

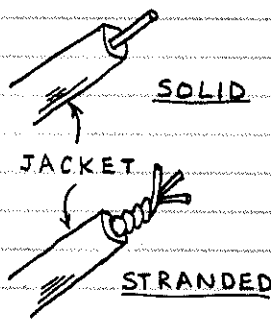
## 2. ELECTRONIC COMPONENTS

DOZENS OF DIFFERENT FAMILIES OF PARTS AND COMPONENTS BLOCK, CARRY, CONTROL, SELECT, STEER, SWITCH, STORE, MANIPULATE, REPLICATE, MODULATE AND EXPLOIT AN ELECTRICAL CURRENT. THOSE THAT USE SEMICONDUCTING CRYSTALS ARE SO IMPORTANT WE'LL DEVOTE AN ENTIRE CHAPTER TO THEM. YOU'LL FIND JUST ABOUT ALL THE REMAINING PARTS YOU SHOULD KNOW ABOUT IN THIS CHAPTER.

### WIRE AND CABLE

USED TO CARRY AN ELECTRICAL CURRENT. MOST WIRE IS MADE FROM A LOW RESISTANCE METAL LIKE COPPER. SOLID WIRE IS A SINGLE CONDUCTOR. STRANDED WIRE IS TWO OR MORE TWISTED OR BRAIDED BARE CONDUCTORS. MOST WIRE IS PROTECTED BY AN INSULATING COVERING OF PLASTIC, RUBBER OR LACQUER. WIRE WHICH HAS BEEN TINNED IS EASIER TO SOLDER.

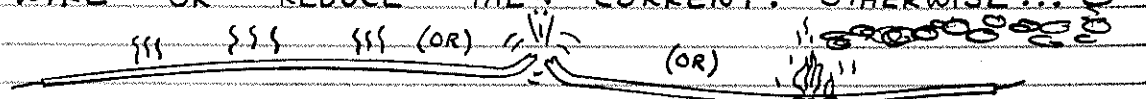
#### SPECIFICATIONS FOR BARE COPPER WIRE



GAUGE	DIAMETER (INCHES)	FEET/POUND	FEET/OHM
16	.05082	127.9	249.00
18	.04030	203.4	156.50
20	.03196	323.4	98.50
22	.02535	514.2	61.96
24	.02010	817.7	38.96
26	.01594	1300.0	24.50
28	.01264	2067.0	15.41
30	.01003	3287.0	9.69

CABLES HAVE ONE OR MORE CONDUCTORS AND MORE INSULATION THAN ORDINARY WIRE. COAXIAL CABLE CAN CARRY HIGH FREQUENCY SIGNALS (LIKE TELEVISION).

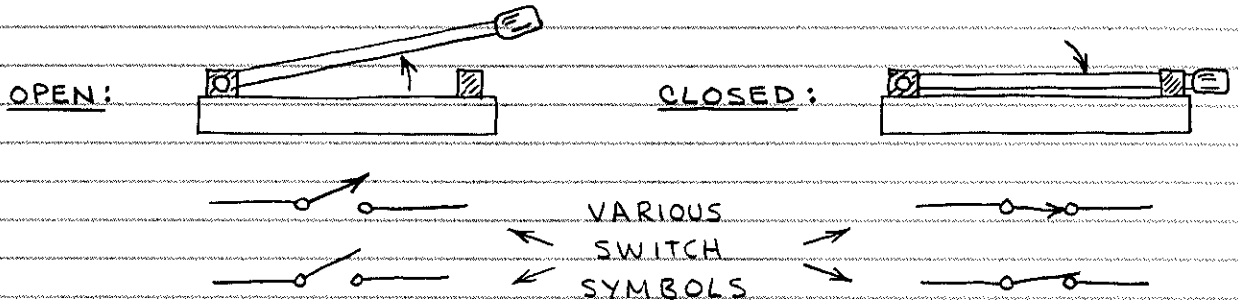
□ CAUTION! ALWAYS USE WIRE RATED FOR THE CURRENT IT IS TO CARRY. IF A WIRE IS HOT TO THE TOUCH, IT'S CARRYING TOO MUCH CURRENT. USE A HEAVIER GAUGE WIRE OR REDUCE THE CURRENT. OTHERWISE...



# SWITCHES

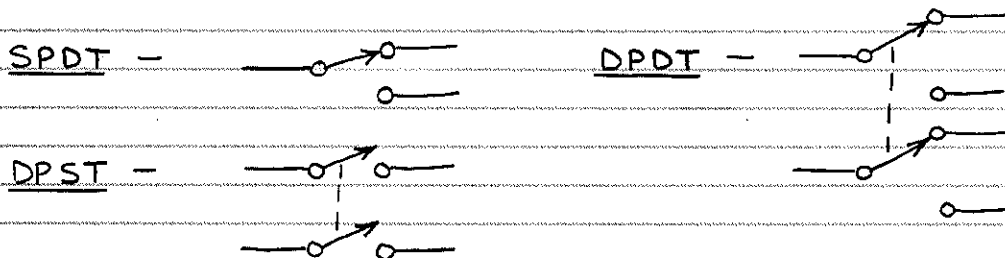
MECHANICAL SWITCHES PERMIT OR INTERRUPT THE FLOW OF CURRENT. THEY ARE ALSO USED TO DIRECT CURRENT TO VARIOUS POINTS.

□ THE BASIC KNIFE SWITCH — THE SIMPLEST SWITCH ...



THIS IS CALLED AN SPST (SINGLE-POLE, SINGLE-THROW) SWITCH.

□ MULTIPLE CONTACT SWITCHES — HERE ARE SYMBOLS FOR THE MAJOR KINDS :



(THE DASHED LINE MEANS BOTH SIDES MOVE TOGETHER.)

SPDT - SINGLE-POLE, DOUBLE-THROW  
 DPST - DOUBLE-POLE, SINGLE-THROW  
 DPDT - DOUBLE-POLE, DOUBLE-THROW

□ OTHER SWITCHES —

PUSHBUTTON. USUALLY SPST, NORMALLY OPEN (NO) OR NORMALLY CLOSED (NC).



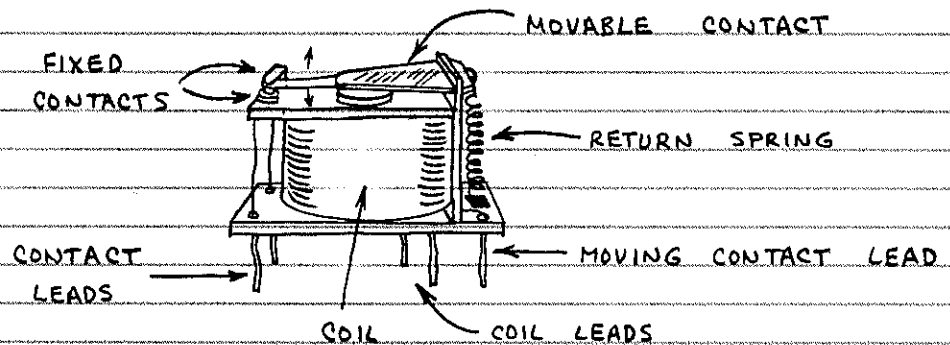
ROTARY. WAFER-LIKE WITH ONE POLE AND 2 OR MORE CONTACTS. WAFERS CAN BE STACKED TO PROVIDE MORE POLES. MANY VARIATIONS ARE POSSIBLE.

MERCURY. MERCURY BLOB CLOSES SWITCH. POSITION SENSITIVE.

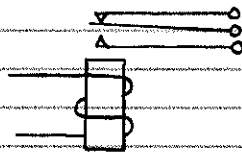
OTHER. MANY KINDS OF TOGGLE, ROCKER, LEVER, SLIDE, PUSH-ON/PUSH-OFF, ILLUMINATED AND OTHER SWITCHES ARE AVAILABLE.

# RELAYS

A RELAY IS AN ELECTROMAGNETIC SWITCH. A SMALL CURRENT FLOWING THROUGH A COIL IN THE RELAY CREATES A MAGNETIC FIELD THAT PULLS ONE SWITCH CONTACT AGAINST OR AWAY FROM ANOTHER.

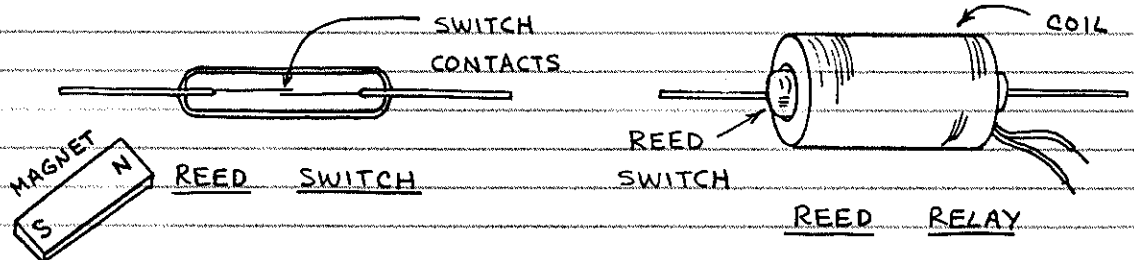


□ RELAY SYMBOL — THE ARRANGEMENT OF CONTACTS CAN PROVIDE SPST, SPDT, DPST, DPDT AND OTHER SWITCH OPERATIONS.



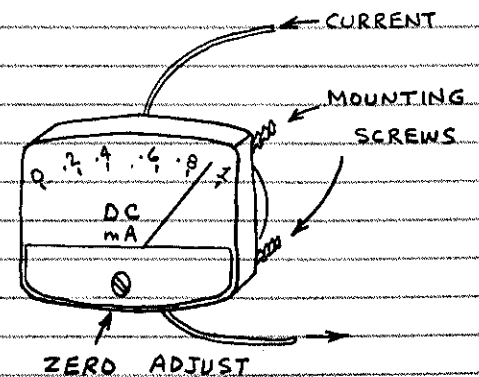
THIS IS THE SYMBOL FOR A RELAY WITH SPDT CONTACTS.

□ REED SWITCH RELAYS — AN ENCLOSED GLASS TUBE HOUSING A PAIR OF CLOSELY SPACED SWITCH CONTACTS IS A REED SWITCH. A MAGNETIC FIELD WILL CLOSE THE CONTACTS. THIS MAKES POSSIBLE A VERY SIMPLE SPST RELAY.



# MOVING COIL METER

A COIL ON A PIVOT BETWEEN THE POLES OF A U-SHAPED MAGNET WILL ROTATE WHEN A CURRENT IS PASSED THROUGH THE COIL. THIS IS THE PRINCIPLE OF THE MOVING COIL METER.



# MICROPHONES AND SPEAKERS

A MICROPHONE CONVERTS SOUND WAVE VARIATIONS INTO CORRESPONDING VARIATIONS IN AN ELECTRICAL CURRENT. THE SOUND WAVE VARIATIONS ARE FIRST CONVERTED TO BACK-AND-FORTH MOVEMENTS OF A FLEXIBLE FILM OR FOIL CALLED A DIAPHRAGM. THESE MOVEMENTS THEN CAUSE VARIATIONS IN AN ELECTRICAL CURRENT BY ANY OF THE FOLLOWING MEANS:

□ CARBON—MOVEMENT OF THE DIAPHRAGM CHANGES THE PRESSURE APPLIED TO A CAPSULE OF CARBON PARTICLES. THIS CAUSES PROPORTIONAL CHANGES IN THE RESISTANCE OF THE CAPSULE.

□ DYNAMIC—A SMALL COIL IS MOVED THROUGH A MAGNETIC FIELD AS THE DIAPHRAGM MOVES. THIS CAUSES A PROPORTIONAL OUTPUT CURRENT TO BE GENERATED.

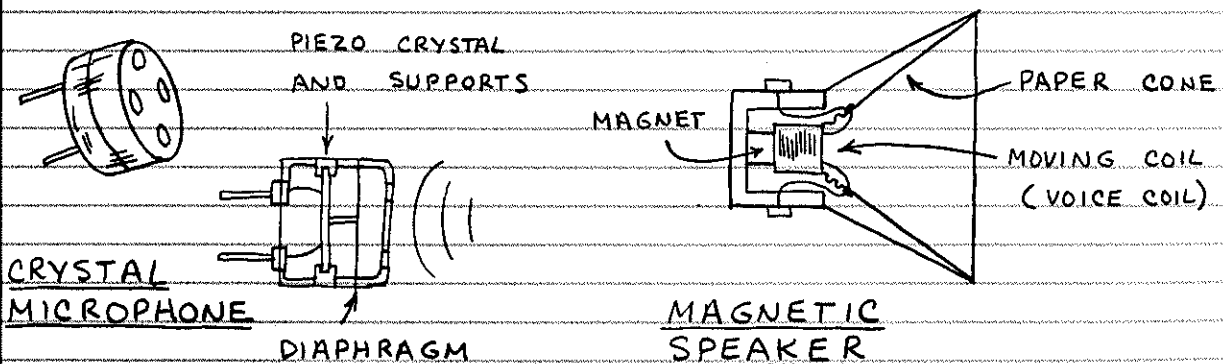
□ CONDENSER—THE MOVING DIAPHRAGM ALTERS THE DISTANCE BETWEEN TWO METAL PLATES. THE RESULT IS A PROPORTIONAL CHANGE IN THE CAPACITANCE OF THE PLATES.

□ CRYSTAL—A WAFER OF PIEZOELECTRIC MATERIAL (WHICH PRODUCES A VOLTAGE WHEN BENT BY THE PRESSURE OF SOUND WAVES) FORMS THE DIAPHRAGM OR IS MECHANICALLY LINKED TO THE DIAPHRAGM.

A SPEAKER CONVERTS VARIATIONS IN A CURRENT OR VOLTAGE INTO SOUND WAVES. THE TWO MOST COMMON SPEAKERS ARE:

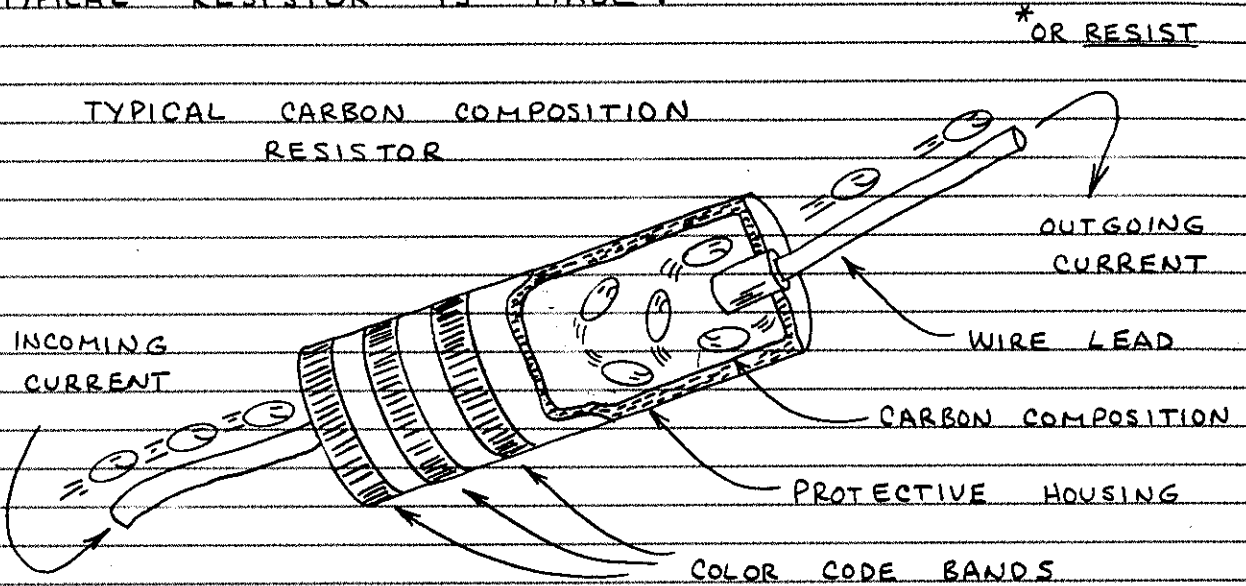
□ MAGNETIC—SIMILAR IN PRINCIPLE TO A DYNAMIC MICROPHONE. IN FACT, A MAGNETIC SPEAKER CAN BE USED AS A MICROPHONE.

□ CRYSTAL—SIMILAR IN PRINCIPLE TO A CRYSTAL MICROPHONE. A CRYSTAL SPEAKER CAN DOUBLE AS A MICROPHONE.



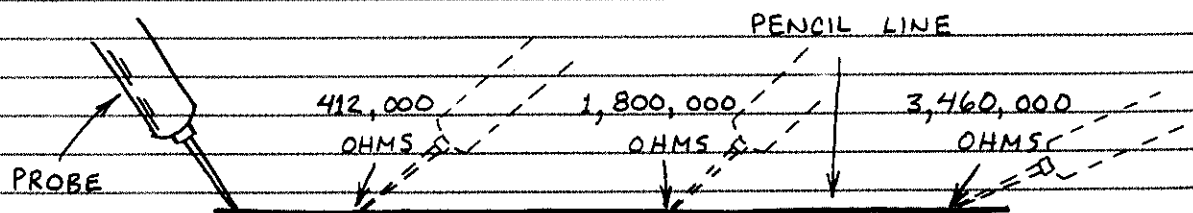
# RESISTORS

RESISTORS COME IN DOZENS OF SIZES AND SHAPES BUT THEY ALL DO THE SAME THING: LIMIT\* CURRENT. MORE ABOUT THAT LATER. FIRST, LET'S SEE HOW A TYPICAL RESISTOR IS MADE:

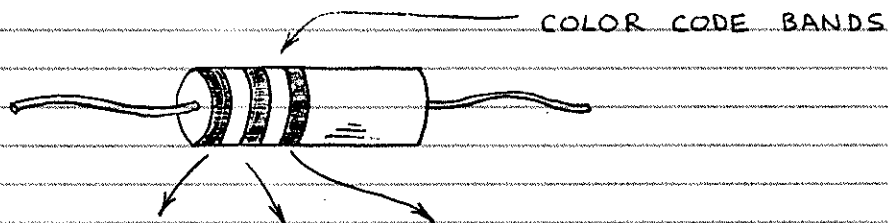


"CARBON COMPOSITION" IS JUST A FANCY WAY OF DESCRIBING POWDERED CARBON MIXED WITH A GLUE-LIKE BINDER. THIS KIND OF RESISTOR IS EASY TO MAKE. AND ITS RESISTANCE CAN BE CHANGED FROM ONE RESISTOR TO THE NEXT SIMPLY BY CHANGING THE RATIO OF CARBON PARTICLES TO BINDER. MORE CARBON GIVES LESS RESISTANCE.

□ DO-IT-YOURSELF RESISTORS — YOU CAN MAKE A RESISTOR BY DRAWING A LINE WITH A SOFT LEAD PENCIL ON A SHEET OF PAPER. MEASURE THE RESISTANCE OF THE LINE OR POINTS ALONG IT BY TOUCHING THE PROBES OF A MULTIMETER TO THE LINE. BE SURE TO SET THE MULTIMETER TO ITS HIGHEST RESISTANCE SCALE. THE RESISTANCE OF A SINGLE LINE MAY BE TOO HIGH TO MEASURE. IF SO, DRAW OVER THE LINE A DOZEN OR SO TIMES. HERE'S WHAT I MEASURED:



□ RESISTOR COLOR CODE — SEE THOSE COLOR CODE BANDS ON THE RESISTOR PICTORIAL? IN REAL LIFE THEY'RE KIND OF PRETTY. BUT THEY HAVE A FAR MORE IMPORTANT PURPOSE: THEY INDICATE THE RESISTANCE OF THE RESISTOR THEY DECORATE. HERE'S HOW:



COLOR	<u>1</u>	<u>2</u>	<u>3</u> (MULTIPLIER)
BLACK	0	0	1
BROWN	1	1	10
RED	2	2	100
ORANGE	3	3	1,000
YELLOW	4	4	10,000
GREEN	5	5	100,000
BLUE	6	6	1,000,000
VIOLET	7	7	10,000,000
GRAY	8	8	100,000,000
WHITE	9	9	(NONE)

NOTE: SOMETIMES THERE'S A FOURTH BAND. IT INDICATES THE TOLERANCE\* OF THE RESISTOR:

GOLD =  $\pm 5\%$   
 SILVER =  $\pm 10\%$   
 NONE =  $\pm 20\%$

\* OR ACCURACY

LOOKS COMPLICATED THE FIRST TIME... BUT YOU'LL QUICKLY LEARN HOW TO USE IT. FOR EXAMPLE, WHAT'S THE RESISTANCE OF A RESISTOR COLOR CODED YELLOW, VIOLET AND RED? YELLOW IS THE FIRST COLOR SO THE FIRST NUMBER IS 4. VIOLET IS THE SECOND COLOR SO THE SECOND NUMBER IS 7. SINCE THE THIRD COLOR IS RED, THE MULTIPLIER IS 100. THEREFORE, THE RESISTANCE IS  $47 \times 100$  OR 4700 OHMS. NO FOURTH COLOR BAND MEANS THE ACTUAL RESISTANCE IS  $4700 \pm 20\%$ . 20% OF 4700 IS 940. THEREFORE, THE ACTUAL VALUE IS BETWEEN 3760 AND 5640 OHMS.

□ SUBSTITUTING RESISTORS — WHAT IF YOU NEED A 6700-OHM RESISTOR BUT CAN ONLY FIND A 6800-OHM UNIT? YOU CAN ALMOST ALWAYS USE ANY VALUE WITHIN 10 OR 20% OF THE REQUIRED VALUE SO GO AHEAD AND USE IT. IF A PARTICULAR CIRCUIT REQUIRES MORE ACCURACY IT WILL TELL YOU. OF COURSE YOU CAN BUILD UP CUSTOM RESISTANCES BY CONNECTING TWO OR MORE RESISTORS IN SERIES OR IN PARALLEL. MORE ABOUT THAT LATER.

□ RESISTOR SUBSTITUTION PRECAUTIONS — RESISTORS THAT CONDUCT LOTS OF CURRENT CAN BECOME VERY HOT! THEREFORE, ALWAYS USE RESISTORS HAVING THE PROPER POWER RATING. IF A PROJECT YOU'RE BUILDING DOESN'T SPECIFY THE POWER RATING FOR ITS RESISTORS, IT'S USUALLY OK TO USE  $\frac{1}{4}$  OR  $\frac{1}{2}$  WATT UNITS.

□ SOME RESISTOR SHORTHAND — OFTEN YOU'LL SEE RESISTORS DESIGNATED WITH A K OR M SUFFIX. LIKE 47K OR 10M. K MEANS KILO, AFTER THE GREEK WORD FOR 1,000. THEREFORE, 47K MEANS  $47 \times 1,000$  OR 47,000. M IS SHORT FOR MEGOHM OR 1,000,000 OHMS. THEREFORE A 1M RESISTOR HAS A RESISTANCE OF  $1 \times 1,000,000$  OR 1,000,000 OHMS. SUMMING UP...

$$K = \times 1,000 \quad (47K = 47 \times 1,000 = 47,000 \text{ OHMS})$$

$$M = \times 1,000,000 \quad (2.2M = 2.2 \times 1,000,000 = 2,200,000 \text{ OHMS})$$

□ OTHER KINDS OF RESISTORS — THE CARBON COMPOSITION RESISTOR IS ONLY ONE OF SEVERAL MAJOR KINDS OF RESISTORS. HERE ARE OTHERS:

METAL FILM RESISTORS. VARIOUS KINDS OF RESISTORS THAT USE A THIN FILM OF METAL OR A METAL PARTICLE MIXTURE TO ACHIEVE VARIOUS RESISTANCES.

CARBON FILM RESISTORS. THESE ARE MADE BY DEPOSITING A CARBON FILM ON A SMALL CERAMIC CYLINDER. A SPIRAL GROOVE CUT INTO THE FILM CONTROLS THE LENGTH OF CARBON BETWEEN THE LEADS, HENCE THE RESISTANCE.

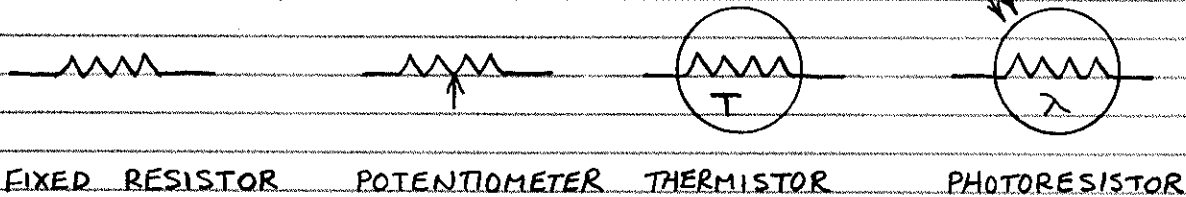
WIRE-WOUND RESISTORS. THESE CONSIST OF A TUBULAR FORM WRAPPED WITH COILS OF RESISTANCE WIRE. THEY ARE VERY ACCURATE AND CAN TAKE LOTS OF HEAT.

PHOTORESISTORS, ALSO CALLED PHOTOCELLS, MADE FROM A LIGHT SENSITIVE MATERIAL LIKE CADMIUM SULFIDE. INCREASING THE LIGHT LEVEL DECREASES THE RESISTANCE. MORE ABOUT THIS LATER.

THERMISTORS. THIS IS A TEMPERATURE SENSITIVE RESISTOR. INCREASING THE TEMPERATURE DECREASES THE RESISTANCE (IN MOST CASES).

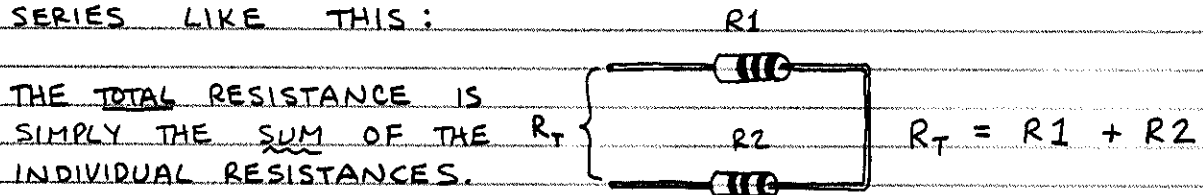
□ VARIABLE RESISTORS — OFTEN IT'S NECESSARY TO CHANGE THE RESISTANCE OF A RESISTOR. VARIABLE RESISTORS ARE CALLED POTENTIOMETERS. THEY ARE USED TO ALTER THE VOLUME OF A RADIO, CHANGE THE BRIGHTNESS OF A LAMP, ADJUST THE CALIBRATION OF A METER, ETC. TRIMMERS ARE POTENTIOMETERS EQUIPPED WITH A PLASTIC THUMBWHEEL OR A SLOT FOR A SCREWDRIVER BLADE. THEY ARE DESIGNED FOR OCCASIONAL ADJUSTMENT.

□ RESISTOR SYMBOLS:

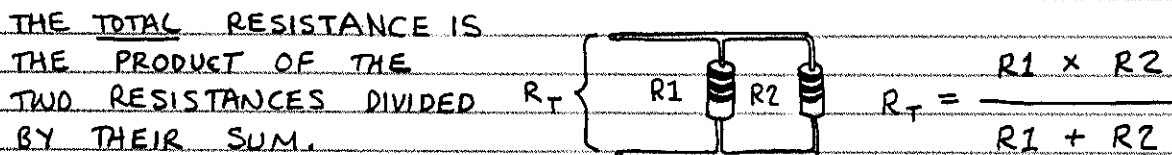


### HOW RESISTORS ARE USED

□ SERIES CIRCUIT — OFTEN RESISTORS ARE CONNECTED IN SERIES LIKE THIS:



□ PARALLEL CIRCUIT — RESISTORS CAN ALSO BE CONNECTED IN PARALLEL LIKE THIS:



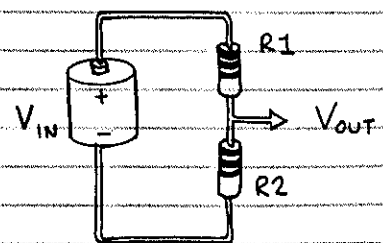
FOR THREE OR MORE IN PARALLEL, GO FIND YOUR CALCULATOR BECAUSE ...

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \dots \text{ETC.}}$$

□ VOLTAGE DIVISION — SUPER IMPORTANT!

$V_{OUT}$  IS DETERMINED BY RATIO OF  $R_1$  AND  $R_2$ . HERE'S THE FORMULA:

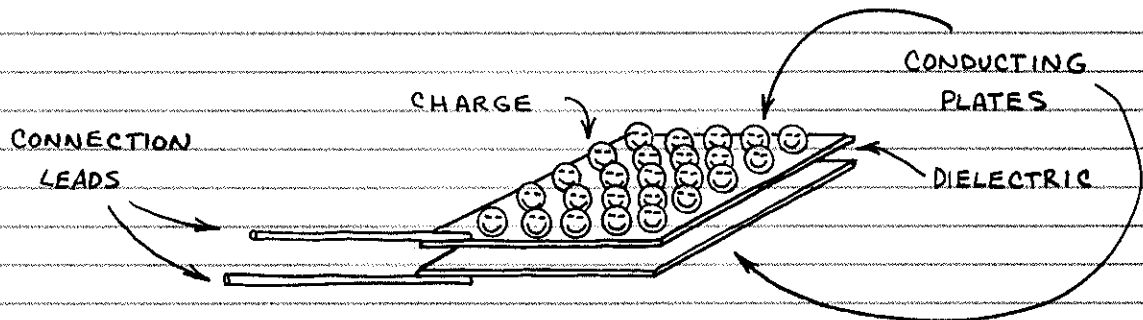
$$V_{OUT} = V_{IN} \left( \frac{R_2}{R_1 + R_2} \right)$$





# CAPACITORS

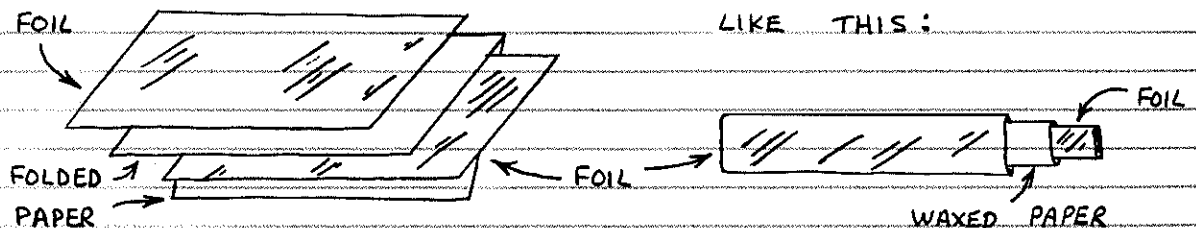
THERE ARE MANY KINDS OF CAPACITORS, BUT THEY ALL DO THE SAME THING: STORE ELECTRONS. THE SIMPLEST CAPACITOR IS TWO CONDUCTORS SEPARATED BY AN INSULATING MATERIAL CALLED THE DIELECTRIC. LIKE THIS:



THE DIELECTRIC CAN BE PAPER, PLASTIC FILM, MICA, GLASS, CERAMIC, AIR OR A VACUUM. THE PLATES CAN BE ALUMINUM DISCS, ALUMINUM FOIL OR A THIN FILM OF METAL APPLIED TO OPPOSITE SIDES OF A SOLID DIELECTRIC. THE CONDUCTOR-DIELECTRIC-CONDUCTOR SANDWICH CAN BE ROLLED INTO A CYLINDER OR LEFT FLAT. MORE ABOUT TYPES OF CAPACITORS LATER.

## HOW TO MAKE A CAPACITOR

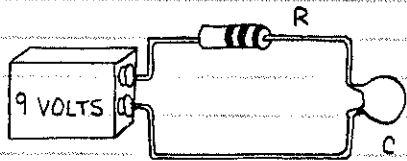
YOU CAN MAKE A CAPACITOR FROM TWO SHEETS OF ALUMINUM FOIL AND ONE SHEET OF WAXED PAPER. FOLD THE PAPER AROUND ONE FOIL SHEET AND STACK THE SHEETS LIKE THIS:



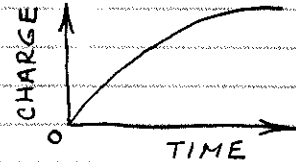
THEN FOLD THE SHEETS LIKE THIS:

BE SURE THE FOIL SHEETS DON'T TOUCH! PRESS THE CONTACTS OF A 9-VOLT BATTERY BRIEFLY TO THE EXPOSED ENDS OF THE FOIL SHEETS. THEN TOUCH THE PROBES OF A HIGH-IMPEDANCE MULTIMETER TO THE FOIL SHEETS. THE METER WILL INDICATE A SMALL VOLTAGE FOR A FEW SECONDS. THE VOLTAGE WILL THEN FALL TO ZERO.

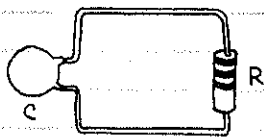
□ CHARGING A CAPACITOR — THE MINUS SIDE OF OUR HOMEMADE CAPACITOR IS CHARGED WITH ELECTRONS ALMOST IMMEDIATELY. SINCE RESISTORS LIMIT CURRENT YOU CAN SLOW DOWN THE CHARGING TIME BY PLACING A RESISTOR BETWEEN THE CAPACITOR AND THE 9-VOLT BATTERY:



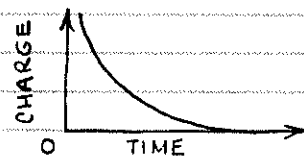
HERE'S A GRAPH OF THE CHARGING TIME:



□ DISCHARGING A CAPACITOR — THE ELECTRONS IN A CHARGED CAPACITOR WILL GRADUALLY LEAK THROUGH THE DIELECTRIC UNTIL BOTH PLATES HAVE AN EQUAL CHARGE. THE CAPACITOR IS THEN DISCHARGED. THE CAPACITOR CAN BE DISCHARGED VERY QUICKLY BY CONNECTING ITS PLATES TOGETHER. OR IT CAN BE DISCHARGED MORE SLOWLY BY CONNECTING A RESISTOR ACROSS IT:



HERE'S A GRAPH OF THE DISCHARGE TIME:



□ SPECIFYING CAPACITORS — THE ABILITY TO STORE ELECTRONS IS KNOWN AS CAPACITANCE. CAPACITANCE IS SPECIFIED IN FARADS. A 1-FARAD CAPACITOR CONNECTED TO A 1-VOLT SUPPLY WILL STORE 6,280,000,000,000,000,000 ( $6.28 \times 10^{18}$ ) ELECTRONS! MOST CAPACITORS HAVE MUCH SMALLER VALUES. SMALL CAPACITORS ARE SPECIFIED IN PICOFARADS (TRILLIONTHS OF A FARAD) AND LARGER CAPACITORS ARE SPECIFIED IN MICROFARADS (MILLIONTHS OF A FARAD). SUMMING UP:

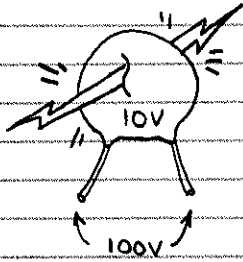
$$1\text{-FARAD} = 1\text{ F}$$

$$1\text{-MICROFARAD} = 1\ \mu\text{F} = 10^{-6}\text{ F} = 0.000\ 001\text{ F}$$

$$1\text{-PICOFARAD} = 1\ \text{pF} = 10^{-12}\text{ F} = 0.000\ 000\ 000\ 001\text{ F}$$

□ SUBSTITUTING CAPACITORS — THE CAPACITANCE SPECIFIED FOR MOST CAPACITORS MAY BE FROM 5 TO 100% AWAY FROM THE ACTUAL VALUE. THEREFORE YOU CAN OFTEN SUBSTITUTE CLOSE VALUES FOR A SPECIFIED VALUE. BE SURE, HOWEVER, TO USE A CAPACITOR RATED AT THE EXPECTED MAXIMUM VOLTAGE LEVEL!

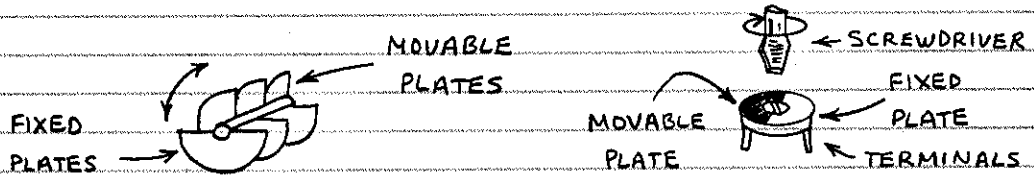
□ CAPACITOR SUBSTITUTION PRECAUTIONS — YOU MUST



MAKE SURE THE CAPACITOR YOU PLAN TO USE MEETS OR EXCEEDS THE REQUIRED VOLTAGE RATING. OTHERWISE ITS DIELECTRIC MAY BE ZAPPED BY THE STORED CHARGE. THE VOLTAGE RATING IS USUALLY PRINTED ON THE CAPACITOR. V MEANS VOLTS. WV IS WORKING VOLTS (SAME THING).

□ KINDS OF CAPACITORS — CAPACITORS ARE OFTEN LABELED ACCORDING TO THEIR DIELECTRIC. THUS YOU'LL SEE REFERENCES TO CERAMIC, MICA, POLYSTYRENE AND MANY OTHERS. ALL THESE ARE FIXED VALUE CAPACITORS. SOME CAPACITORS HAVE A VARIABLE CAPACITY AND A SPECIAL CLASS OF FIXED CAPACITORS HAS MUCH MORE CAPACITY THAN OTHER CAPACITORS. HERE'S MORE:

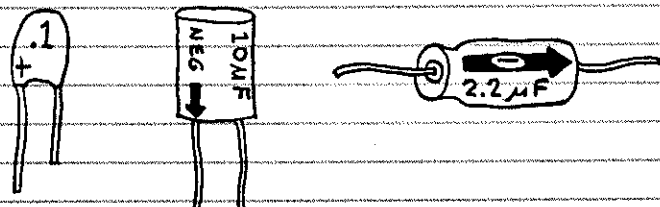
VARIABLE CAPACITORS. THESE USUALLY HAVE ONE OR MORE NON-MOVING PLATES AND ONE OR MORE MOVING PLATES. THE CAPACITANCE IS CHANGED BY ROTATING A ROD AFFIXED TO ONE SIDE OF THE MOVABLE PLATES.



THIS KIND IS USED TO TUNE RADIO RECEIVERS AND TRANS-MITTERS. THE DIELECTRIC IS USUALLY AIR.

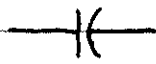
THIS KIND IS USED TO TUNE OSCILLATORS LIKE THOSE USED IN DIGITAL WATCHES. THEY'RE SMALL.

ELECTROLYTIC CAPACITORS. UNIQUE IN THAT A THIN OXIDE LAYER FORMED ON ALUMINUM OR TANTALUM FOIL IS THE DIELECTRIC. MUCH HIGHER CAPACITANCE THAN NON-ELECTROLYTIC TYPES. TANTALUM UNITS HAVE MORE CAPACITANCE PER VOLUME AND A LONGER LIFE THAN ALUMINUM ELECTROLYTICS. BUT THEY COST MORE. MOST ELECTROLYTICS ARE POLARIZED. THEY MUST BE CONNECTED INTO A CIRCUIT IN THE PROPER DIRECTION:

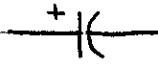


POSITIVE LEAD MUST GO TO MOST POSITIVE CONNECTION POINT!

## □ CAPACITOR SYMBOLS:



FIXED

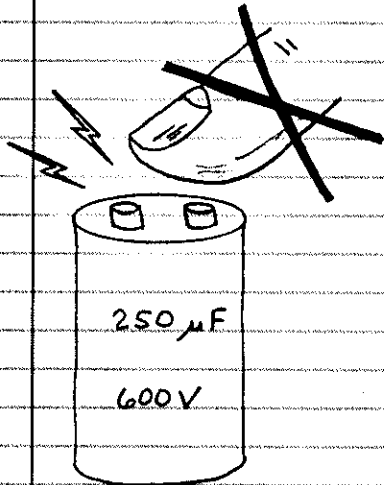


FIXED

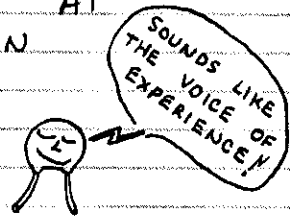


VARIABLE

## □ WARNING!



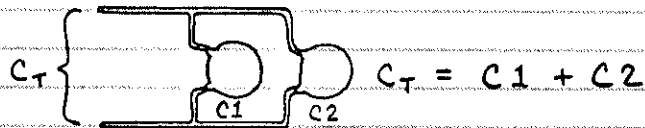
CAPACITORS CAN STORE A CHARGE FOR A CONSIDERABLE TIME AFTER THE POWER TO THEM HAS BEEN SWITCHED OFF. THIS CHARGE CAN BE DANGEROUS! A LARGE ELECTROLYTIC CHARGED TO ONLY 5 OR 10 VOLTS CAN MELT THE TIP OF A SCREWDRIVER PLACED ACROSS ITS TERMINALS! HIGH VOLTAGE CAPACITORS LIKE THOSE USED IN TELEVISION SETS AND PHOTOFLASH UNITS CAN STORE A LETHAL CHARGE! NEVER TOUCH THE LEADS OF SUCH A CAPACITOR. AT THE VERY LEAST THE JOLT CAN THROW YOU ACROSS A ROOM!



## HOW CAPACITORS ARE USED

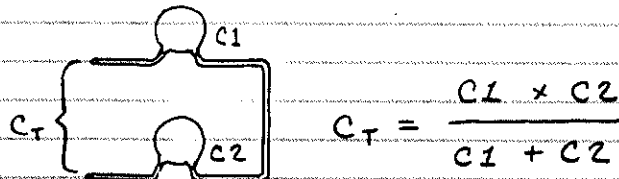
□ PARALLEL CIRCUIT — OFTEN CAPACITORS ARE CONNECTED IN PARALLEL LIKE THIS:

THE TOTAL CAPACITANCE IS THE SUM OF THE INDIVIDUAL CAPACITANCES.



□ SERIES CIRCUIT — SOMETIMES CAPACITORS ARE CONNECTED IN SERIES LIKE THIS:

THE TOTAL CAPACITANCE IS THE PRODUCT OF THE TWO CAPACITANCES DIVIDED BY THEIR SUM.



THREE OR MORE CAPACITORS IN SERIES? HERE'S THE FORMULA:

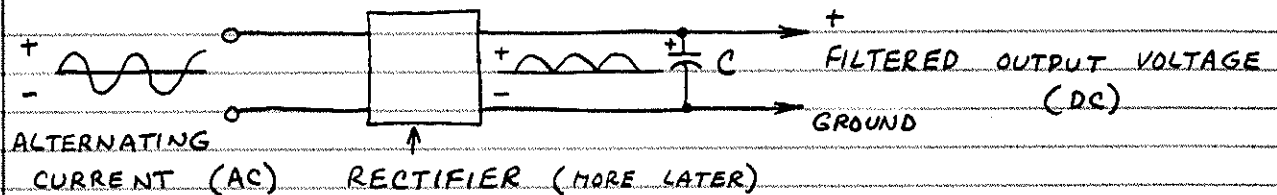
$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \dots \text{ETC.}}$$

□ AND MORE — THERE ARE MANY OTHER WAYS TO USE CAPACITORS, SOME OF WHICH ARE SHOWN NEXT...

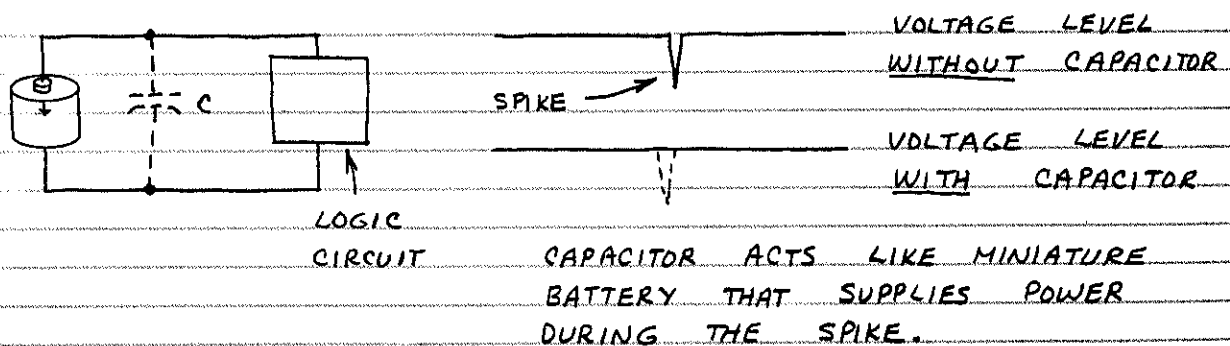
# RESISTOR AND CAPACITOR APPLICATIONS

RESISTORS AND CAPACITORS ARE THE KEY INGREDIENTS OF MANY ELECTRONIC CIRCUITS. HERE ARE SOME REASONS WHY:

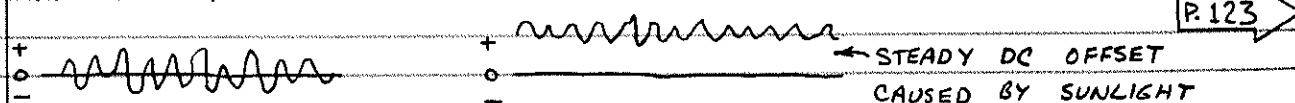
□ POWER SUPPLY FILTER — A CAPACITOR WILL SMOOTH (FILTER) THE PULSATING VOLTAGE FROM A POWER SUPPLY INTO A STEADY DIRECT CURRENT (DC).



□ SPIKE REMOVER — DIGITAL LOGIC CIRCUITS, WHICH WE'LL FIND OUT MORE ABOUT LATER, CAN USE LOTS OF CURRENT MOMENTARILY WHEN THEY SWITCH FROM OFF TO ON OR VICE VERSA. THIS CAN CAUSE VERY BRIEF BUT SUBSTANTIAL REDUCTIONS IN POWER APPLIED TO NEARBY CIRCUITS. THESE POWER SPIKES (OR GLITCHES, AS THEY ARE SOMETIMES CALLED) CAN BE ELIMINATED BY PLACING A SMALL (0.1  $\mu$ F) CAPACITOR ACROSS THE POWER LEADS OF THE LOGIC CIRCUIT:



□ AC-DC SELECTIVE FILTER — OFTEN AN ELECTRICAL SIGNAL WILL BE RIDING ATOP A STEADY DC SIGNAL. FOR EXAMPLE, THE SIGNAL FROM A LIGHTWAVE COMMUNICATION SYSTEM MAY LOOK LIKE THIS WHEN IT'S DARK: BUT SUNLIGHT CAUSES THIS:

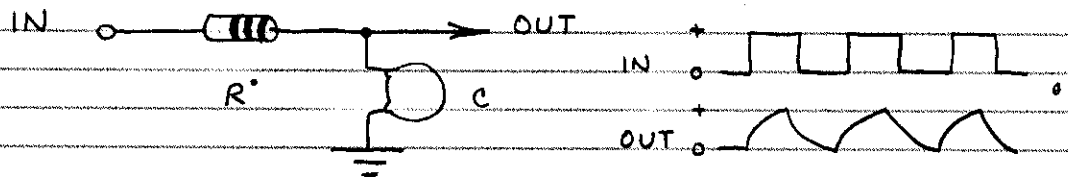


A CAPACITOR WILL PASS THE FLUCTUATING SIGNAL AND COMPLETELY BLOCK THE STEADY DC LEVEL.

□ R-C CIRCUITS — TWO CIRCUITS THAT COMBINE A RESISTOR (R) AND CAPACITOR (C) ARE VERY IMPORTANT. THEY ARE THE INTEGRATOR AND DIFFERENTIATOR. BOTH THESE CIRCUITS ARE USED TO RESHAPE AN INCOMING STREAM OF WAVES OR PULSES.

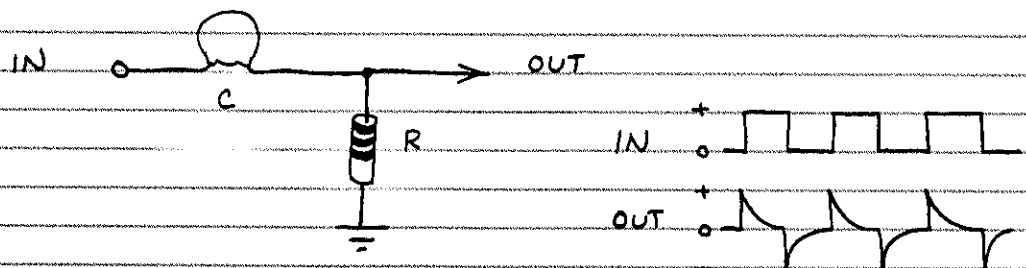
THE PRODUCT OF R AND C IN THESE CIRCUITS IS CALLED THE RC TIME CONSTANT. FOR THE CIRCUITS SHOWN BELOW, THE RC TIME CONSTANT (IN SECONDS) IS AT LEAST TEN TIMES THE INTERVAL BETWEEN INCOMING CYCLES OR PULSES.

1. INTEGRATOR. HERE'S A BASIC RC INTEGRATOR:



IF THE INPUT PULSES ARE SPEEDED UP, THE OUTPUT WAVEFORMS (OFTEN CALLED A SAWTOOTH) WILL NOT REACH THEIR FULL HEIGHT (AMPLITUDE). IT'S EASY TO DESIGN AN AMPLIFIER THAT IGNORES WAVES WITH LESS THAN A DESIRED AMPLITUDE. THEREFORE, THE INTEGRATOR CAN FUNCTION AS A FILTER WHICH PASSES ONLY SIGNALS BELOW A CERTAIN FREQUENCY.

2. DIFFERENTIATOR. HERE'S A BASIC RC DIFFERENTIATOR:



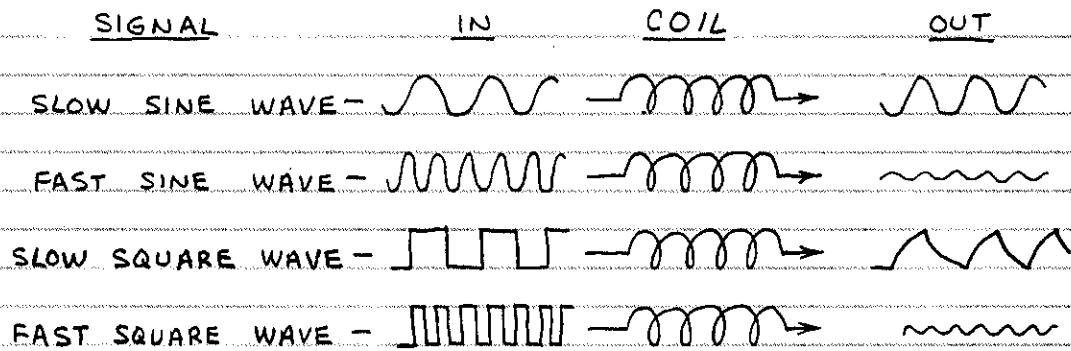
THIS CIRCUIT PRODUCES SYMMETRICAL OUTPUT WAVES WITH SHARP POSITIVE AND NEGATIVE PEAKS. IT'S USED TO MAKE NARROW PULSE GENERATORS FOR TELEVISION RECEIVERS AND TO TRIGGER DIGITAL LOGIC CIRCUITS.

□ MORE ABOUT R-C — YOU WILL OFTEN SEE REFERENCES TO THE RC TIME CONSTANT OF A CIRCUIT. IT'S THE TIME IN SECONDS FOR A CHARGING OR DISCHARGING CAPACITOR TO GO THROUGH 63.3% OF THE CHANGE IN CHARGE.

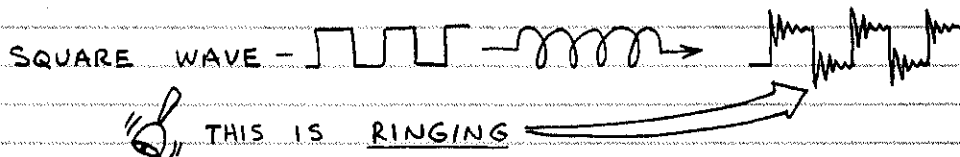
# COILS

ELECTRONS MOVING THROUGH A WIRE CAUSE AN ELECTROMAGNETIC FIELD TO ENCIRCLE THE WIRE. AS YOU KNOW FROM CHAPTER 1, PASSING A CURRENT THROUGH A WIRE THAT'S BEEN WRAPPED AS A COIL (P.15) CREATES AN EVEN STRONGER FIELD. THIS FIELD MAKES POSSIBLE SOLENOIDS, MOTORS AND ELECTROMAGNETS. COILS HAVE OTHER IMPORTANT ROLES, TOO:

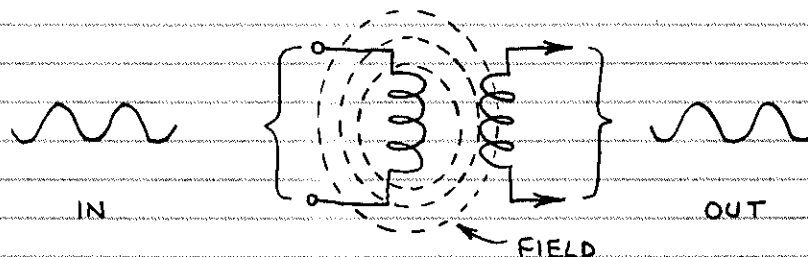
1. COILS RESIST RAPID CHANGES IN THE CURRENT FLOWING THROUGH THEM WHILE FREELY PASSING STEADY (DC) CURRENT. HERE ARE SOME EXAMPLES:



SOMETIMES A COIL WILL ADD RINGING TO A SQUARE WAVE PASSING THROUGH IT. THIS CAN HAPPEN WHEN THE RESISTANCE OF THE EXTERNAL CURRENT PATH THAT CONNECTS THE ENDS OF THE COIL IS HIGH.



2. SOME OF THE ENERGY IN THE FIELD AROUND A COIL CAN BE INDUCED (TRANSFERRED) INTO A SECOND, NEARBY COIL. THIS IS THE PRINCIPLE OF THE TRANSFORMER:

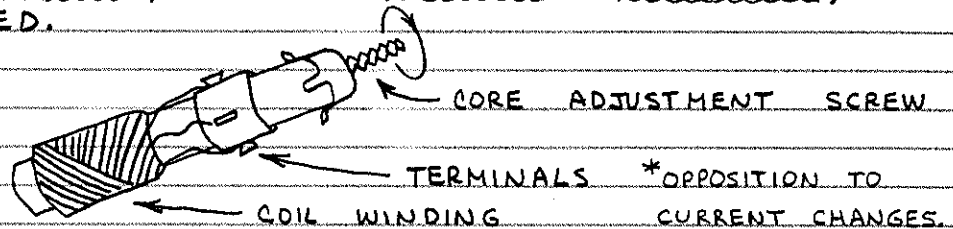


THE INPUT SIDE OF THE TRANSFORMER IS CALLED THE PRIMARY. THE OUTPUT SIDE IS CALLED THE SECONDARY.

□ TYPES OF COILS — THERE ARE MANY DIFFERENT TYPES OF COILS. HERE ARE SOME OF THEM:

TUNING COIL. RADIOS USE VARIOUS COILS TO HELP SELECT A DESIRED SIGNAL. TUNING COILS HAVE A SERIES OF TAPS OR A MOVABLE CORE SO THEIR INDUCTANCE\*, HENCE RESONANT FREQUENCY, CAN BE CHANGED.

TYPICAL TUNING COIL

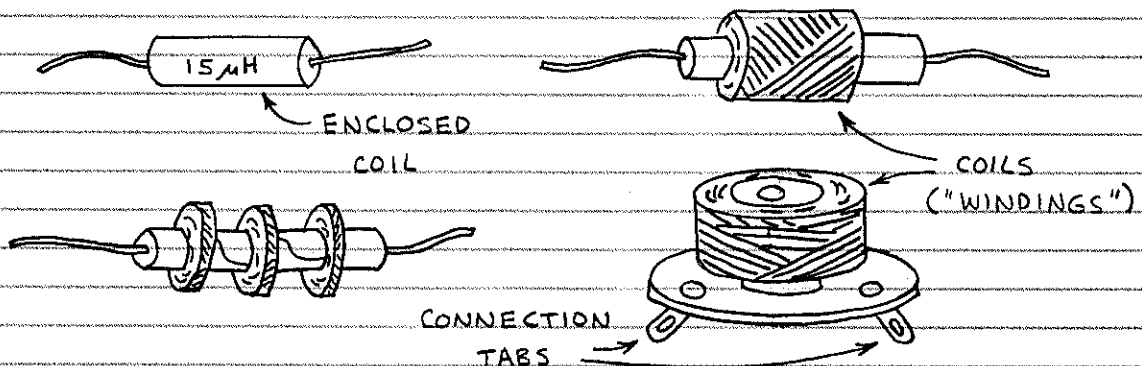


ANTENNA COIL. RADIOS OFTEN USE A BROADLY TUNED COIL TO PICK UP RADIO SIGNALS.

TYPICAL ANTENNA COIL



CHOKES. USED IN MANY CIRCUITS TO LIMIT OR SUPPRESS FLUCTUATING SIGNALS WHILE PASSING A STEADY CURRENT. CHOKES ARE AVAILABLE IN MANY SHAPES AND SIZES:



TRANSFORMER. SO IMPORTANT WE'LL DEVOTE A COMPLETE SECTION TO IT.

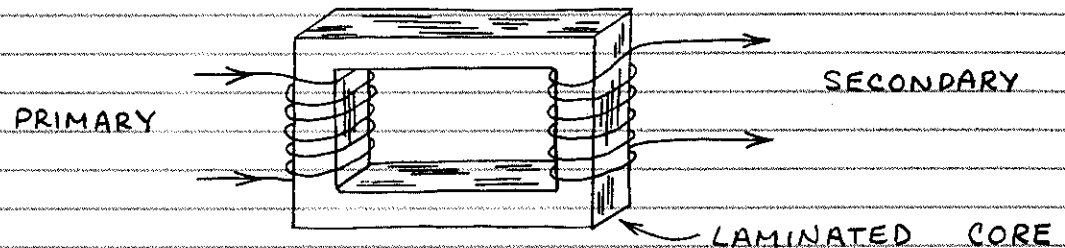
□ APPLICATIONS FOR COILS — IN ADDITION TO THOSE ALREADY DESCRIBED, COILS ARE USED IN FILTERS THAT SELECTIVELY PASS SPECIFIC FREQUENCY BANDS.

□ CAUTION! A HIGH VOLTAGE PULSE CAN BE PRODUCED IN A CHOKES WHEN THE CURRENT FLOWING THROUGH IT IS INTERRUPTED. BE CAREFUL.



# TRANSFORMERS

TRANSFORMERS ARE A MAJOR CLASS OF COILS HAVING TWO OR MORE WINDINGS USUALLY WRAPPED AROUND A COMMON CORE MADE FROM LAMINATED IRON SHEETS. HERE'S A SIMPLE TRANSFORMER:

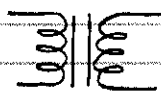


IF THE CURRENT FLOWING THROUGH THE PRIMARY COIL IS FLUCTUATING, THEN A CURRENT WILL BE INDUCED INTO THE SECONDARY WINDING. A STEADY (DC) CURRENT WILL NOT BE TRANSFERRED FROM ONE COIL TO THE OTHER.

□ HOW THEY WORK — TRANSFORMERS HAVE THE ABILITY TO TRANSFORM VOLTAGE AND CURRENT TO HIGHER OR LOWER LEVELS. THEY DO NOT, OF COURSE, CREATE POWER FROM NOTHING. THEREFORE, IF A TRANSFORMER BOOSTS THE VOLTAGE OF A SIGNAL, IT REDUCES ITS CURRENT. AND IF IT CUTS THE VOLTAGE OF A SIGNAL, IT RAISES ITS CURRENT. IN OTHER WORDS... THE POWER FLOWING FROM A TRANSFORMER CANNOT EXCEED THE INCOMING POWER!

□ TURNS RATIO — THE RATIO OF PRIMARY TO SECONDARY TURNS DETERMINES A TRANSFORMER'S VOLTAGE RATIO...

1:1 RATIO.



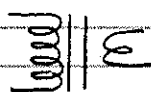
THE PRIMARY VOLTAGE AND CURRENT ARE TRANSFERRED UNALTERED TO THE SECONDARY. OFTEN CALLED AN ISOLATION TRANSFORMER.

STEP-UP.



THE VOLTAGE IS INCREASED BY THE TURNS RATIO. THUS A 1:5 TURNS RATIO WILL BOOST 5-VOLTS AT THE PRIMARY INTO 25-VOLTS AT THE SECONDARY.

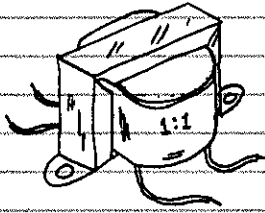
STEP-DOWN.



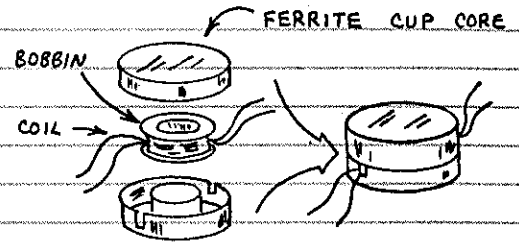
THE VOLTAGE IS REDUCED BY THE TURNS RATIO. THUS A 5:1 TURNS RATIO WILL DROP 25-VOLTS AT THE PRIMARY TO 5-VOLTS AT THE SECONDARY.

□ TRANSFORMER TYPES AND APPLICATIONS — HERE ARE SOME OF THE MAJOR TRANSFORMER TYPES :

ISOLATION.



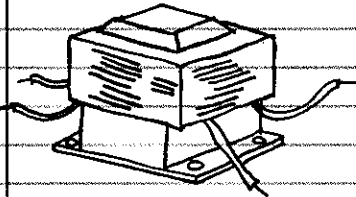
USED TO ISOLATE DIFFERENT PARTS OF A CIRCUIT AND TO PROVIDE PROTECTION FROM ELECTRICAL SHOCK.



STANDARD 1:1 ISOLATION

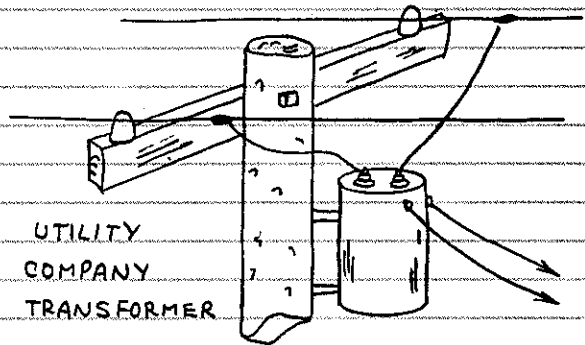
MINIATURE 1:1 ISOLATION

POWER CONVERSION.



POWER TRANSFORMER

OFTEN USED TO REDUCE POWER LINE VOLTAGE TO USABLE LEVEL.



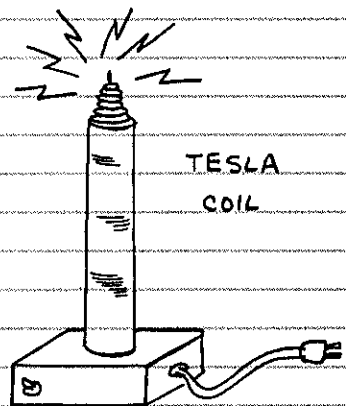
UTILITY COMPANY TRANSFORMER

HIGH - VOLTAGE.



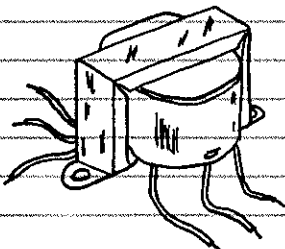
AUTOMOTIVE IGNITION COIL

USED TO PRODUCE IGNITION SPARKS IN GASOLINE ENGINES. ALSO USED TO POWER TV PICTURE TUBES, SOME LASERS, NEON LIGHTS, ETC.



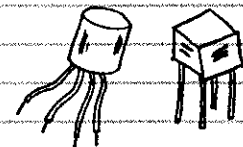
TESLA COIL

AUDIO.



TAPPED PRIMARY AND SECONDARY WINDINGS

USED TO MATCH THE IMPEDANCE\* OF AN AMPLIFIER TO THAT OF A MICROPHONE, SPEAKER OR OTHER DEVICE.  
\* OPPOSITION TO THE FLOW OF ALTERNATING CURRENT.



MINIATURE

NOTE: LEADS OF TRANSFORMERS ARE COLOR CODED.