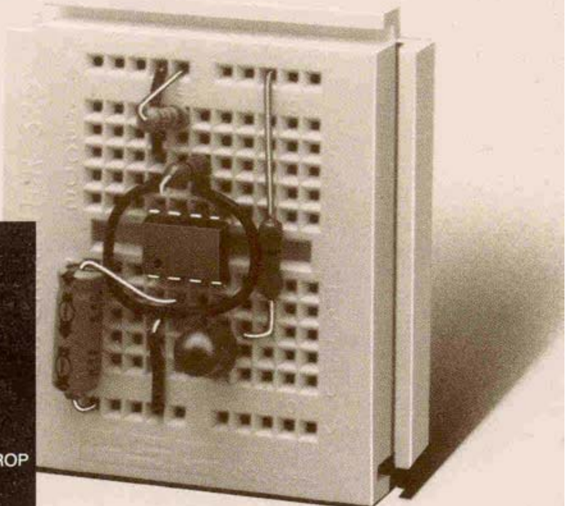
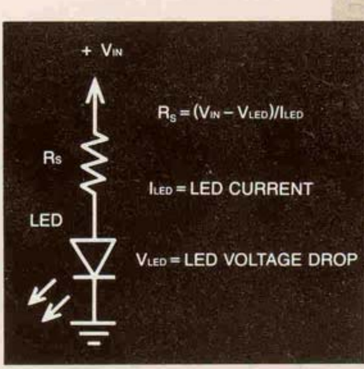
Radio Shack®

Cat. No. 62-5016

# Engineer's Mini-Notebook

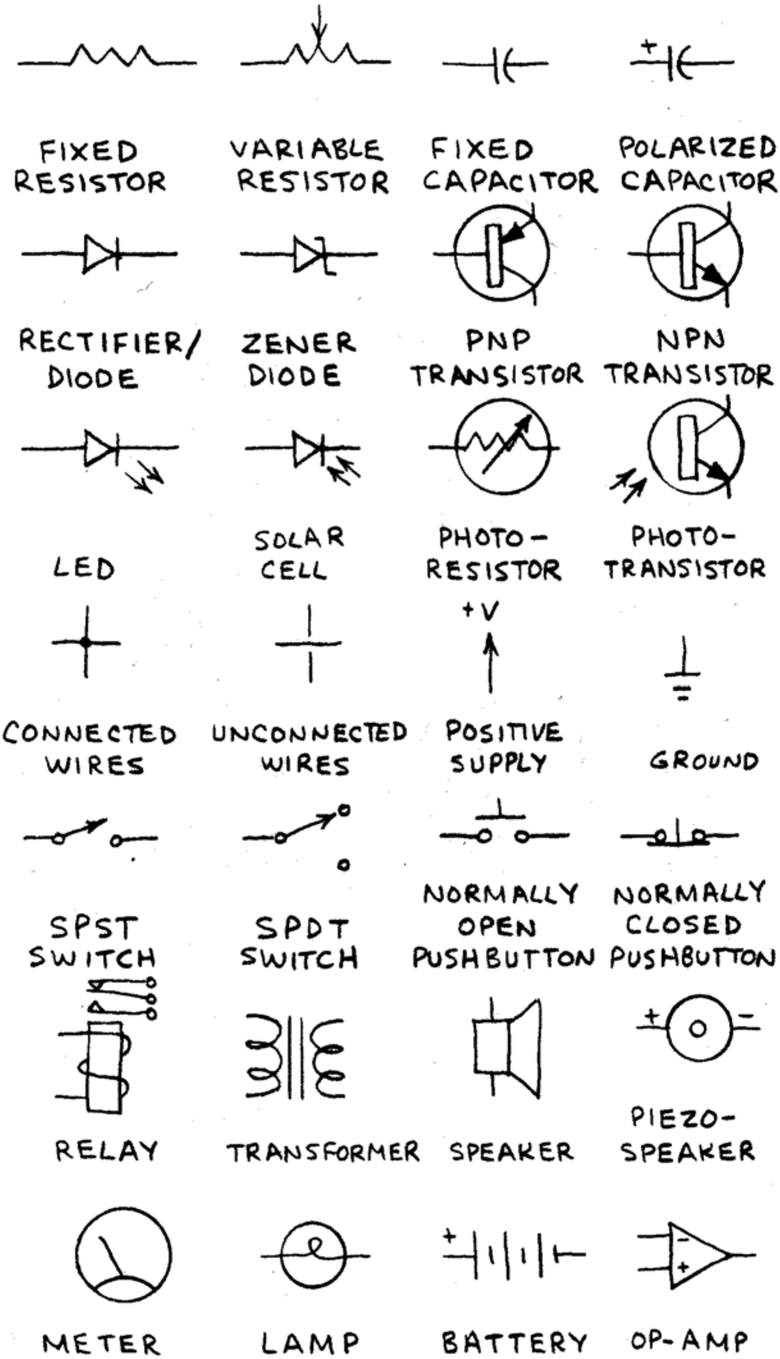
## Formulas, Tables and Basic Circuits






Forrest M. Mims III

# CIRCUIT SYMBOLS



# ENGINEER'S MINI-NOTEBOOK

## FORMULAS, TABLES AND BASIC CIRCUITS

BY

FORREST M. MIMS, III

SEVENTH PRINTING - 1998

A SILICONCEPTS™ BOOK



PRINTED IN THE UNITED STATES OF AMERICA

THIS BOOK INCLUDES STANDARD APPLICATION CIRCUITS AND CIRCUITS DESIGNED BY THE AUTHOR. EACH CIRCUIT WAS ASSEMBLED AND TESTED BY THE AUTHOR AS THE BOOK WAS DEVELOPED. AFTER THE BOOK WAS COMPLETED, THE AUTHOR REASSEMBLED EACH CIRCUIT TO CHECK FOR ERRORS. WHILE REASONABLE CARE WAS EXERCISED IN THE PREPARATION OF THIS BOOK, VARIATIONS IN COMPONENT TOLERANCES AND CONSTRUCTION METHODS MAY CAUSE THE RESULTS YOU OBTAIN TO DIFFER FROM THOSE GIVEN HERE. THEREFORE THE AUTHOR AND RADIO SHACK ASSUME NO RESPONSIBILITY FOR THE SUITABILITY OF THIS BOOK'S CONTENTS FOR ANY APPLICATION. SINCE WE HAVE NO CONTROL OVER THE USE TO WHICH THE INFORMATION IN THIS BOOK IS PUT, WE ASSUME NO LIABILITY FOR ANY DAMAGES RESULTING FROM ITS USE. OF COURSE IT IS YOUR RESPONSIBILITY TO DETERMINE IF COMMERCIAL USE, SALE OR MANUFACTURE OF ANY DEVICE THAT INCORPORATES INFORMATION IN THIS BOOK INFRINGES ANY PATENTS, COPYRIGHTS OR OTHER RIGHTS.

DUE TO THE MANY INQUIRIES RECEIVED BY RADIO SHACK AND THE AUTHOR, IT IS NOT POSSIBLE TO PROVIDE PERSONAL RESPONSES TO REQUESTS FOR ADDITIONAL INFORMATION (CUSTOM CIRCUIT DESIGN, TECHNICAL ADVICE, TROUBLESHOOTING ADVICE, ETC.). IF YOU WISH TO LEARN MORE ABOUT ELECTRONICS, SEE OTHER BOOKS IN THIS SERIES AND RADIO SHACK'S "GETTING STARTED IN ELECTRONICS." ALSO, READ MAGAZINES LIKE <u>MODERN ELECTRONICS</u> AND <u>RADIO-ELECTRONICS</u>. THE AUTHOR WRITES A MONTHLY COLUMN, "ELECTRONICS NOTEBOOK," FOR <u>MODERN ELECTRONICS</u>.

# CONTENTS

# 1. ELECTRONIC FORMULAS

## DIRECT CURRENT

A DIRECT CURRENT (DC) FLOWS IN ONE DIRECTION, EITHER STEADILY OR IN PULSES.

<u>CURRENT</u> (I) – THE QUANTITY OF ELECTRONS PASSING A GIVEN POINT. (UNIT: AMPERE)

<u>VOLTAGE</u> (V) – ELECTRICAL PRESSURE OR FORCE. (UNIT: VOLT)

<u>RESISTANCE</u> (R) – RESISTANCE TO THE FLOW OF A CURRENT. (UNIT: OHM)

<u>POWER</u> (P) – THE WORK PERFORMED BY A CURRENT. (UNIT: WATT)

<u>POTENTIAL DIFFERENCE</u> – THE DIFFERENCE IN VOLTAGE BETWEEN THE TWO ENDS OF A CONDUCTOR THROUGH WHICH A CURRENT FLOWS. ALSO KNOWN AS VOLTAGE DROP.

## OHM'S LAW

A POTENTIAL DIFFERENCE OF 1 VOLT WILL FORCE A CURRENT OF 1 AMPERE THROUGH A RESISTANCE OF 1 OHM, OR:

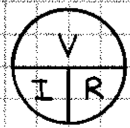
$V = I \times R$

$I = \dfrac{V}{R}$

$R = \dfrac{V}{I}$

$P = I \times V$ (OR) $I^2 \times R$

<u>OHM'S LAW HELPER</u>

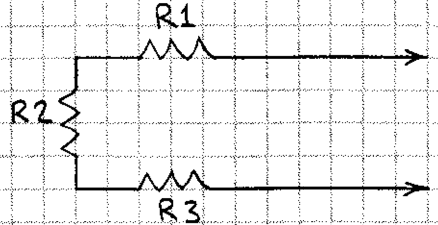



THIS DIAGRAM SHOWS THE RELATIONSHIP OF V, I AND R.

# RESISTOR NETWORKS

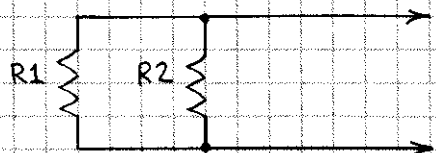
## SERIES

$R_T$ = TOTAL RESISTANCE



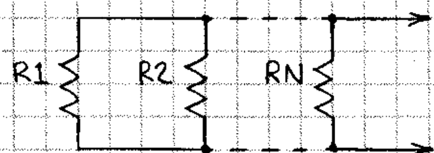

$$R_T = R1 + R2 + R3$$

## PARALLEL (2)



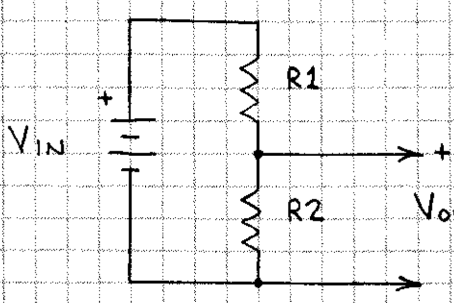

$$R_T = \frac{R1 \times R2}{R1 + R2}$$

## PARALLEL (2 OR MORE)




$$R_T = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \frac{1}{RN}}$$

## VOLTAGE DIVIDER

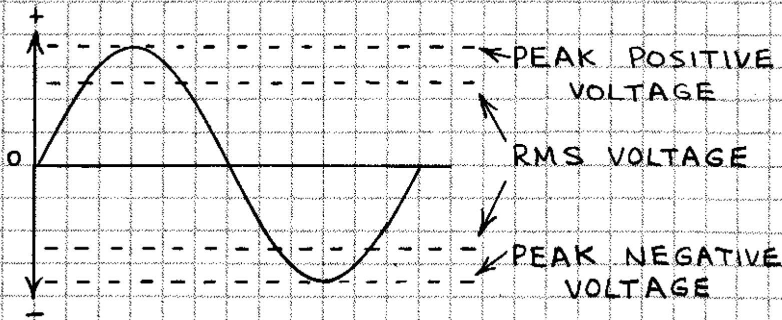



$$V_{OUT} = V_{IN} \times \left( \frac{R2}{R1 + R2} \right)$$

R1 AND R2 CAN BE A POTENTIOMETER.

# ALTERNATING CURRENT

AN ALTERNATING CURRENT (AC) FLOWS IN BOTH DIRECTIONS THROUGH A CONDUCTOR.




SEE THE DEFINITIONS OF I, V, R AND P ON PAGE 4.

<u>PEAK VOLTAGE</u> — MAXIMUM POSITIVE AND NEGATIVE EXCURSIONS OF AN ALTERNATING CURRENT.

<u>RMS VOLTAGE</u> — (ROOT-MEAN-SQUARE VOLTAGE) THAT AC VOLTAGE THAT EQUALS A DC VOLTAGE THAT DOES THE SAME WORK. FOR A SINE WAVE, 0.707 TIMES THE PEAK VOLTAGE.

<u>IMPEDANCE</u> (Z) — THE OPPOSITION TO AN ALTERNATING CURRENT PRESENTED BY A CIRCUIT. (UNIT: OHM)

AVERAGE AC VOLTAGE = 0.637 × PEAK
= 0.9 × RMS

RMS AC VOLTAGE = 0.707 × PEAK
= 1.11 × AVERAGE

PEAK AC VOLTAGE = 1.414 × RMS
= 1.57 × AVERAGE

# OHM'S LAW

$V = I \times Z$

$I = \frac{E}{Z}$

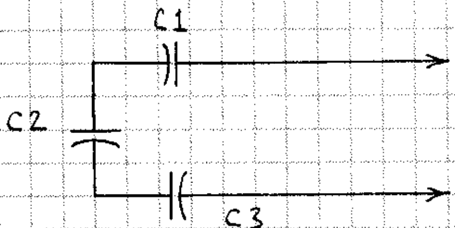
$Z = \frac{E}{I}$

$P = E \times I \times \cos\theta$

$\theta$ IS PHASE ANGLE, THE DIFFERENCE IN DEGREES BETWEEN CURRENT AND VOLTAGE. CURRENT LEADS VOLTAGE IN A CAPACITIVE CIRCUIT AND LAGS VOLTAGE IN A REACTIVE CIRCUIT. IN A RESISTIVE CIRCUIT $\theta$ IS 0°. THE COSINE OF 0° IS 1. THUS IN A RESISTIVE CIRCUIT P= E×I.

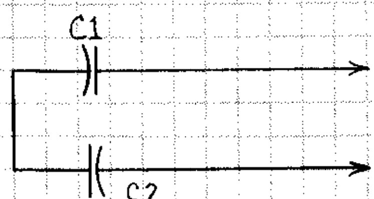
# CAPACITOR NETWORKS

<u>SERIES</u>



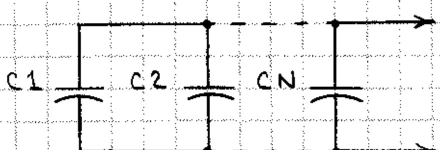

$$C_T = \frac{1}{\frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3}}$$

<u>SERIES</u>




$$C_T = \frac{C1 \times C2}{C1 + C2}$$

<u>PARALLEL</u> (2 OR MORE)




$$C_T = C1 + C2 + CN$$

# 2. MATHEMATICS

## SYMBOLS

| | |
|---|---|
| $+$ | PLUS, POSITIVE OR ADD |
| $-$ | MINUS, NEGATIVE OR SUBTRACT |
| $\times$ OR $*$ | MULTIPLY |
| $\div$ OR $/$ | DIVIDE |
| $=$ | EQUAL (S) |
| $\neq$ | DOES NOT EQUAL |
| $\cong$ | APPROXIMATELY EQUAL |
| $>$ | GREATER THAN |
| $\geq$ | EQUAL TO OR GREATER THAN |
| $<$ | LESS THAN |
| $\leq$ | LESS THAN OR EQUAL TO |
| $\pm$ | PLUS OR MINUS; CHANGE SIGN |
| $1/n$ | RECIPROCAL ($1/2 = 0.5$) |
| $\sqrt{n}$ | SQUARE ROOT OF $n$ |
| $\sqrt[3]{n}$ | CUBE ROOT OF $n$ |

## POWERS OF TEN

| | | |
|---|---|---|
| $10^{-9}$ | $= 0.000000001$ | 1 BILLIONTH (NANO) |
| $10^{-8}$ | $= 0.00000001$ | |
| $10^{-7}$ | $= 0.0000001$ | |
| $10^{-6}$ | $= 0.000001$ | 1 MILLIONTH (MICRO) |
| $10^{-5}$ | $= 0.00001$ | |
| $10^{-4}$ | $= 0.0001$ | |
| $10^{-3}$ | $= 0.001$ | 1 THOUSANDTH (MILLI) |
| $10^{-2}$ | $= 0.01$ | |
| $10^{-1}$ | $= 0.1$ | |
| $10^{0}$ | $= 1$ | 1 UNIT |
| $10^{1}$ | $= 10$ | |
| $10^{2}$ | $= 100$ | |
| $10^{3}$ | $= 1,000$ | THOUSAND (KILO) |
| $10^{4}$ | $= 10,000$ | |
| $10^{5}$ | $= 100,000$ | |
| $10^{6}$ | $= 1,000,000$ | MILLION (MEGA) |
| $10^{7}$ | $= 10,000,000$ | |
| $10^{8}$ | $= 100,000,000$ | |
| $10^{9}$ | $= 1,000,000,000$ | BILLION (GIGA) |

# ALGEBRAIC TRANSPOSITION

IF $A + B = C$, THEN:

$$A = C - B$$
$$B = C - A$$
$$A + B - C = 0$$

IF $A = \frac{B}{C}$, THEN:

$$B = AC$$
$$C = \frac{B}{A}$$

IF $\frac{A}{B} = \frac{C}{D}$, THEN:

$$AD = BC$$
$$A = \frac{BC}{D}$$
$$B = \frac{AD}{C}$$
$$C = \frac{AD}{B}$$
$$D = \frac{BC}{A}$$

# LAW OF EXPONENTS

$$\left(\frac{a}{b}\right)^x = \frac{a^x}{b^x} \qquad (a^x)(a^y) = a^{x+y}$$

$$\frac{a^x}{a^y} = a^{x-y} \qquad (a^x)^y = a^{xy}$$

$$a^{-x} = \frac{1}{a^x} \qquad a^{\frac{x}{y}} = \sqrt[y]{a^x}$$

# COMMON LOGARITHMS

THE <u>COMMON LOGARITHM</u> ($LOG_{10}$ OR LOG) OF A NUMBER IS THE POWER OF 10 THAT EQUALS THE NUMBER. SINCE $10^2 = 100$, 2 IS THE LOG OF 100. THE <u>ANTILOGARITHM</u> (ANTILOG) IS THE NUMBER THAT EQUALS A LOGARITHM. THUS THE ANTILOG OF 2 IS 100. THE LOG OF NUMBERS GREATER THAN 1 IS POSITIVE; THE LOG OF NUMBERS LESS THAN 1 IS NEGATIVE. THUS THE LOG OF $10^{-2}$ OR 0.01 IS -2. $A \times B$ = ANTILOG (LOG A + LOG B); $A \div B$ = ANTILOG (LOG A - LOG B). SCIENTIFIC CALCULATORS HAVE LOG AND ANTILOG KEYS.

# THE DECIBEL

THE DECIBEL (dB) IS A UNIT OF MEASURE THAT PERMITS TWO DIFFERENT SIGNALS TO BE COMPARED ON A LOGARITHMIC SCALE. THE SENSITIVITY OF RECEIVERS AND THE GAIN OF AMPLIFIERS ARE OFTEN GIVEN IN DECIBELS. THE DIFFERENCE IN dB BETWEEN THE POWER OF A SIGNAL AT THE INPUT OF AN AMPLIFIER (P1) AND THE POWER OF THE AMPLIFIER'S OUTPUT (P2) IS:

$$dB = 10\ LOG\ (P2/P1)$$

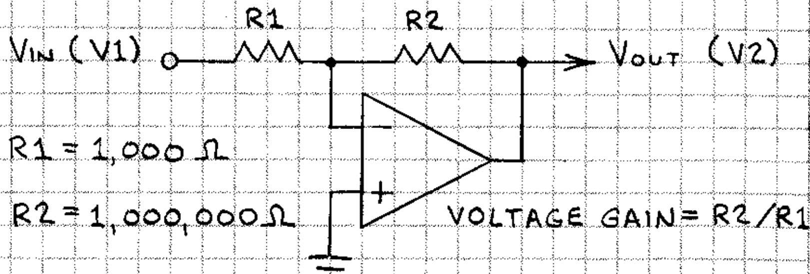
THE DIFFERENCE IN dB BETWEEN THE VOLTAGE (V) AND CURRENT (I) AT THE INPUT (V1 AND I1) AND OUTPUT (V2 AND I2) OF AN AMPLIFIER IS:

$$dB = 20\ LOG\ (V2/V1)$$

$$dB = 20\ LOG\ (I2/I1)$$

NOTE THAT DECIBELS DEFINE THE <u>RATIO</u> BETWEEN TWO SIGNAL LEVELS, NOT THEIR ABSOLUTE VALUE.

EXAMPLE: DETERMINE THE VOLTAGE GAIN IN dB OF THIS OPERATIONAL AMPLIFIER.




$$dB = 20\ LOG\ (V2/V1)$$

$$dB = 20\ LOG\ (1{,}000\ /\ 1) = 20\ LOG\ 1{,}000$$

LOG 1000 = 3 (FROM TABLE OR CALCULATOR)
GAIN = 20 × 3 = 60 dB

# DECIBEL (dB) TABLE

| − | | | + | |
|---|---|---|---|---|
| VOLTAGE OR CURRENT RATIO | POWER RATIO | dB | VOLTAGE OR CURRENT RATIO | POWER RATIO |
| 1.0000 | 1.0000 | 0 | 1.0000 | 1.0000 |
| .8913 | .7943 | 1 | 1.1220 | 1.2589 |
| .7943 | .6310 | 2 | 1.2589 | 1.5849 |
| .7079 | .5012 | 3 | 1.4125 | 1.9953 |
| .6310 | .3981 | 4 | 1.5849 | 2.5119 |
| .5623 | .3162 | 5 | 1.7783 | 3.1623 |
| .5012 | .2512 | 6 | 1.9953 | 3.9811 |
| .4467 | .1995 | 7 | 2.2387 | 5.0119 |
| .3981 | .1585 | 8 | 2.5119 | 6.3096 |
| .3548 | .1259 | 9 | 2.8184 | 7.9433 |
| .3162 | .1000 | 10 | 3.1623 | 10.000 |
| .1000 | .0100 | 20 | 10.000 | 100.00 |
| .0316 | .0010 | 30 | 31.623 | 1,000.0 |
| .0100 | .0001 | 40 | 100.00 | 10,000 |
| .0032 | .00001 | 50 | 316.23 | 100,000 |
| .0010 | $10^{-6}$ | 60 | 1,000.0 | $10^{6}$ |
| .0003 | $10^{-7}$ | 70 | 3,162.3 | $10^{7}$ |
| .0001 | $10^{-8}$ | 80 | 10,000 | $10^{8}$ |
| .00003 | $10^{-9}$ | 90 | 31,623 | $10^{9}$ |
| .00001 | $10^{-10}$ | 100 | 100,000 | $10^{10}$ |

# POWER - dBm EQUIVALENTS

RECEIVER SENSITIVITY IS OFTEN GIVEN IN dB WITH RESPECT TO 1 MILLIWATT.

| dBm | POWER (mW) | UNITS |
|---|---|---|
| 10 | 10.000000 | 10 MILLIWATTS |
| 0 | 1.000000 | 1 MILLIWATT |
| −10 | .100000 | 100 MICROWATTS |
| −20 | .010000 | 10 MICROWATTS |
| −30 | .001000 | 1 MICROWATT |
| −40 | .000100 | 100 NANOWATTS |
| −50 | .000010 | 10 NANOWATTS |
| −60 | .000001 | 1 NANOWATT |

# NUMBER SYSTEMS

A NUMBER SYSTEM CAN BE BASED ON ANY NUMBER OF DIGITS. THE COMMON DECIMAL SYSTEM HAS 10 DIGITS. THE BINARY SYSTEM HAS 2 DIGITS; THE HEXADECIMAL SYSTEM HAS 16 DIGITS. NUMBERS ARE WRITTEN AS SUCCESSIVE POWERS OF THE BASE OF THE NUMBER SYSTEM. THUS:

$4327_{10}$

$$
\begin{aligned}
7 \times 10^0 &= 7 \times 1 &&= 7\\
2 \times 10^1 & \quad 2 \times 10 &&= 20\\
3 \times 10^2 & \quad 3 \times 100 &&= 300\\
4 \times 10^3 &= 4 \times 1000 &&= \underline{4000}\\
& && \quad 4327
\end{aligned}
$$

# BINARY NUMBERS

IN ELECTRONIC CIRCUITS DECIMAL NUMBERS ARE USUALLY REPRESENTED BY BINARY NUMBERS. BINARY NUMBERS ALSO SERVE AS CODES THAT REPRESENT LETTERS OF THE ALPHABET, VOLTAGES, COMPUTER INSTRUCTIONS, ETC. A BINARY 0 OR 1 IS A <u>BIT</u>. A PATTERN OF 4 BITS IS A <u>NIBBLE</u>. A PATTERN OF 4 BITS IS A <u>BYTE</u> OR <u>WORD</u>.

<u>BINARY TO DECIMAL</u>

10011

$$
\begin{aligned}
1 \times 2^0 &= 1\\
1 \times 2^1 &= 2\\
0 \times 2^2 &= 0\\
0 \times 2^3 &= 0\\
1 \times 2^4 &= \underline{16}\\
& \quad 19
\end{aligned}
$$

<u>DECIMAL TO BINARY</u>

$$
\begin{aligned}
19 \div 2 &= 9 + 1\\
9 \div 2 &= 4 + 1\\
4 \div 2 &= 2 + 0\\
2 \div 2 &= 1 + 0\\
& \qquad\quad 1^{*}\\
19 &= 10011
\end{aligned}
$$

*FINAL QUOTIENT IS FINAL REMAINDER

<u>BINARY CODED DECIMAL</u> (BCD): A SYSTEM IN WHICH EACH DECIMAL DIGIT IS ASSIGNED ITS BINARY EQUIVALENT (19 = 0001 1001).

# NUMBER SYSTEM EQUIVALENTS

DEC (DECIMAL) BIN (BINARY)
BCD (BINARY CODED DECIMAL) HEX (HEXADECIMAL)

| DEC | BIN | BCD | HEX |
|---|---|---|---|
| 0 | 0 | 0000 0000 | 0 |
| 1 | 1 | 0000 0001 | 1 |
| 2 | 10 | 0000 0010 | 2 |
| 3 | 11 | 0000 0011 | 3 |
| 4 | 100 | 0000 0100 | 4 |
| 5 | 101 | 0000 0101 | 5 |
| 6 | 110 | 0000 0110 | 6 |
| 7 | 111 | 0000 0111 | 7 |
| 8 | 1000 | 0000 1000 | 8 |
| 9 | 1001 | 0000 1001 | 9 |
| 10 | 1010 | 0001 0000 | A |
| 11 | 1011 | 0001 0001 | B |
| 12 | 1100 | 0001 0010 | C |
| 13 | 1101 | 0001 0011 | D |
| 14 | 1110 | 0001 0100 | E |
| 15 | 1111 | 0001 0101 | F |
| 16 | 10000 | 0001 0110 | 10 |
| 17 | 10001 | 0001 0111 | 11 |
| 18 | 10010 | 0001 1000 | 12 |
| 19 | 10011 | 0001 1001 | 13 |
| 20 | 10100 | 0010 0000 | 14 |
| 21 | 10101 | 0010 0001 | 15 |
| 22 | 10110 | 0010 0010 | 16 |
| 23 | 10111 | 0010 0011 | 17 |
| 24 | 11000 | 0010 0100 | 18 |
| 25 | 11001 | 0010 0101 | 19 |
| 26 | 11010 | 0010 0110 | 1A |
| 27 | 11011 | 0010 0111 | 1B |
| 28 | 11100 | 0010 1000 | 1C |
| 29 | 11101 | 0010 1001 | 1D |
| 30 | 11110 | 0011 0000 | 1E |
| 31 | 11111 | 0011 0001 | 1F |
| 32 | 100000 | 0011 0010 | 20 |
| 64 | 1000000 | 0110 0100 | 40 |
| 96 | 1100000 | 1001 0110 | 60 |
| 99 | 1100011 | 1001 1001 | 63 |

# 3. CONSTANTS AND STANDARDS

## U.S. WEIGHTS AND MEASURES

### LINEAR

1,000 MILS = 1 INCH (IN)    3 FT = 1 YARD (YD)
12 INCHES = 1 FOOT (FT)    5,280 FT = 1 MILE (MI)

### AREA

1 FOOT$^2$ = 144 IN$^2$    1 ACRE = 43,560 FT$^2$
1 YARD$^2$ = 9 FT$^2$    1 MILE$^2$ = 640 ACRES

### VOLUME

1 FOOT$^3$ = 1,728 IN$^3$    1 YARD$^3$ = 27 FEET$^3$

### MASS

16 OUNCES (OZ) = 1 POUND (lb)

## METRIC WEIGHTS AND MEASURES

### LINEAR

1,000 MICROMETERS ($\mu$m) = 1 MILLIMETER (mm)
10 mm = 1 CENTIMETER (cm)    100 cm = 1 METER (m)
1,000 METERS = 1 KILOMETER (KM)

### AREA

100 mm$^2$ = 1 cm$^2$    10,000 cm$^2$ = 1 m$^2$

### VOLUME

1 cm$^3$ = 1 MILLILITER (ml)    1,000 ml = 1 LITER (l)

### MASS

1,000 MILLIGRAMS (mg) = 1 gram (g)

# U.S.-METRIC CONVERSION

| TO CONVERT | INTO | MULTIPLY BY |
|---|---|---|
| MICROMETERS | MILS | $3.937 \times 10^{-2}$ |
| MILS | MICROMETERS | 25.4 |
| MILLIMETERS | MILS | 39.37 |
| MILS | MILLIMETERS | $2.54 \times 10^{-2}$ |
| MILLIMETERS | INCHES | $3.937 \times 10^{-2}$ |
| INCHES | MILLIMETERS | 25.4 |
| CENTIMETERS | INCHES | 0.3937 |
| INCHES | CENTIMETERS | 2.54 |
| INCHES | METERS | $2.54 \times 10^{-2}$ |
| METERS | INCHES | 39.37 |
| FEET | METERS | $30.48 \times 10^{-2}$ |
| METERS | FEET | 3.281 |
| METERS | YARDS | 1.094 |
| YARDS | METERS | 0.9144 |
| KILOMETERS | FEET | 3281 |
| FEET | KILOMETERS | $3.408 \times 10^{-4}$ |
| KILOMETERS | MILES | 0.6214 |
| MILES | KILOMETERS | 1.609 |
| GRAMS | OUNCES | $3.527 \times 10^{-2}$ |
| OUNCES | GRAMS | 28.3495 |
| KILOGRAMS | POUNDS | 2.205 |
| POUNDS | KILOGRAMS | 0.4536 |

# FAMILIAR EXAMPLES

## DIMENSIONS

DIME ≈ 1 mm × 1.8 cm
NICKEL ≈ 2 mm × 2.1 cm
QUARTER ≈ 2 mm × 2.4 cm
1-MIL PLASTIC FILM = 25.4 μm

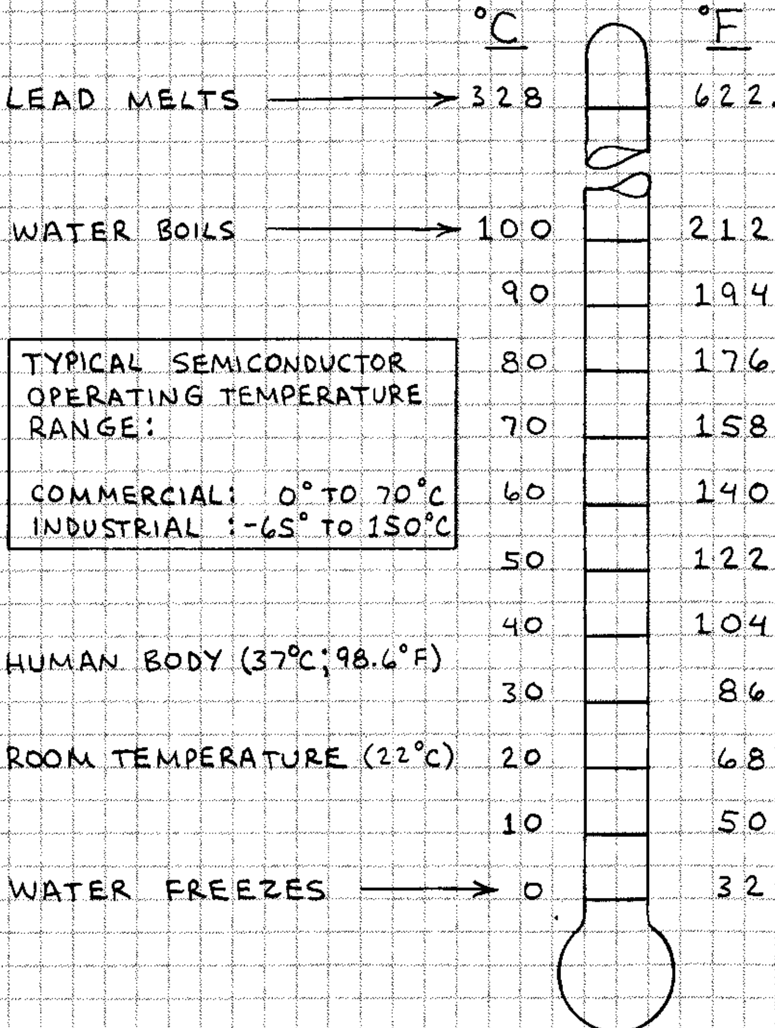
## MASS

PLASTIC TO-92 TRANSISTOR ≈ 0.25 g
8-PIN MINI DIP IC ≈ 0.5 g
16-PIN DIP IC ≈ 1.05 g
NICKEL ≈ 5 g

# TEMPERATURE

°FAHRENHEIT = (°CELSIUS × $\frac{9}{5}$) + 32 = °F

°CELSIUS = $\frac{5}{9}$ × (°FAHRENHEIT − 32) = °C




TYPICAL SEMICONDUCTOR OPERATING TEMPERATURE RANGE:

COMMERCIAL: 0° TO 70°C
INDUSTRIAL : −65° TO 150°C

# SOLDER

THE MOST COMMON ELECTRONIC SOLDER IS 60/40 (60% TIN AND 40% LEAD). ITS MELTING POINT IS 183° TO 190°C (361° TO 374°F).

# COPPER WIRE

| AWG | DIA | OHMS PER 1000 FT | FT PER POUND |
|---|---|---|---|
| 10 | 101.9 | .9989 | 31.82 |
| 12 | 80.8 | 1.588 | 50.59 |
| 14 | 64.1 | 2.525 | 80.44 |
| 16 | 50.8 | 4.016 | 127.9 |
| 18 | 40.3 | 6.385 | 203.4 |
| 20 | 32.0 | 10.15 | 323.4 |
| 22 | 25.4 | 16.14 | 514.2 |
| 24 | 20.1 | 25.67 | 817.7 |
| 26 | 15.9 | 40.81 | 1,300.0 |
| 28 | 12.6 | 64.90 | 2,067.0 |
| 30 | 10.0 | 103.2 | 3,287.0 |
| 32 | 7.9 | 164.1 | 5,227.0 |
| 34 | 6.3 | 260.9 | 8,310.0 |
| 36 | 5.0 | 414.8 | 13,210.0 |
| 38 | 4.0 | 659.6 | 21,010.0 |
| 40 | 3.1 | 1,049.0 | 33,410.0 |

AWG – AMERICAN WIRE GAUGE
DIA – DIAMETER IN MILS
OHMS PER 1000 FT – 20° C (68° F)

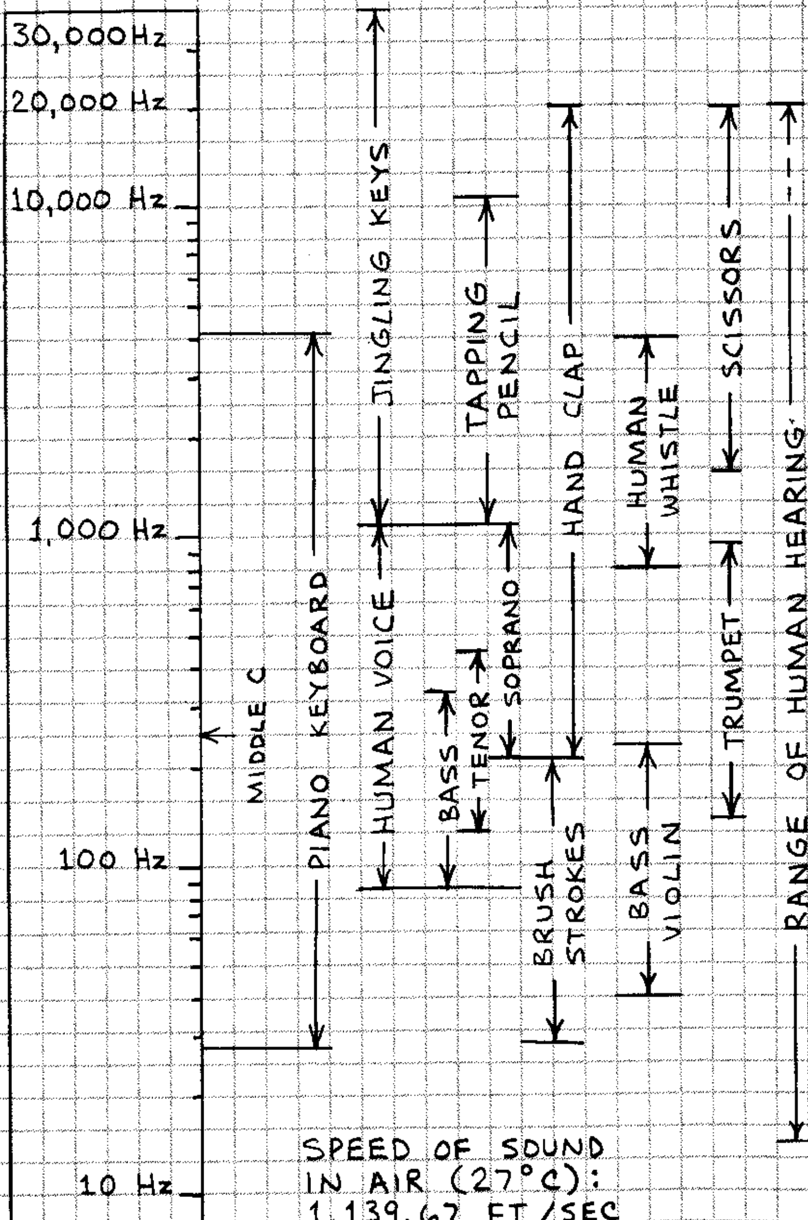
# RELATIVE RESISTANCES

| | |
|---|---|
| SILVER | 0.936 |
| COPPER | 1.000 |
| GOLD | 1.403 |
| CHROMIUM | 1.530 |
| ALUMINUM | 1.549 |
| TUNGSTEN | 3.203 |
| BRASS | 4.822 |
| PHOSPHOR-BRONZE | 5.533 |
| NICKEL | 5.786 |
| IRON | 5.799 |
| TIN | 6.702 |
| STEEL | 9.932 |
| LEAD | 12.922 |
| STAINLESS STEEL | 52.941 |
| NICHROME | 65.092 |

RESISTANCE RELATIVE TO COPPER. 1 FOOT OF CIRCULAR COPPER WIRE 1 MIL IN DIAMETER HAS A RESISTANCE OF 10.37 OHMS. ALTERNATIVELY, COPPER WIRE HAS A RESISTANCE OF 10.37 OHMS PER CIRCULAR MIL FOOT.

# AUDIO FREQUENCY SPECTRUM

MECHANICAL VIBRATION IN SOLIDS, FLUIDS AND GASES PRODUCES WHAT THE BRAIN PERCEIVES AS SOUND.




SPEED OF SOUND IN AIR (27°C): 1,139.67 FT/SEC

# SOUND INTENSITY LEVELS

| SOUND SOURCE (DISTANCE FROM OBSERVER) | LEVEL (dB) |
|---|---|
| THRESHOLD OF PAIN | 120+ |
| AIRCRAFT ENGINE (20') | 120+ |
| AMPLIFIED ROCK MUSIC | 110 |
| THUNDER | 110 |
| PIEZOELECTRIC BUZZER (12") | 108 |
| AIR FORCE T-38 (2,500' OVERHEAD) | 90 |
| $CO_2$ PELLET GUN (12") | 90 |
| DIGITAL ALARM CLOCK (12") | 85 |
| ELECTRIC TYPEWRITER (18") | 80 |
| AIR FORCE T-38 (1 MILE) | 70 |
| TYPICAL CONVERSATION | 65 |
| PAPER CLIP DROPPED ON DESK (12") | 62 |
| TELEPHONE DIAL TONE (1") | 56 |
| PENCIL ERASER TAPPED ON DESK (12") | 54 |
| COMPUTER KEYBOARD (18") | 61 |
| AVERAGE RESIDENCE | 45 |
| SOFT BACKGROUND MUSIC | 30 |
| QUIET WHISPER | 20 |
| THRESHOLD OF HEARING | 0 |

# ELECTROMAGNETIC SPECTRUM

| | |
| --- | --- |
| 10 pm | |
| | GAMMA RAYS |
| 100 pm | |
| 1 nm | X-RAYS |
| 10 nm | |
| 100 nm | ULTRAVIOLET |
| | VISIBLE LIGHT |
| 1 $\mu$m | |
| 10 $\mu$m | |
| | INFRARED |
| 100 $\mu$m | |
| 1 mm | |
| 10 mm | MICROWAVES |
| 100 mm | |
| 1 m | |
| | RADIO WAVES |
| 10 m | |
| 100 m | |

BEYOND 10pm:
COSMIC RAYS

400 nm

VIOLET*
MAGENTA
BLUE
CYAN
GREEN
YELLOW
ORANGE
RED*

750 nm

* THE EYE'S SENSITIVITY TO VIOLET AND RED VARIES WITH THE OBSERVER AND THE BACKGROUND ILLUMINATION.

$$f = c/\lambda$$

f = FREQUENCY
$\lambda$ = WAVELENGTH
$c = 3 \times 10^8$ m/sec

(SEE NEXT PAGE)

# RADIO FREQUENCY SPECTRUM

| FREQUENCY | CLASSIFICATION |
|---|---|
| 3-30 KHz | VERY LOW FREQUENCIES (VLF) |
| 30-300 KHz | LOW FREQUENCIES (LF) |
| 300-3000 KHz | MEDIUM FREQUENCIES (MF) |
| 3-30 MHz | HIGH FREQUENCIES (HF) |
| 30-300 MHz | VERY HIGH FREQUENCIES (VHF) |
| 300-3000 MHz | ULTRA HIGH FREQUENCIES (UHF) |
| 3-30 GHz | SUPER HIGH FREQUENCIES (SHF) |
| 30-300 GHz | EXTREMELY HIGH FREQUENCIES (EHF) |
| 300-3000 GHz | MICROWAVE FREQUENCIES |

# FREQUENCY VS. WAVELENGTH

$$\lambda = \frac{c}{f} \qquad f = \frac{c}{\lambda}$$

$\lambda$ – WAVELENGTH (METERS)
C – SPEED OF LIGHT ($3 \times 10^8$ METERS/SEC)
F – FREQUENCY (HERTZ)

EXAMPLE: THE WAVELENGTH OF A 108 MHz SIGNAL IS $3 \times 10^8 / 1.08 \times 10^6$ OR 2.78 METERS.

# IMPORTANT FREQUENCIES (MHz)

| | |
|---|---|
| .15 - .54: | NAVIGATION BEACONS |
| .5 : | INTERNATIONAL DISTRESS |
| .54 - 1.6: | AM BROADCAST BAND |
| 1.61: | AIRPORT INFORMATION |
| 1.8 - 2.0: | 160 METER AMATEUR BAND |
| 2.3 - 2.498: | 120 METER INT. BROADCAST |
| 2.5: | WWV TIME SIGNAL |
| 3.5 - 4.0: | 80 METER AMATEUR BAND |
| 5.0: | WWV TIME SIGNAL |
| 5.95 - 6.2: | 49 METER INT. BROADCAST |
| 6.2 - 6.525: | MARITIME COMMUNICATIONS |
| 7.0 - 7.3: | 40 METER AMATEUR |
| 7.0 - 7.3: | 40 METER INT. BROADCAST |
| 9.5 - 9.9: | 31 METER INT. BROADCAST |
| 10.0: | WWV TIME SIGNAL |
| 10.1 - 10.15: | 30 METER AMATEUR BAND |
| 10.15 - 11.175: | INT. BROADCAST |
| 11.7 - 11.975: | 25 METER INT. BROADCAST |
| 14.0 - 14.35: | 20 METER AMATEUR BAND |
| 15.0: | WWV TIME SIGNAL |
| 20.0: | WWV TIME SIGNAL |
| 21.0 - 21.45: | 15 METER AMATEUR BAND |
| 21.45 - 21.85 | 13 METER INT. BROADCAST |
| 24.89 - 24.99: | 12 METER AMATEUR BAND |
| 25.67 - 26.1: | 11 METER INT. BROADCAST |
| 26.9 - 27.4: | CITIZENS BAND |
| 28.0 - 29.7: | 10 METER AMATEUR BAND |
| 49.82 - 49.9: | LOW POWER COMMUNICATIONS |
| 50.0 - 54.0: | 6 METER AMATEUR BAND |
| 54.0 - 88.0: | TELEVISION (CH. 2-6) |
| 72.03 - 72.9: | RADIO CONTROL (AIRCRAFT ONLY) |
| 75.43 - 75.87: | RADIO CONTROL |
| 88.0 - 108.0: | FM BROADCAST BAND |
| 88.0 - 108.0: | WIRELESS MICROPHONES |
| 108.0 - 118.0: | AIR NAVIGATION BEACONS |
| 118.0 - 136.0: | AIRCRAFT |
| 153 - 155: | POLICE, FIRE, MUNICIPAL |
| 158 - 159: | POLICE, FIRE, MUNICIPAL |
| 162.4 - 162.55: | NOAA WEATHER |
| 174 - 216: | TELEVISION (CH. 7-13) |
| 470 - 890: | TELEVISION (CH. 14-83) |

# TIME CONVERSIONS

| UTC | PST | MST | CST | EST | AST |
|---|---|---|---|---|---|
| 0000 | 4 PM | 5 PM | 6 PM | 7 PM | 8 PM |
| 0100 | 5 PM | 6 PM | 7 PM | 8 PM | 9 PM |
| 0200 | 6 PM | 7 PM | 8 PM | 9 PM | 10 PM |
| 0300 | 7 PM | 8 PM | 9 PM | 10 PM | 11 PM |
| 0400 | 8 PM | 9 PM | 10 PM | 11 PM | MIDNT |
| 0500 | 9 PM | 10 PM | 11 PM | MIDNT | 1 AM |
| 0600 | 10 PM | 11 PM | MIDNT | 1 AM | 2 AM |
| 0700 | 11 PM | MIDNT | 1 AM | 2 AM | 3 AM |
| 0800 | MIDNT | 1 AM | 2 AM | 3 AM | 4 AM |
| 0900 | 1 AM | 2 AM | 3 AM | 4 AM | 5 AM |
| 1000 | 2 AM | 3 AM | 4 AM | 5 AM | 6 AM |
| 1100 | 3 AM | 4 AM | 5 AM | 6 AM | 7 AM |
| 1200 | 4 AM | 5 AM | 6 AM | 7 AM | 8 AM |
| 1300 | 5 AM | 6 AM | 7 AM | 8 AM | 9 AM |
| 1400 | 6 AM | 7 AM | 8 AM | 9 AM | 10 AM |
| 1500 | 7 AM | 8 AM | 9 AM | 10 AM | 11 AM |
| 1600 | 8 AM | 9 AM | 10 AM | 11 AM | 12 AM |
| 1700 | 9 AM | 10 AM | 11 AM | 12 AM | 1 PM |
| 1800 | 10 AM | 11 AM | 12 AM | 1 PM | 2 PM |
| 1900 | 11 AM | 12 AM | 1 PM | 2 PM | 3 PM |
| 2000 | 12 AM | 1 PM | 2 PM | 3 PM | 4 PM |
| 2100 | 1 PM | 2 PM | 3 PM | 4 PM | 5 PM |
| 2200 | 2 PM | 3 PM | 4 PM | 5 PM | 6 PM |
| 2300 | 3 PM | 4 PM | 5 PM | 6 PM | 7 PM |

UTC - COORDINATED UNIVERSAL TIME
(GREENWICH MERIDIAN TIME, LONDON)

PST - PACIFIC STANDARD TIME

MST - MOUNTAIN STANDARD TIME

CST - CENTRAL STANDARD TIME

EST - EASTERN STANDARD TIME

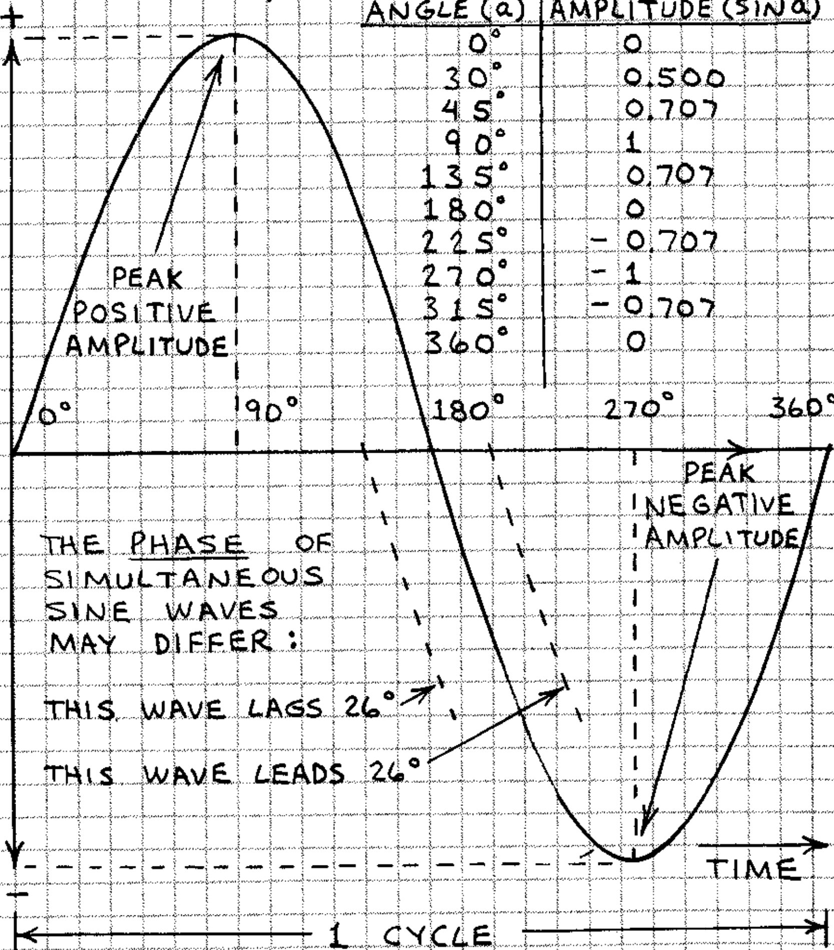
AST - ATLANTIC STANDARD TIME

DAYLIGHT SAVINGS TIME - ADD 1 HOUR

# THE SINE WAVE

THE SINE OR SINUSOIDAL WAVE IS THE MOST COMMON PERIODIC WAVE IN ANALOG ELECTRONIC CIRCUITS. IF PEAK AMPLITUDES ARE +1 AND −1, THEN:

| ANGLE (a) | AMPLITUDE (SIN a) |
|---|---|
| 0° | 0 |
| 30° | 0.500 |
| 45° | 0.707 |
| 90° | 1 |
| 135° | 0.707 |
| 180° | 0 |
| 225° | −0.707 |
| 270° | −1 |
| 315° | −0.707 |
| 360° | 0 |



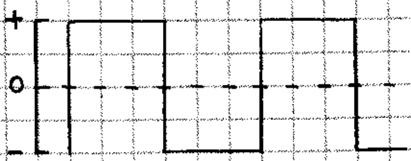

FREQUENCY OF A SINE WAVE IS THE NUMBER OF CYCLES PER SECOND. HERTZ (Hz) IS THE UNIT OF FREQUENCY. ONE HERTZ (1 Hz) IS ONE CYCLE PER SECOND (1 CPS).

PERIOD OF A SINE WAVE IS THE TIME FOR ONE COMPLETE CYCLE TO OCCUR.

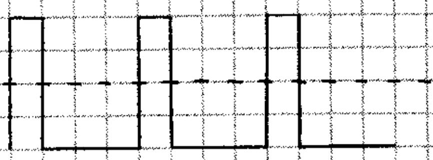
# PERIODIC WAVES

MANY DIFFERENT PERIODIC WAVEFORMS CAN BE PROCESSED OR GENERATED BY ANALOG ELECTRONIC CIRCUITS. THEY INCLUDE:

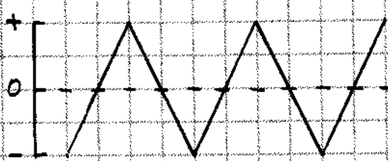
SQUARE WAVE



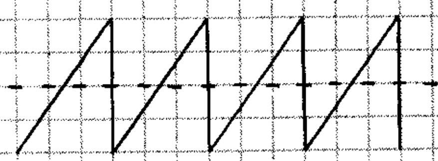

RECTANGULAR WAVE



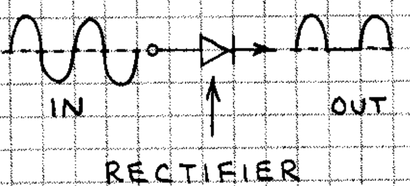
TRIANGLE WAVE

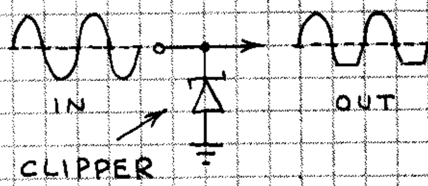



SAWTOOTH WAVE

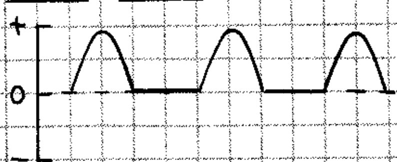


PERIODIC WAVES CAN BE RECTIFIED BY DIODES AND CLIPPED BY ZENER DIODES:

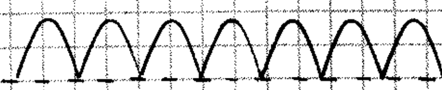


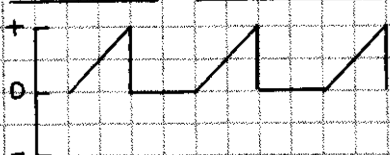

HALF-WAVE RECTIFIED SINE WAVE



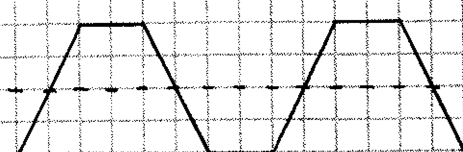

FULL-WAVE RECTIFIED SINE WAVE



CLIPPED SAWTOOTH



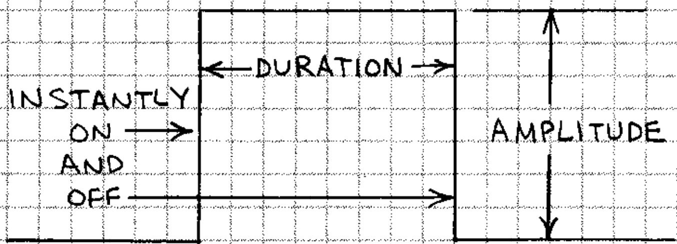

TRAPEZOIDAL WAVE



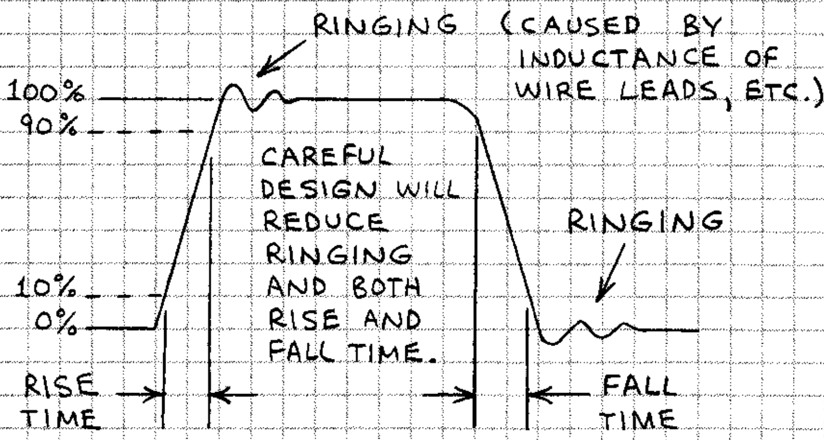
# PULSES

SINGLE PULSES OR TRAINS OF PERIODIC PULSES ARE PROCESSED AND GENERATED BY DIGITAL ELECTRONIC CIRCUITS. THEY ARE ALSO USED TO TRIGGER (ACTIVATE) MANY KINDS OF CIRCUITS.

# THE IDEAL PULSE




# A REAL PULSE




# PULSE TRAIN

THE NUMBER OF PULSES PER SECOND IS THE PULSE REPETITION RATE.

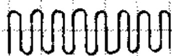
# SIGNALS

ELECTRONIC SIGNALS RANGE FROM AUDIBLE TONES TO COMPLEX INFORMATION CARRIED BY A FLUCTUATING (ANALOG) OR PULSATING (DIGITAL) WAVE, CURRENT OR VOLTAGE. MANY MODULATION METHODS ARE USED TO IMPRESS A SIGNAL ON A CARRIER.

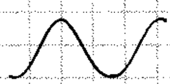
## MODULATION METHODS

### ANALOG

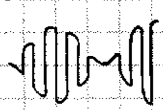
UNMODULATED CARRIER WAVE



ANALOG SIGNAL



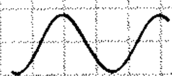
AMPLITUDE MODULATION



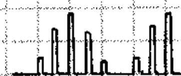
FREQUENCY MODULATION

### PULSE

ANALOG SIGNAL

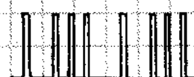


PULSE AMPLITUDE



PULSE DURATION

PULSE FREQUENCY



### DIGITAL

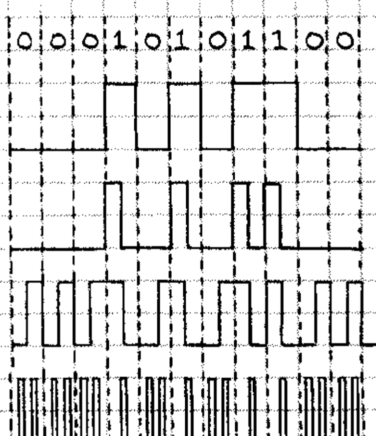
BINARY BIT PATTERN

NON-RETURN TO ZERO (NRZ)

RETURN TO ZERO (RZ)

MANCHESTER

FREQUENCY SHIFT KEYING (FSK)



# 4. CODES AND SYMBOLS

## ALPHABET, ASCII & MORSE CODE

| ALPHABET | ASCII | MORSE CODE |
|---|---|---|
| A | 100 0001 | · − |
| B | 100 0010 | − · · · |
| C | 100 0011 | − · − · |
| D | 100 0100 | − · · |
| E | 100 0101 | · |
| F | 100 0110 | · · − · |
| G | 100 0111 | − − · |
| H | 100 1000 | · · · · |
| I | 100 1001 | · · |
| J | 100 1010 | · − − − |
| K | 100 1011 | − · − |
| L | 100 1100 | · − · · |
| M | 100 1101 | − − |
| N | 100 1110 | − · |
| O | 100 1111 | − − − |
| P | 101 0000 | · − − · |
| Q | 101 0001 | − − · − |
| R | 101 0010 | · − · |
| S | 101 0011 | · · · |
| T | 101 0100 | − |
| U | 101 0101 | · · − |
| V | 101 0110 | · · · − |
| W | 101 0111 | · − − |
| X | 101 1000 | − · · − |
| Y | 101 1001 | − · − − |
| Z | 101 1010 | − − · · |
| 0 | 011 0000 | − − − − − |
| 1 | 011 0001 | · − − − − |
| 2 | 011 0010 | · · − − − |
| 3 | 011 0011 | · · · − − |
| 4 | 011 0100 | · · · · − |
| 5 | 011 0101 | · · · · · |
| 6 | 011 0110 | − · · · · |
| 7 | 011 0111 | − − · · · |
| 8 | 011 1000 | − − − · · |
| 9 | 011 1001 | − − − − · |

# ASCII

| $b_7$ | $b_6$ | $b_5$ | $b_4$ | $b_3$ | $b_2$ | $b_1$ | COLUMN → / ROW ↓ | 0 & 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $b_7$ | | 0 | 0 | 1 | 1 | 1 | 1 |
| | | | | | | | $b_6$ | | 1 | 1 | 0 | 0 | 1 | 1 |
| | | | | | | | $b_5$ | | 0 | 1 | 0 | 1 | 0 | 1 |
| | | | 0 | 0 | 0 | 0 | 0 | | SP | 0 | @ | P | ` | p |
| | | | 0 | 0 | 0 | 1 | 1 | | ! | 1 | A | Q | a | q |
| | | | 0 | 0 | 1 | 0 | 2 | | " | 2 | B | R | b | r |
| | | | 0 | 0 | 1 | 1 | 3 | | # | 3 | C | S | c | s |
| | | | 0 | 1 | 0 | 0 | 4 | | $ | 4 | D | T | d | t |
| | | | 0 | 1 | 0 | 1 | 5 | | % | 5 | E | U | e | u |
| | | | 0 | 1 | 1 | 0 | 6 | | & | 6 | F | V | f | v |
| | | | 0 | 1 | 1 | 1 | 7 | | ' | 7 | G | W | g | w |
| | | | 1 | 0 | 0 | 0 | 8 | | ( | 8 | H | X | h | x |
| | | | 1 | 0 | 0 | 1 | 9 | | ) | 9 | I | Y | i | y |
| | | | 1 | 0 | 1 | 0 | 10 | | * | : | J | Z | j | z |
| | | | 1 | 0 | 1 | 1 | 11 | | + | ; | K | [ | k | { |
| | | | 1 | 1 | 0 | 0 | 12 | | , | < | L | \ | l | ¦ |
| | | | 1 | 1 | 0 | 1 | 13 | | - | = | M | ] | m | } |
| | | | 1 | 1 | 1 | 0 | 14 | | . | > | N | ^ | n | ~ |
| | | | 1 | 1 | 1 | 1 | 15 | | / | ? | O | _ | o | DEL |

SP - SPACE

CONTROL CHARACTERS (NON PRINTING)

ASCII - AMERICAN STANDARD CODE FOR INFORMATION INTERCHANGE. ASCII IS THE PRINCIPLE COMPUTER KEYBOARD CODE. ASSEMBLY LANGUAGE PROGRAMMERS CONVERT BINARY ASCII (ABOVE) TO HEXADECIMAL. PRINCIPLE HEX EQUIVALENTS:

| | | | | | |
|---|---|---|---|---|---|
| A- 41 | G- 47 | M- 4D | S- 53 | Y- 59 | 4- 34 |
| B- 42 | H- 48 | N- 4E | T- 54 | Z- 5A | 5- 35 |
| C- 43 | I- 49 | O- 4F | U- 55 | Ø- 30 | 6- 36 |
| D- 44 | J- 4A | P- 50 | V- 56 | 1- 31 | 7- 37 |
| E- 45 | K- 4B | Q- 51 | W- 57 | 2- 32 | 8- 38 |
| F- 46 | L- 4C | R- 52 | X- 58 | 3- 33 | 9- 39 |

# GREEK ALPHABET

| NAME | U | L | NAME | U | L |
|---|---|---|---|---|---|
| ALPHA | A | α | NU | N | ν |
| BETA | B | β | XI | Ξ | ξ |
| GAMMA | Γ | γ | OMICRON | O | ο |
| DELTA | Δ | δ | PI | Π | π |
| EPSILON | E | ϵ | RHO | P | ρ |
| ZETA | Z | ζ | SIGMA | Σ | σ |
| ETA | H | η | TAU | T | τ |
| THETA | Θ | θ | UPSILON | Y | υ |
| IOTA | I | ι | PHI | Φ | φ |
| KAPPA | K | κ | CHI | X | χ |
| LAMBDA | Λ | λ | PSI | Ψ | ψ |
| MU | M | μ | OMEGA | Ω | ω |

U - UPPER CASE L - LOWER CASE

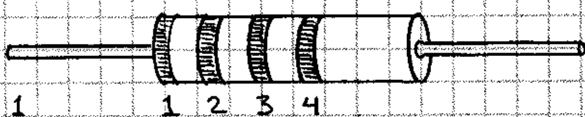
# COMMON GREEK SYMBOLS

| LETTER | SYMBOLIZES OR DESIGNATES |
|---|---|
| α | ANGLES, ACCELERATION, AREA |
| β | ANGLES, |
| γ | CONDUCTIVITY, SPECIFIC GRAVITY |
| Δ | INCREMENT, DECREMENT |
| ϵ | DIELECTRIC CONSTANT |
| E | ENERGY |
| Z | IMPEDANCE |
| η | FM MODULATION INDEX |
| θ | ANGLES, TIME CONSTANT, TEMPERATURE |
| λ | WAVELENGTH, CONDUCTIVITY |
| μ | MICRO (PREFIX), AMPLIFICATION FACTOR |
| ν | FREQUENCY |
| π | CIRCUMFERENCE ÷ DIAMETER (3.14159...) |
| ρ | RESISTIVITY, REFLECTANCE |
| Σ | SUMMATION SIGN |
| τ | TIME CONSTANT, TRANSMITTANCE |
| Φ | ANGLE, RADIANT POWER |
| ω | ANGLE, ANGULAR FREQUENCY |
| Ω | SOLID ANGLE, RESISTANCE (OHMS) |

# RESISTOR COLOR CODE

| COLOR | SIGNIFICANT DIGITS (1 & 2) | MULTIPLIER (3) | TOL. (4) |
|---|---|---|---|
| BLACK | 0 | 1 | |
| BROWN | 1 | 10 | ± 1% |
| RED | 2 | 100 | |
| ORANGE | 3 | 1,000 | |
| YELLOW | 4 | 10,000 | NO COLOR BAND: ± 20% |
| GREEN | 5 | 100,000 | |
| BLUE | 6 | 1,000,000 | |
| VIOLET | 7 | 10,000,000 | |
| GRAY | 8 | 100,000,000 | |
| WHITE | 9 | — | |
| GOLD | — | — | ± 5% |
| SILVER | — | — | ± 10% |

EXAMPLE:




1 = BROWN = 1
2 = BLACK = 0
3 = YELLOW = × 10,000
4 = SILVER = ± 10% TOLERANCE

$\boxed{100{,}000\ \Omega \pm 10\%}$

# TRANSFORMER COLOR CODE

AUDIO INTERSTAGE AND OUTPUT:


POWER: UNTAPPED PRIMARY - BLACK; FILAMENT SECONDARY - GREEN (ADDITIONAL FILAMENT - YELLOW, BROWN AND SLATE); HIGH-VOLTAGE SECONDARY - RED. COLORS MAY VARY.

NOTE: THESE ARE EIA RECOMMENDED COLORS. SEE TRANSFORMER SPECIFICATIONS TO VERIFY CODE.

# 5. ELECTRONIC ABBREVIATIONS

AC - ALTERNATING CURRENT
AF - AUDIO FREQUENCY
AFC - AUTOMATIC FREQUENCY CONTROL
AGC - AUTOMATIC GAIN CONTROL
AM - AMPLITUDE MODULATION
AMP - AMPLIFIER
ANL - AUTOMATIC NOISE LIMITER
ANT - ANTENNA
AVC - AUTOMATIC VOLUME CONTROL
AWG - AMERICAN WIRE GAUGE
B - BASE OF TRANSISTOR
BC - BROADCAST
BFO - BEAT FREQUENCY OSCILLATOR
BP - BANDPASS
C - COLLECTOR OF TRANSISTOR
CAL - CALIBRATE
CAP - CAPACITOR
CB - CITIZENS BAND
CKT - CIRCUIT
CLK - CLOCK
CRT - CATHODE RAY TUBE
C/S - CYCLES PER SECOND (HERTZ; HZ)
CT - CENTER TAP
CW - CONTINUOUS WAVE
CY - CYCLE
°C - DEGREES CELSIUS
D - DRAIN OF FET
dB - DECIBEL
DBLR - DOUBLER
DC - DIRECT CURRENT
DEG - DEGREES
DEMOD - DEMODULATION
DF - DIRECTION FINDER
DPDT - DOUBLE POLE DOUBLE THROW
DPST - DOUBLE POLE SINGLE THROW
DSB - DOUBLE SIDEBAND
E - EMITTER OF TRANSISTOR; ENERGY
EM - ELECTROMAGNETIC
EMF - ELECTROMOTIVE FORCE
EMP - ELECTROMAGNETIC PULSE
ERP - EFFECTIVE RADIATED POWER

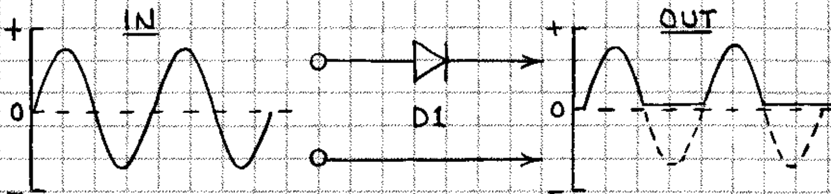
F - FREQUENCY
°F - DEGREES FAHRENHEIT
FDBK - FEEDBACK
FET - FIELD EFFECT TRANSISTOR
FF - FLIP FLOP
FIL - FILAMENT
FM - FREQUENCY MODULATION
FREQ - FREQUENCY
FSC - FULL SCALE
FWHM - FULL WIDTH HALF MAXIMUM
G - GATE OF FET
GA - GAUGE
GND - GROUND
HF - HIGH FREQUENCY
HI FI - HIGH FIDELITY
HV - HIGH VOLTAGE
HZ - HERTZ
I - CURRENT
IC - INTEGRATED CIRCUIT
IMPD - IMPEDANCE
IR - INFRARED
JFET - JUNCTION FIELD EFFECT TRANSISTOR
KWH - KILOWATT HOUR
LED - LIGHT EMITTING DIODE
LP - LOW PASS
LSI - LARGE SCALE INTEGRATION
MA - MILLIAMPERES
MIC - MICROPHONE
MOS - METAL-OXIDE-SEMICONDUCTOR
MOSFET - MOS FIELD EFFECT TRANSISTOR
NC - NO CONTACT
NEG - NEGATIVE
NF - NOISE FIGURE
NO - NORMALLY OPEN
NOM - NOMINAL
NPN - NEGATIVE-POSITIVE-NEGATIVE
OP AMP - OPERATIONAL AMPLIFIER
OSC - OSCILLATOR
OUT - OUTPUT
PAM - PULSE AMPLITUDE MODULATION
PC - PRINTED CIRCUIT
PCM - PULSE CODE MODULATION
PDM - PULSE DURATION MODULATION

PF - PICOFARAD
PFM - PULSE FREQUENCY MODULATION
PK - PEAK
PLL - PHASE LOCKED LOOP
PNP - POSITIVE-NEGATIVE-POSITIVE
POS - POSITIVE
POT - POTENTIOMETER
PREAMP - PREAMPLIFIER
PRI - PRIMARY
PRV - PEAK REVERSE VOLTAGE
PVC - POLYVINYL CHLORIDE
PWR - POWER
PWR SUP - POWER SUPPLY
PZ - PIEZOELECTRIC
Q - QUALITY FACTOR
QTZ - QUARTZ
R - RESISTANCE
RAD - RADIAN
RC - RESISTANCE-CAPACITANCE
RCDR - RECORDER
RCV - RECEIVE
RCVR - RECEIVER
RECHRG - RECHARGE
RECT - RECTIFIER
REF - REFERENCE
RF - RADIO FREQUENCY
RFC - RADIO FREQUENCY CHOKE
RFI - RADIO FREQUENCY INTERFERENCE
RL - RESISTANCE-INDUCTANCE
RLC - RESISTANCE-INDUCTANCE-CAPACITANCE
RLY - RELAY
RMS - ROOT MEAN SQUARE
RMT - REMOTE
ROT - ROTATE
RPM - REVOLUTIONS PER MINUTE
RPS - REVOLUTIONS PER SECOND
RTTY - RADIO TELETYPEWRITER
RY - RELAY
S - SOURCE OF FET
SB - SIDEBAND
SCR - SILICON CONTROLLED RECTIFIER
SEC - SECONDARY
SERVO - SERVOMECHANISM

SHLD - SHIELD
SIG - SIGNAL
SNR - SIGNAL-TO-NOISE RATIO (ALSO S/N)
SPDT - SINGLE POLE DOUBLE THROW
SPKR - SPEAKER
SPST - SINGLE POLE SINGLE THROW
SQ - SQUARE
SSB - SINGLE SIDEBAND
SUBMIN - SUBMINIATURE
SW - SHORTWAVE
SWL - SHORTWAVE LISTENING
SWR - STANDING WAVE RATIO
SYM - SYMBOL
T - TIME
TACH - TACHOMETER
TEL - TELEPHONE
TELECOM - TELECOMMUNICATIONS
TEMP - TEMPERATURE
TERM - TERMINAL
TRF - TUNED RADIO FREQUENCY
TTL - TRANSISTOR-TRANSISTOR LOGIC
TVI - TELEVISION INTERFERENCE
UHF - ULTRA HIGH FREQUENCY
UJT - UNIJUNCTION TRANSISTOR
UTC - COORDINATED UNIVERSAL TIME
V - VOLTAGE
VAC - VACUUM; AC VOLTAGE
VC - VOICE COIL
VCO - VOLTAGE CONTROLLED OSCILLATOR
VF - VARIABLE FREQUENCY
VHF - VERY HIGH FREQUENCY
VID - VIDEO
VLF - VERY LOW FREQUENCY
VOL - VOLUME
VOM - VOLT-OHM METER
VT - VACUUM TUBE
VOX - VOICE-OPERATED TRANSMITTER
W - WATT
WHM - WATT-HOUR METER
WV - WORKING VOLTAGE
X - REACTANCE
XMTR - TRANSMITTER
Z - IMPEDANCE

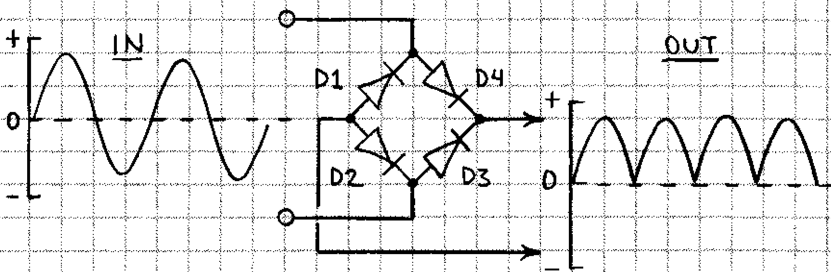
# 6. BASIC ELECTRONIC CIRCUITS

## HALF-WAVE RECTIFIER



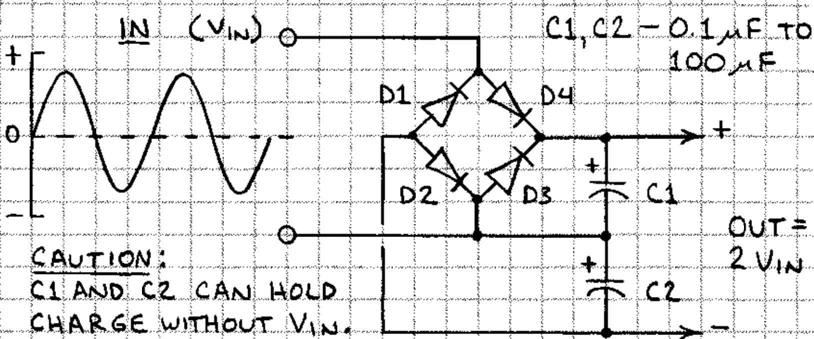

D1 MUST BE RATED FOR THE INPUT VOLTAGE.

## FULL-WAVE RECTIFIER




D1 - D4 MUST BE RATED FOR THE INPUT VOLTAGE.
USE INDIVIDUAL DIODES OR RECTIFIER MODULE.

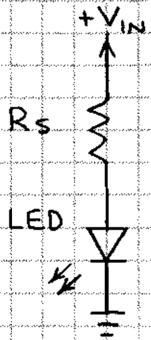
## VOLTAGE DOUBLER




CAUTION:
C1 AND C2 CAN HOLD CHARGE WITHOUT $V_{IN}$.

D1 - D4, C1 AND C2 MUST BE RATED FOR AT LEAST TWICE THE INPUT VOLTAGE.

# BASIC LED DRIVER




$$R_S = \frac{V_{IN} - V_{LED}}{I_{LED}}$$

$V_{IN}$ = INPUT VOLTAGE

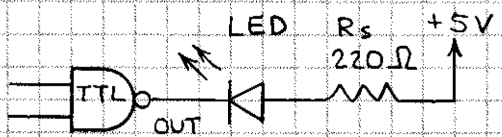
$I_{LED}$ = LED FORWARD CURRENT (DESIRED OR SPECIFIED)

$V_{LED}$ = LED VOLTAGE DROP

<u>EXAMPLE</u>: ASSUME $V_{IN} = 9$ VOLTS AND $V_{LED} = 1.7$ VOLTS. CALCULATE VALUE OF $R_S$ FOR $I_{LED} = 20$ mA.

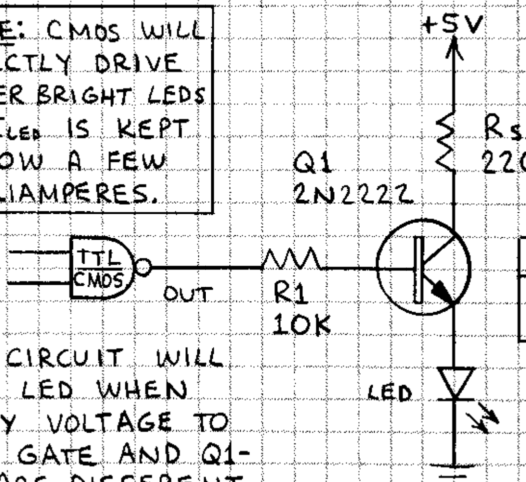
$$R_S = \frac{9 - 1.7}{.02} = 365 \text{ OHMS}$$ (OK TO USE CLOSEST STANDARD VALUE)

# LOGIC GATE LED DRIVERS




| OUT | LED |
|---|---|
| LO | ON |
| HI | OFF |

<u>NOTE</u>: CMOS WILL DIRECTLY DRIVE SUPER BRIGHT LEDS IF $I_{LED}$ IS KEPT BELOW A FEW MILLIAMPERES.

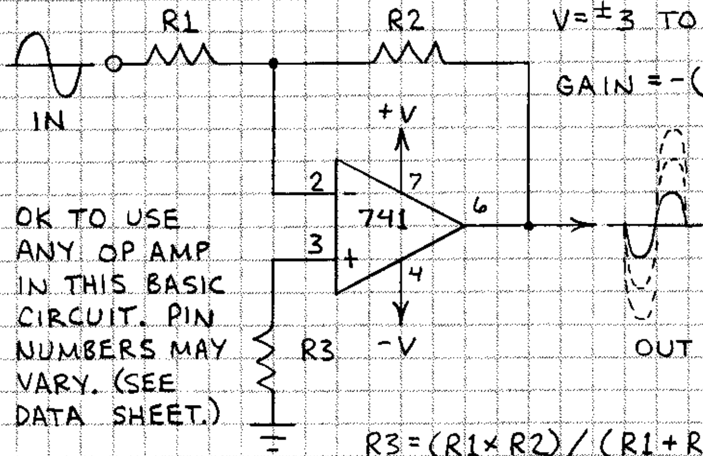



| OUT | LED |
|---|---|
| LO | OFF |
| HI | ON |

$I_{LED} \approx 15$ mA

THIS CIRCUIT WILL DRIVE LED WHEN SUPPLY VOLTAGE TO LOGIC GATE AND Q1-LED ARE DIFFERENT.

# INVERTING AMPLIFIER




V = ±3 TO ±15 V

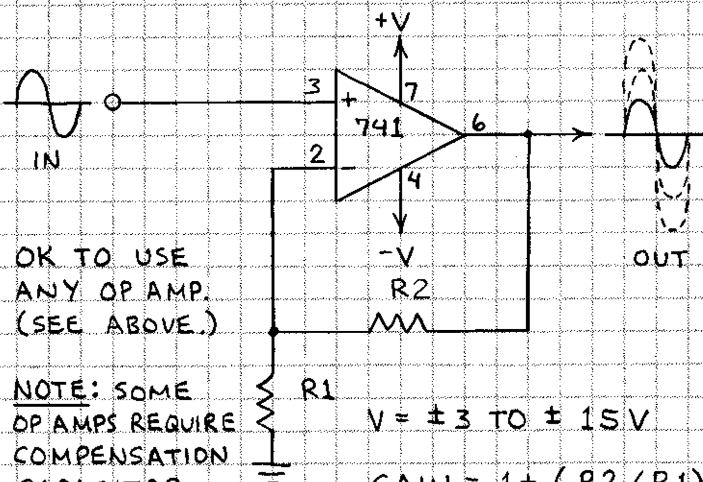
GAIN = -(R2/R1)

OK TO USE ANY OP AMP IN THIS BASIC CIRCUIT. PIN NUMBERS MAY VARY. (SEE DATA SHEET.)

R3 = (R1 × R2) / (R1 + R2)

<u>EXAMPLE</u>: IF R1 = 4,700 OHMS AND R2 = 47,000 OHMS, THEN GAIN IS -(47,000/4,700) OR -10. R3 = 4,273 OHMS (USE CLOSEST STANDARD VALUE).

# NON-INVERTING AMPLIFIER




OK TO USE ANY OP AMP. (SEE ABOVE.)

<u>NOTE</u>: SOME OP AMPS REQUIRE COMPENSATION CAPACITOR.

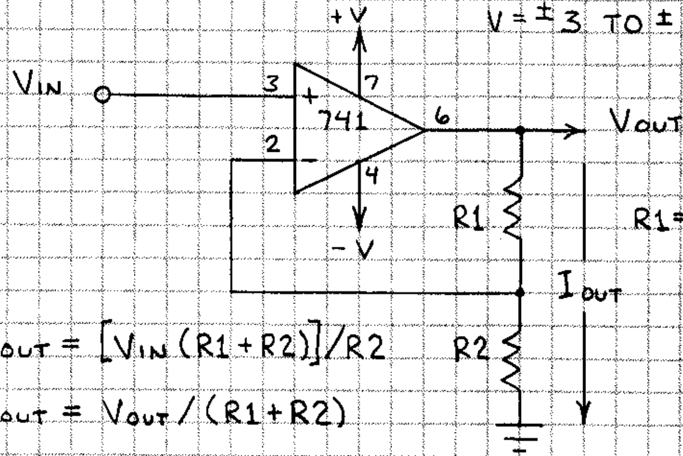
V = ±3 TO ±15V

GAIN = 1 + (R2/R1)

<u>EXAMPLE</u>: IF R1 = 4,700 OHMS AND R2 = 47,000 OHMS, THEN GAIN IS 1 + (47,000 / 4,700) OR 11.

# VOLTAGE-TO-CURRENT CONVERTER

$V = \pm 3$ TO $\pm 15$V



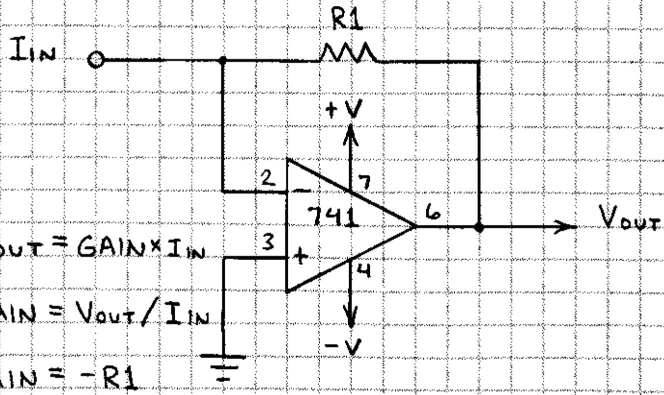

$V_{OUT} = [V_{IN}(R1+R2)]/R2$

$I_{OUT} = V_{OUT}/(R1+R2)$

$I_{OUT} = V_{IN}/R2$

EXAMPLE: ASSUME R1 IS A RESISTOR AND LED WITH COMBINED RESISTANCE OF 1,000 OHMS AND R2 IS 470 OHMS. WHEN $V_{IN}$ = 5 VOLTS, CURRENT ($I_{OUT}$) THROUGH LED IS 10.6 MA.

# CURRENT-TO-VOLTAGE CONVERTER



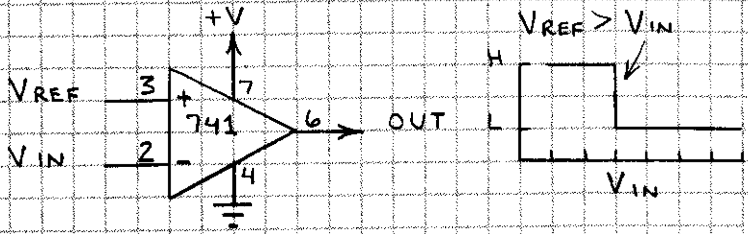

$V_{OUT} = GAIN \times I_{IN}$

$GAIN = V_{OUT}/I_{IN}$

$GAIN = -R1$

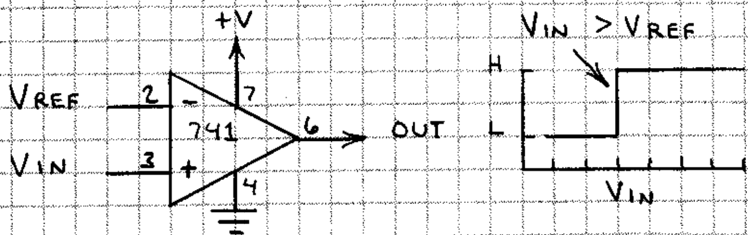
EXAMPLE: ASSUME A SOLAR CELL CONNECTED TO $I_{IN}$ DELIVERS A CURRENT OF 1 MA. IF R1 IS 1,000 OHMS, THEN $V_{OUT} = -(1{,}000 \times 0.001) = -1$ VOLT.

# INVERTING COMPARATOR



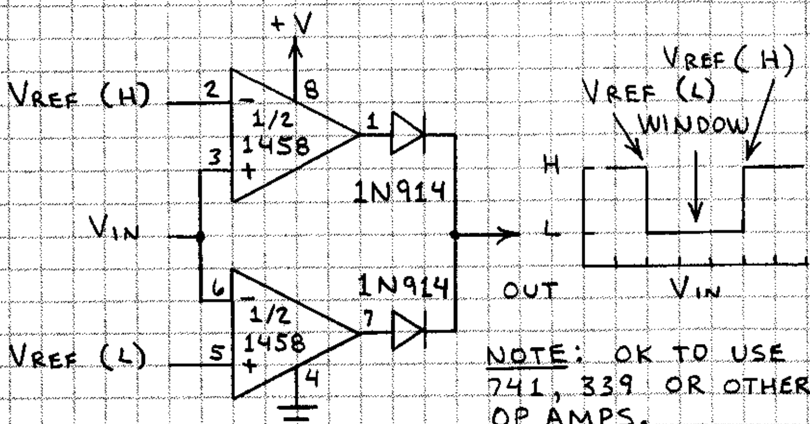

WHEN VREF EXCEEDS VIN, OUTPUT SWINGS FROM HIGH TO LOW.

# NON-INVERTING COMPARATOR



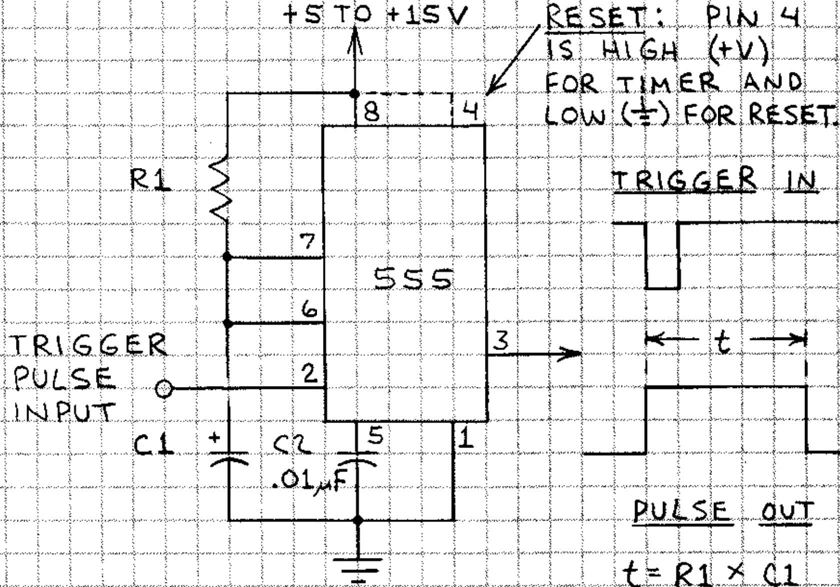

WHEN VIN EXCEEDS VREF, OUTPUT SWINGS FROM LOW TO HIGH.

# WINDOW COMPARATOR



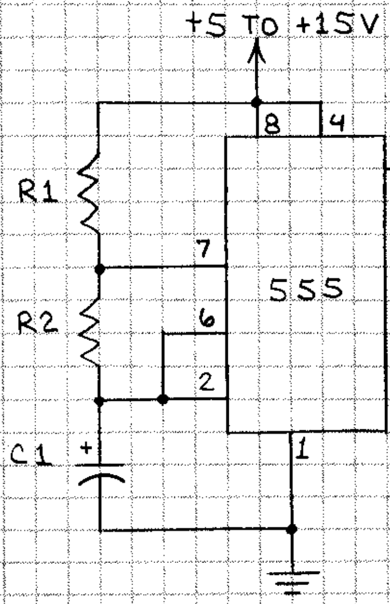

NOTE: OK TO USE 741, 339 OR OTHER OP AMPS.

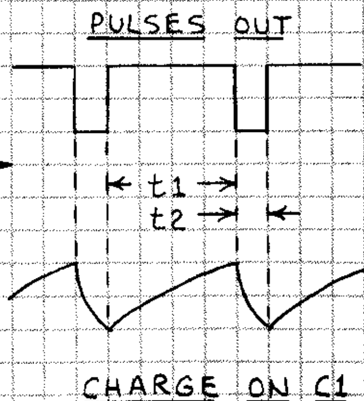
# TIMER




$t = R1 \times C1$

# PULSE GENERATOR



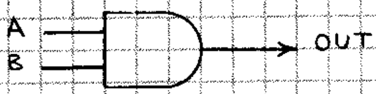

$t1 = .693\ (R1 + R2) \times C1$

$t2 = .693\ R2 \times C1$

$\text{FREQUENCY} = \dfrac{1.44}{(R1 + 2R2) \times C1}$

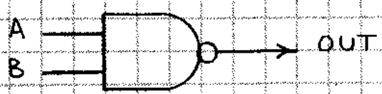
# 7. BASIC LOGIC CIRCUITS

## AND GATE



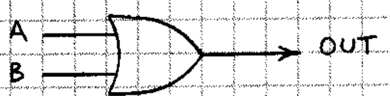

| A | B | OUT |
|---|---|---|
| L | L | L |
| L | H | L |
| H | L | L |
| H | H | H |

## NAND GATE



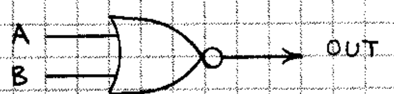

| A | B | OUT |
|---|---|---|
| L | L | H |
| L | H | H |
| H | L | H |
| H | H | L |

## OR




| A | B | OUT |
|---|---|---|
| L | L | L |
| L | H | H |
| H | L | H |
| H | H | H |

## NOR




| A | B | OUT |
|---|---|---|
| L | L | H |
| L | H | L |
| H | L | L |
| H | H | L |

## EXCLUSIVE OR

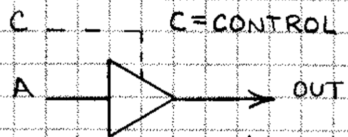

| A | B | OUT |
|---|---|---|
| L | L | L |
| L | H | H |
| H | L | H |
| H | H | L |

# EXCLUSIVE NOR


| A | B | OUT |
|---|---|---|
| L | L | H |
| L | H | L |
| H | L | L |
| H | H | H |

# BUFFER (3-STATE BUFFER)

C = CONTROL

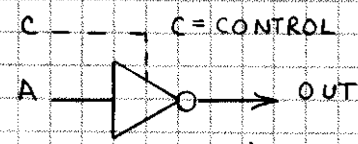



X = DON'T CARE

| (C) | A | OUT |
|---|---|---|
| (L) | L | L |
| (L) | H | H |
| (H) | (X) | (HI-Z) |

# INVERTER (3-STATE INVERTER)

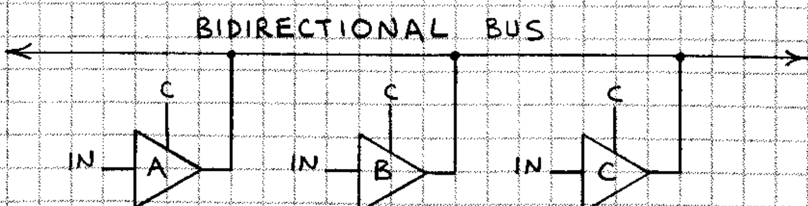
C = CONTROL




X = DON'T CARE

| (C) | A | |
|---|---|---|
| (L) | L | H |
| (L) | H | L |
| (H) | (X) | (HI-Z) |

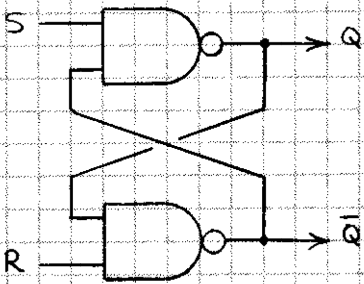
# 3-STATE BUS




COMPUTERS USUALLY HAVE A 3-STATE BUS.

| CONTROL | | | GATE OUTPUT TO BUS |
|---|---|---|---|
| A | B | C | |
| L | H | H | A |
| H | L | H | B |
| H | H | L | C |
| H | H | H | NONE |

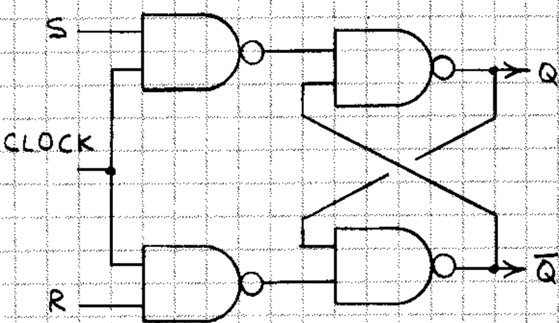
# RS FLIP-FLOP (LATCH)




| S | R | Q | $\bar{Q}$ |
|---|---|---|---|
| L | L | (DISALLOWED) | |
| L | H | H | L |
| H | L | L | H |
| H | H | NO CHANGE | |

$\bar{Q}$ = NOT Q

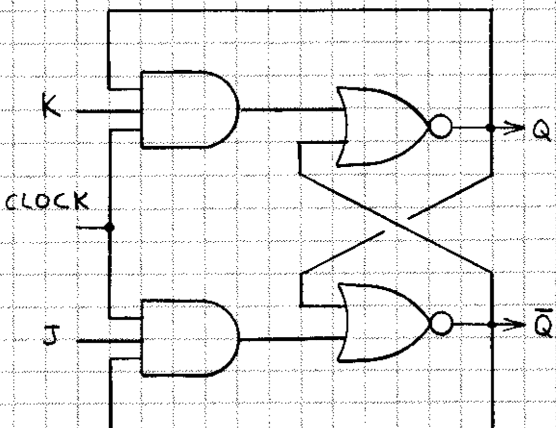
# CLOCKED RS FLIP-FLOP




AFTER CLOCK PULSE ARRIVES:

| S | R | Q | $\bar{Q}$ |
|---|---|---|---|
| L | L | NO CHANGE | |
| L | H | L | H |
| H | L | H | L |
| H | H | (DISALLOWED) | |

# JK FLIP-FLOP




AFTER CLOCK PULSE ARRIVES:

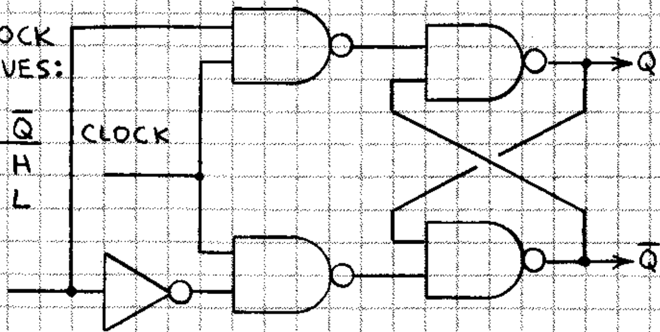
| J | K | Q | $\bar{Q}$ |
|---|---|---|---|
| L | L | NO CHANGE | |
| L | H | L | H |
| H | L | H | L |
| H | H | TOGGLE* | |

*SEE FACING PAGE.

# D (DATA OR DELAY) FLIP-FLOP

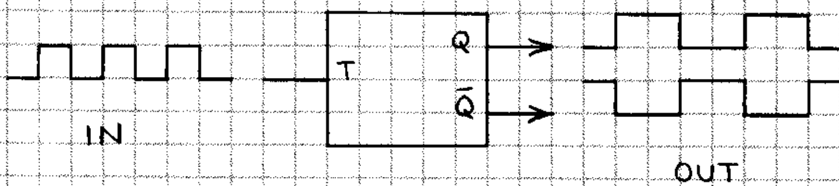
AFTER CLOCK PULSE ARRIVES:

| D | Q | $\overline{Q}$ |
|---|---|---|
| L | L | H |
| H | H | L |

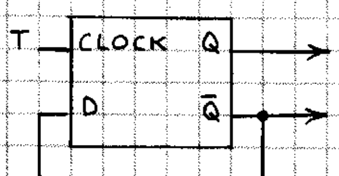



# T (TOGGLE) FLIP-FLOPS

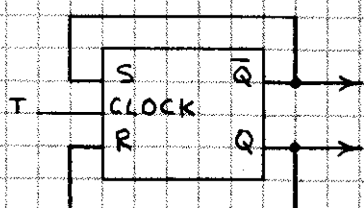
THE Q (OR $\overline{Q}$) OUTPUT IS L (OR H) FOR EVERY OTHER INPUT PULSE. THEREFORE THE OUTPUT IS THE INPUT ÷ 2:




CHAINS OF T FLIP-FLOPS ARE USED TO MAKE BINARY COUNTERS. THE JK FLIP-FLOP (FACING PAGE) FUNCTIONS AS A T FLIP-FLOP WHEN BOTH THE J AND J INPUTS ARE KEPT HIGH AND INPUT PULSES ARE APPLIED TO THE CLOCK INPUT. OTHER T FLIP-FLOPS:




D FLIP-FLOP

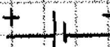



CLOCKED RS FLIP-FLOP

# 8. POWER SUPPLIES

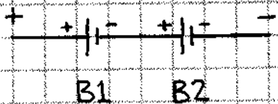
# BATTERIES

SYMBOLS

SINGLE CELL:  MULTIPLE CELL: 

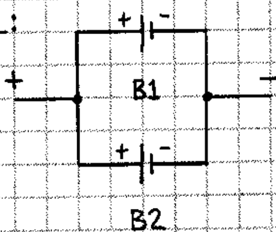
CONNECTIONS

SERIES:



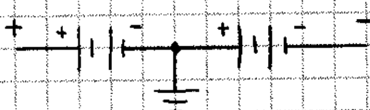

TOTAL VOLTAGE IS SUM OF EACH CELL VOLTAGE.

PARALLEL:




TOTAL CURRENT CAPACITY IS SUM OF EACH CELL CAPACITY. CELLS SHOULD HAVE EQUAL CAPACITY.

BIPOLAR:




USE TO POWER OPERATIONAL AMPLIFIERS.

# STORAGE BATTERIES

STORAGE BATTERIES CAN BE USED AND RECHARGED MANY TIMES. PRINCIPLE TYPES:

LEAD-ACID — 2.0 VOLTS PER CELL. HIGH CURRENT CAPACITY. GOOD AT LOW TEMPERATURE.

NICKEL-CADMIUM (NICAD) — 1.2 VOLTS PER CELL. CAN BE STORED FOR EXTENDED TIME WHEN DISCHARGED. MANY DIFFERENT KINDS AVAILABLE. VERY ECONOMICAL POWER SOURCE.

# PRIMARY BATTERIES

PRIMARY BATTERIES ARE NOT RECHARGEABLE. CHIEF AMONG THE MANY TYPES AVAILABLE:

CARBON-ZINC — 1.5 VOLTS PER CELL. READILY AVAILABLE AND LOW COST.

ZINC-CHLORIDE — 1.5 VOLTS PER CELL. TWICE THE ENERGY DENSITY OF CARBON-ZINC.

ALKALINE — 1.5 VOLTS PER CELL. USE FOR HIGH CURRENT LOADS (MOTORS, LAMPS, ETC.).

MERCURY — 1.35 AND 1.4 VOLTS PER CELL. UNIFORM VOLTAGE DURING DISCHARGE.

SILVER OXIDE — 1.5 VOLTS PER CELL. NEARLY UNIFORM VOLTAGE DURING DISCHARGE.

LITHIUM MANGANESE — 3.0 VOLTS PER CELL. EXCEPTIONALLY LONG STORAGE LIFE. VERY HIGH ENERGY DENSITY.

# BATTERY PRECAUTIONS

1. DO NOT CHARGE PRIMARY CELLS.

2. BATTERIES MAY EXPLODE WHEN HEATED.

3. DO NOT SOLDER LEADS TO A BATTERY. USE A BATTERY CLIP OR HOLDER.

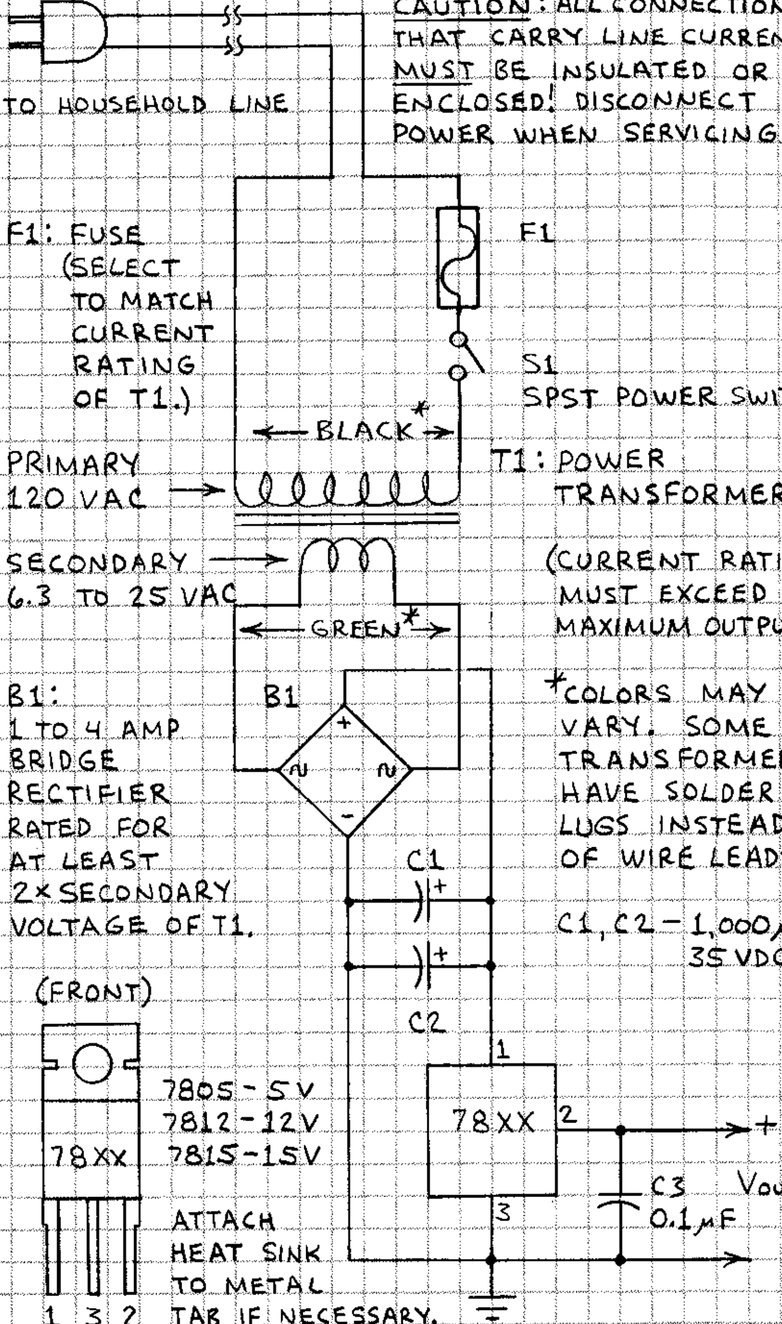
4. NEVER SHORT CIRCUIT A BATTERY'S TERMINALS.

5. MOST BATTERIES SHOULD BE REMOVED FROM EQUIPMENT IN STORAGE. EXCEPTIONS ARE STORAGE BATTERIES AND LITHIUM CELLS.

6. WHEN BATTERY LEADS EXCEED ≈ 6 INCHES, CONNECT 0.1 μF CAPACITOR ACROSS LEADS AT CIRCUIT BOARD.

# LINE-POWERED SUPPLY

CAUTION: ALL CONNECTIONS THAT CARRY LINE CURRENT MUST BE INSULATED OR ENCLOSED! DISCONNECT POWER WHEN SERVICING!




F1: FUSE (SELECT TO MATCH CURRENT RATING OF T1.)

S1 SPST POWER SWITCH

T1: POWER TRANSFORMER

(CURRENT RATING MUST EXCEED MAXIMUM OUTPUT.)

*COLORS MAY VARY. SOME TRANSFORMERS HAVE SOLDER LUGS INSTEAD OF WIRE LEADS.

B1: 1 TO 4 AMP BRIDGE RECTIFIER RATED FOR AT LEAST 2× SECONDARY VOLTAGE OF T1.

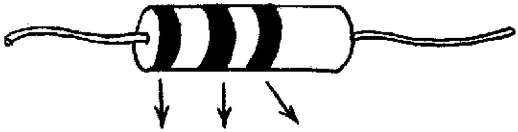
C1, C2 – 1,000µF 35 VDC

(FRONT)

7805 - 5V
7812 - 12V
7815 - 15V

ATTACH HEAT SINK TO METAL TAB IF NECESSARY.

# RESISTOR COLOR CODE



| | | | |
|---|---|---|---|
| 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 | — |

FOURTH BAND INDICATES TOLERANCE (ACCURACY):
GOLD = ±5% SILVER = ±10% NONE = ±20%

# OHM'S LAW: $V = IR$ $R = V/I$ $I = V/R$ $P = VI = I^2R$

# ABBREVIATIONS

A = AMPERE
F = FARAD
I = CURRENT
P = POWER
R = RESISTANCE
V (OR E) = VOLT
W = WATT
Ω = OHM

M (MEG-) = × 1,000,000
K (KILO-) = × 1,000
m (MILLI-) = .001
μ (MICRO-) = .000 001
n (NANO-) = .000 000 001
p (PICO-) = .000 000 000 001

Radio Shack

A Division of Tandy Corporation
Fort Worth, TX 76102

PRINTED IN U.S.A.

62-5016

0 40293 10895 3