovered" in 1897 by Sir J. J. Thompson (Noble prize – 1906)
- Electrons create an electrical field which can apply force on other charged particles in their vicinity.
  - Like charges repel
  - Opposite charges attract
- The measure of this force was done by Charles Coulomb in 1784. ($F = k\frac{qq''}{r^2}$)
- Electrons in motion create magnetic fields

Electrical Terminology

- Volt – measure of potential energy in an electric field. 1 volt = one joule of energy per one coulomb of charge. (1 watt = 1 joule/second)
  - Alessandro Volta (1745 – 1827)
  - Created the first chemical battery
- Coulomb – mks system's unit of charge. 1 coulomb of charge passing a point in a wire in 1 second equals one ampere. 1 coulomb = 6.24×10^{18} electrons
  - Charles Augustin Coulomb (1736 – 1806)

Electrical Terminology

– Ampere – The unit of current = a “flow rate” of one coulomb per second in a wire
  - Andre Marie Ampere (1775 – 1836)
  - Established the relationship between electricity and magnetism.
– Ohm – the unit of resistance = 1 ohm is the ratio of one volt/one ampere. The reciprocal of resistance is conductance.
  - Georg Simon Ohm (1789 – 1854)
  - Discovered the direct proportionality of current in a conductor to the voltage applied (V = IR, R = V/I, I = V/R)

Electrical Terminology

- Watt – Unit of power in the mks system. The rate of using energy. 1 watt equals 1 joule of energy per second. 1 watt = 1 volt x 1 ampere. $P = VI = I^2R = V^2/R$
  - James Watt (1736 – 1819)
  - Inventor of the first highly efficient steam engine
  - Developed the concept of horsepower
  - About your electric bill:
    - You purchase electricity (actually energy) in kilowatt-hours (kwh)
    - 1 kwh = 1000 watt-hours = 3,600,000 watt-seconds = 3.6×10^6 joules
    - 1 kwh = energy to run a 100 watt light bulb for 10 hours

Electricity vs. Water

ELECTRICAL CONCEPT	WATER CONCEPT
Voltage (volts)	Pressure (P.S.I.)
Current (ampere)	Flow Rate (mL/min)
Resistance (ohms)	Restriction (Δ P.S.I.)
Wire (A.W.G.*)	Pipe (diameter)
Capacitor (µfarad)	Tank (gallons)
Power Source (outlet)	Water source (water main)
Leakage current (µamp)	Water leak (mL)

* = American Wire Gauge (works like needles – the higher the number the smaller the wire)

Fluke 87 Multimeter

Yellow Button – selects capacitance in ohms position, temperature in mV position and ac or dc current in ampere positions.

Min Max – Records MAX, MIN, AVG, and present reading over time for any switch position

Range – Switches between available ranges for selected function and between ºF and ºC

AutoHOLD – captures reading on display and beeps

Beeper – Turns the beeper on/off for continuity checks

Rel Δ - creates reference value and compares all future readings to the reference value

Hz % - Switches to frequency measurements

Applying the concepts

- What is the expected resistance of a 1000 watt heater rod rated for 120 volts?
  - $P = V^2/R$ therefore $R = V^2/P$
  - $R = (120)^2/1000 = 14400/1000 = 14.4$ ohms
- Under the same voltage requirement will a 2000 watt heater rod have a higher or lower resistance than the 1000 watt rod?

Fundamental Trouble Shooting

- There are only two reasons an electrical component will not work.
  - It has no power
  - The component is broken
- Checking for power
  - Is the Power source functioning?
  - Is the device plugged in?
  - Is it fused …. properly? Fuses don't just fail!
  - Does it run off a power supply? What voltage?
  - Is that voltage being applied to the component?

Trouble shooting a component

- First, you must know how the component operates.
- Components like thermistors, solenoids, and photoresistors can be tested for resistance.
- Solid state circuits cannot be tested using a multimeter. Exchanging circuits may be the only way to verify failure, but check the power first!
- Wires should always have low resistance.
- Diodes conduct in one direction, but not the other.
- Conductivity cells can't be tested for resistance.

The Patient at Risk

- Skin protection is voided by metal fistula needles.
- The needles are inserted into an electrolyte (blood).
- The electrolyte path is directly to the heart.
- The patient can make direct contact with the dialysis equipment.

Medical Electrical Equipment

- Defined in IEC 60601 – 1 Section 2.2.15
  - One connection to a Supply Mains
  - Intended to diagnose, treat, or monitor the patient under medical supervision
  - Patient Interface:
    - Makes physical or electrical contact to patient
    - Transfers energy to or from the patient
    - Detects energy transfer to or from the patient

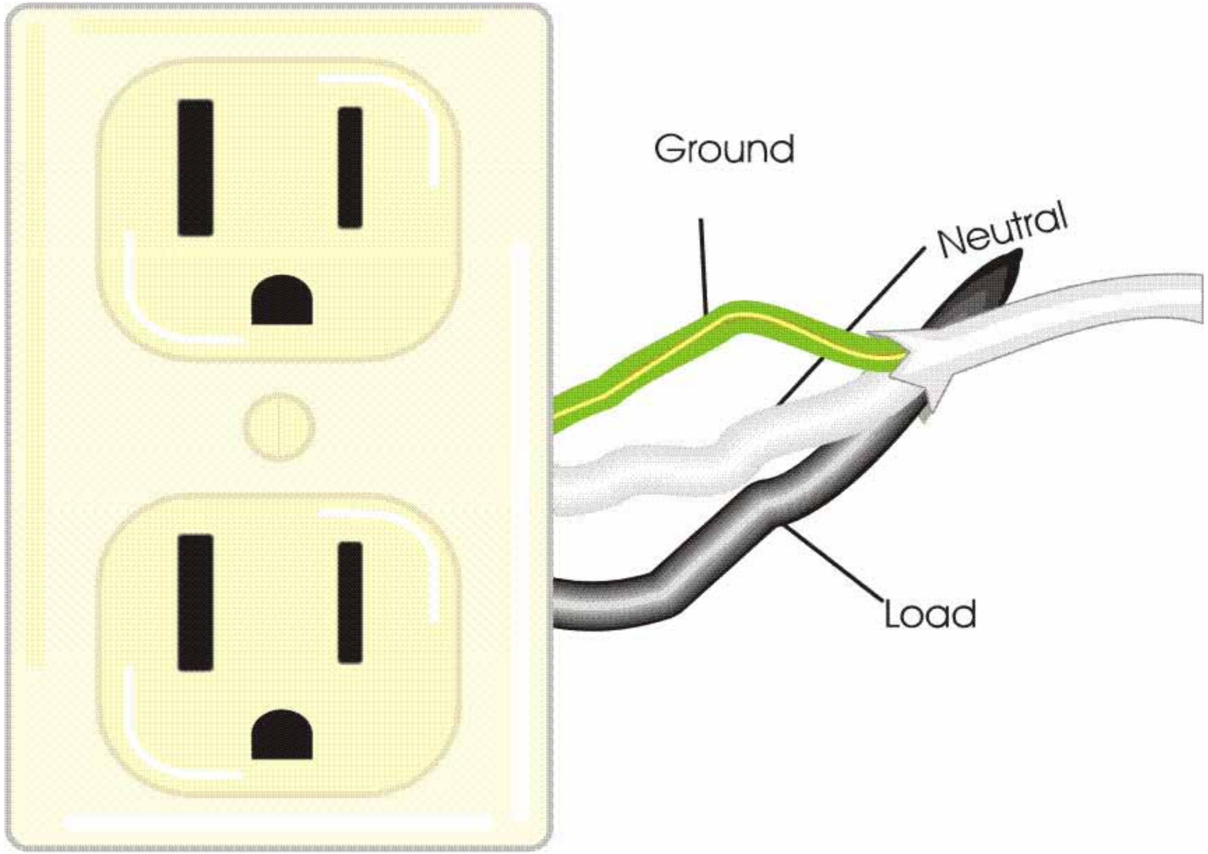
Class I Equipment

- Applies to Hemodialysis Equipment
- Protection from electrical shock does not rely on basic insulation only.
- Means provided for connection to a protective earth conductor.
  - Uses fixed wiring through an a/c power cord.
  - Accessible metal parts can't become "live" if basic insulation fails.

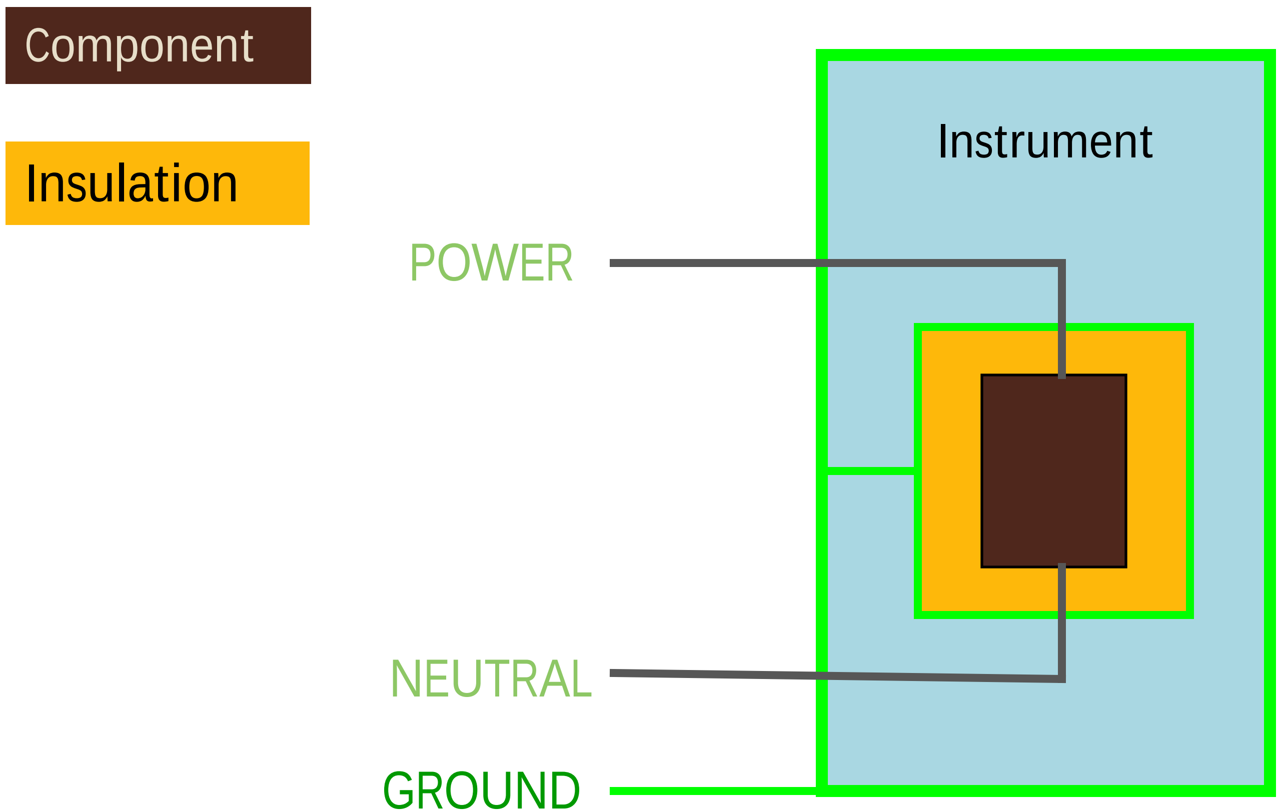
Class 1 Equipment Types

- Type CF
  - applied parts in direct contact with the heart
  - doesn’t apply to hemodialysis equipment
- Type BF (Blood Pump)
  - less stringent than CF
  - Have conductive patient contact (not the heart)
  - have medium to long contact times
  - no earth ground connection
- Type B (Hemodialysis Machine)
  - least stringent
  - applied parts not conductive
  - Can be immediately released from patient
  - May connect to earth ground

Everything *Must* Go to Electrical Ground!



Preventing Shock by Grounding



AAMI Standards

- ANSI/AAMI/ISO 60601-2-16 Standards (2008)
- Medical Electrical Equipment
- Electric Safety Requirements
  - Non-isolated Patient Connection.
    - Chassis risk current = 100 microamperes.
    - Patient risk current = 50 microamperes.
  - Electrical Ground Required.
  - Metal/Components – Corrosion Resistant.
  - Instrument Outlets – Shielding from fluid spills
  - Electric circuits separate from hydraulics.
  - Supply mains electrical failure for system and components must create audible alarm.

The IEC 60601-1 Safety Tests

- Earth leakage current.
  - Current through the ground conductor
  - Max = 0.5 mA for Normal Condition
  - Max = 1.0 mA for Single Fault Condition
- Enclosed leakage current.
  - Current from an enclosure if touched
  - Max = 0.3 mA patient vicinity
  - Max = 0.5 mA nonpatient area
- Applied part leakage.
  - Called patient lead leakage
  - Any flow from, between, or into an applied part.

Typical Electrostatic Voltages

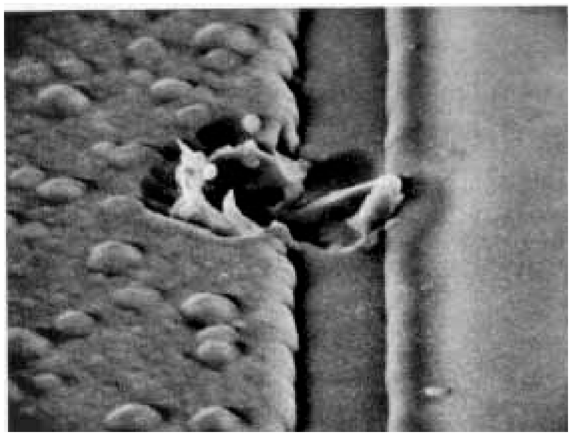
MEANS OF STATIC GENERATION	10 TO 20% RELATIVE HUMIDITY	65 TO 90% RELATIVE HUMIDITY
WALKING ACROSS A CARPET	35,000	1,500
WALKING OVER A VINYL FLOOR	12,000	250
COMMON POLY BAG PICKED UP FROM BENCH	20,000	1,200
WORK CHAIR PADDED WITH POLYURETHANE FOAM	18,000	1,500
WORKER AT BENCH	6,000	100

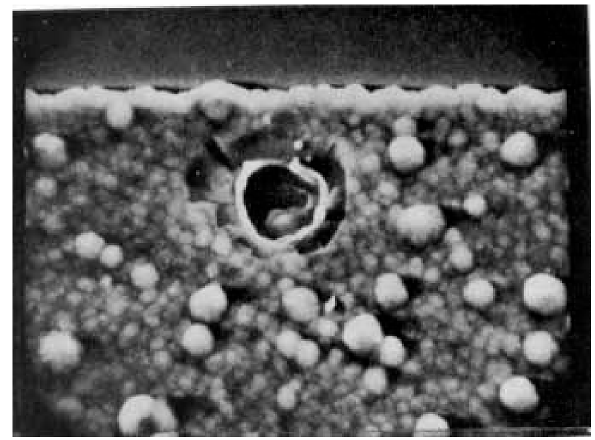
Bill Pellegrin-3M

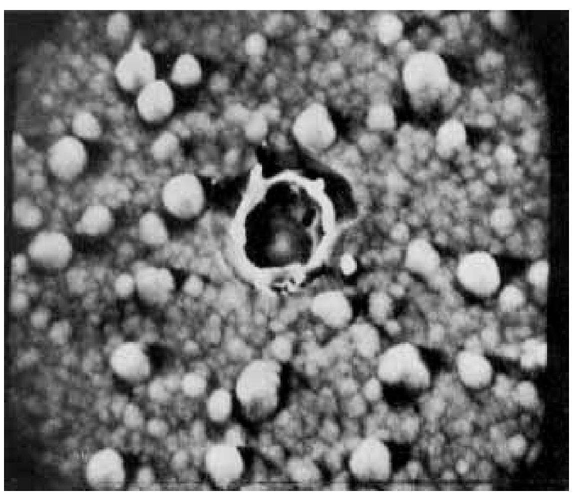
Semiconductor Sensitivities

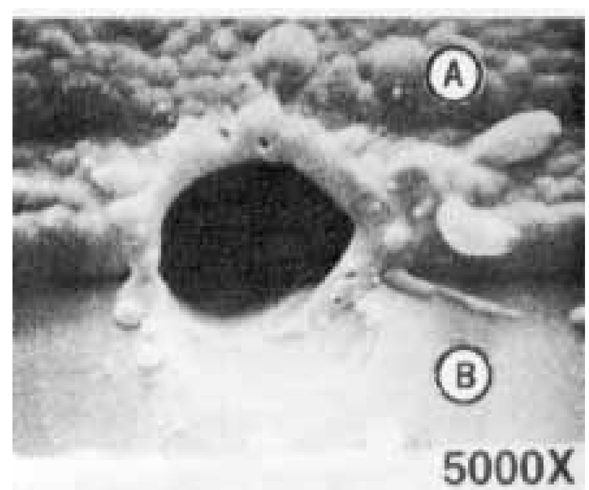
Device Type	Threshold Susceptibility (volts)
MOSFET	10-100
EPROM	100+
CMOS	200-3,000
OpAMP	190-2,500
Schottky Diode	300-2,500
Film Resistor	300-3,000
SCR	500-1000

DAMAGES CAUSED BY ESD









ESD Standard

ESD association standard

ANSI/ESD S20.20-1999

ANSI/ESD S20.20-1999

for the Development of an Electrostatic Discharge Control Program for –

Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

ESD ASSOCIATION ™

Electrostatic Discharge Association
7900 Turin Road, Bldg 3, Ste 2
Rome, NY 13440-2069

An American National Standard
Approved August 4, 1999

The Industry Standard for ESD is ANSI/ESD S20.20