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Theory 01

Basic Definitions
A Brief History
Atoms & Charge
Conductors & Insulators
Basic Soldering

Definitions:

Atom: The smallest particle of an element that retains all the properties of the element.
Electron: An atomic particle; the smallest particle that carries a negative (-) charge.
Electronics: The study of electrons in motion.
Neutron: An atomic particle that has neutral (0) charge.
Proton: An atomic particle that has positive (+) charge.

A Brief History

600 BC -- Greeks found that by rubbing a piece of amber with fur that you could get feathers to stick to it.

200 BC -- Chinese found that a small needle of iron rubbed with a lodestone (magnetite, natural magnetic material) and floated on water would always point in the same direction.

1200 AD -- Chinese "compass" principle brought to Europe by Arab traders.

1600 -- William Gilbert writes "De Magnete" ("About Magnets") where he describes the earth as a giant magnet.

1660 -- Otto von Guericke makes an "earth model" of sulfur rubbed with a cloth to make a continuous source of static electricity.

1746 -- Pieter van Musschenbroek finds that a jar filled with water and wrapped in foil would store Guericke's static electricity. He almost kills himself when he inadvertently touches his "Leyden jar" and knocks himself on his keester.

1752 -- Benjamin Franklin flies kite in stormy weather to prove that lightning was static electricity. Uses van Musschenbroek's "leyden jar" to store electricity. (*Note: Franklin was no fool. He did NOT fly his kites IN a thunderstorm. He flew them when thunderstorms were nearby.)*

1782 -- Luigi Galvani uses two different metals on a dead frog leg to make the leg "kick". He concludes that the frog leg was generating electricity. He sticks one of the metals in his mouth and the other metal to a corner of his eye and almost blinds himself with the flash of light generated by this small electric cell.

"Galvani! Stop playing with those batteries and eat your frog legs!"

1799 -- Alessandro Volta follows up Galvani's work with many metal strips separated by cardboard soaked in salt water to prove that it was the metal, not the frog leg that was generating the electricity. This was the first "battery" of cells stacked in series.

1800 -- Hans Oersted notes that passing electricity through a wire near a compass causes the compass to deflect. He concludes that there is a "field" around a wire that is carrying electric current.

1820 -- Michael Faraday shows that rotating a wire near a magnet produces electricity. He also shows that passing electricity through a wire near a magnet produces rotation (the first electric motor). He also shows that if you wind an iron ring with two separate windings of wire that an alternating current in one winding induces an alternating current in the other winding (the first transformer).

1829 -- Joseph Henry builds a large powerful battery to power a large powerful electromagnet. He uses the electromagnet to lift hundreds of pounds of iron ore. He uses his wife's silk dress as the insulator for the electromagnet. His wife is neither impressed nor pleased with this turn of events.

1832 -- Hippolyte Pixii builds a relatively powerful alternating current generator.

1837 -- Thomas Davenport invents an electric motor that is powerful enough to run a small printing press. It was inefficient and noisy; the world did not beat a path to his door.

1837 -- Charles Wheatstone establishes the first telegraph line … a distance of nearly 2 miles.

1844 -- Samuel Morse establishes a telegraph line between Washington DC and Baltimore and earns the disgust of every Boy Scout that had to learn Morse Code. dit dit dit daaah.

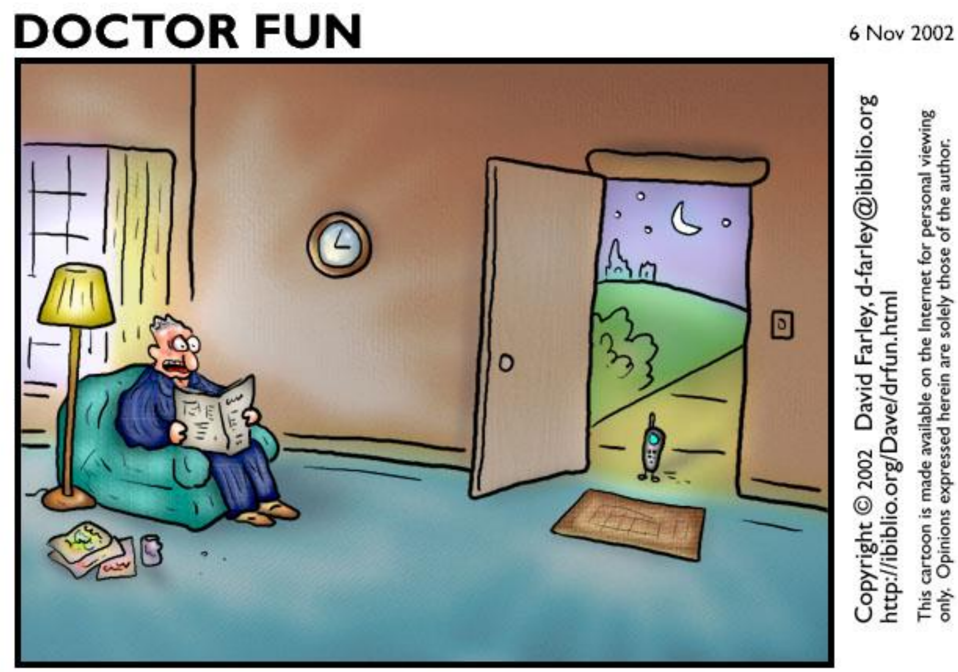
1850 -- Floris Nollet improves on Pixii's design and builds a 50 volt ac generator that is used to plate metal, the first widespread industrial use of electricity.

1861 -- California is connected to New York in the first transcontinental telegraph.

1875 -- Alexander Bell invents the sound telegraph … the telephone. "Watson come here, I need help."

1878 -- William Crookes investigates electron beams in an evacuated (vacuum) glass tube.

1878 -- William Swan demonstrates the first electric light bulb.



"You've been out roaming again."

1879 -- Thomas Edison does NOT invent the light bulb. He invents a bulb that will burn for a long time without burning out.

1882 -- Edison builds the first electric generating plant in Manhattan, New York. It serves 7200 light bulbs but is direct current. Edison loses out on the efficient alternating current generator.

1883 -- Nikola Tesla invents the first practical alternating current motor.

1884 -- Paul Nipkow invents a machine to transmit pictures over wires (tele-vision).

1888 -- Heinrich Hertz demonstrates the existence of "radio waves".

1893 -- Charles Steinmetz does a tremendous amount of work applying complex number theory to the design of alternating current motors and generators, taking the design of ac devices out of black art and into scientific design.

1895 -- George Westinghouse buys Tesla's patents and establishes the first large scale ac generator at Niagara Falls to light up Buffalo NY.

1895 -- Wilhelm Roentgen notices that radiation from one side of his lab caused crystals on the other side of the lab to glow, even if they were shielded by thin metal sheets. He calls this radiation X-radiation because he was not sure what the X stood for. Later he finds that he can see the bones in his wife's hand when irradiated by these X-rays. No fool Roentgen, he didn't use his OWN hand in the experiment.

1897 -- Joseph Thomson discovers and identifies the electron.

1900 -- Electric powered cars outsell gasoline powered cars.

1900 -- Tesla uses radio waves to remote control a small boat.

1901 -- Guglielmo Marconi sends radio waves (Morse code) across the Atlantic Ocean.

1905 -- Albert Einstein uses quantum physics to explain the photoelectric effect -- where light shining on metal produces electrons.

1905 -- John Fleming takes an Edison bulb and puts another piece of metal inside the bulb creating the first vacuum tube (a diode).

1907 -- Lee DeForest takes a Fleming tube and puts a grid between the filament (cathode) and plate (anode) to create a vacuum tube with power gain.

1906 -- Reginald Fessenden transmits voice and music from an amplitude modulated transmitter in Massachusetts.

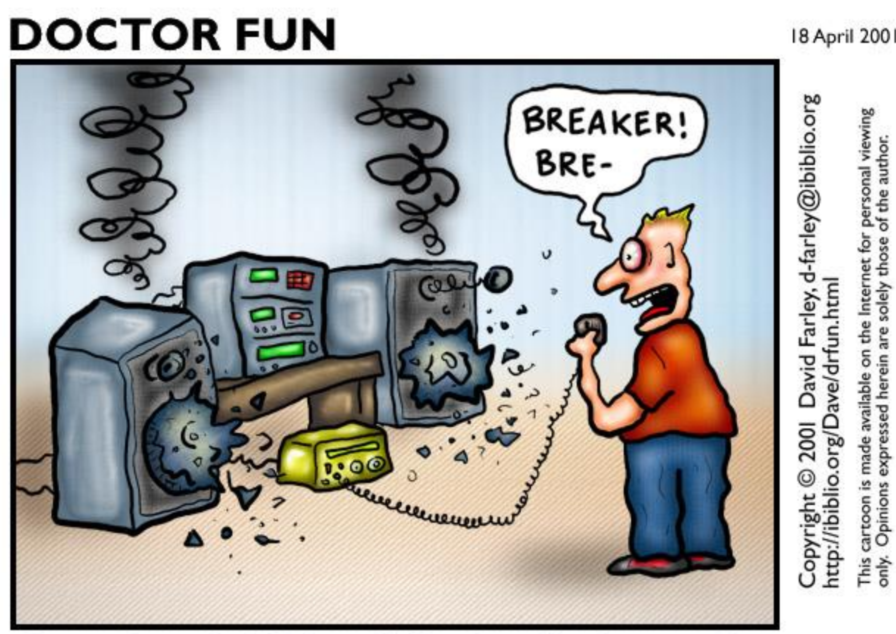
1908 -- The electric vacuum cleaner comes onto the market.

1913 -- The electric refrigerator makes its debut.

1920 -- George Westinghouse receives the first radio station license for KDKA in Pittsburgh PA and goes "on the air" with the first radio broadcast on 2 November.

1925 -- The electric clothes washer and dishwasher are introduced.

1934 -- Edwin Armstrong invents frequency modulation.



Every week somebody finds an old CB radio, and hooks it up to their stereo.

1935 -- The electric clothes dryer comes onto the market.

1936 -- Philo Farnsworth and Vladimir Zworwykin independently invent an electronic form of sending pictures over radio waves using cathode ray tubes (tele-vision, from the Latin “Seeing at a distance.”).

1939 -- NBC transmits the first television pictures at the World Fair.

1942 -- John Mauchly and Presper Eckert design and produce the Electronic Numerical Integrator and Computer (ENIAC) at the University of Pennsylvania. It was first used to aim the guns of the battleship Missouri. It is widely accepted as the first electronic computer. It occupied one entire floor of the science lab building.

1942 -- Enrico Fermi splits the atom in the first controlled fission reaction under the bleachers at the football stadium of the University of Illinois.

1947 -- John Bardeen, Walter Brattain, and William Shockley invent the transistor at Bell Labs.

1952 -- RCA develops the NTSC color television standard and demonstrates color television.

BELL TELEPHONE LABORATORIES INCORPORATED ~~B.T.L. CONFIDENTIAL~~

COVER SHEET FOR TECHNICAL MEMORANDA

SUBJECT: Terminology for Semiconductor Triodes - Committee Recommendations - Case 38139-8

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THIS COPY FOR

MM- 48-130-10
DATE May 28, 1948
AUTHOR L.A. Meacham
C.O. Mallinckoodt
H.L. Barney

Surface States - Terminology

ABSTRACT

Recommendations are made for an equivalent circuit representation, and terminology relating to semiconductor triodes.

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Terminology for Semiconductor Triodes - Committee Recommendations - Case 38139-8

MM-48-130-10

May 28, 1948

MEMORANDUM FOR FILE

This memorandum is a report of the recommendations of a committee which was set up* for the purpose of standardizing the terminology relating to semiconductor triodes. The need for such standardization is apparent, and it is hoped that these recommendations will be useful either in providing a generally acceptable terminology, or in stimulating discussion which will lead to nomenclature which can be standardized.

1. Name

On the subject of a generic name to be applied to this class of devices, the committee is unable to make an unanimous recommendation. A discussion of some proposed names is given here.

Semiconductor triode. This is considered to be a fairly good name, being satisfactorily descriptive, but a shorter name would be preferable. The "triode" describes the three element device; if more elements were added it might be a tetrode or pentode, for instance. A single point contact rectifier might be referred to as a semiconductor diode in line with this terminology.

Surface States triode. This is in the same class as the first name suggested above; it is descriptive, but is not brief.

Crystal triode. The objection to this is that the term "crystal" is usually associated with the piezoelectric types, such as quartz.

Solid triode. This has the advantage of brevity, and is descriptive in the sense that the device may be explained by the physics of the solid state, and also that the active

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*At a conference held May 6, 1948, reported in a letter to Messrs. J. W. McRae and R. K. Potter dated May 10, 1948 - Case 38139-8 by W. E. Kock.

element is a solid rather than vacuum or gas filled. However, the word "solid" also commonly means sturdy, massive, rugged, or strong, which terms are contradictory to the actual physical characteristics of the unit.

<u>Iotatron.</u> This term satisfactorily conveys the sense of a minute element, as contrasted to the previous name. However, in view of the many vacuum or gas filled devices such as thyratrons, dynatrons, transitrons, etc., it lacks the distinguishing property which would differentiate it from such devices.

<u>Transistor.</u> This is an abbreviated combination of the words "transconductance" or "transfer", and "varistor". The device logically belongs in the varistor family, and has the transconductance or transfer impedance of a device having gain, so that this combination is descriptive.

If a general term ("transistor", for example) were adopted for the entire class of semiconductive devices, there would be considerable merit in having additional descriptive terms for particular sub-classes. To illustrate, there might someday be a "120B transistor", which was a "germanium triode", and a "196A transistor" which was a "silicon diode", etc. A "germanium tetrode" has already been explored with some promise, and many other variations are likely to appear as time goes on.

In view of these considerations, it is the recommendation of the committee that the particular device with which we have worked so far; that is, a germanium block with two point contacts, be referred to as a <u>germanium triode</u>.

For the purposes of this memorandum, the device will be referred to in more general terms as a semiconductor triode.

Accompanying this memorandum is a ballot. It is suggested that each person to whom the memorandum is routed, fill out the ballot and return it, in order that the resultant vote may be used by the committee as the basis of a recommendation for a generic name.

BALLOT

Designate by the numbers 1, 2 and 3, the order of your preference for the names listed below:

____ Semiconductor Triode

____ Surface States Triode

____ Crystal Triode

____ Solid Triode

____ Iotatron

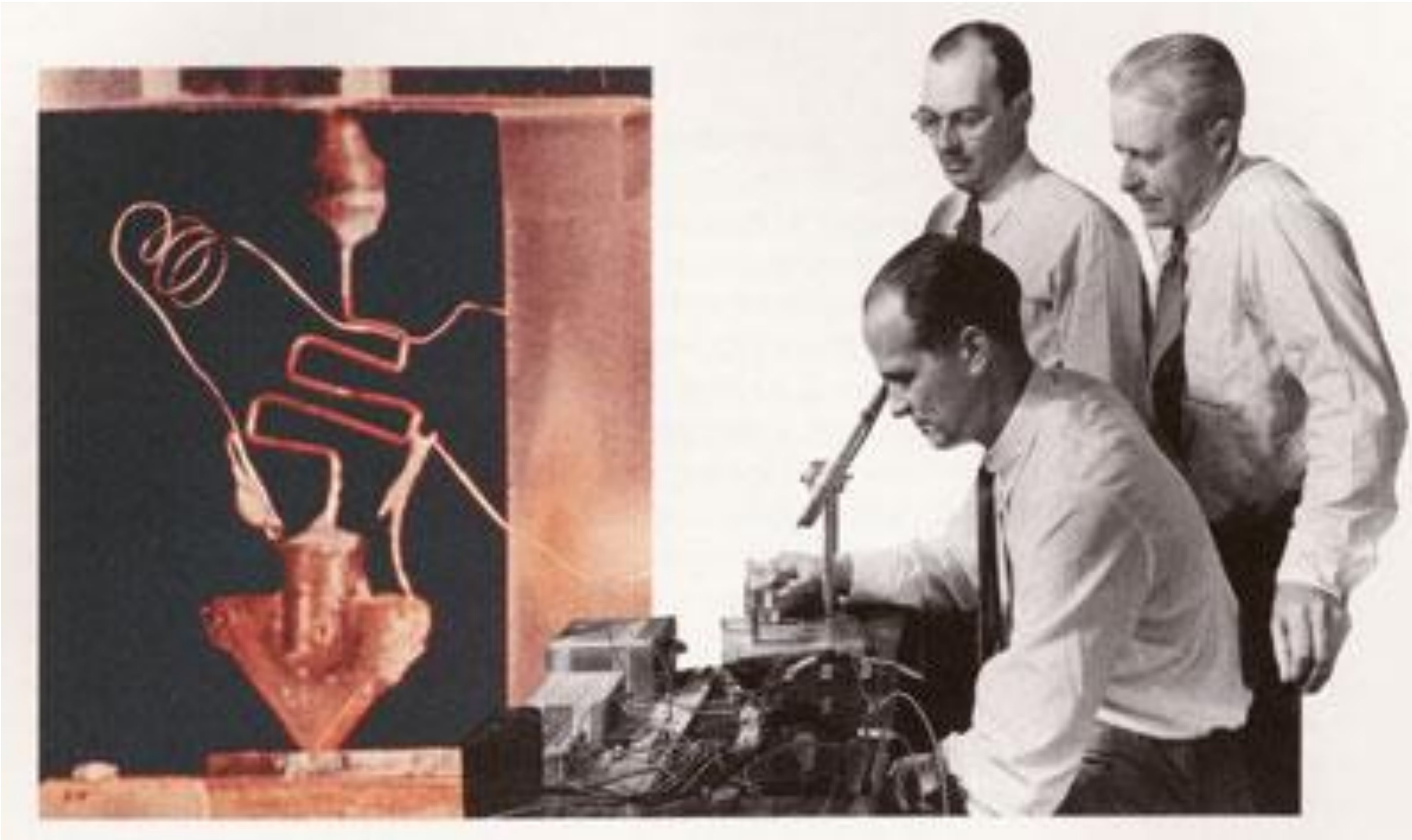
____ Transistor

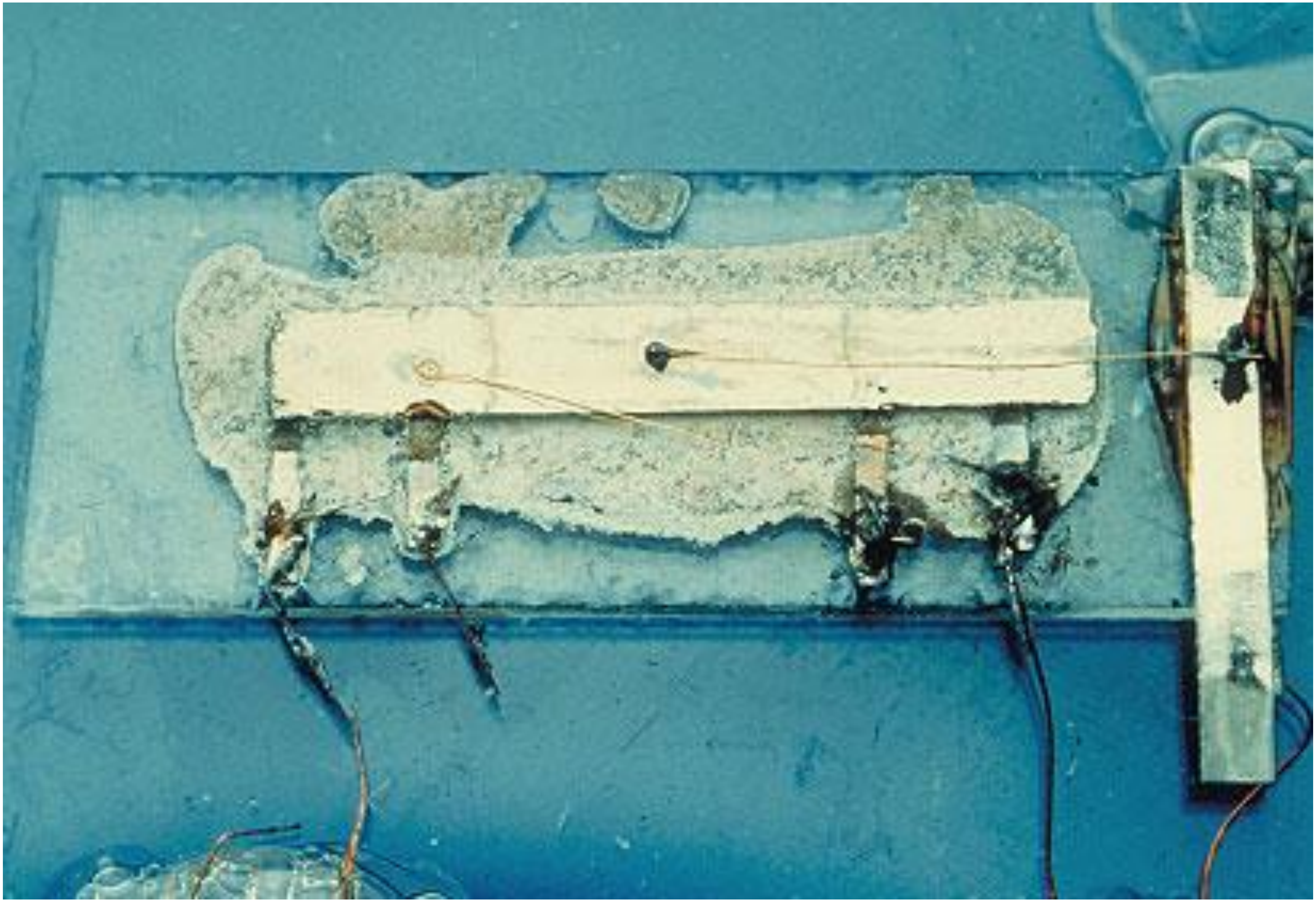
____ ____________________(Other suggestion)

Comments:______________________________

Signed ________________

Please return this ballot to Miss G. R. Callender in 1A-323 at Murray Hill.





1958 -- Robert Noyce and Jack Kilby, working separately, invent the integrated circuit.

1958 -- Charles Townes and Arthur Schawlow author a paper in which a device called Light Amplification by the Stimulated Emission of Radiation (laser) was described.

1959 -- Wilson Greatbatch and W.M. Chardack invent the heart pacemaker implant.

1960 -- Theodore Maiman builds the first working laser. He used a pure ruby rod to generate the light.

1968 -- Robert Noyce and Gordon Moore found the INTegrated Electronics Corporation (Intel).

Wacky things computer service technicians buy

1972 -- Pong, the first computer-based game appears.

1973 -- Godfrey Hounsfeld uses a computer and x-rays to produce a 3-d image of the body. He patents the CAT scan.

1977 -- Steve Jobs introduces the first microprocessor based computer, the Apple II.

Atoms & Charge

In about 420 BC, the philosopher Democritus postulated that the entire world consisted of nothing but atoms and empty space.

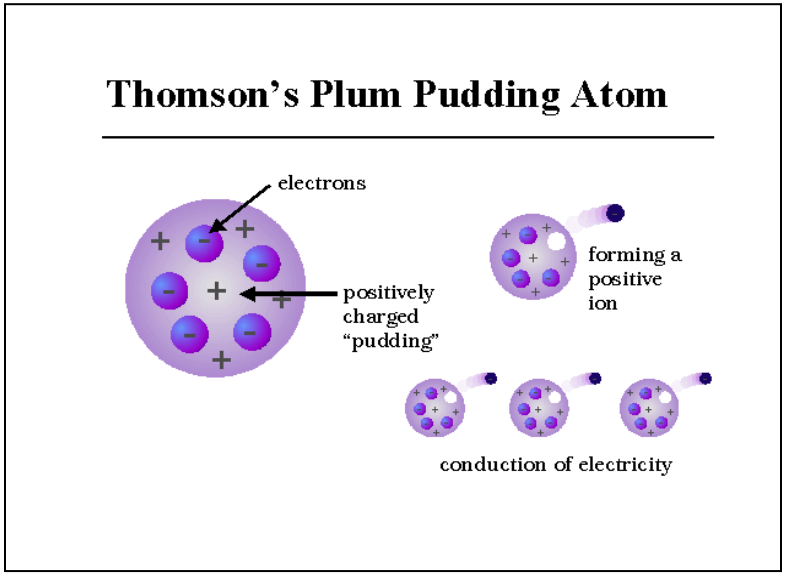
> *There are two forms of knowledge: one legitimate, one bastard. To the sort belong all the following: sight, hearing, smell, taste, touch. The legitimate is quite distinct from this. When the bastard form cannot see more minutely, nor hear nor smell nor taste nor perceive through the touch, then another finer form must be employed.* - Democritus, Fragment 11, The Symmetry of Life

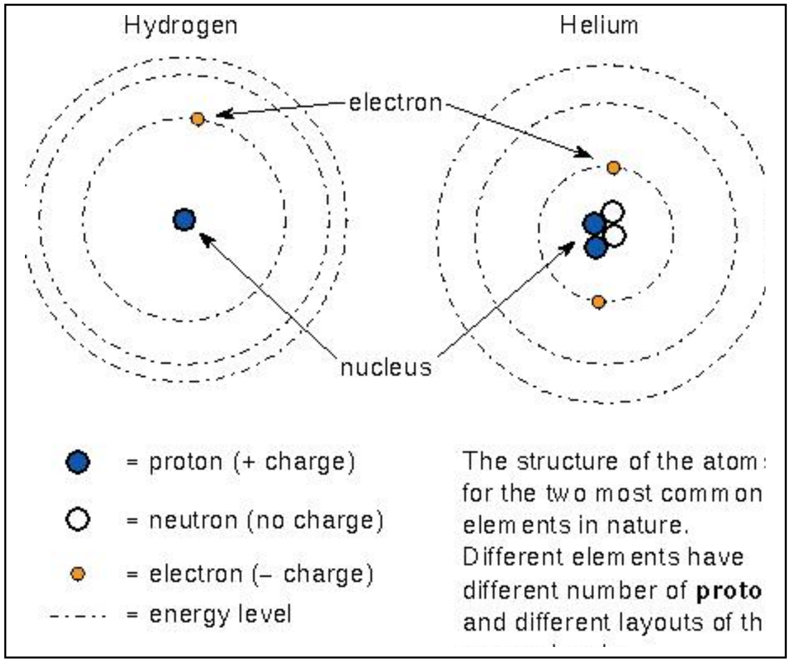
Democritus reasoned, quite properly, that atoms were far too small to be seen, so we would have to experience them through other means.

It fell to Thomson in 1903 to describe the atom as "plum pudding" with the electrons scattered about randomly in a pudding of positive charge.

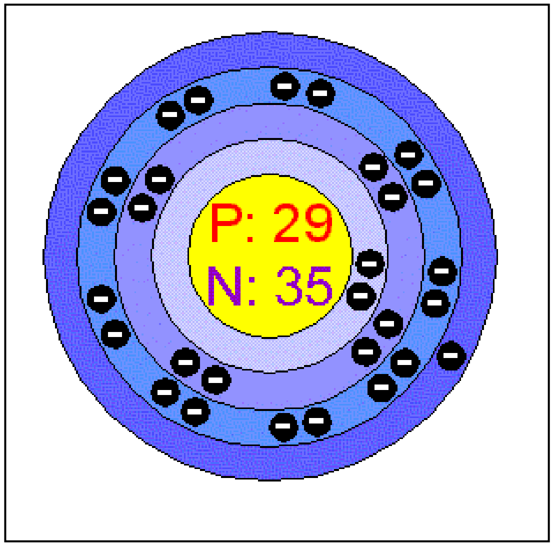
In 1911, Rutherford proved that description false by firing alpha particles at a gold foil and having some of them bounce back. It was, in Rutherford's words, as though I fired a cannon at a sheet of paper and the cannon ball came back whizzing by my ears. The "cannon ball" had hit the nucleus of the atom and had rebounded directly back.

In 1913 Niels Bohr postulated the atom as "a little solar system" with the nucleus (made up of protons and neutrons) in the sun-center and the electrons whizzing about this nucleus. Further refinement of this model had the electrons in "shells" around the nucleus. Although further experimentation with this model has shown that it is technically inadequate, it is sufficient for our purposes to think of the atom this way.



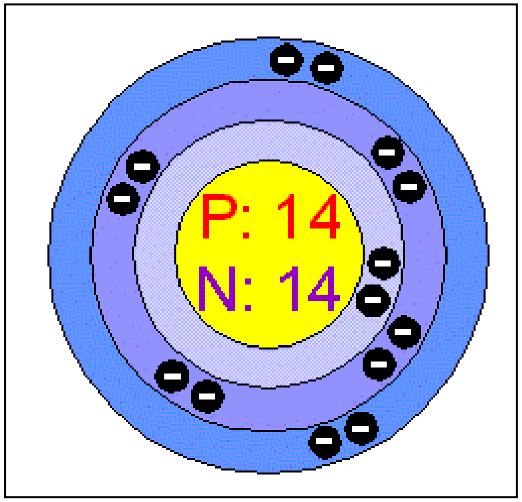


Think about a baseball park. The nucleus is a baseball sitting on second base. There are seats on the field level, the first deck, the second deck, the third deck (the nosebleed section, sometimes called the Uecker seats), and the bleachers. No fan-electron can sit halfway between the first and second deck -- they have to be in one deck or the other. And, if an earthquake hits PacBell Park, a fan COULD be tossed up from the first deck to the second deck. However, as soon as the usher sees the fan out of his ticket seat, he can toss the fan over the railing to the deck below. The fan gives up a large amount of energy (splat!!) in making this transition back to a lower deck.



Let's consider copper. Copper has 29 protons and 35 neutrons in its nucleus. To be electrically neutral, we've got to neutralize that positive 29 protons with negative 29 electrons. You can see them in their "shells" to the right. The first shell has two electrons, the second shell has 8 electrons, the third shell has 18 electrons, and the outer shell has one electron.

This outer shell is important to the study of electronics. Take me at my word; if the outer shell only has one electron, it will conduct both heat and electricity quite well. That single electron can be swapped with the atom next door, who will swap with the atom next to it, and so forth. Electrons can be made to move in copper quite easily.



Consider silicon. Silicon has 14 protons and 14 neutrons and 14 electrons in 3 shells. However, the OUTER ("valence") shell (or band) has FOUR electrons, and is rather unwilling to share those electrons with its neighbors.

Silicon, therefore, is a rather POOR conductor of electricity and we call it an INSULATOR.

Let's talk about molecules for a moment. Molecules are built from atoms of more than one element. In particular, we can build molecules from gallium, arsenic, phosphorus, indium, nitrogen, and aluminum in limitless combinations.

In 1952, General Electric engineers found that a mixture of aluminum, gallium and **arsenic (aluminum gallium arsenide) could be used to make a diode, and if electric current were passed through that diode, it would glow red** and thus was born the Light Emitting Diode (LED). Further experiments with these 6 elements gave us LEDs that glow orange, yellow, and green.

In 1989, Nagoya University researchers combined **gallium with nitrogen (gallium nitride) to produce the first blue** LED. Later experiments with indium gallium nitride gave us better efficiency in the blue LEDs.

But WHITE eluded us for a goodly number of years. It wasn't until some unknown experimenter realized that the regular old fluorescent tube was nothing more than a blue light (mercury vapor) surrounded by a phosphor that glowed white when hit with high energy blue light.

Voila … coat a blue led with a white phosphor and you have a white led. The phosphor of choice these days (for some very esoteric reasons) is cerium-doped yttrium aluminum garnet. By replacing the cerium with other rare earths (such as ytterbium and gadolinium) you can adjust the "color temperature" of the phosphor from slightly reddish (warm white) to bluish white (cold white).

More recent experiments with zinc and selenium to form zinc selenide which glows blue and yellow simultaneously to simulate white light without the need of phosphors has been demonstrated.

Color	Wavelength	Voltage	Material	Efficacy
Red	685	1.8	Aluminum Gallium Arsenide	85
Orange	615	2.1	Gallium Arsenide Phosphide	90
Yellow	575	2.2	Aluminum gallium indium phosphide	90
Green	535	2.9	Gallium Phosphide	100
Blue	475	3.1	Indium Gallium Nitride / Gallium Nitride	150
Indigo	445	3.2	Indium Gallium Nitride / Gallium Nitride	150
Violet	415	3.4	Indium Gallium Nitride / Gallium Nitride	150
White	390-700	3.1	Blue + Yttrium-Aluminum-Garnet phosphor (YAG)	175 - 200

Color is the standard eye perceived color. Wavelength is the center of this color band in nanometers (nm). Voltage is the nominal forward voltage of the diode at the recommended forward current. Material is the most common chemical compound for this color. Efficacy is the amount of lumens emitted per watt consumed.

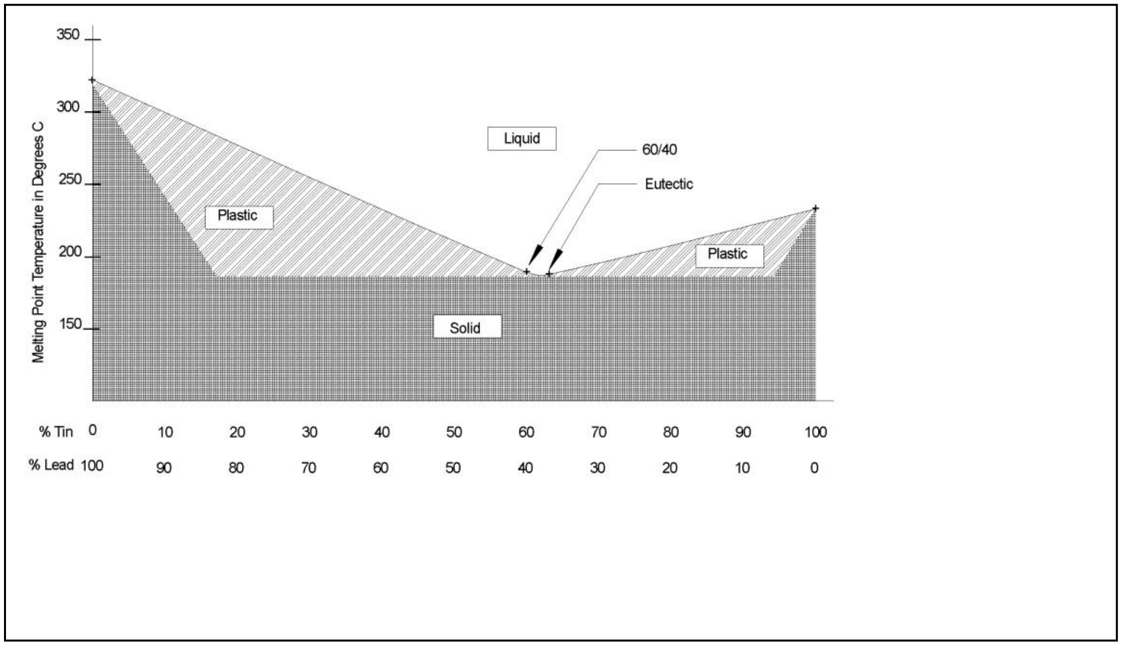
A common way of remembering how the diode voltage is related to color is by remembering the name of a fellow named Roy G. Biv. (Red, Orange, Yellow, Green Blue, Indigo, Violet). Strangely enough, this is also the same progression in the relative energy contained in a lumen of the particular color. You may also note that these are the progressive colors of a rainbow.

Soldering

https://www.youtube.com/watch?v=Qps9woUGkvI&spfreload=10

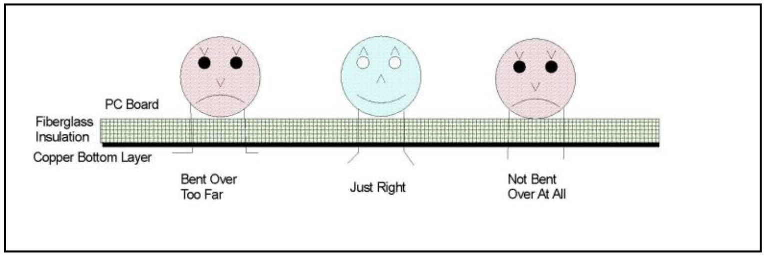
1. Soldering

   a. Soldering is more of an art than a science. When we want to join two metal parts together electrically, we use an alloy of tin and lead called "solder". While pure lead melts at 320°C (620°F) and pure tin melts at 232° (450°F), the alloy melts at a much lower temperature. **The "eutectic" point (lowest melting point of an alloy) happens at a tin/lead mixture of 63% tin, 37% lead** at a temperature of 183°C (361°F), but most common solder is alloyed at a 60-40 mixture that melts at 188°C (370°F).

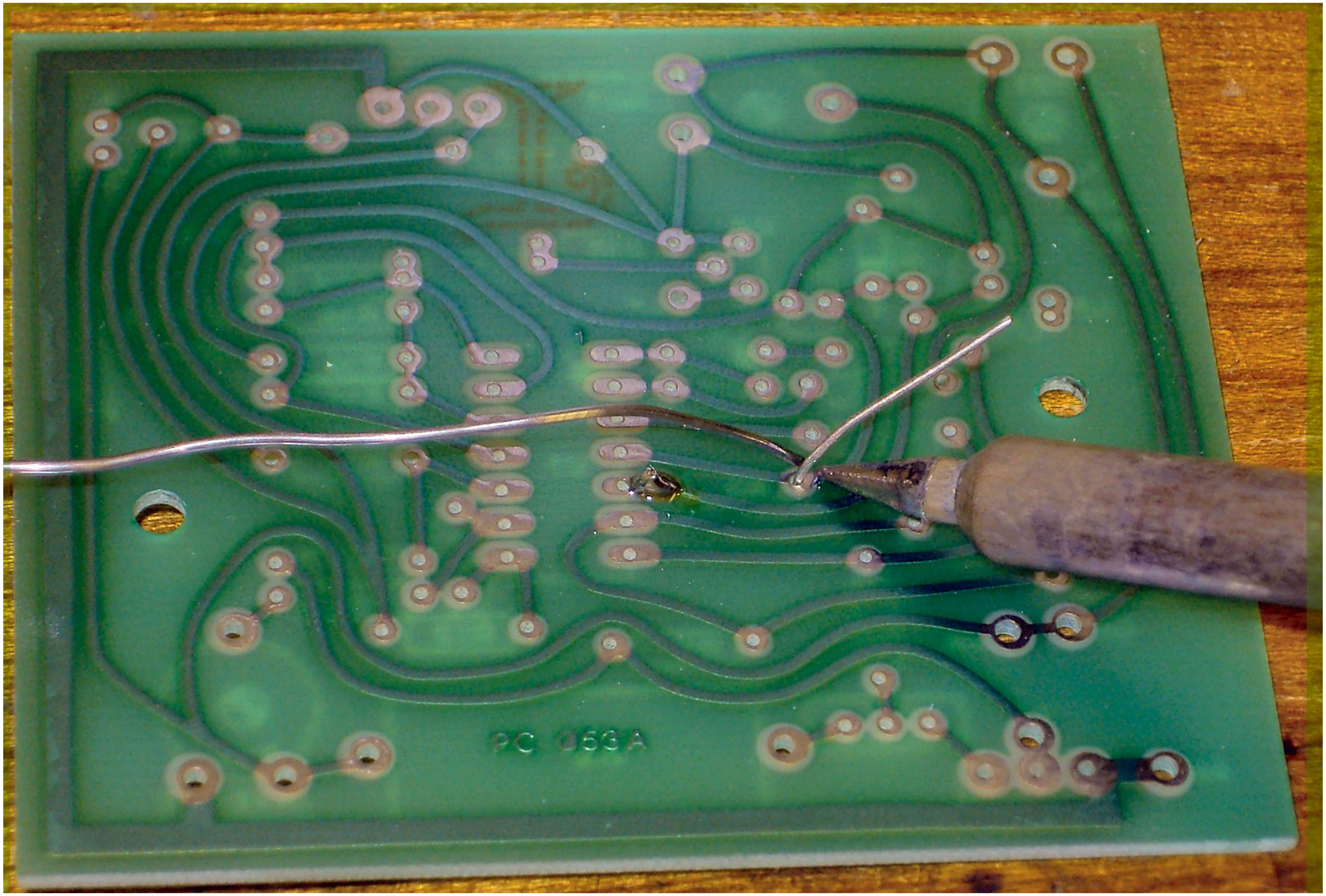


   b. Eutectic goes from the solid to the liquid state directly. All other alloys go through a "plastic" state where the solder is an unhappy blend of both solid and liquid. If the joint is allowed to move, even slightly, during this plastic state, when the solder moves to the solid state the joint will have cracks and other voids called a "cold" solder joint. Cold solder joints are responsible for a lot of unreliable equipment. Just remember that **solder makes a poor glue** and to make sure that the metal parts to be joined are mechanically rigid before trying to solder them.

   c. Once mechanically rigid and soldered together properly, the joint is usually difficult to take apart for repair. We can make it a little easier to repair during the construction phase by only bending the lead over on the pc board as far as is necessary to keep the part mechanically secure (generally a 45° bend of the component lead). Bending it over at right angles before soldering almost guarantees that the part AND the pc board pad come off as one.



d. To solder a joint well, it will be the joint itself that melts the solder. Put the soldering iron on one side of the joint and feed the solder in from the other side. When the joint gets hot enough to melt the solder, you can generally assume that the joint was properly made. Here you see a photo of the iron coming in from the right side of the picture and the solder feeding from the left side. The iron is touching both the component lead (bent over at a 45° angle) and the pc board pad. Note the well-made joint to the left of the joint being done.

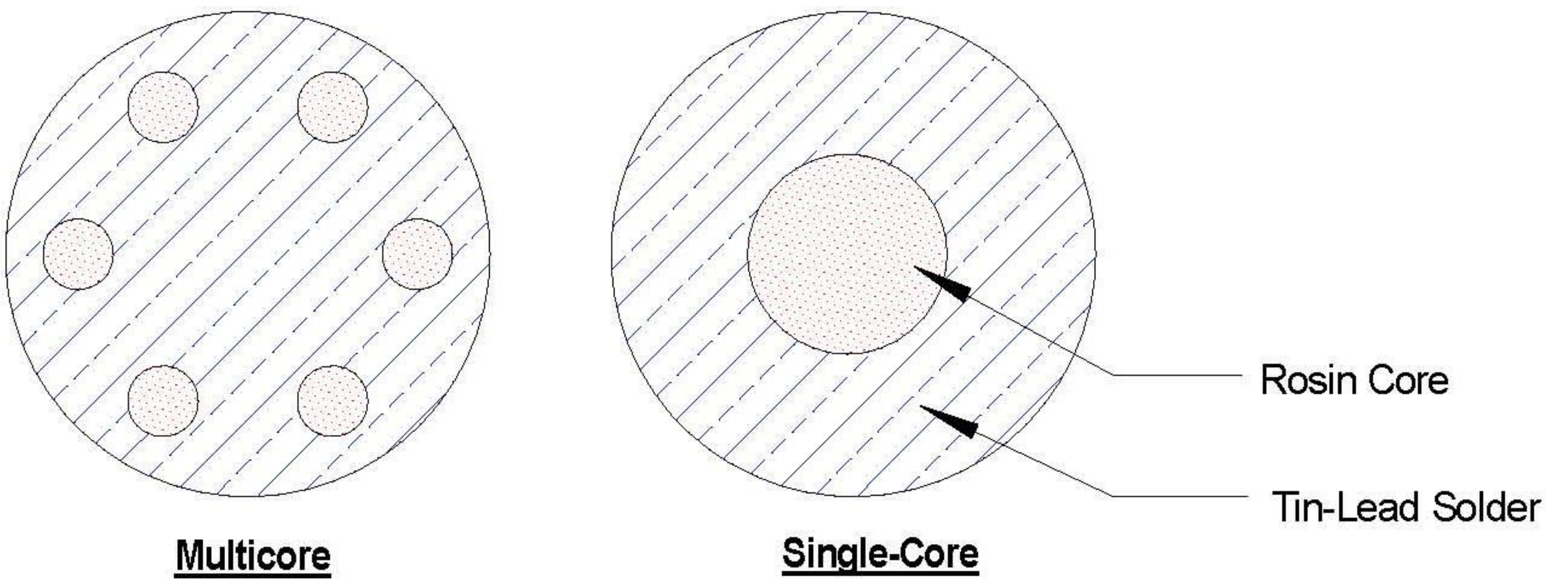


e. Electronic solder isn't just tin and lead. **"Rosin core solder" is actually a tube of solder with a "flux" inside the tube, or core.** This flux is made from a variety of pine sap called rosin. This rosin core chemically reacts with the metals that you are soldering together and (when heated) cleans any light corrosion or oxidation from the joint you are making. Do NOT expect the rosin to take off half an inch of accumulated grease and dirt; preclean the parts with a copper cleaner if they are filthy

Some people prefer to take the rosin flux off of the board when the board has been soldered and some just let it be. There is argument that the used rosin is hydroscopic (takes water out of the air) and will eventually corrode the board. Other say that there are electronic devices made before World War II that are functioning just fine with the original rosin still on the joint.

Rosin is soluble in isopropanol (plain old rubbing alcohol) and ethanol and is also soluble in some halogenated hydrocarbons like freon -- but the hydrocarbons are not recommended for shop use.

Caution -- A lot of components are also soluble in the alcohols and hydrocarbons. Dipping the board in a flux stripper solution may take off the flux, but it may well take off some components as well.



Here are the steps to making a successful joint:

i. Get the soldering iron reasonably hot. 315°C (600°F) is a good place to start.

ii. Once the iron is warm, brush it a couple of times on a water-wet sponge to remove the oxidized solder and flux

iii. If the components or board are dirty, clean them with an abrasive cleanser, water, and a kitchen pot scrubber.

iv. Put the component into the pc board and be sure that it is down as reasonably far on the board as it will go.

v. Bend the component leads over at a 45° angle

vi. Touch the soldering iron to both component lead and PC board pad at the same time.

vii. Feed the solder in from the other side and let the pad/component lead melt the solder

viii. Do not let the joint move while the solder is cooling.