BOOK EVOLUTION

This book and associated CD evolved from a series of *HANDS-ON* instructional courses originally developed by NOESS LLC as a summer program for kids. In addition to these courses, the *College for Kids* program run by Saddleback College Community Education in Orange County California offers a wide variety of other summer classes for kids of all ages.

Because no hard-copy of this course was provided to the students, many parents asked for CD copies for review at home. Most found that without a knowledgeable instructor to explain them, many of the slides appeared incomplete.

Adding explanatory text to each slide was found to be impractical. Therefore, this book format was created by adding supporting notes to those slides needing more technical detail. These added BOOK NOTES are printed in blue in order to differentiate them from the original material.

INTRODUCTION & ADMINISTRATION

Welcome to *KidsTricity Two*. The material in this presentation is intended to be conducted in a classroom which is instructor lead.

This *intermediate level* course is specifically designed for students at least 10 years old. Experience has shown few younger than this have the attention span or maturity to sufficiently comprehend the DC and AC principles supporting the analog and digital electronic processes explored in the course.

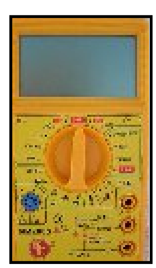
The material covers enough *fundamentals* to teach the operation, design and construction of AM, FM and other current wire and wireless technologies, as they are presented in a simplified form. It supports a base of knowledge adequate for subsequently undertaking other electro-technology courses.

For an *introductory level* course designed for kids at least 7 years old, see *KidsTricity One*.

COURSE MATERIALS

The projects as executed in this course are based on Electronic Snap Circuits® SC500 kit with associated book numbers 753102 Rev E, 753098 Rev E and 753104 Rev C from Elenco® Electronics, Inc.

In addition to the SC500 Kit, two inexpensive multimeters are required in order to adequately complete many of the Projects in the Course.

LESSON LIST

Lesson 1	Learning how to use the kit to build circuits.
Lesson 2	Learning about VOLTAGE, CURRENT and RESISTANCE.
Lesson 3	Learning how to measure VOLTAGE, CURRENT and RESISTANCE.
Lesson 4	Learning about POWER and SIGNAL applications.
Lesson 5	Learning about SIGNAL FORMS.
Lesson 6	Learning about DIGITAL GATES and SWITCHES.
Lesson 7	Learning about CAPACITORS, INDUCTORS, OSCILLATORS, AMPLIFIERS and IC's
Lesson 8	Survey of ANALOG & DIGITAL convergence.
Lesson 9	Building several versions of AM & FM RADIOS.
Lesson 10	Other interesting stuff.

LEARNING OBJECTIVES

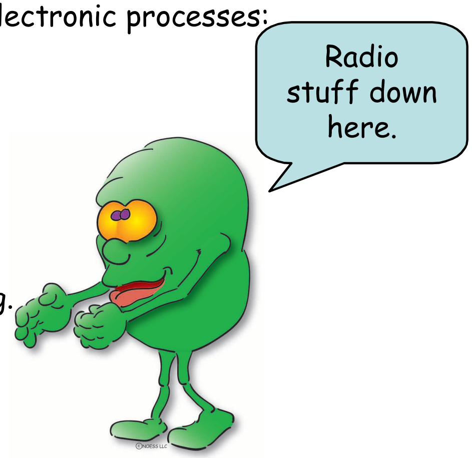
Build selected SC-500 Projects with the final one being a working FM radio.

Explain the general electronic principals of project operations.

Safely use simple test equipment to measure circuits and components of selected Projects.

Experiment with these electric/electronic processes:

- Voltage.
- Current.
- Resistance.
- Capacitance.
- Inductance.
- Amplification.
- Oscillation.
- Gating & Switching.
- Modulation.
- Multiplexing.



SC500 KIT

EACH STUDENT WILL RECEIVE A SC500 Snap Circuit Kit WHICH BECOMES THEIR PERSONAL PROPERTY AT THE END OF THE COURSE.

PERIODICALLY, EACH TEAM OF 2 WILL RECEIVE ONE DIGITAL AND ONE ANALOG MULTIMETER WHICH MUST BE RETURNED AT THE END OF EACH CLASS DAY.

Put your name on the outside and inside of the box and books.

This is your kit…if you lose or break parts you will have to replace them!

As may become evident to many readers during the progression of the course material, this author's bias is toward electronic transmission systems.

Ultimately, the focus of this course is understanding the processes and systems which transport information from one human to another. At its base this requires *signals* of some sort to be exchanged between two (or more) humans. We often use very sophisticated intermediate (electronic) systems to accomplish the task. This course explores some of them.

SIGNALING SUB-CATS

ANALOG PROCESSES

Variable changes in signal characteristics.

(Needed for understanding AM & FM radio.)

DIGITAL PROCESSES

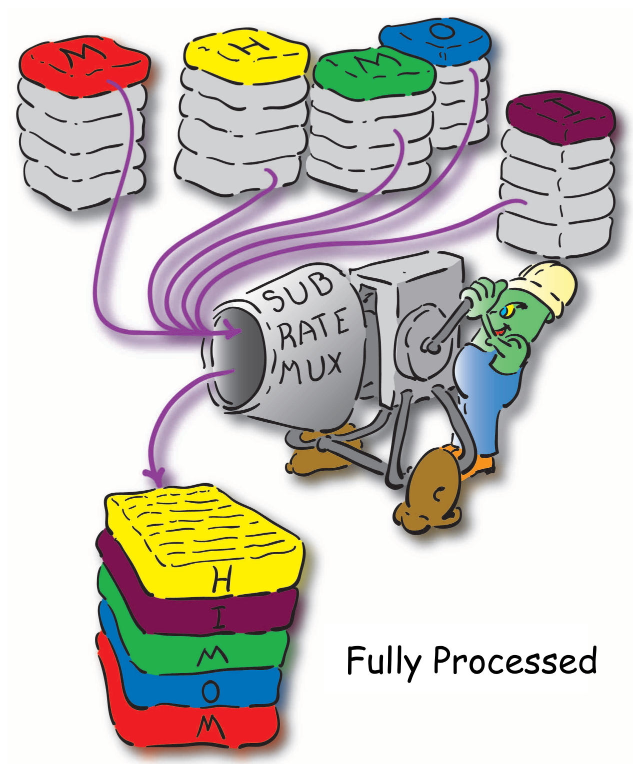
Abrupt changes in signal characteristics.

(Needed for understanding DATA applications.)

COMBINED AND/OR CONVERTED PROCESSES

Abrupt changes being represented by variable changes or vice-versa.

(Needed for understanding CATV, Digital TV and Cellular Radio.)



Fully Processed

BOOK NOTES

Here begins but a few snow flakes of the veritable blizzard of terms and acronyms which a serious student of electronics must master. Only a few are needed for this course of instruction.

FUN-DA-MENTALS

To gain a fundamental understanding of these applications, we need to agree on some simplified concepts of electricity.

We will begin our learning by defining some basic terminology and measurement names.

1) In a metallic (wires) electric circuit, the *flow* of electric current (electrons) = *AMPERES.*
2) The value of circuit *power* = *WATTS*.
3) The electrical *pressure* which causes electron flow = *VOLTS* of EMF (Electro-Motive Force).
4) The *resistance* to electron (current) flow = *OHMS.*
5) The *magnetic field* around a wire with electron (current) flow = *HENRIES.*
6) The *electric field* in a charged circuit = *FARADS.*
7) The *alternations* (cycles) of current flow = *HERTZ.*

BOOK NOTES

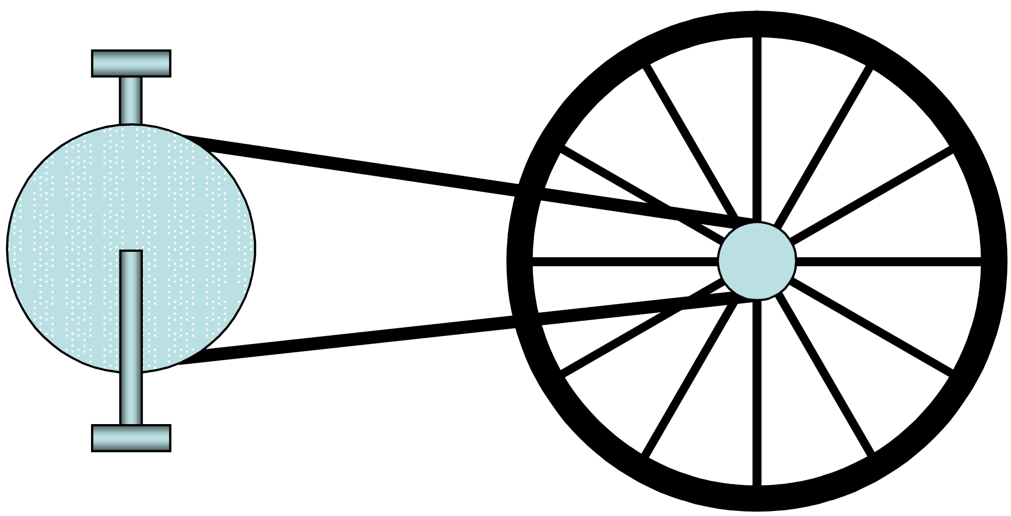
Labeling the men whose names are used for these electrical measurements as “old geezers with beards” helps a lot of the kids to remember their names.

Many times the movement of water thru pipes is used to describe the flow of current in an electrical circuit. While this can be initially useful, it sometimes leaves the impression that it is the physical flow which is doing the work at the circuit's load point.

A more accurate analogy is that of a single link in a bicycle chain representing a single electron. Even the smallest movement (in either direction) will result in energy transfer to the load (wheel). The links don't get used up and don't have to physically get all the way out to the load for energy transfer to take place.

LIKE A BIKE CHAIN

1) Pumping the pedals inserts power into the system. (ENERGY)
2) Crank transfers power to move chain links. (ELECTRONS)
3) Links transfer power to wheel. (LOAD)

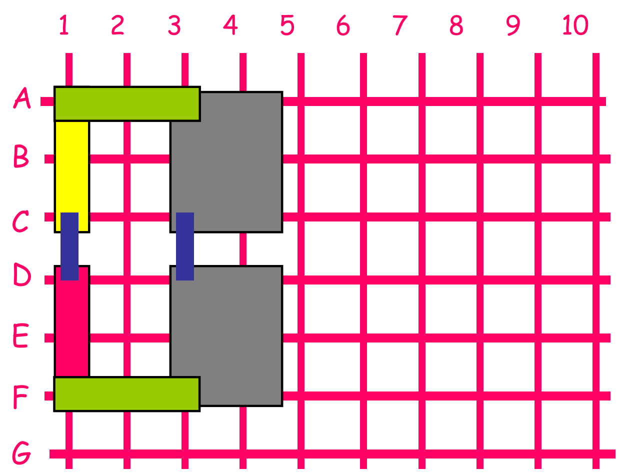


NOTE – no chain links (electrons) get "used up" in this energy transfer.

The energy is instantaneously coupled from the source to the load with even the slightest movement of the pedals…minus a little chain slack.

THE BIG BUILD

1) Open your Kit and find Book 102-305 (Rev E).
2) Go to page 8 and completely read the info in the objectives and directions boxes for Project #102.
3) Build Project #102.
4) Insert cells into B1's but leave switch in OFF position.



MAKE SURE YOU CHECK THE + & - ON ALL OF THE MARKED COMPONENTS!!

BOOK NOTES

If you have not purchased a Kit or gone to the Elenco web site and downloaded the free PDF versions of the Project books you will not have the details of the components used to build a Project.

In early versions of KidsTricity-1 a photo of each project was used instead of the generalized drawing as shown on the slide page. This resulted in the kids looking at the projection screen instead of using the Project books. The current version of KT-1 and this version of KT-2 changed over to use these generalized drawings in order to force the kids to practice using the books, as that is all they have to use after the formal class.

A PUNISHMENT PIE

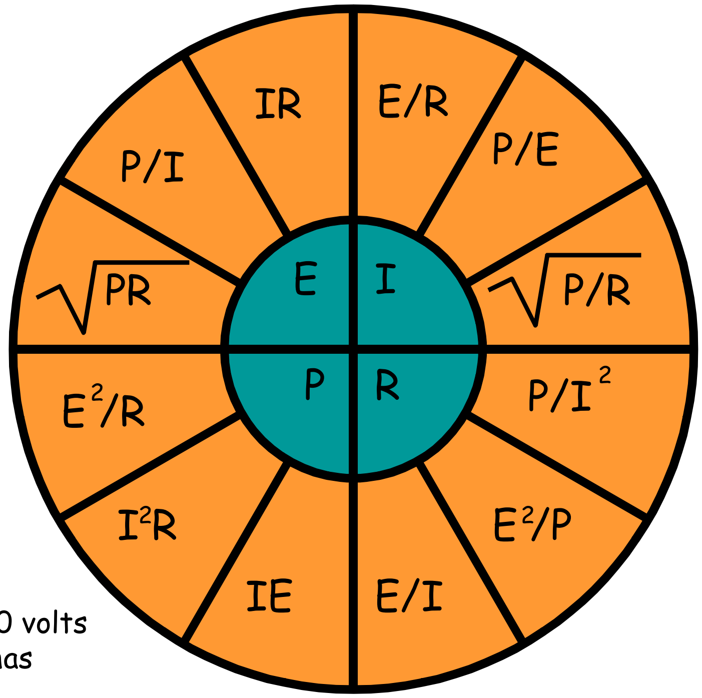
A picture not everyone wants to see: A combo of Ohms and Watts laws.

E = voltage in volts.

I = current in amps.

P = power in watts.

R = resistance in ohms.



Example: P=IE

Power = current x voltage.

A 100 watt light bulb draws 1 amp at 100 volts and if you keep it burning for 1 hour it has used 0.1 kWh of power.

BOOK NOTES

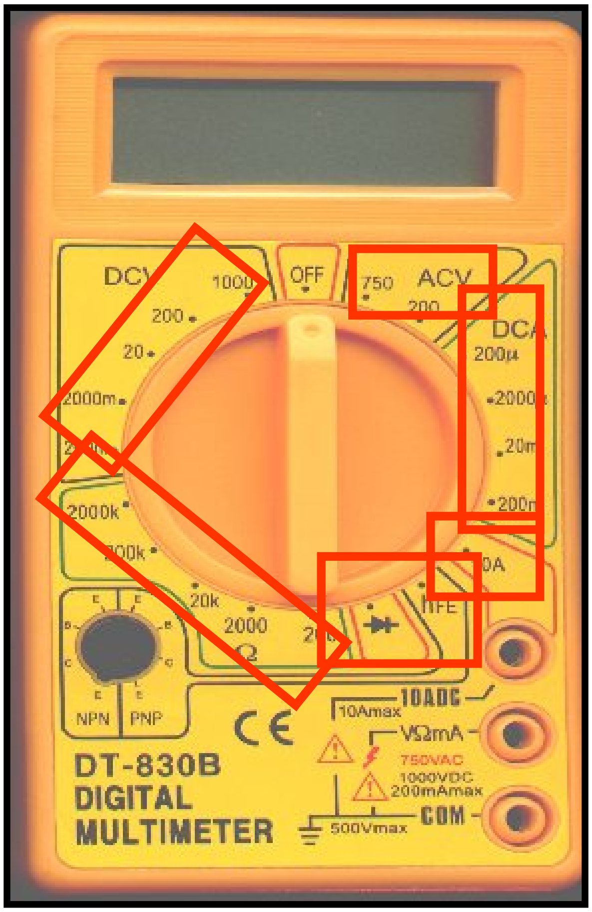
The technical answer to the question of 60W verses 100W bulbs is clearly shown by choosing the correct formula in the pie.

For those who prefer to noodle it out, it's as easy as PIE. Consider, the two bulbs experience the same voltage E. As can be seen by looking at them, the only thing which can be different in their manufacture is the resistance R of the little wire filament inside each bulb.

The previous Kit Project using RV with the LED's showed that by lowering the circuit resistance the LED's will get brighter. Since the only thing which can be changed in a simple light bulb is the filament, it's logical to assume from our newly acquired base of electronic knowledge that a lower resistance filament would allow more current to flow. More current flow would result in more heat being generated in the filament. More heat means more light.

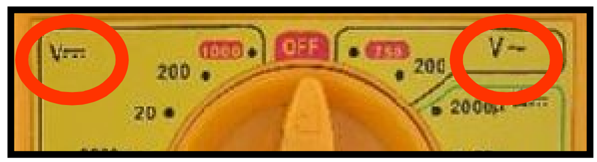
Light bulb wattage (P) calculates from the amount of current (I) flowing as a result of voltage (E) across the filament. P=IE. The amount of current (I) is a result of the common to both bulbs voltage (E) divided by their different filament resistances (R). I=E/R shows when R goes down I goes up, and when I goes up, P goes up.

DIGITAL MULTI METER (DMM)



The display is in fixed digits as generated by an internal sampling circuit and is thus called a *digital* meter.

- This model will measure:
  - DC volts.
  - AC volts.
  - DC amps (two inputs and ranges).
  - Resistance.
- This model will also test transistors and diodes.
- Some models may use symbols for DC and AC ranges (strait line for DC and sine wave for AC)



BOOK NOTES

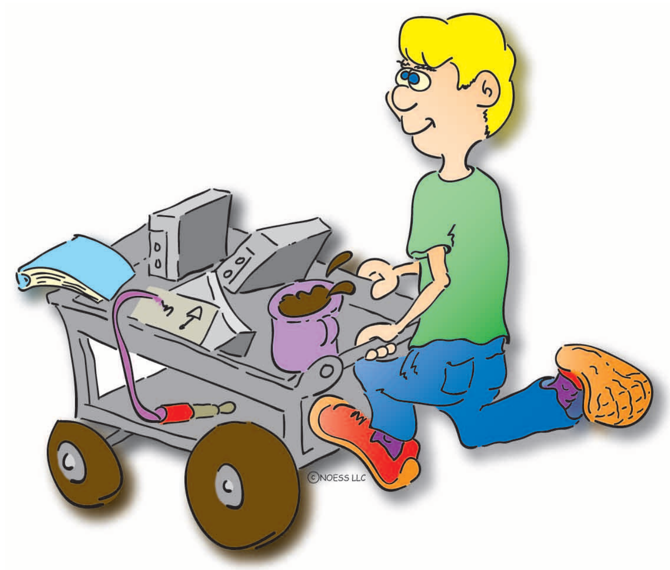
When working with electricity the safest mind set to maintain at all times is the expectation of dangerous voltage on components and devices about to be measured.

Even though there is absolutely no electrical danger to a student when using the Kit, this expectation is important to teach at the beginning of any course dealing with measuring devices.

Aside from personal danger in high voltage circuits, if a meter is set to read high voltage and is applied across a low voltage device, no harm done. If set low and put across a high voltage, damage to the meter is possible.

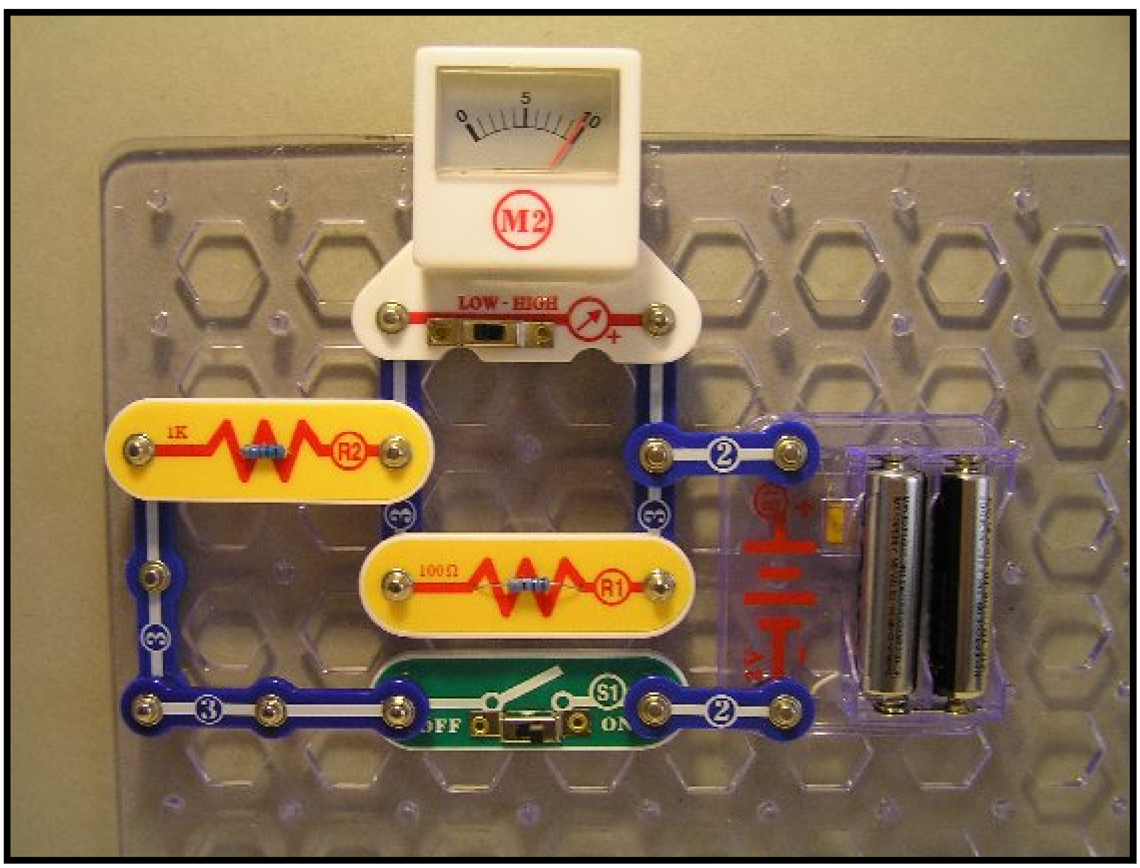
Another good habit to create is the use of only one hand when connecting test probes. Attach the first one and only then (using same hand) attach the second one. This one hand rule can be a life saver when dealing with lethal voltages such as those inside power system cabinets. If properly insulated from ground, using one hand will not create a current path thru your body. However, reaching inside equipment with both hands can create a current path from one to the other thus sending current across your heart.

PART B: BUILD CIRCUITS



BOOK NOTES

The name of this Project is *3mA Meter* and its objective is: *To build a 3mA meter circuit.*

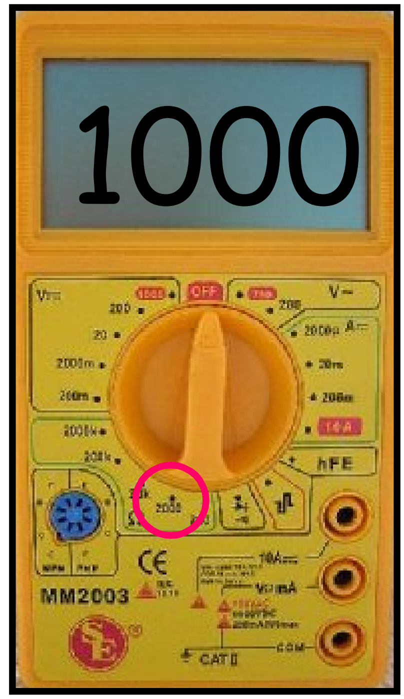


The most accurate reading for the 1000Ω R2 will be obtained when the range switch is set on 2000 ohms.

If the resistance being measured had been above this 2kΩ range, the meter would have "blanked" to a single 1 on the left (with no following zeros).

The meter will show less accurate numbers on higher range settings so it is best to start high and move down.

Practice using this Ωmeter function of the DMM on some of the other resistors in your kit.



KIRCHOFF KICK'IN IN

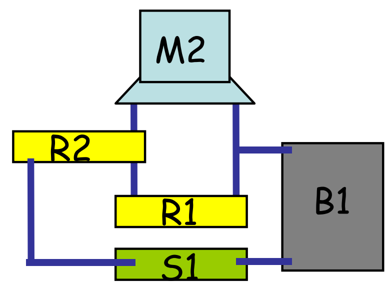
Now that Project #323's values have been measured, they can be used to build a deeper understanding of electronic processes.

Gustav Kirchoff's law concerning current states that at any point in a circuit the same amount of current going in will come out.

His second law say the sum of the voltage drops in a circuit must equal the source voltage.

Also, recall that resistors in series combine values but in parallel they are less than the largest.

Now that you know how to use a multi-meter, experiment with the various measurements made on this circuit to see if Kirchoff got it right.



BOOK NOTES

The source (B1) voltage was measured at 3.38 with the switch on, Per Kirchoff, this means the load must completely drop this amount of voltage. Measuring the voltage drop across R2 resulted in 3.09 volts, which means .29 volts must be dropping across the rest of the circuit.

The rest of the circuit is the parallel combination of R1 and M2 plus the resistance of the switch and blue metal straps. Measuring across the parallel R1/M2 shows .25 volts dropped, which leaves about .04 volts dropped by the straps and the S1 switch (including the loss of the metal snaps on the straps). Looks like Kirchoff got it right.

DIGITAL EXAMPLE

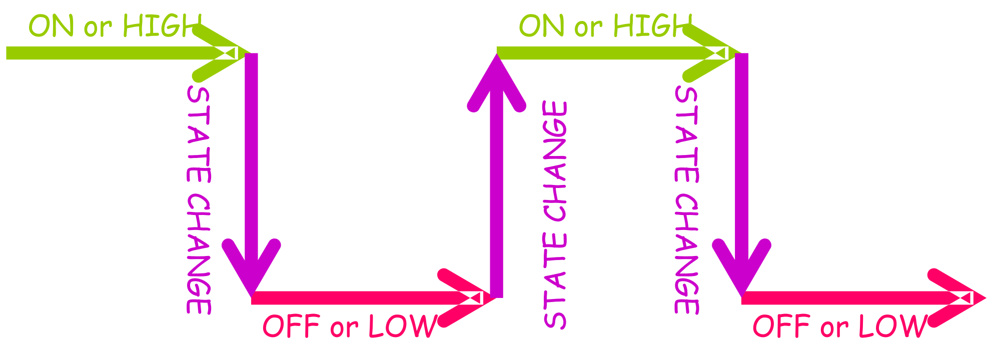
Fundamentally DIGITAL signals are defined by their STATE.

In many applications they have only two (*binary*) states:

ON or OFF – HI or LOW – RED or GREEN – ETC.

They are graphically represented as state changes over time (arrows and color added to show direction of time).

The lowest functional unit (usually) in digital is called a *BIT* (binary digit) and has a numerical value of either 0 (zero) or 1 (one).



BOOK NOTES

This graphic often requires an explanation. The easiest way to show how it can be created is to draw a picture of the needle on an AMM with a pencil attached at the pointer end. Under the pencil point is a moving strip of paper. When, for instance, a steady 3 volts are suddenly measured from some source the pencil/needle will jump almost instantly to the right and will stay there making a straight black vertical line down the length of the paper. When the voltage is taken off it will make a horizontal line across the paper to the left and then stay there making a vertical black line down the moving paper.

The pencil/needle line on the meter's left is the red one on the graphic. The line on the meter's right is the green line on the graphic. The transition from one side to the other is the purple line on the graphic.

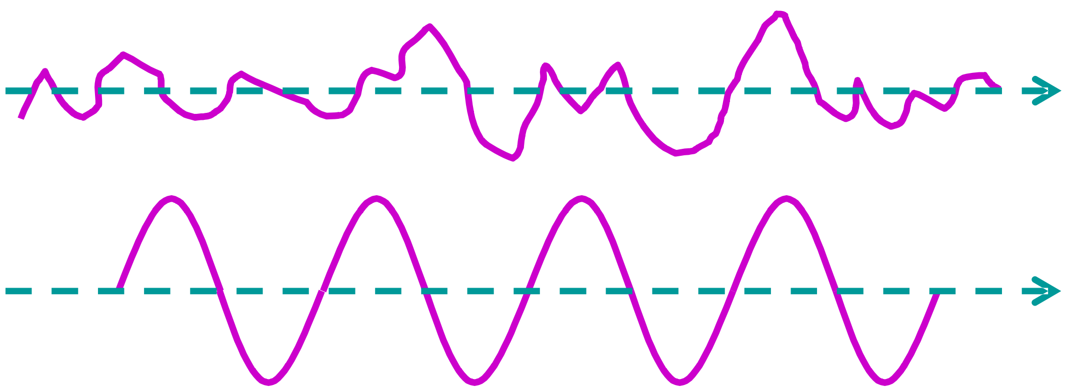
This square wave is only a representation of some form of energy changing from one fixed value or state to another. Until a specific system is identified, the type of energy (volts, amps, tone, etc.) will not be known.

ANALOG EXAMPLE

Fundamentally ANALOG signals are defined by their VARIATIONS.

They have no fixed state and can take any value within the range of their acoustical, electrical or optical application.

They are graphically represented as value fluctuations over time and are typically described as either irregular or sinusoidal WAVES.



BOOK NOTES

The AMM needle/pencil works OK here too. This time also picture a dimmer knob for room lights. The AMM is measuring the voltage across one of the light bulbs. If the knob is twisted back and forth in a very jerky manner the pencil will show a continuous line like the top one on the graphic. If it is slowly moved one way and then slowly reversed, the bottom trace will result.

Both of these traces are *analogs* of the physical movement of the dimmer knob. There is no regularity in the top one. This is typical of electrical and acoustical signal traces showing human speech.

The bottom one is very regular and is typical of electrical and acoustical signal traces showing a pure, single frequency tone.

BITS CAN BYTE

In many applications bits are grouped together in a fixed length serial sequence in order to represent values above a zero or a one.

Because of historic reasons, the most prevalent grouping of bits is 8 (an OCTET).

Although other groupings also may go by the name, a *byte* is generally assumed to indicate this 8 bit string.

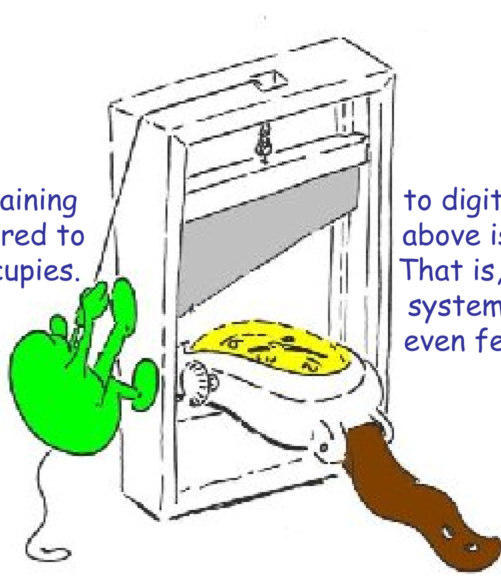
Byte (OCTET) of bits (green ON, red OFF)

1	2	3	4	5	6	7	8	
1	2	4	8	16	32	64	128	= positional value
1		4		16		64		= transmitted value 85

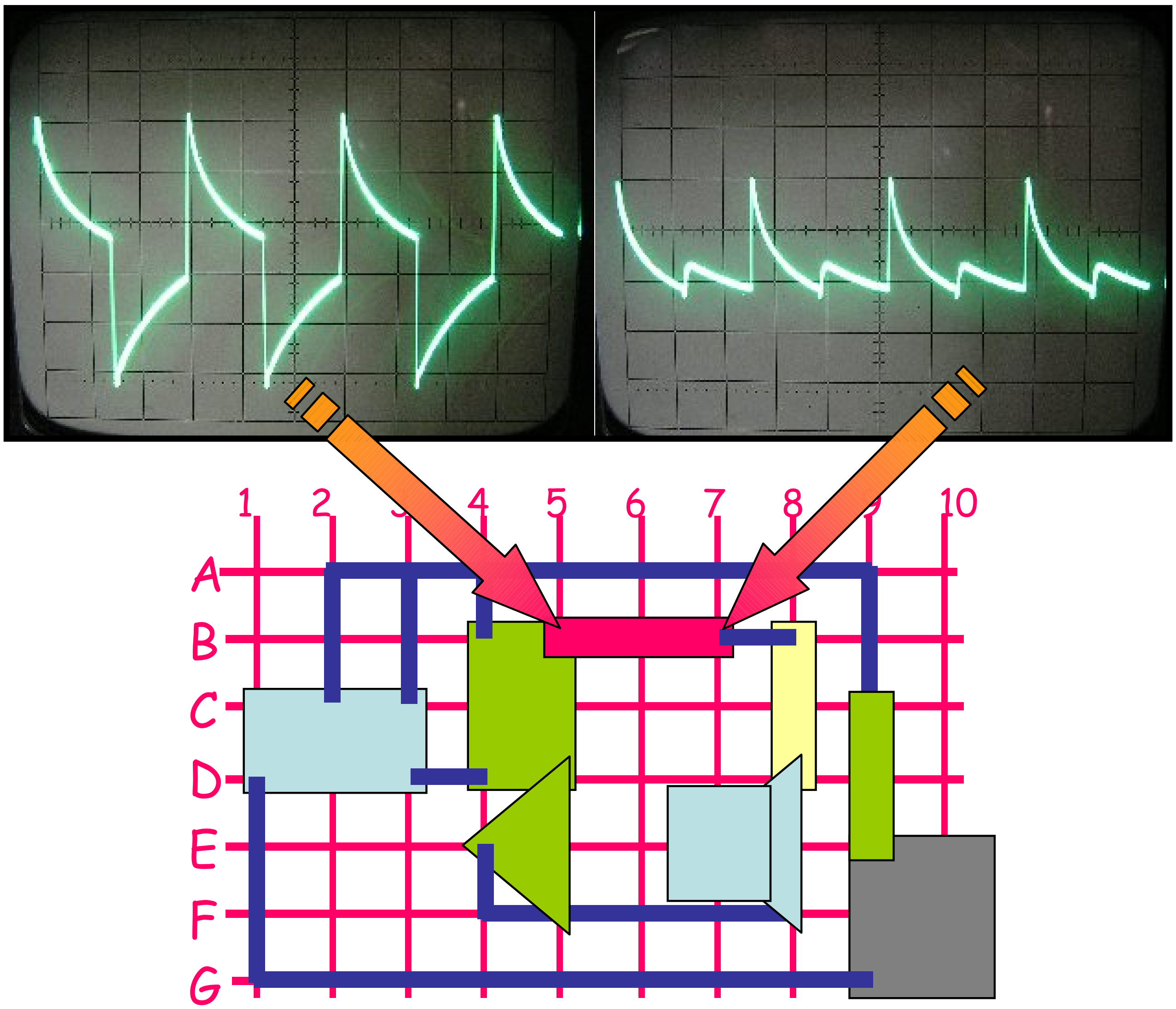
The digital *rate* (not SPEED) of individual bits passing a fixed point is normally referred to as *bits per second* (bps).

BOOK NOTES

In any discussion pertaining to digital signals, timing underlies it all. The "length" referred to above is referencing a period of time that a signal state occupies. That is, how long the signal is off or on. Some fiber optic systems use bit times that are measured in pico or even femto seconds.



Below on the left is the signal going into the D1 LED at position B5 and on the right is the signal coming out of D1 LED at position B7. Notice how the diode reduced, chopped off, and mangled the bottom of the signal energy.



SIMPLY TWO STATES

Even though DIGITAL applications generally incorporate only two (binary) states, it is possible to create very complicated circuits by interconnecting many individual digital components such as:

Electromechanical relay (Kit part S3).

Silicon Controlled Rectifier (Kit part Q3).

Positive Negative Positive transistor (Kit part Q1).

Negative Positive Negative transistor (Kit part Q2).

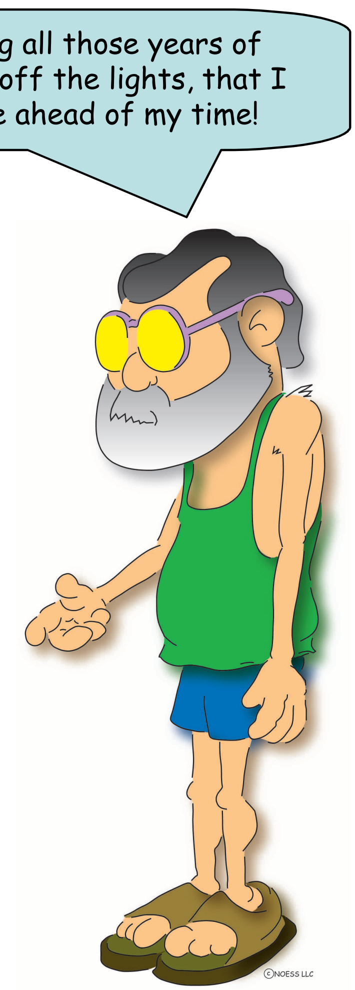
The term transistor means the device can *transfer* a signal across its internal *resistor*.

For the purposes of this Lesson, all of the above function as binary switches or gates.

Conducting *ON* (digital bit state going thru).

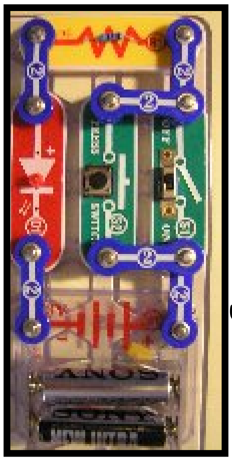
Not conducting *OFF* (digital bit state not going thru).

As will be seen in a later lesson, some of these devices can also be used in analog applications.

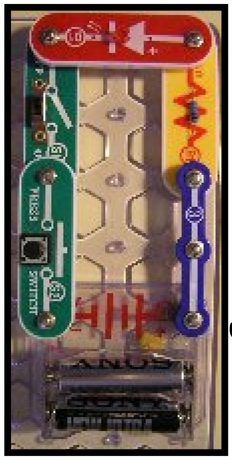


While these three solid state electronic devices can be used to build gate circuits, there are several other mechanical switch Projects in the Kit that can also demonstrate gating.

See Projects #47 OR, #48 AND, #49 NOR and #50 NAND.



S1 *OR* S2 will light LED



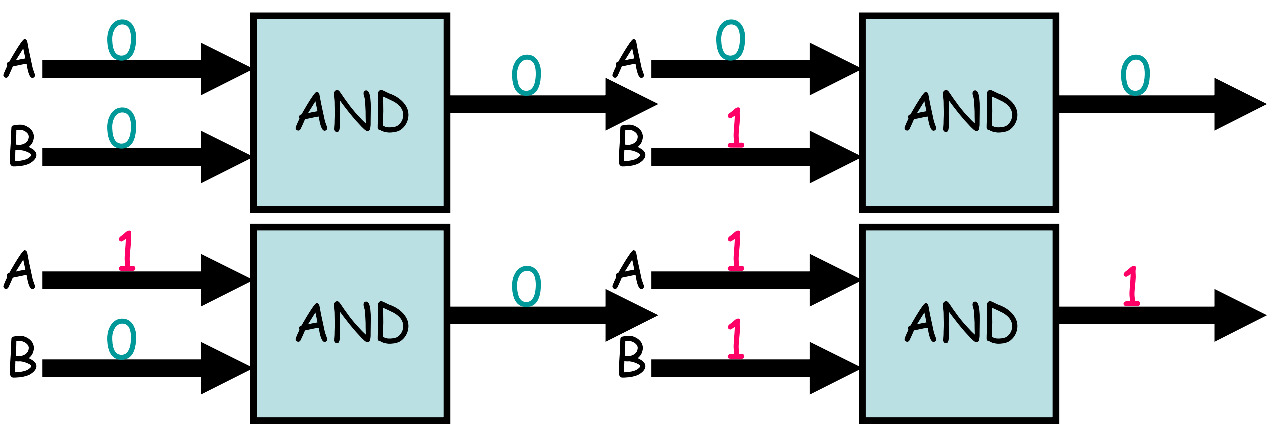
S1 *AND* S2 will light LED

Neither S1 *NOR* S2

Not S1 *AND* S2

BOOK NOTES

Digital logic (gate) circuits process inputs to outputs as either *true* or *false*. The true may be represented as: 1, High, +V or ON. The false may be represented as: 0, Low, -V or OFF. Below is an example of a two input AND gate circuit.



CAN WE MEASURE L (henrys)?

Yes – but not with the meters we have in this class.

However, we can use the AMM or DMM to see how they have *continuity* from one side to the other.

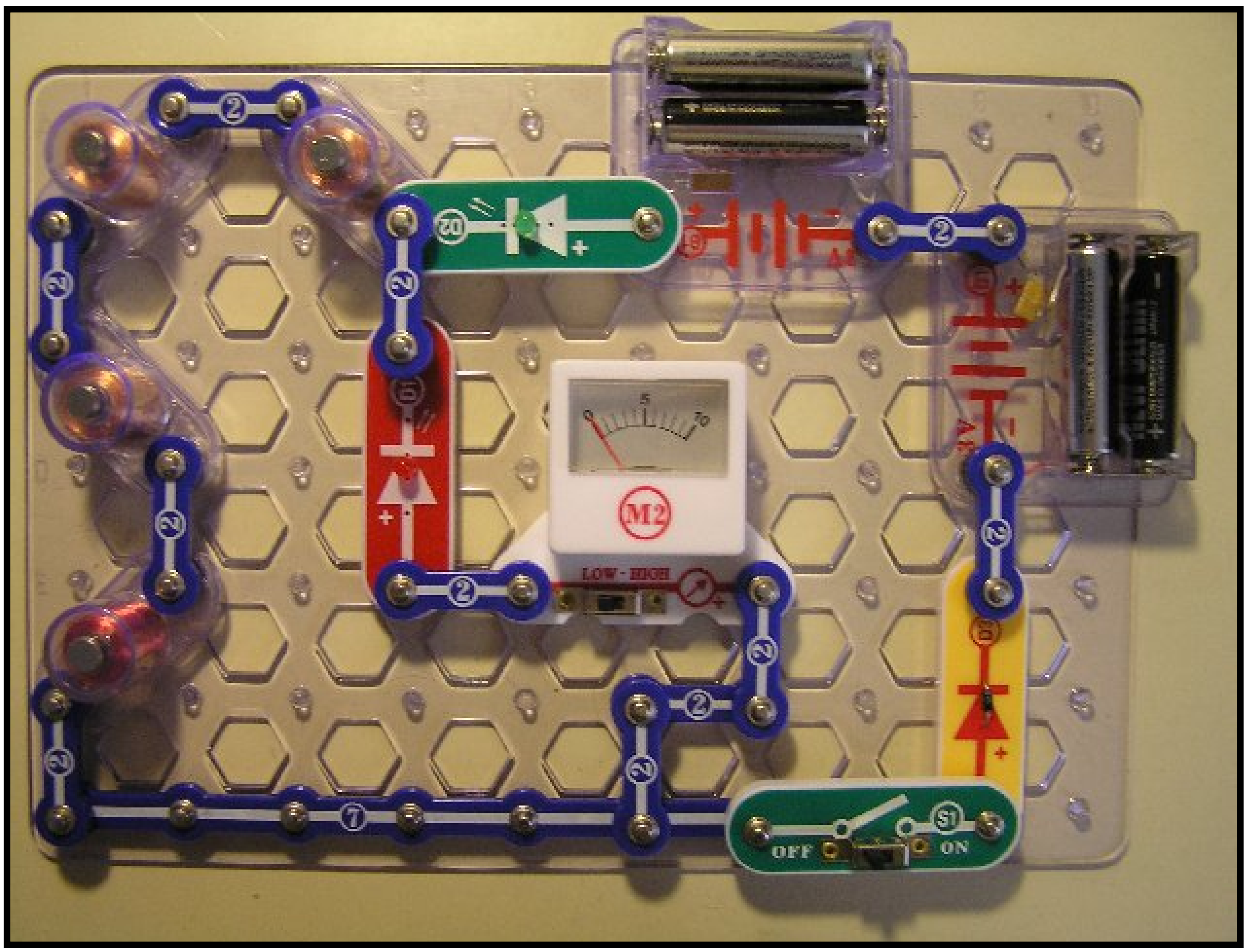
It is interesting to note that sometimes inductor coils are used to make very big electromagnets for picking up large metal objects such as crushed cars at the junk yard.

Any of the components in the Kit containing wire coils will produce a magnetic field when current is passed thru them.

BOOK NOTES

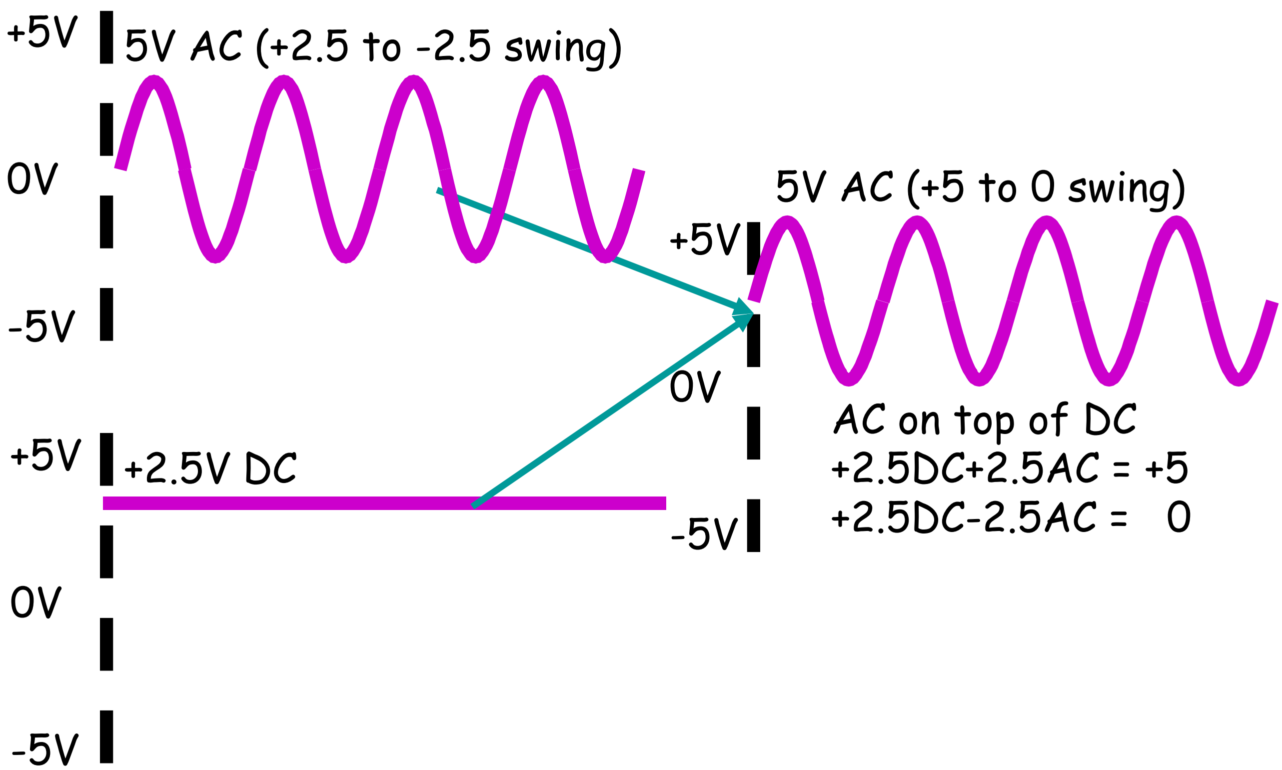
The coils in the SC500 Kit components have little inductance. This makes it difficult to show how they store and release energy. The circuit below uses 4 of the larger coils referenced in a previous BOOK NOTES page.

In order to keep the photo large enough to see clearly, the circuit description will be on the following BOOK NOTES page.



At this point in the Course it is often helpful to investigate a little more deeply the relationship between AC voltages (or analog signals) and DC voltages.

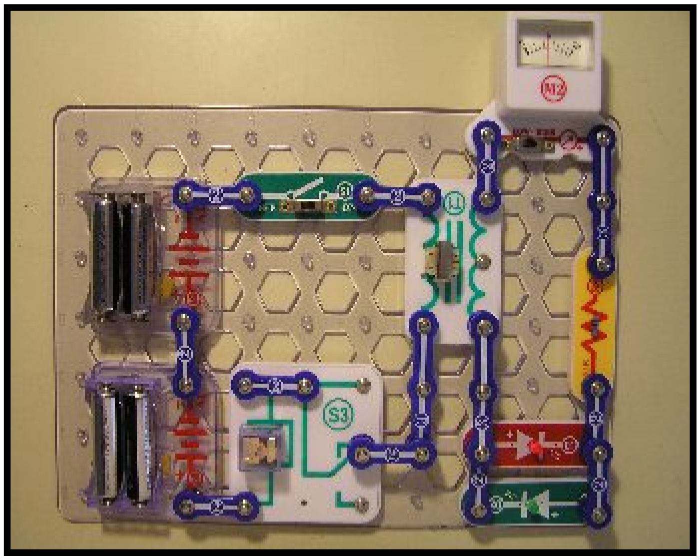
So far the analog/AC ones have been drawn as squiggly lines and the DC ones as straight lines but no particular voltage values have been applied to either. To do this for either one requires that a reference point be set for each. Although later examples may be different, for this one the reference value will be zero volts.



BOOK NOTES

In many applications an AC can "ride" on top (or bottom) of a positive (or negative) DC voltage. If this type of AC (or analog signal) is applied to a transformer only the AC component will couple to the secondary. The DC will not go across the transformer. This would then put the AC swings back to a zero voltage reference.

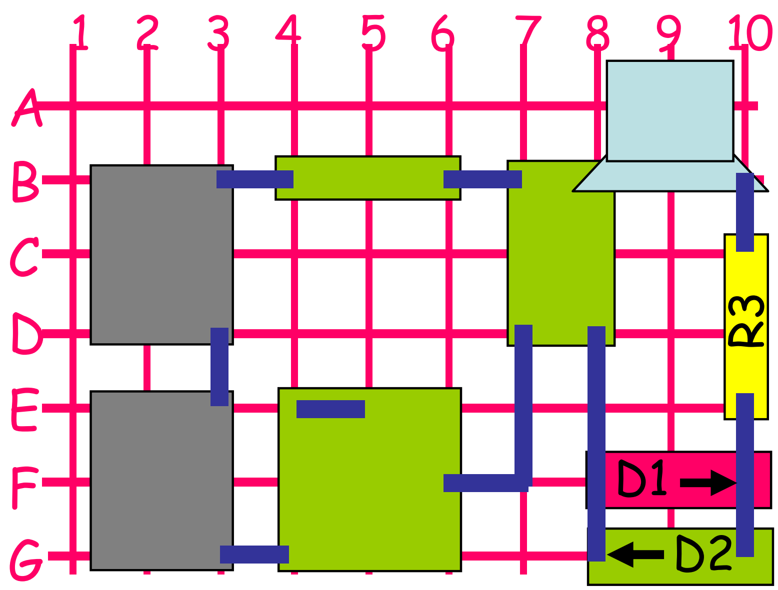
INDUCTOR CIRCUIT



Build and test Project #343, *but with the modification shown below*.

Add LED D2 in opposite direction of D1 and use R3 instead of R2.

This modification creates an *INVERTER* circuit (DC to AC converter).



BOOK NOTES

Although this Project is titled *Half Wave Rectifier Circuit* it actually functions like a DC to AC INVERTER. By adding the second LED (D2) we can visualize the reversals (positive going and negative going) cycles of current that are originating from T1's secondary winding.

When S1 is turned on, DC current (electron flow) passes thru the primary of T1, then thru the *break* contact of S3 and lastly thru the inductor coil of the S3. The DC current causes the coil to energize. This action then operates the *break* relay contacts which shuts off the DC current, demagnetizing the relay coil. The break contact then snaps back to its closed position allowing DC to resume. The result is a DC current that pulses on and off thru the primary of T1 producing an AC at the secondary. (FYI, the unused S3 contact is called the *make*.)

MODULATION – ANALOG 4-7

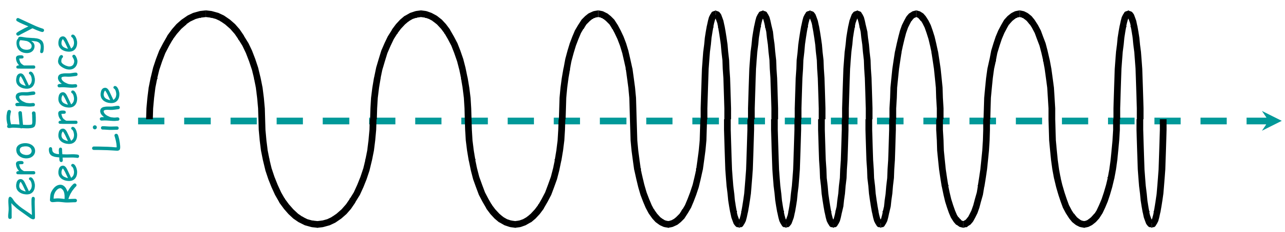
Modulating the *frequency* or number of cycles per second (Hz) of an energy wave can carry analog or code digital information (it's the one used in FM radios and FSK data).

Audio system = amount of pitch change.

Electronic system = number of voltage cycle swings per second.

Wireless system = number of cycles in carrier wave per second.

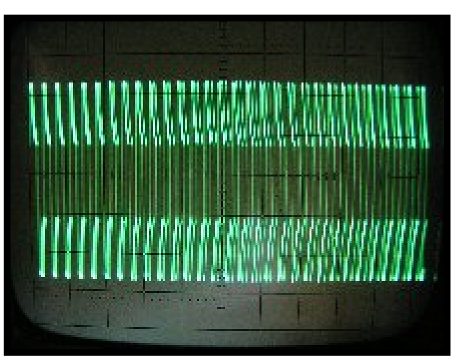
Optic system = amount of color change.

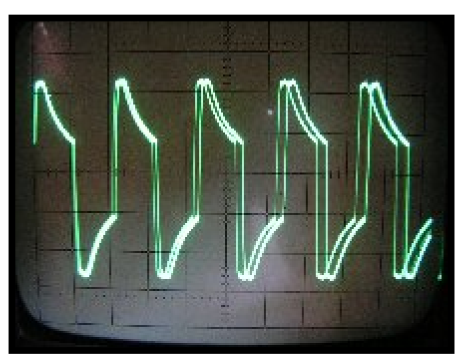


BOOK NOTES

These two devices are used for tracing wire such as that used in telephone applications in a residence. The transmitter creates an FM oscillation which can be clipped on to a pairs of wires. The other smaller device is an inductive receiver which can detect this oscillation without having to touch the wire. The receiver outputs the oscillation as an audible tone and lamp indication.

Below is the oscilloscope trace of the signal on the red and black clips of the transmitter unit. Note the amplitude of the signal does not change. However, the frequency does change as indicated by the increasing double trace on the right side.



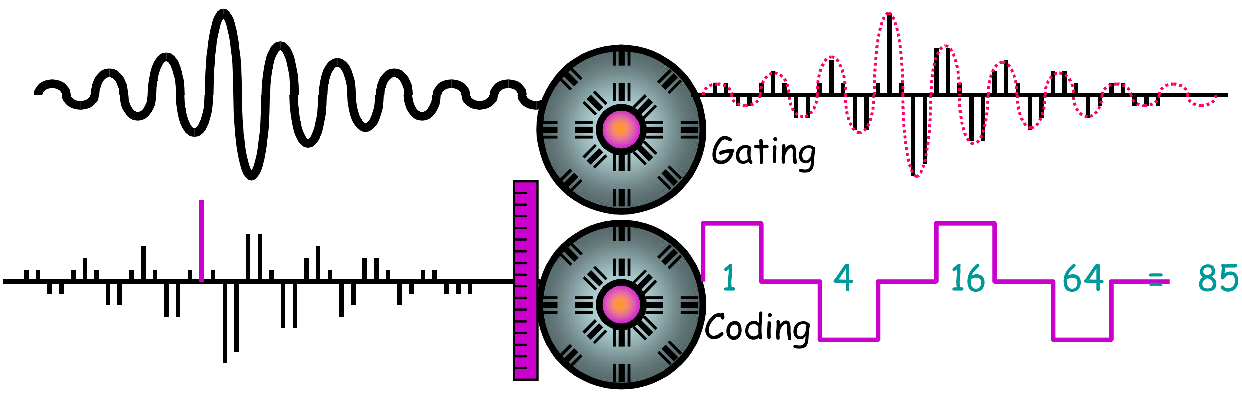


MODULATION – DIGITAL 4-4

CODEC's produce PULSE CODE MODULATION (PCM)
The most common method of converting analog voice signals into bytes for transmission over digital facilities.
This and similar AtoD technologies can be used to convert any analog source signal into digital bytes.

Voice or Video CODEC's.

SAMPLE – QUANTIFY - ENCODE

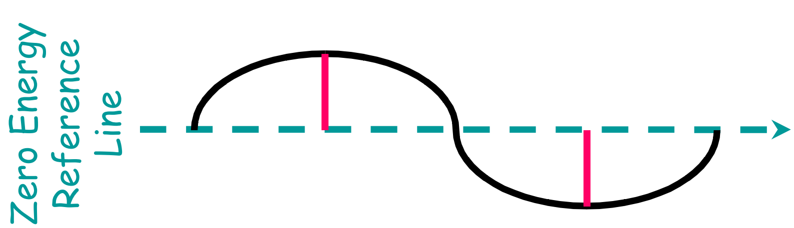


BOOK NOTES

Although this material is intended to be general in nature, there are some specific requirements even within these generalities. Massively simplified, the Nyquist–Shannon sampling theorem requires that any analog signal being converted to digital requires a sample rate of at least twice its highest frequency.

As example: standard telephone channels are band limited to less than 4 KHz. In order to adequately sample this signal (i.e., periodically measure the signal voltage) a rate of 8 thousand measurements per second must be done. An audio CD with 20 KHz range requires over 40 thousand samples per second.

While a lot of math can prove this, an easier way to see the truth of it is to look at a single cycle of any analog signal. In order to "know" there was a complete cycle, at least one measurement must be taken on the signal's upswing and one on the downswing. More samples per cycle would result in more accuracy in reproducing the wave at the distant end of the transmission facility, but the minimum is obviously two.

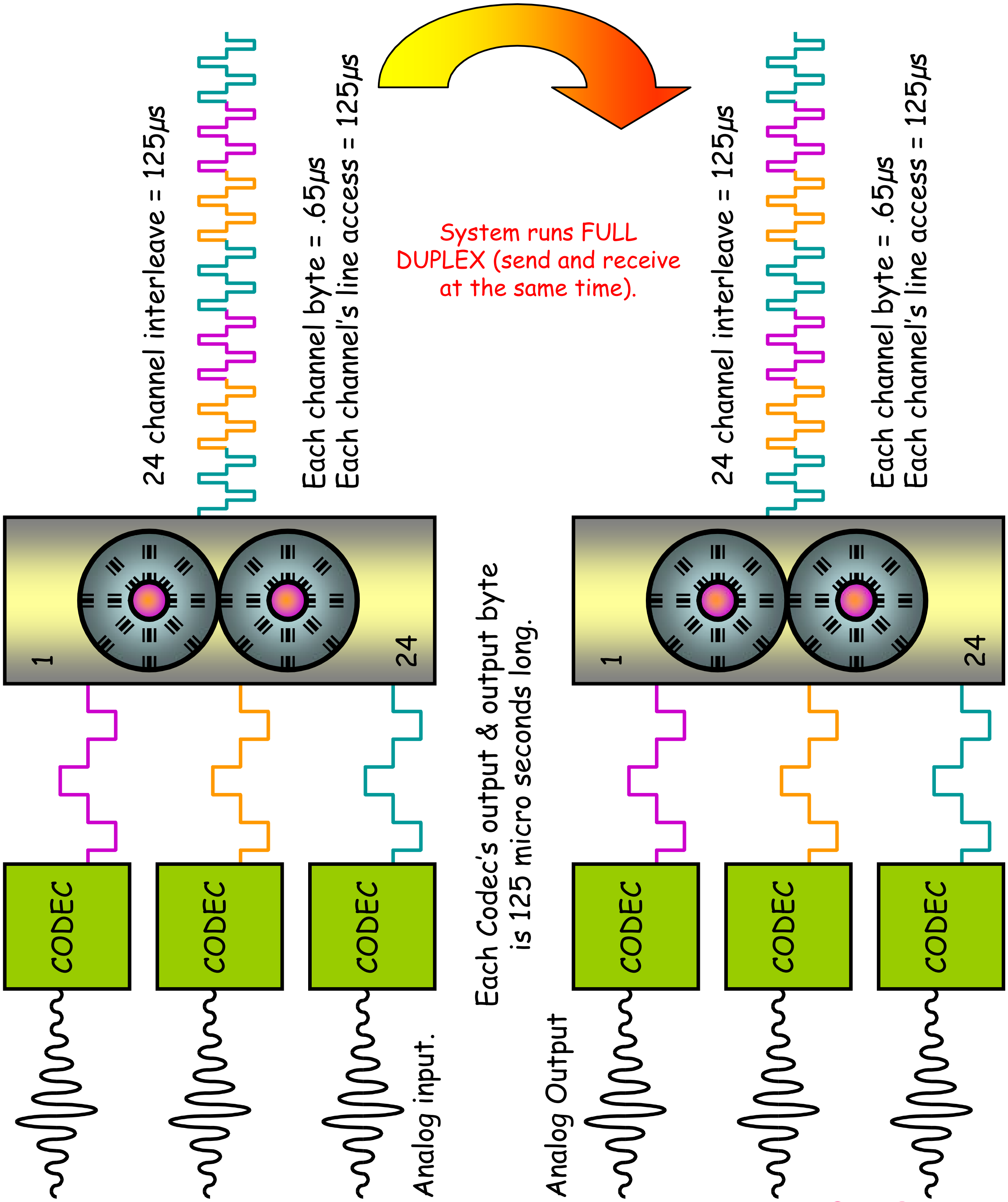


MULTIPLEXING - DIGITAL

TDM *Time Division Multiplexing* is the oldest and least complicated *serial* method of sending *sequentially* several information streams on a single wire line or wireless path.

The block diagram below shows a *simplified* version of the most common 24 channel digital TDM process used in (USA) telephony.

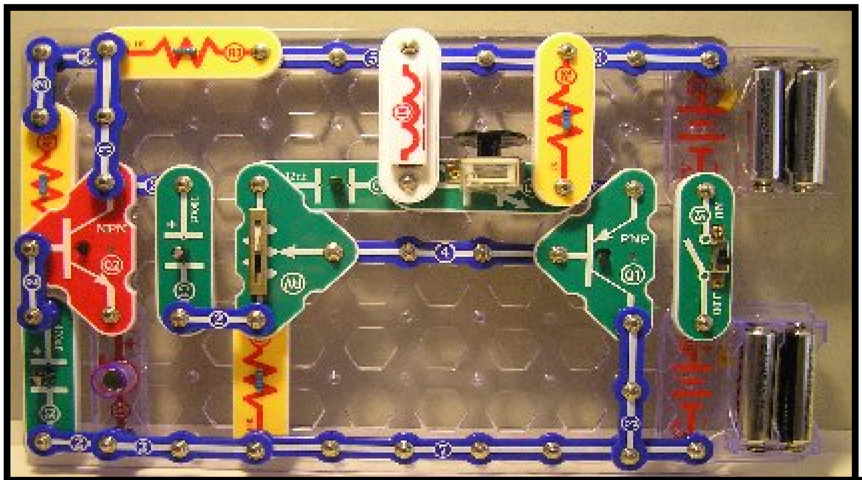
NOTE: in digital transmission SPEED is the wrong word to use.



BOOK NOTES

Below left is *Project 198 Radio Announcer* using microphone X1 in place of the speaker listed in the instructions (it works better). Below right is *Project 242 AM Radio.*

Tuning the transmitter (#198) to the middle of the AM range at approximately 1000 kHz supports voice transmission to the receiver (#242) when it is tuned to the same range.



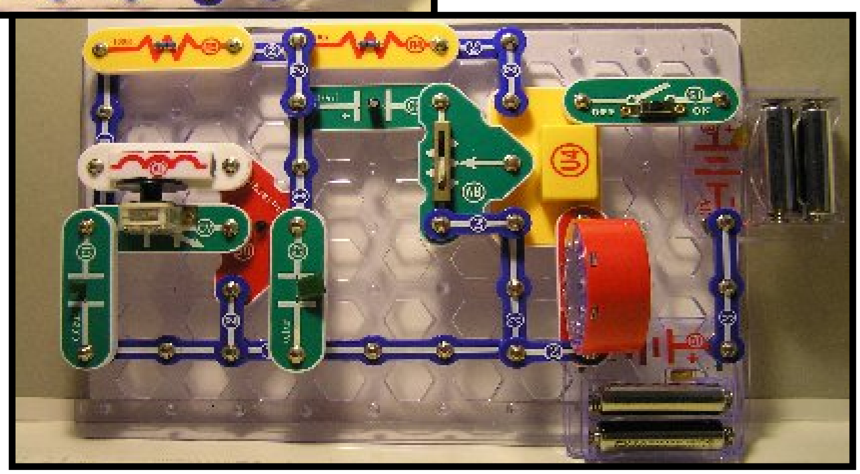
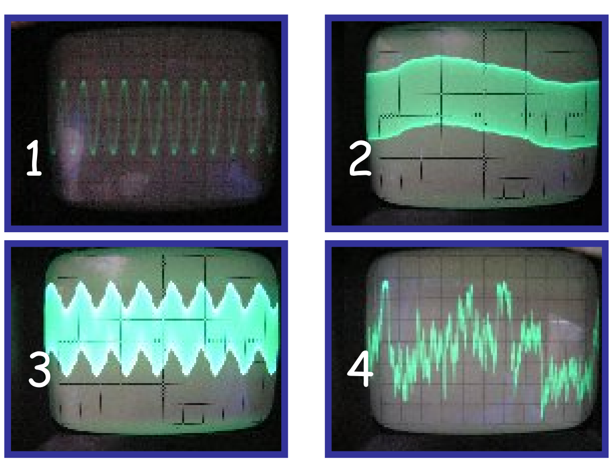


Photo 1 shows the individual cycles of the (approximate) 1000 kHz AM carrier wave going into the A1 antenna of Project 198. Photo 2 shows more cycles in a slower oscilloscope sweep of the radio's carrier wave. Photo 3 is an even slower sweep (the sawtooth wave seen is noise on the carrier wave). Photo 4 shows the same sweep time as 3, but with a voice signal from the X1 microphone amplitude modulating it.



KidsTricity - 2

Assessment

Of

Knowledge

Two primary applications of electricity are:

A) Burpinslurfulling.
B) Powering.
C) Zapping Vermicious Kanids.
D) Signaling.
E) Hornswogeling.
F) Current limiting LEDs.
G) None of the above.

KidsTricity:

A) Is a kool course.
B) Is a valuable learning experience.
C) Will make more advanced courses easier to complete.
D) Provides components to make noisy circuits.
E) All of the above.

E (always do "D" on Sunday morning,
as told to you by INSTRUCTOR Mr. Smith.