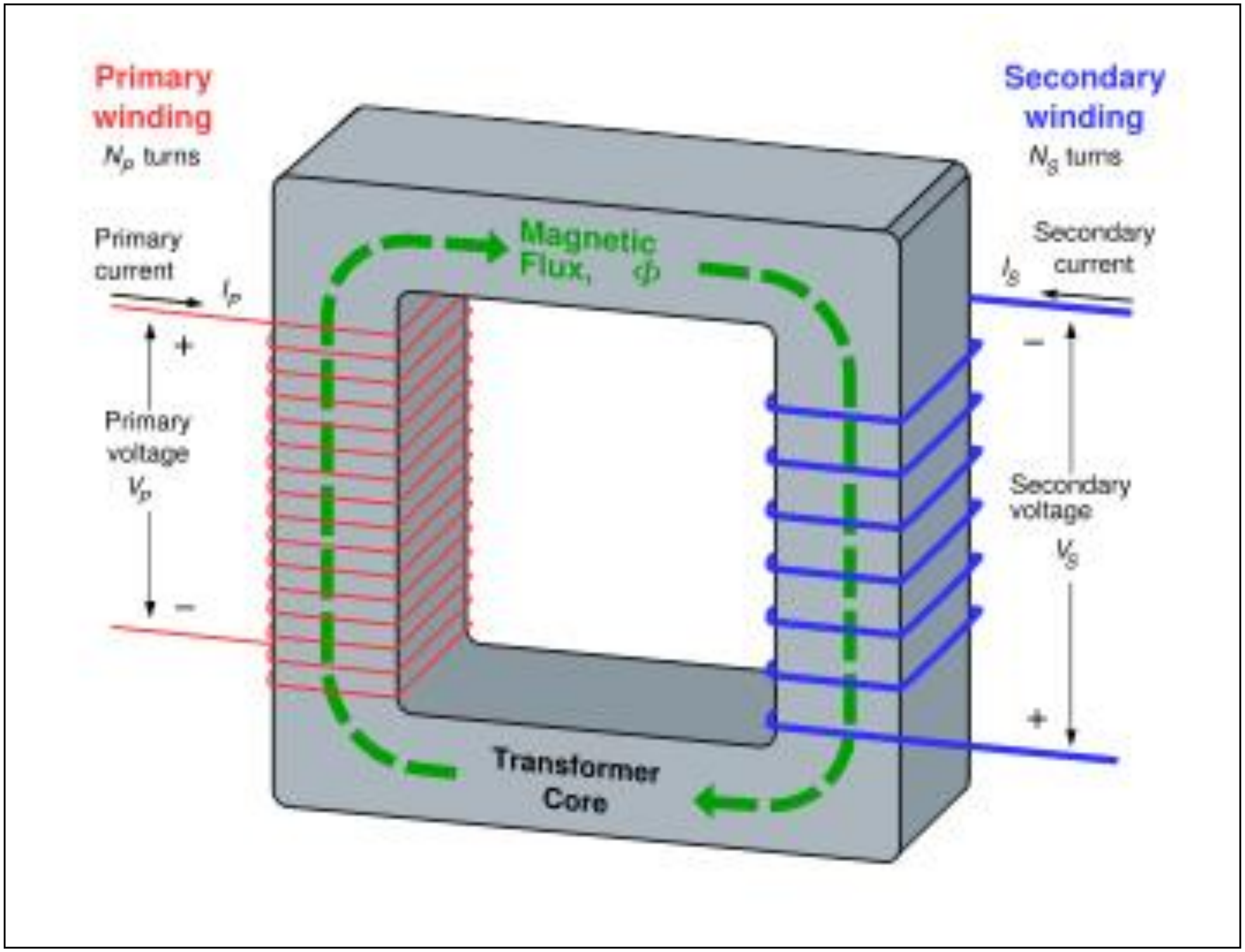
Sierra College **CIE-01**
Jim Weir **530.272.2203**
jweir43@gmail.com
www.rstengineering.com/sierra

Lesson 07

Transformers, Diodes, Capacitors
Putting It All Together

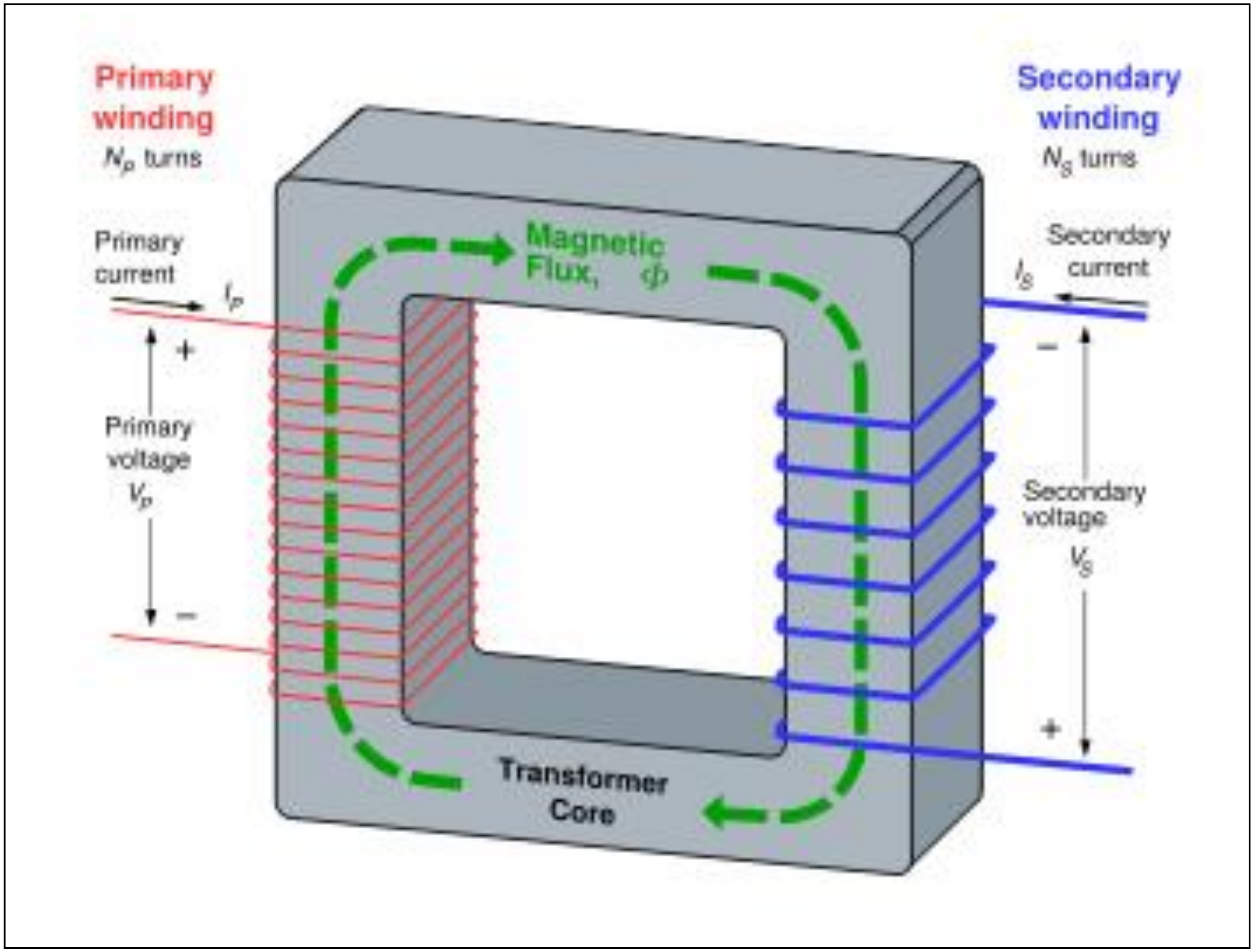
Some time ago, we began the study of electronics by examining some of the components that make up the art and science of electronics. Let's do a little review.

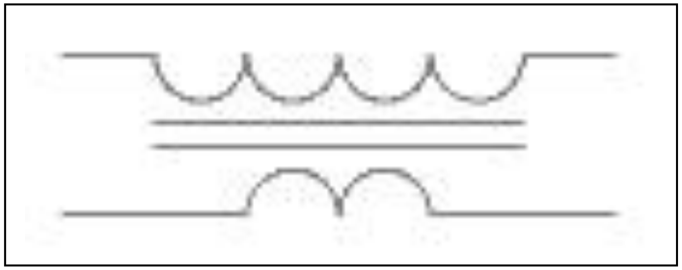


Transformers: We found that two coils of wire "close" to one another would couple to one another such that an ac voltage in one of the coils would induce an ac voltage in the other coil. What we MIGHT not have made perfectly clear is that there is something called a "turns ratio" that tells us what voltage in one coil will induce as voltage in the second coil.

We also found out that the EFFICIENCY of a transformer is greatly enhanced if we use ferrite or iron in the core of the transformer.

Let's examine our transformer. We have something that we call the "primary" winding and something we call the "secondary" winding. In general, we put a voltage and current INTO the primary and expect a voltage and current OUT OF the secondary. In the transformer shown, there are 15 turns on the primary and 6 turns on the secondary (generally there are several HUNDRED turns on the primary, but this will do for illustration). The voltage induced into the secondary due to the voltage in the primary is a direct function of the number of turns on the primary and the number of turns on the secondary. In fact, the voltage at the secondary is simply the voltage at the primary multiplied by (the number of turns on the secondary divided by the number of turns on the primary). Or, if you prefer math, $Vs = Vp * \left(Ns / Np \right)$.





For this example, Ns is 6 turns. Np is 15 turns Ns/Np is 0.4. If we put 120 vac (wall voltage) into the primary, we would expect the secondary voltage to be (120 * 0.4) 48 volts. And so it will be.

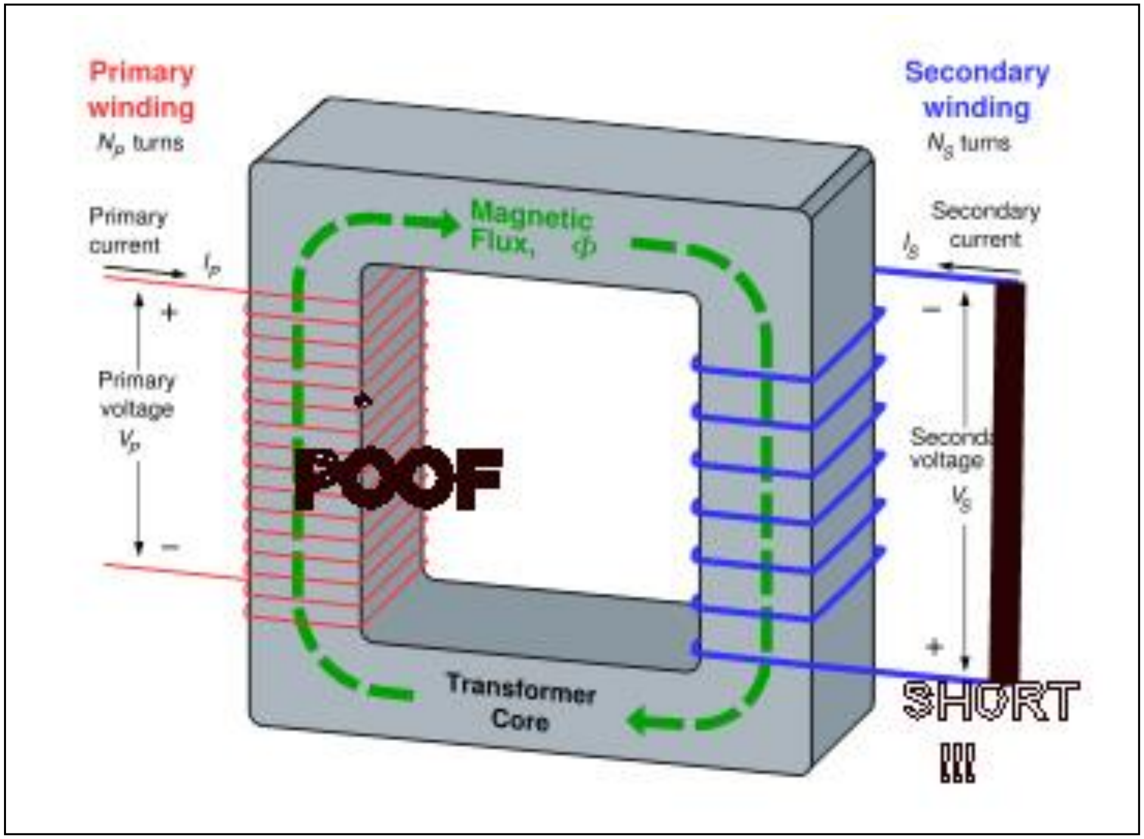
Now, here's the magic. The CURRENT in the primary is determined by the CURRENT in the secondary in exactly the same way. That is, if we put a load onto the secondary, the primary will draw just enough current from the source to feed the secondary. Or, again mathematically,

$Ip = Is\left(Ns/Np \right)$.

Again, for this example, let's presume that we put a load on our 48 volt secondary that draws 1 ampere. How much current will be drawn in the primary? 1 ampere times 0.4 or 400 milliamperes.

Now we have a problem. Let's say that Harry (or Harriet) Hamhand gets to the transformer area with a big screwdriver and shorts across the secondary. Lots and lots of current for a brief time. What happens in the primary? Lots and lots of current (times 0.4) for a brief time. How brief a time? Just long enough for the fairly fine wire in the primary to melt (or "burn") and we wind up with a burnt-out transformer.

Gee, that's not a particularly good idea. We need to take care of that little problem.

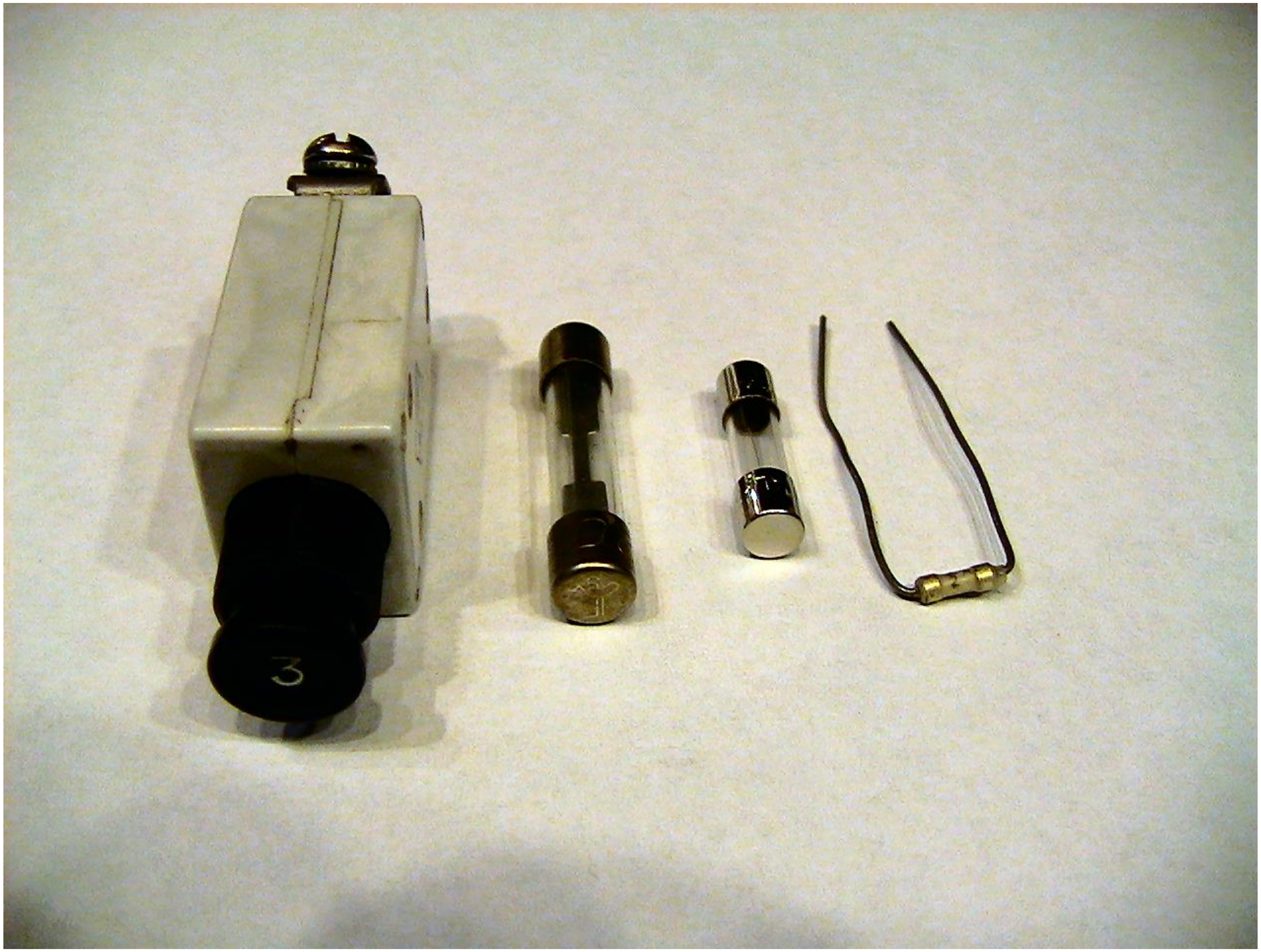


Fuse: A **FUSE** is nothing more than a wire that is designed to melt at a particular current level. A circuit breaker does the same thing, except that a heater inside the circuit breaker expands and throws a switch when the current exceeds the design current level.

The melting wire is enclosed in a glass or ceramic case so that any red hot wire (from the melting process) does not come into contact with anything that could catch fire.

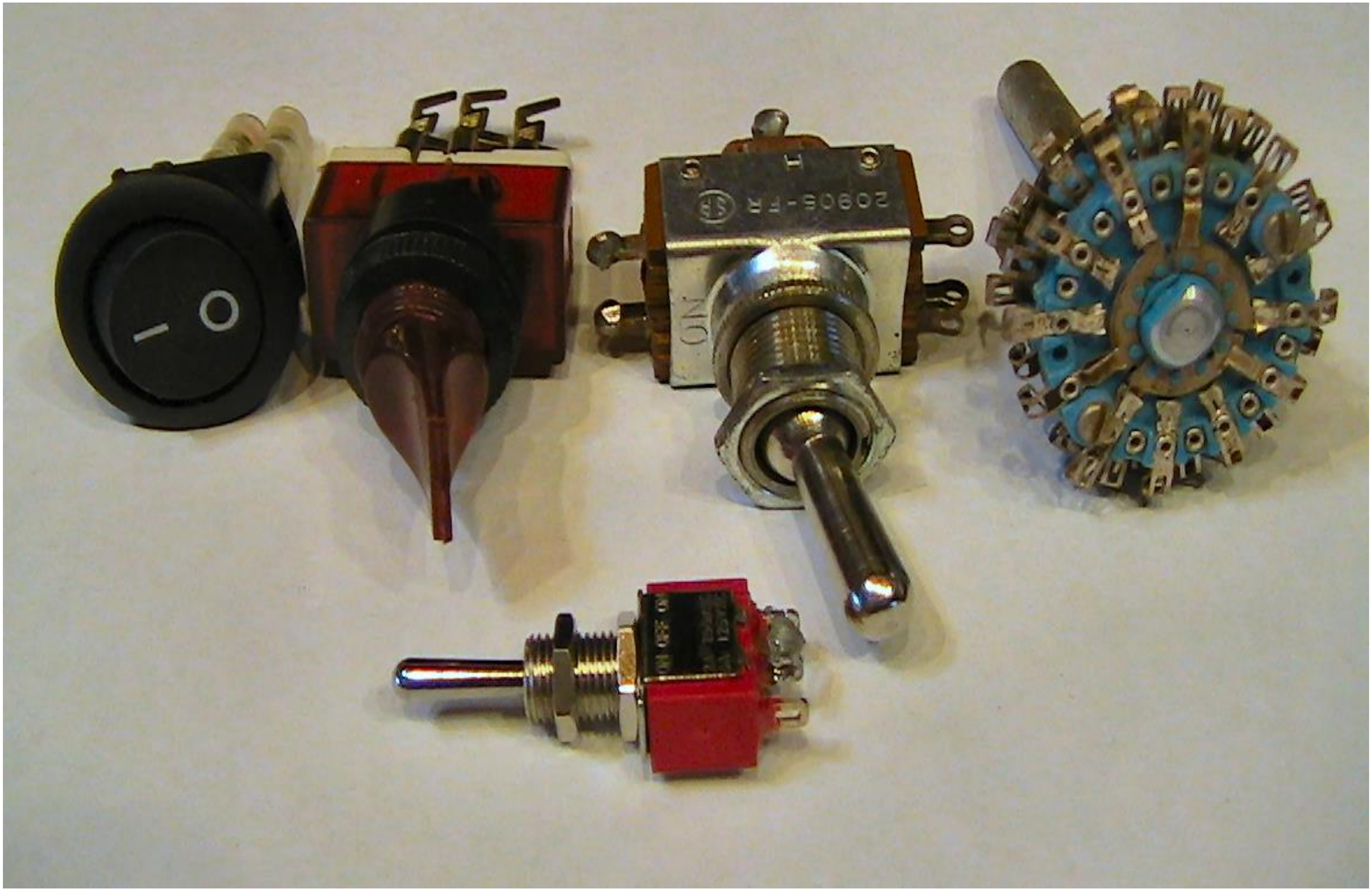
Some of you may have acquainted yourselves with fuses when you attempted to measure voltage on the current scale of the digital multimeter. Poof. However, it illustrates the point well. We protected a $5 meter with a 50¢ fuse.

Likewise with our transformer above. If we are going to have a chance of shorting the secondary wires together, then we had best protect the $15 transformer with a 50¢ fuse (not to mention the added possibility of the transformer catching on fire when the primary wire melts).



From left to right: A 3 amp aircraft type circuit breaker, a 20 ampere heavy current fuse, a 250 milliampere instrument fuse (look familiar???), and a 250 milliampere "last chance" solder-in fuse.

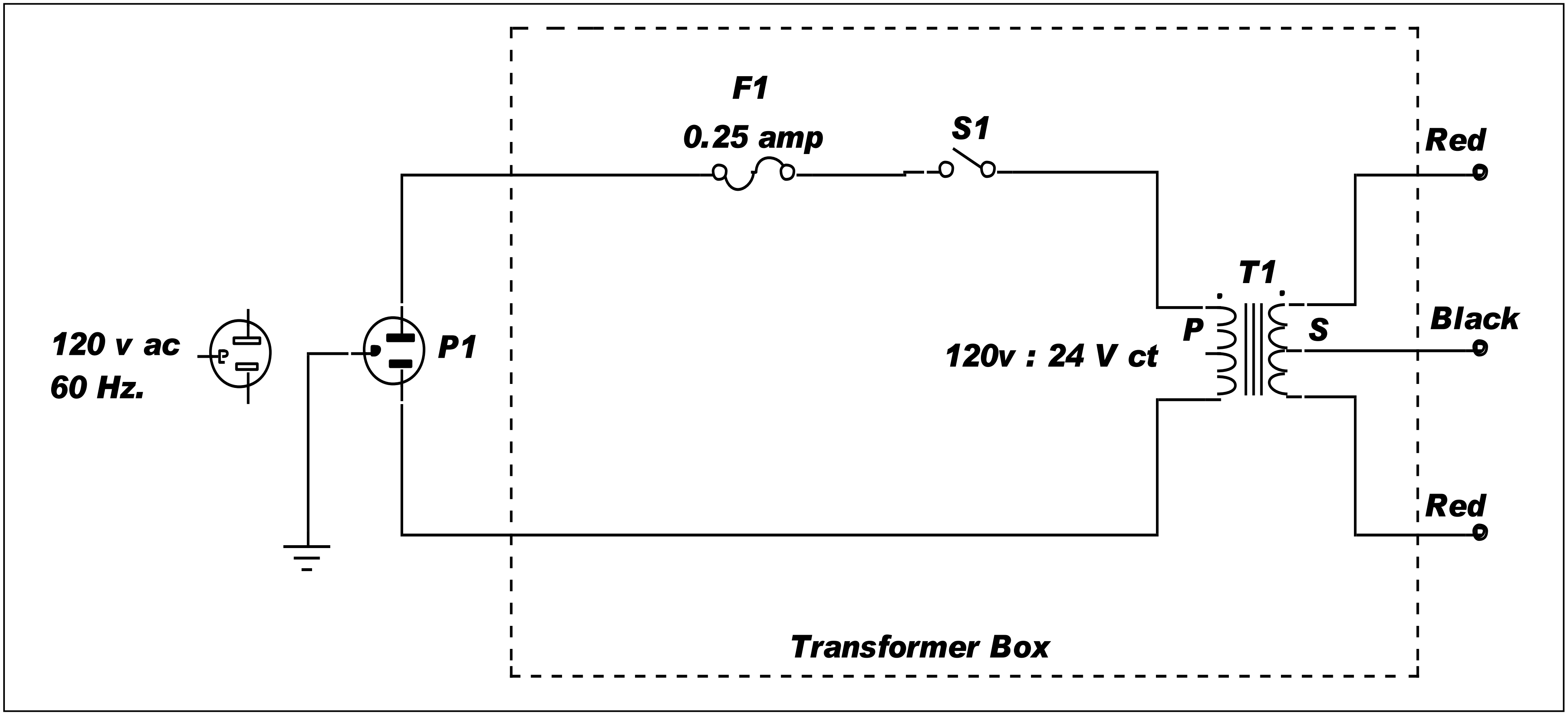
Switch: The lowly switch is nothing but two pieces of metal that may short together and "make" or separate and "break" to control current in an electronic circuit. Switches may come in toggle, pushbutton, rotary, and several lesser known combinations.



Putting all this together, and enclosing it inside of a box where you cannot accidentally come into contact with the line voltage, we have a premade "transformer box" with a 24 volt center tapped transformer inside. Please note that the colored (red-black) connectors may be reversed, but there will always be two of one color and one of another color.

Note: The fuse is the VERY FIRST THING you come to after the wall plug. If anything goes wrong inside or outside of the box, we want the fuse to blow first.

Murphy's IV-22 Law states: An expensive transistor protected by a cheap fuse will protect the fuse by blowing first. (See attachment to this document.)



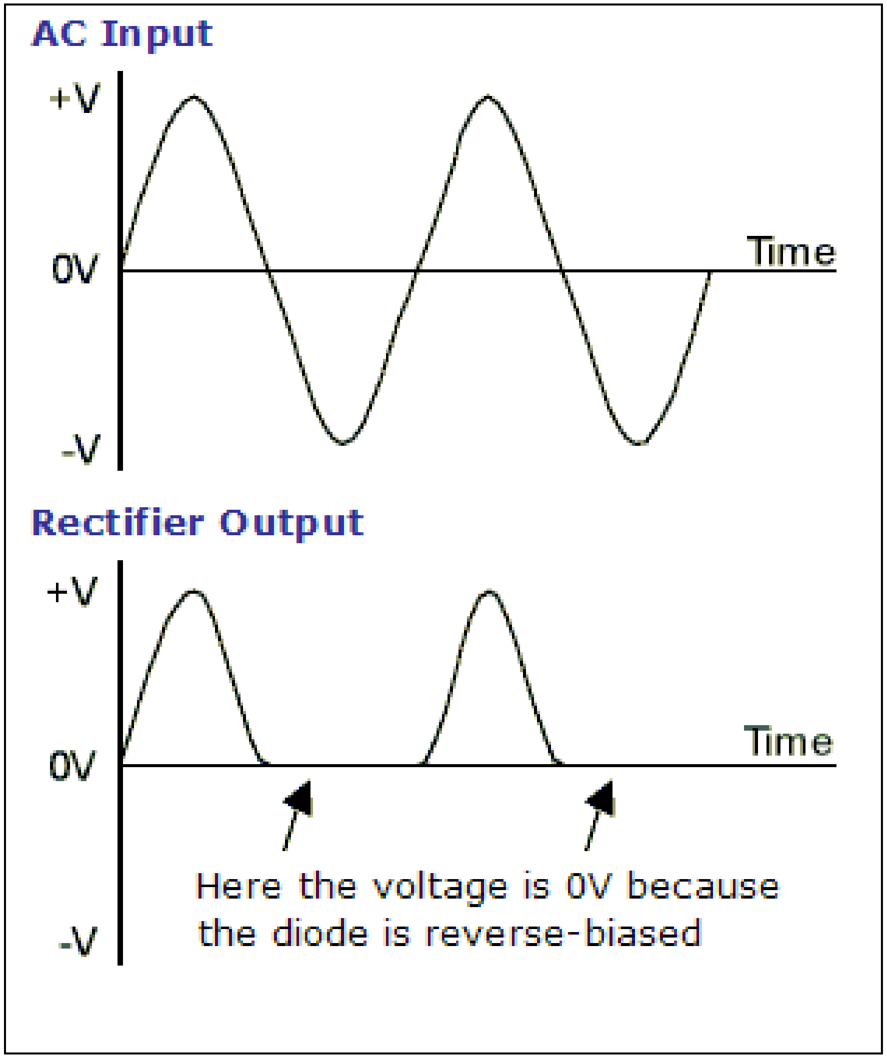
So now we've got a source of 12-0-12 volts AC (24 volts center tapped is 12 volts each side of center). How do we make a dc power supply?

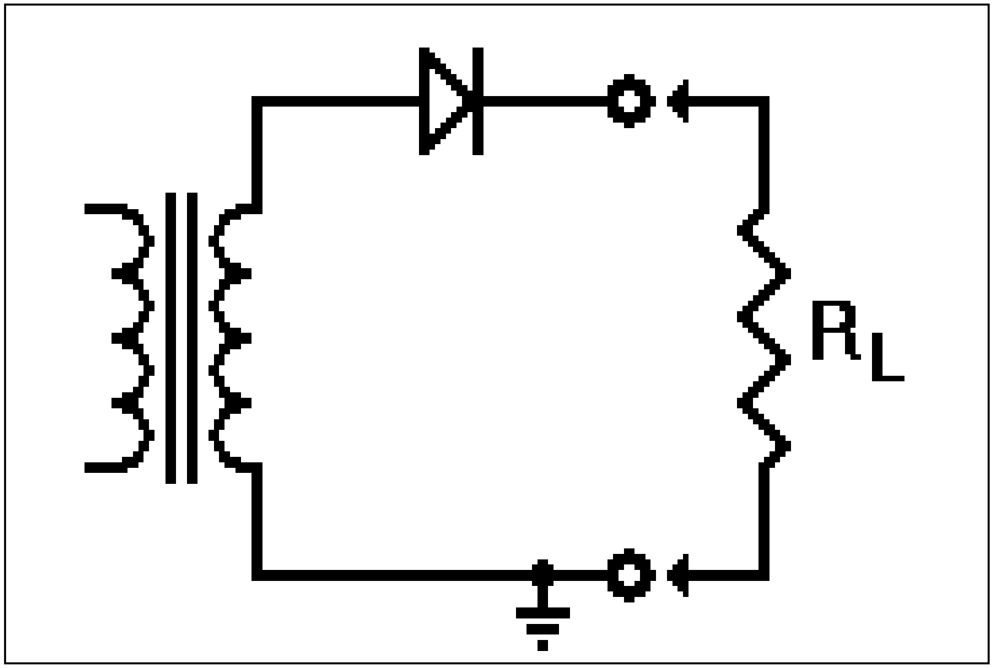
Diodes: The elementary half-wave rectifier will do for primitive supplies. Here we see our transformer (center tap on the bottom, second half of the transformer not shown).

This configuration is not very efficient and it is somewhat difficult to get "pure" dc from it because it shuts off half of the cycle for every cycle of input.

Here is what the output waveform of a half wave rectifier looks like as viewed on an oscilloscope:

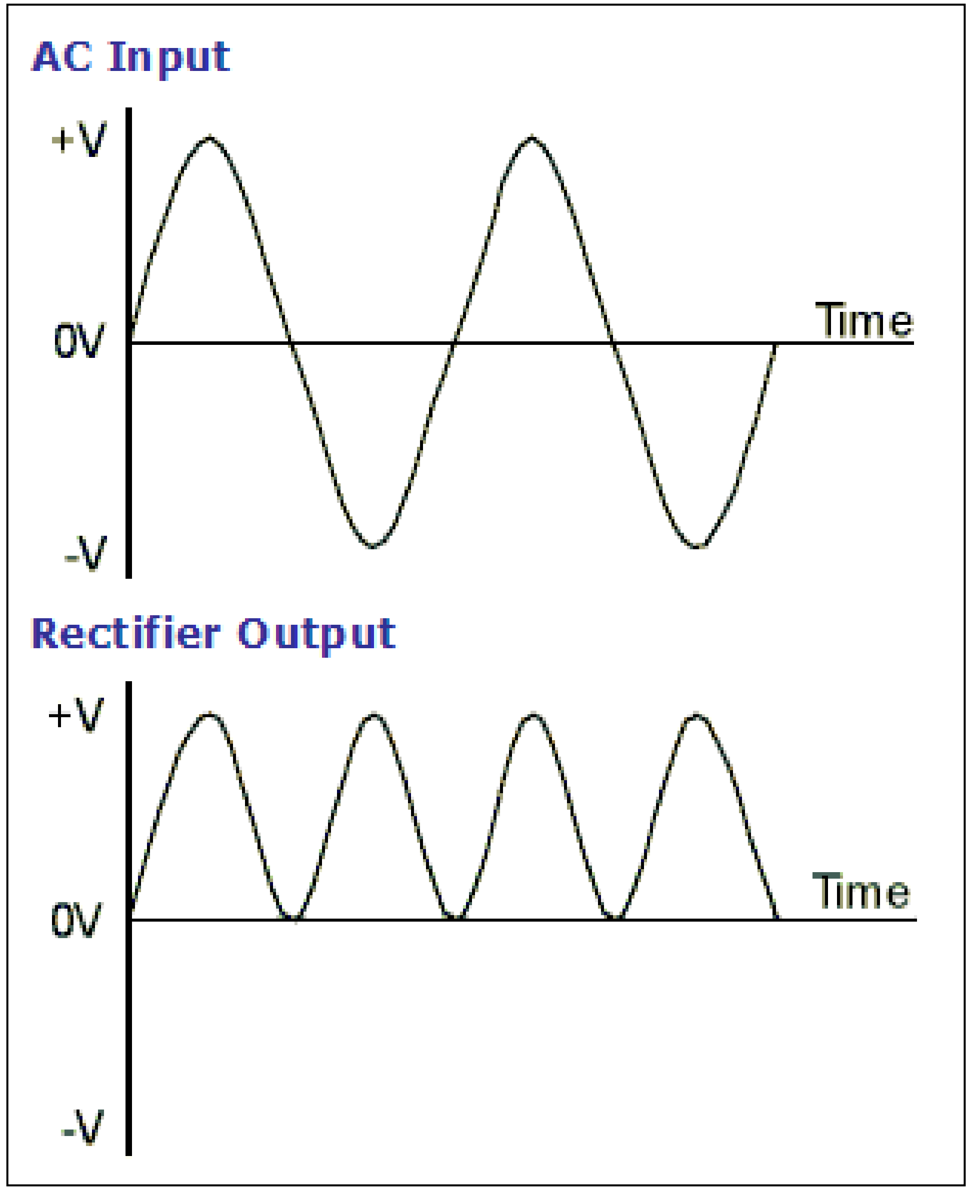
Note that the rectifier output starts at zero, goes to a peak, then back to zero where it stays for the negative half-cycle, then repeats. The problem is that this configuration needs a lot of filtering (see later) to get rid of the hum that this configuration produces.





One way of making this half-cycle dropout problem go away is to use a full-wave rectifier with two diodes as shown. Now when one half of the transformer is going positive one of the diodes conducts and when the other half of the transformer is going positive the other half conducts.

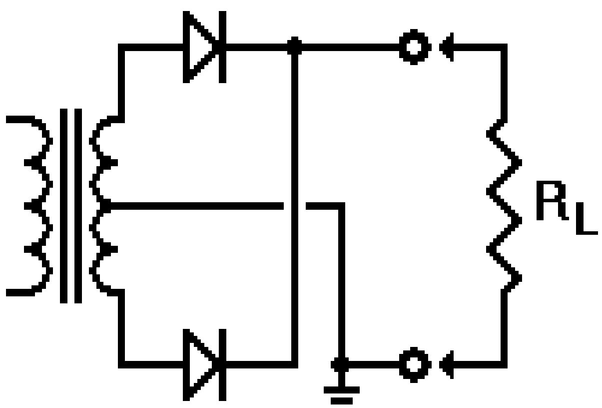
And the waveform that you get looks like this:



While this is quite an improvement over the half-wave rectifier, it is still only "pulsating dc", and really not usable for any electronic purpose except perhaps a battery charger -- and even then, more like an automobile battery charger and not a more sensitive battery such as a lithium-ion battery.

What we need is to "smooth" the ripple to where we can use it in a true electronic circuit.

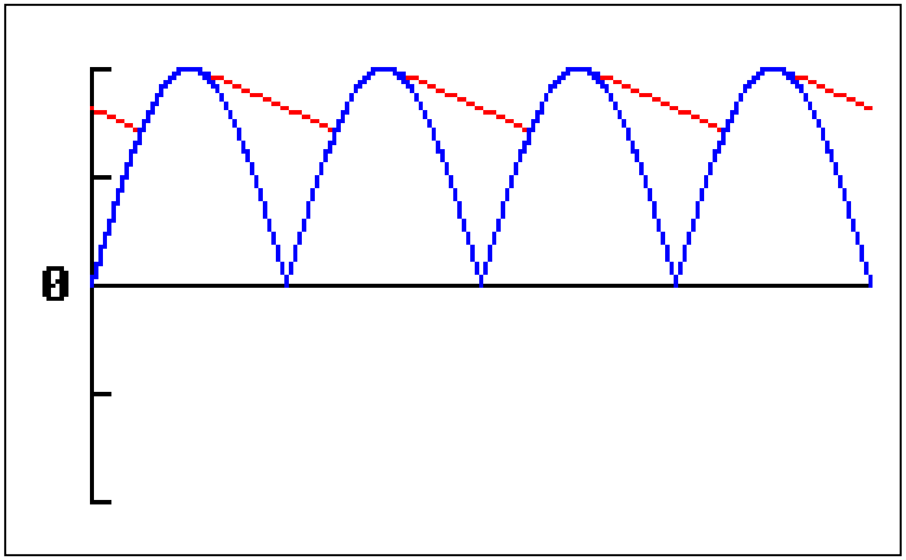
Let's see … we want to keep the voltage constant, what kind of electronic component acts to keep a constant voltage …???

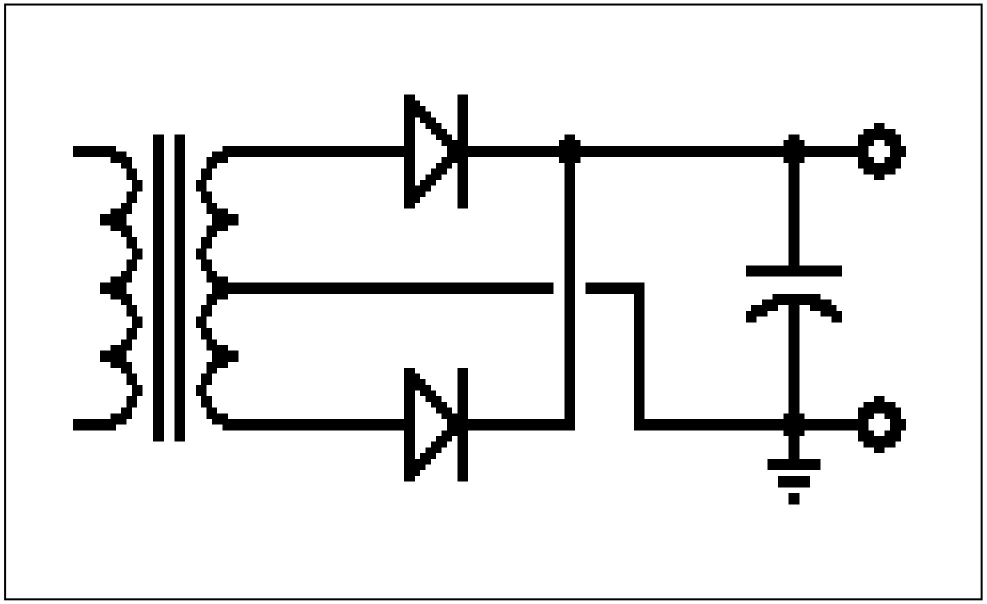


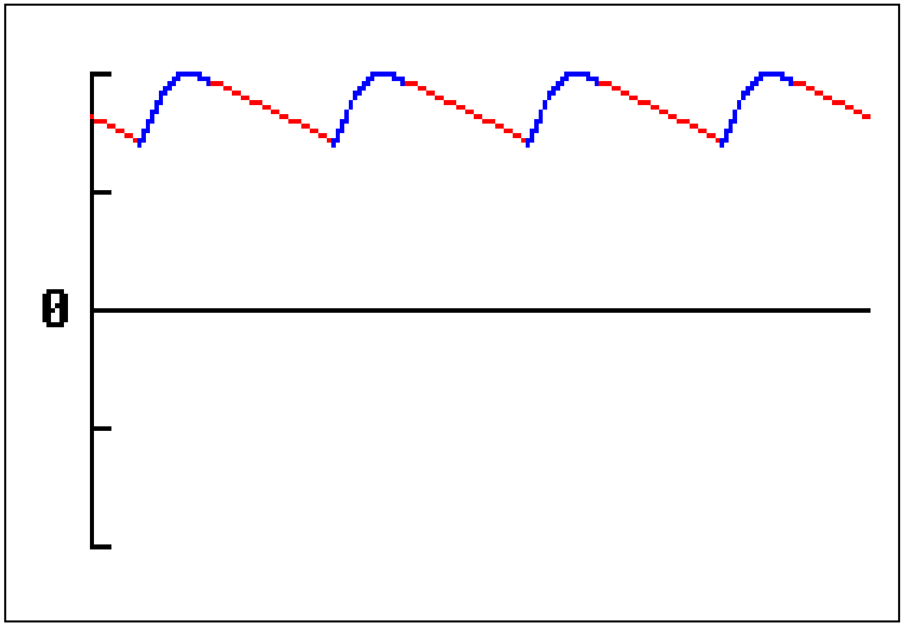
Did I hear "capacitor"??? Good. That's the circuit element that we'll use to smooth out our "rippley" supply voltage.

Here we see the voltage across the capacitor (red) charging up to the peak voltage of the rectifier output (blue). As the rectifier output drops to near zero, the load discharges the capacitor until the next cycle comes along to charge the capacitor back up.

hat we get, in essence, is a rather decent dc voltage with a little ripple on it. You don't like the amount of ripple? Simply put in a larger capacitor.

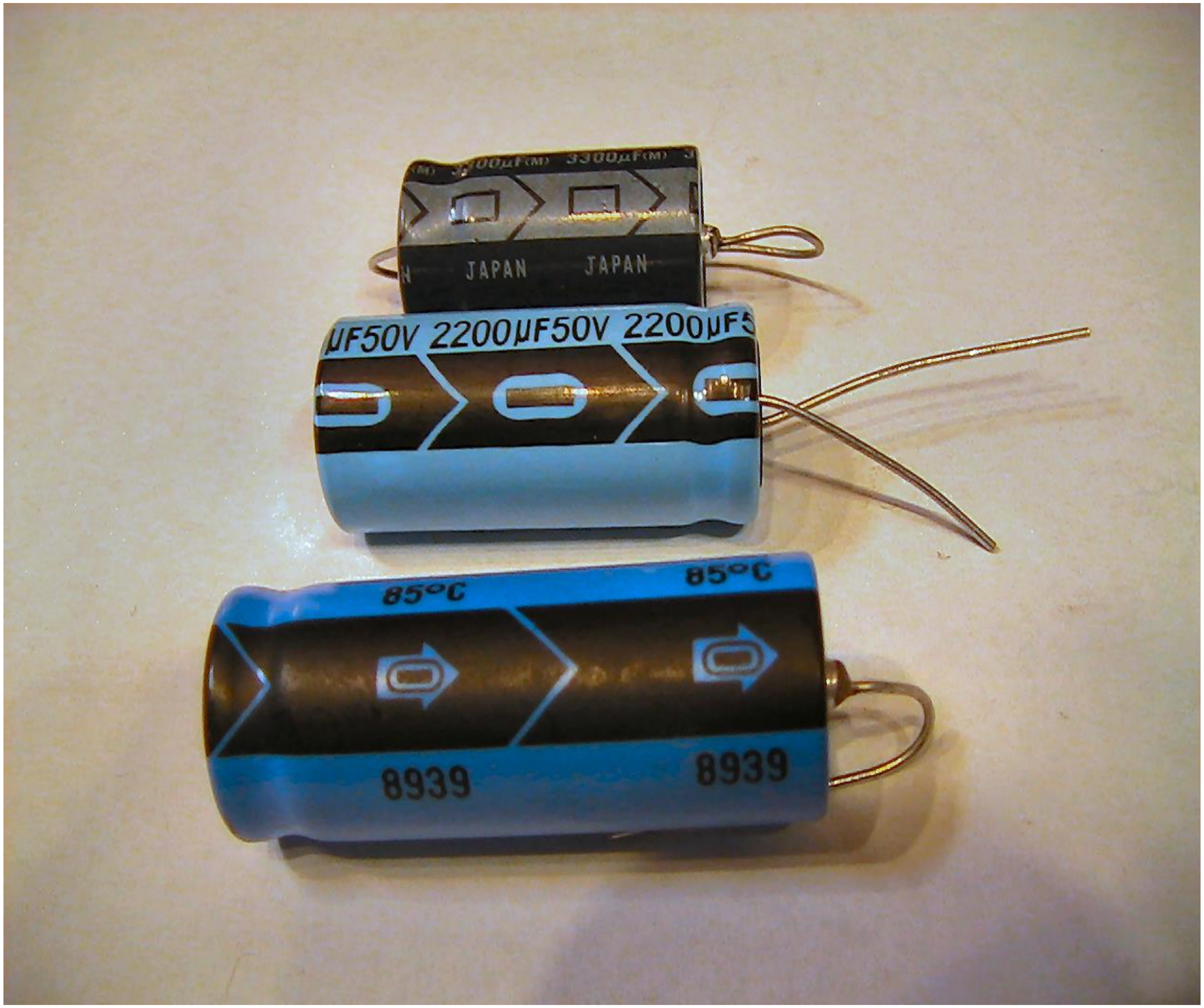




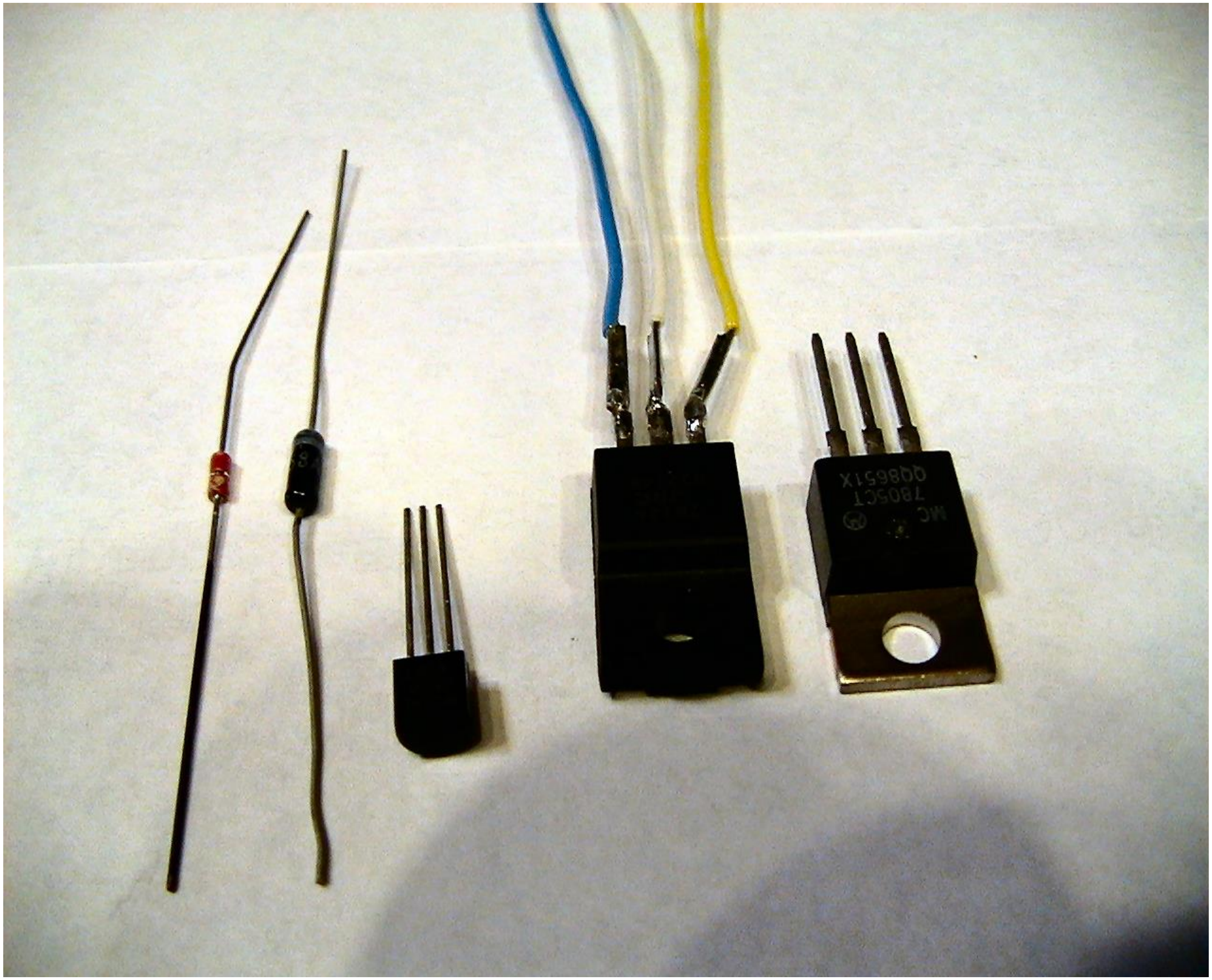


Here are some typical filter capacitors for a low voltage dc power supply. Please note:

- The capacitors are several thousand microfarads. Typical values for moderate voltage and current power supplies are between 1000 and 4700 microfarads and rated for a voltage that will not be exceeded by the peak value of the rectifier output.
- The capacitors all have arrows pointing to the NEGATIVE lead of the capacitor. Electrolytic capacitors are POLARIZED and must be installed into the circuit in the correct direction…positive to positive and negative to negative.
- **Electrolytic capacitors are made out of aluminum foil and "goop". If installed backwards, they can and will explode, scattering foil and goop all over the workbench.**



Regulator ("Zener") Diodes. As we have seen, a zener diode makes a very good voltage regulator, but only over a rather narrow range of currents. What we would like to have is a "super zener" that would regulate from a few milliamperes to an ampere or so.



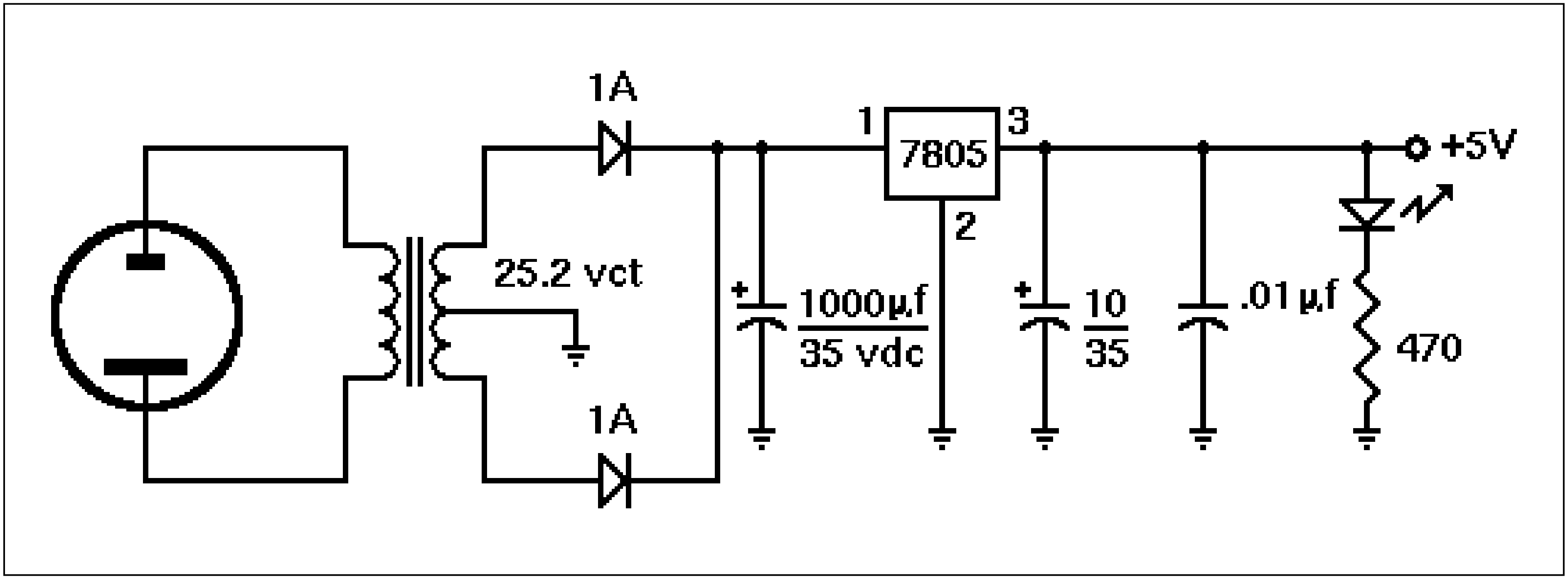
From left to right in this picture, we have plain zener diodes of the same voltage and same power rating, just different packaging. Next we have a little 3-lead "super zener" comprised of a linear amplifier (which we know nothing about yet) and a moderate power output transistor (which we know nothing about yet. Finally we have two high-current regulators with a high power output transistor (which we know nothing about yet).

Putting the regulator into the circuit, we have a useful power supply with a regulated output.

The "7805" is the super-zener that we alluded to above. It is possibly the "integrated circuit" (about which we know nothing yet) that has sold more units than any other chip in the history of electronics.

The "78" refers to the fact that it is a POSITIVE voltage regulator (puts out a positive voltage) and the 05 determines that it is a 5 volt fixed regulator. We have our choice of many voltages for a fixed regulator, and if (and when) you ever take CIE-14 we will be using a VARIABLE regulator to choose our output voltage by means of a variable resistor (potentiometer).

Note the + signs on the electrolytic capacitors in this circuit. These capacitors MUST be installed with the correct polarization.



Cahners Publishing Co., EEE Magazine, Vol. 15, No. 8, August 1967

The Contributions of Edsel Murphy to the Understanding of the Behavior of Inanimate Objects

D. L. KLIPSTEIN

Abstract - Consideration is given to the effects of the contributions of Edsel Murphy to the discipline of electronics engineering. His law is stated in both general and special form. Examples are presented to corroborate the author's Thesis that the law is universally applicable.

I. INTRODUCTION

It has long been the consideration of the author that the contributions of Edsel Murphy, specifically his general and special laws delineating the behavior of inanimate objects, have not been fully appreciated. It is deemed that this is, in large part, due to the inherent simplicity of the law itself.

It is the intent of the author to show, by references drawn from the literature, that the law of Murphy has produced numerous corollaries. It is hoped that by noting these examples, the reader may obtain a greater appreciation of Edsel Murphy, his law, and its ramifications in engineering and science.

As is well known to those versed in the state-of-the-art, Murphy's Law states that "If anything can go wrong, it will." Or, to state it in more exact mathematical form:

1 + 1 ☞ 2

where ☞ is the mathematical symbol for "hardly ever".

Some authorities have held that Murphy's Law was first expounded by H. Cohen[1] when he stated that ,,If anything can go wrong, it will - during the demonstration." However, Cohen has made it clear that the broader scope of Murphy's general law obviously takes precedence.

To show the all-pervasive nature of Murphy's work, the author offers a small sample of the application of the law in electronics engineering.

II. GENERAL ENGINEERING

II.1. A patent application will be preceded by one week by a similar application made by an independent worker.

II.2. The more innocuous a design change appears, the further its influence will extend.

II.3. All warranty and guarantee clauses become void upon payment of invoice.

II.4. The necessity of making a major design change increases as the fabrication of the system approaches completion.

II.5. Firmness of delivery dates is inversely proportional to the tightness of the schedule.

II.6. Dimensions will always be expressed in the least usable term. Velocity, for example, will be expressed in furlongs per fortnight.[2]

II.7. An important Instruction Manual or Operating Manual will have been discarded by the Receiving Department.

II.8. Suggestions made by The Value Analysis group will increase costs and reduce capabilities.

II.9. Original drawings will be mangled by the copying machine.[3]

III. MATHEMATICS

III.1. In any given miscalculation, the fault will never be placed if more than one person is involved.

III.2. Any error that can creep in, will. lt will be in the direction that will do the most damage to the calculation.

III.3. All constants are variables.

III.4. In any given computation, the figure that is most obviously correct will be the source of error.

III.5. A decimal will always be misplaced.

III.6. In a complex calculation, one factor from the numerator will always move into the denominator.

IV. PROTOTYPING AND PRODUCTION

IV.l. Any wire cut to length will be too short.

IV.2. Tolerances will accumulate unidirectionally toward maximum difficulty of assembly.

IV.3. Identical units tested under identical conditions will not be identical in the field.

IV.4. The availability of a component is inversely proportional to the need for that component.

IV.5. If a project requires n components, there will be n-1 units in stock.[4]

IV.6. If a particular resistance is needed, that value will not be available. Further, it cannot be developed with any available series or parallel combination.[5]

IV.7. A dropped tool will land where it can do the most damage. (Also known as the law of selective gravitation.)

IV.8. A device selected at random from a group having 99% reliability, will be a member of the 1 % group.

IV.9. When one connects a 3-phase line, the phase sequence will be wrong.[6]

IV.10. A motor will rotate in the wrong direction.[7]

IV.11. The probability of a dimension being omitted from a plan or drawing is directly proportional to its importance.

IV.12. Interchangeable parts won't.

IV.13. Probability of failure of a component, an assembly, subsystem or system is inversely proportional to ease of repair or replacement.

IV.14. lf a prototype functions perfectly, subsequent production units will malfunction.

IV.15. Components that must not and cannot be assembled improperly will be.

IV.16. A dc meter will be used on an overly sensitive range and will be wired in backwards.[8]

IV.17. The most delicate component will drop.[9]

IV.18. Graphic recorders will deposit more ink on humans than on paper.[10]

IV.19. If a circuit cannot fail, it will.[11]

IV.20. A fail-safe circuit will destroy others.[12]

IV.21. An instantaneous power-supply crowbar circuit will operate too late.[13]

IV.22. A transistor protected by a fast-acting fuse will protect the fuse by blowing first.[14]

IV.23. A self-starting oscillator won't.

IV.24. A crystal oscillator will oscillate at the wrong frequency - if it oscillates.

IV.25. A pnp transistor will be an npn.[15]

IV.26. A zero-temperature-coefficient capacitor used in a critical circuit will have a TC of -750 ppm/^{0}C.

IV.27. A failure will not appear till a unit has passed Final lnspection.[16]

IV.28. A purchased component or instrument will meet its specs long enough, and only long enough, to pass Incoming Inspection.[17]

IV.29. If an obviously defective component is replaced in an instrument with an intermittent fault, the fault will reappear after the instrument is returned to service.[18]

IV.30. After the last of 16 mounting screws has been removed from an access cover, it will be discovered that the wrong access cover has been removed.[19]

IV.31. After an access cover has been secured by 16 hold-down screws, it will be discovered that the gasket has been omitted.[20]

IV.32. After an instrument bas been fully assembled, extra components will be found on the bench.

IV.33. Hermetic seals will leak.

V. SPECIFYING

V.1. Specified environmental conditions will always he exceeded.

V.2. Any safety factor set as a result of practical experience will be exceeded.

V.3. Manufacturers' spec sheets will be incorrect by a factor of 0.5 or 2.0, depending on which multiplier gives the most optimistic value. For salesmen's claims these factors will be 0.1 or 10.0.

V.4. In an instrument or device characterized by a number of plus-or-minus errors, the total error will be the sum of all errors adding in the same direction.

V.5. In any given price estimate, cost of equipment will exceed estimate by a factor of 3. [21]

V.6. In specifications, Murphy's Law supersedes Ohm's.

REFERENCES *

[1] H. Cohen, Roundhill Associates, private communication.

[2] P. Birman, Kepco**,** private communication.

[3] T. Emma, Western Union. private communication.

[4] K. Sueker, Westinghouse Semiconductor, private communication.

[5] ------------, *loc. cit.*

[6] ------------, *loc. cit.*

[7] ------------, *loc. cit.*

[8] P. Muchnick, Sorensen, private communication.

[9] A. Rosenfeld Micro Power, private communication.

[10] P.Muchnik, *loc. cit.*

[11] R. Cushman, McCann/ITSM, private communication.

[12] ---------------, *loc. cit.*

[13] ---------------, *loc. cit.*

[14] S. Froud, Industrial Communications Associates, private communication.

[15] L. LeVieux, Texas Instruments, private communication.

[16] G. Toner, Sylvania, private communication.

[17] H. Roth, Power Designs, private communication.

[18] W. Buck, Marconi Instruments, private communication.

[19] A. de la Lastra, SBD Systems, private communication.

[20] ------------------, *loc. cit.*

[21] P. Dietz, Data Technology, private communication.
*In some cases where no reference is given, the source material was misplaced during preparation of this paper (another example of Murphy's Law). In accordance with the law, these misplaced documents will turn up on the date of publication of this paper.

The man who developed one of the most profound concepts of the twentieth century is practically unknown to most engineers. He is a victim of his own law. Destined for a secure place in the engineering hall of fame, something went wrong.

His real contribution lay not merely in the discovery of the law but more in its universality and in its impact. The law itself, though inherently simple, has formed a foundation on which future generations will build.

Manuscript received April 17, 1967; revised June 3, 1967. The work reported herein has not been supported by grants from the Central Intelligence Agency.

The author is Director of Engineering at Measurement Control Devices, 2445 Emerald Street, Philadelphia, Pa.