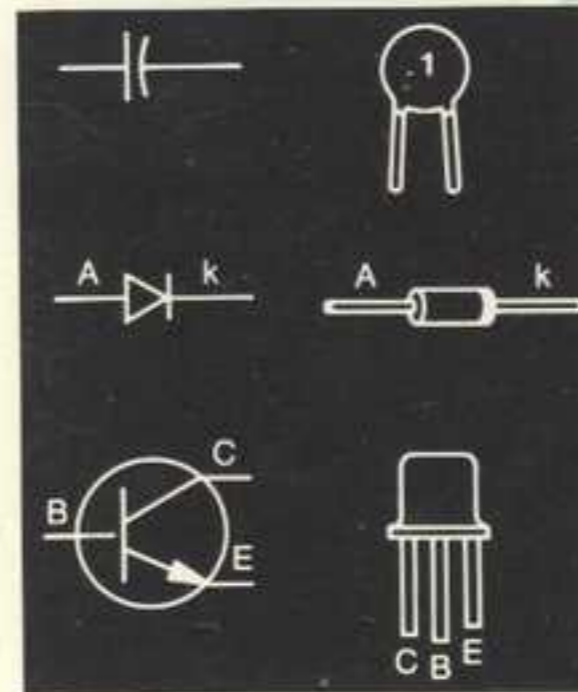
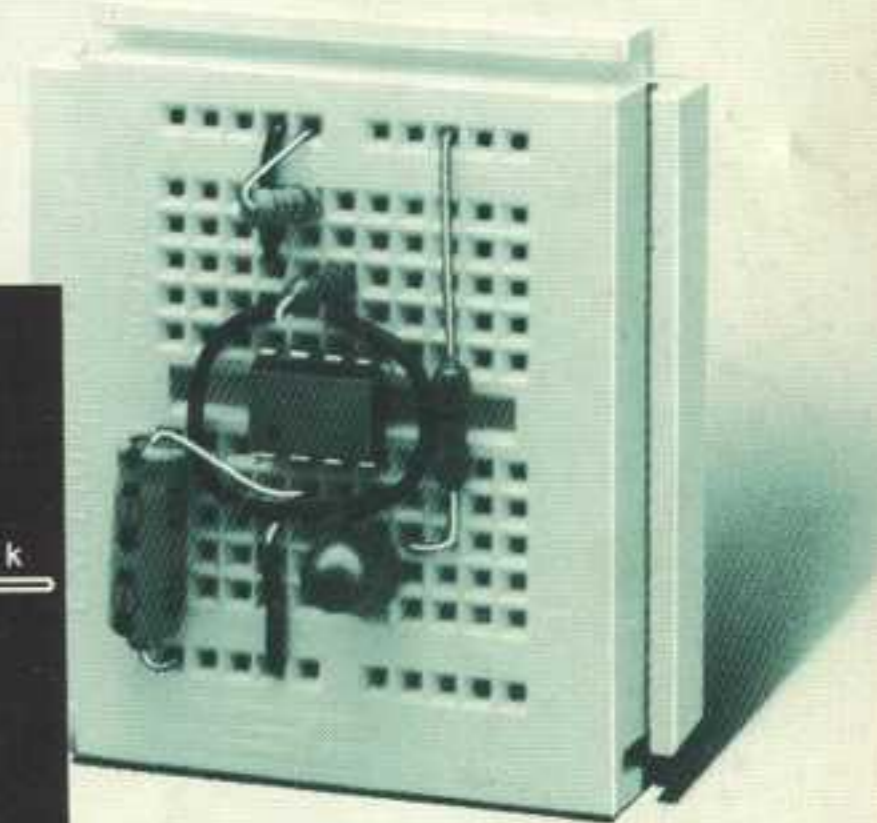


Engineer's Mini-Notebook

Schematic Symbols, Device Packages,
Design and Testing



Forrest M. Mims III

Radio Shack

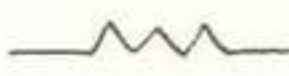

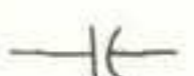
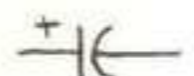
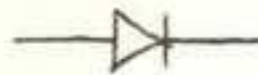
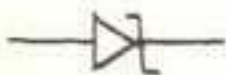


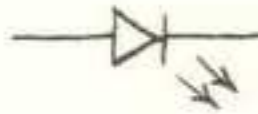
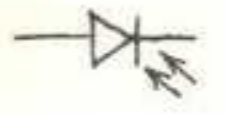







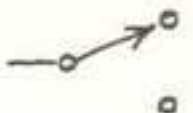
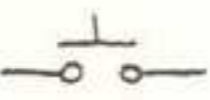
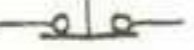
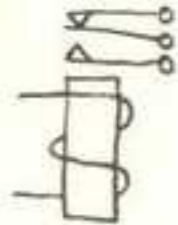
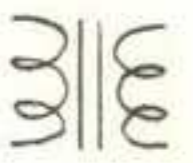
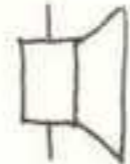


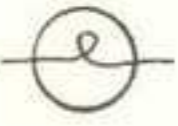
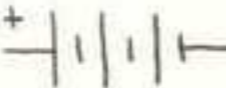
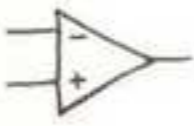
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Fort Worth, TX 76102

PRINTED IN U.S.A.



276-5017

CIRCUIT SYMBOLS

			
FIXED RESISTOR	VARIABLE RESISTOR	FIXED CAPACITOR	POLARIZED CAPACITOR
			
RECTIFIER/ DIODE	ZENER DIODE	PNP TRANSISTOR	NPN TRANSISTOR
			
LED	SOLAR CELL	PHOTO-RESISTOR	PHOTO-TRANSISTOR
			
CONNECTED WIRES	UNCONNECTED WIRES	POSITIVE SUPPLY	GROUND
			
SPST SWITCH	SPDT SWITCH	NORMALLY OPEN PUSHBUTTON	NORMALLY CLOSED PUSHBUTTON
			
RELAY	TRANSFORMER	SPEAKER	PIEZO-SPEAKER
			
METER	LAMP	BATTERY	OP-AMP

ENGINEER'S MINI-NOTEBOOK

SCHEMATIC SYMBOLS, DEVICE PACKAGES, DESIGN AND TESTING

BY
FORREST M. MIMS, III

CONTRIBUTING EDITOR
MODERN ELECTRONICS

FIRST EDITION
SECOND PRINTING - 1990

A SILICONCEPTS™ BOOK

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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 MODERN ELECTRONICS AND RADIO-ELECTRONICS. THE AUTHOR WRITES A MONTHLY COLUMN, "ELECTRONICS NOTEBOOK," FOR MODERN ELECTRONICS.

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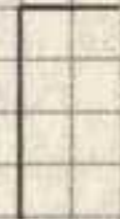
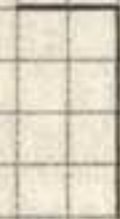
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1. SCHEMATIC SYMBOLS

ANTENNAS

EXTERNAL

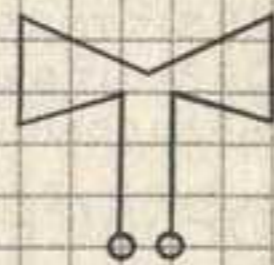
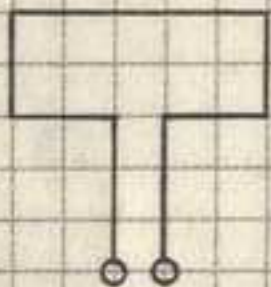
DIPOLE



FOLDED DIPOLE

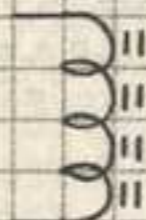
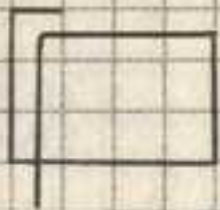
UHF LOOP

UHF BOWTIE



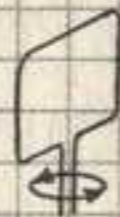
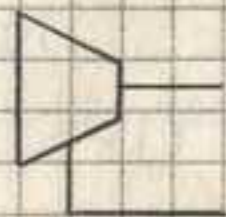
LOOP

TELESCOPIC FERRITE CORE



MICROWAVE HORN

ROTATABLE LOOP



EARTH STATION



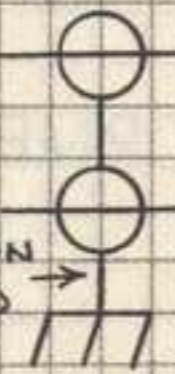
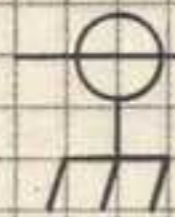
WIRE

CONNECTED

NOT CONNECTED



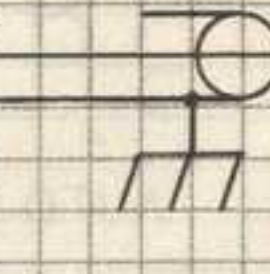
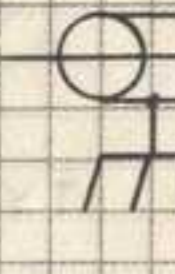
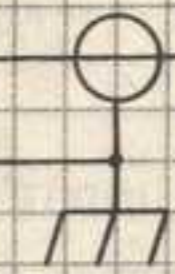
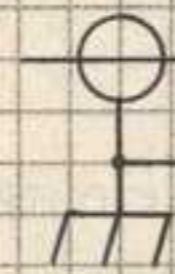
SHIELDED WIRE AND COAXIAL CABLE



COMMON GROUND

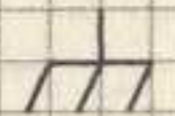
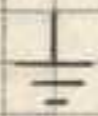
SHIELDED PAIR

CABLE SHIELDED AT 2 POINTS

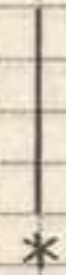


EARTH GROUND

CHASSIS GROUND

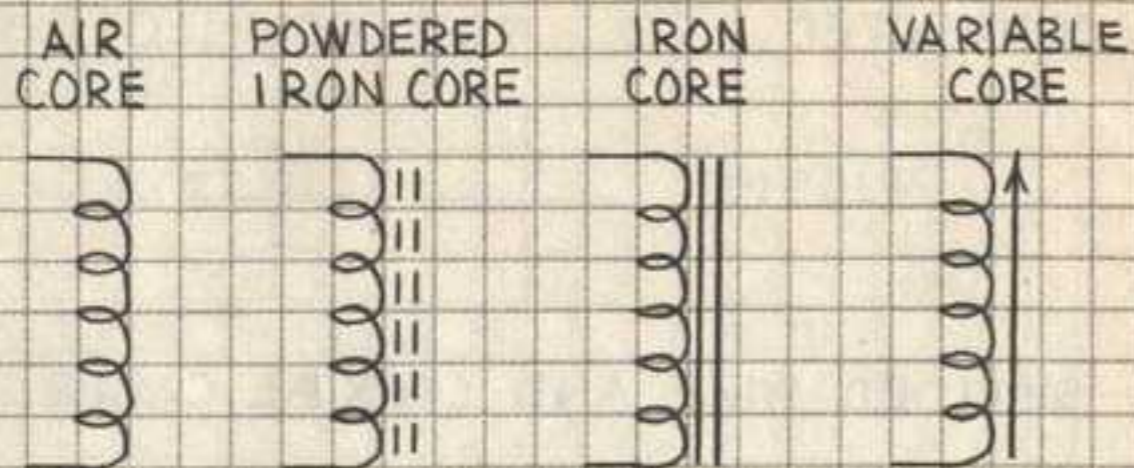


COMMON TIE POINTS

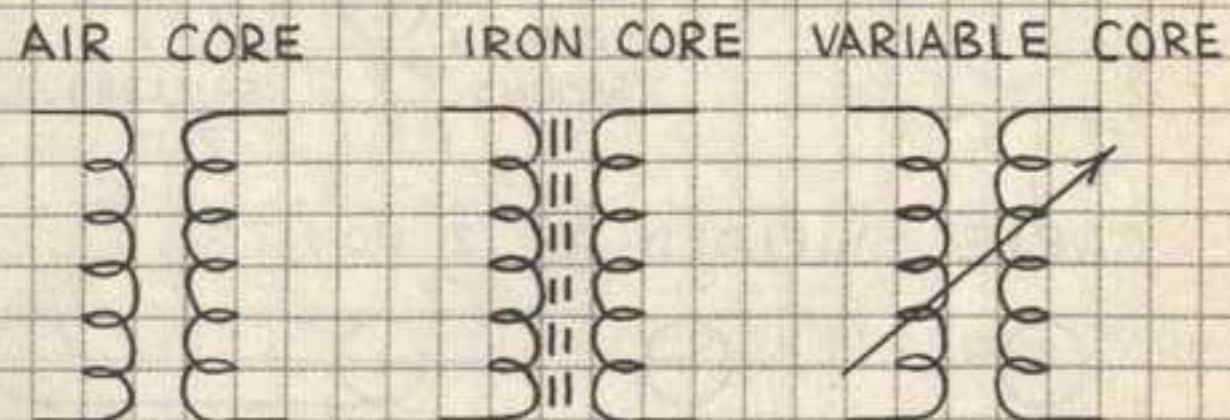


* USE FOR TWO OR MORE COMMON TIE POINTS IN SAME CIRCUIT AND INSERT NUMBER OF RELEVANT TIE POINT.

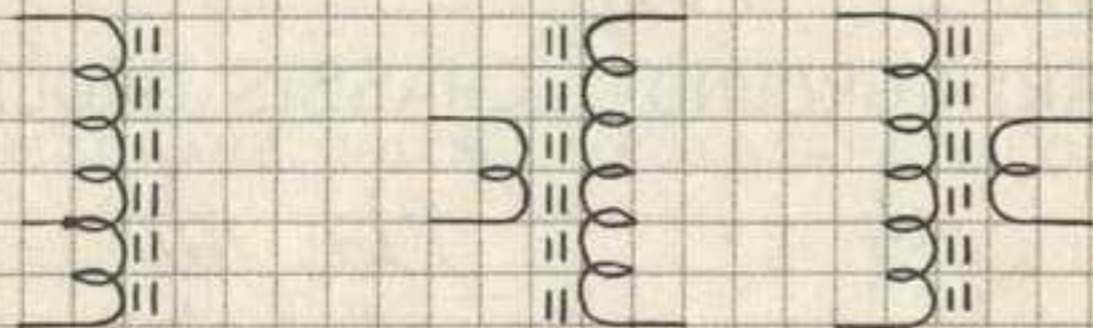
INDUCTORS



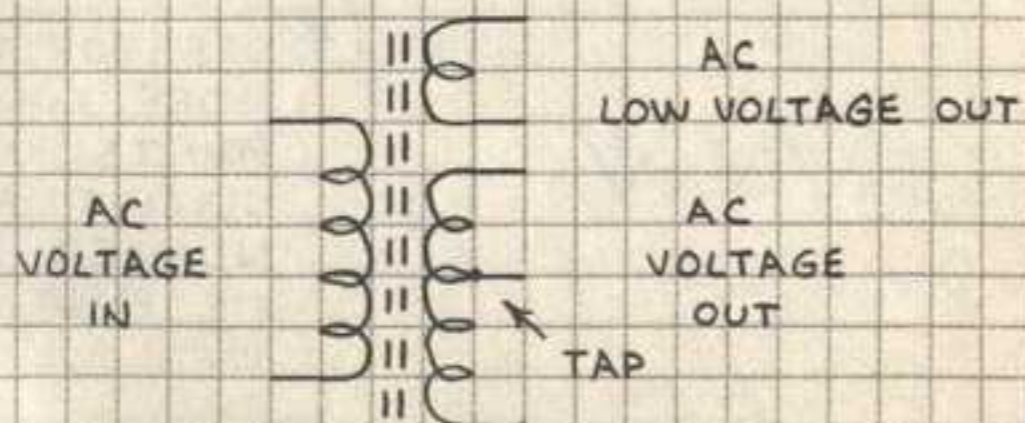
TRANSFORMERS



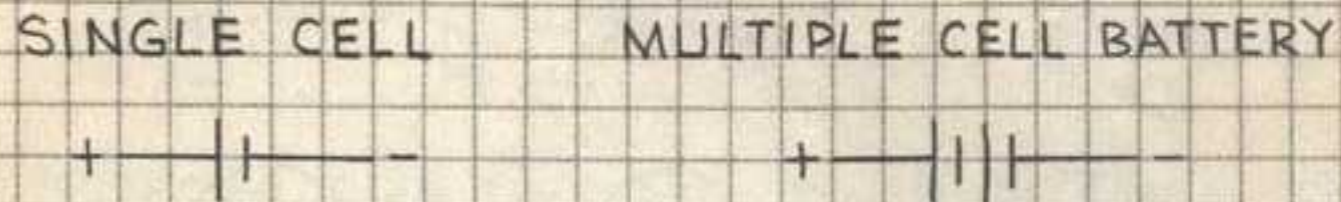
AUTO TYPICAL INPUT TYPICAL OUTPUT



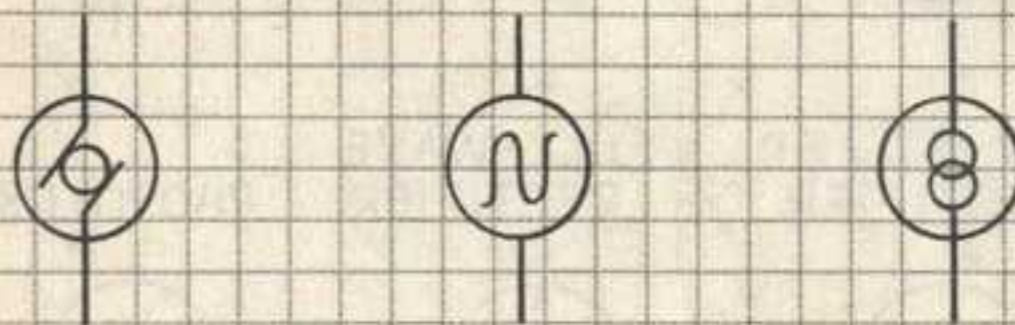
TYPICAL POWER TRANSFORMER (TAPPED)



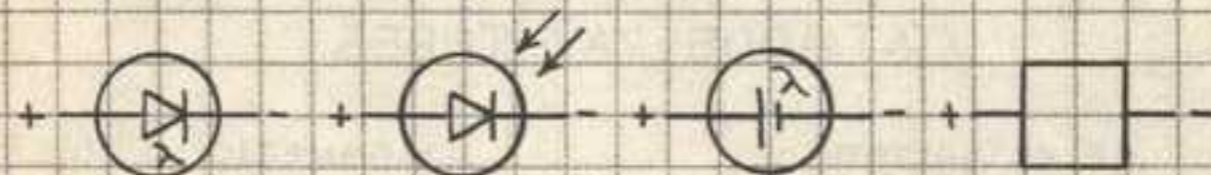
POWER SUPPLIES



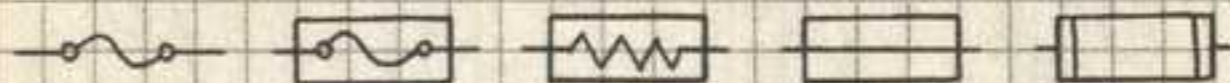
AC CURRENT SOURCES



SOLAR CELLS



FUSES



SHIELDING

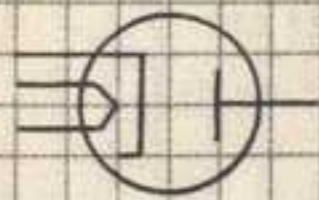
NOTE: DASHED LINE(S) ALSO USED TO INDICATE MECHANICAL CONNECTION.

SHIELDED ENCLOSURE

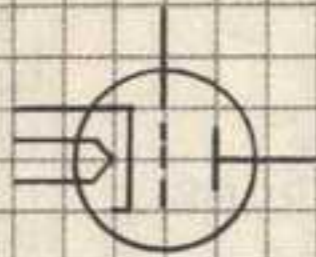


ELECTRON TUBES

DIODE



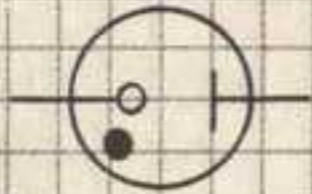
TRIODE



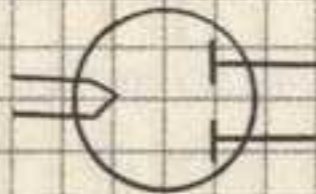
TETRODE



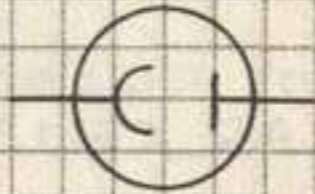
GAS-FILLED RECTIFIER



FULL-WAVE RECTIFIER

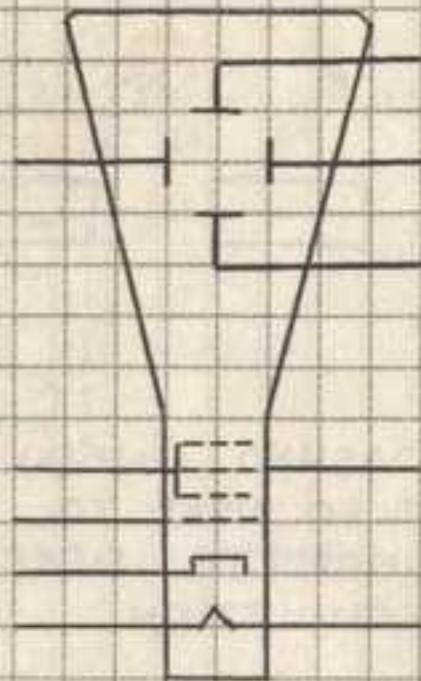


PHOTOTUBE

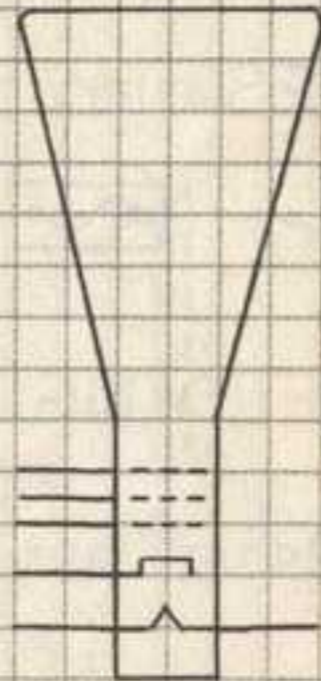


CATHODE-RAY TUBES

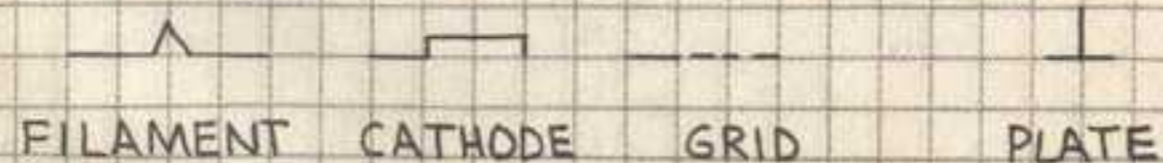
ELECTROSTATIC



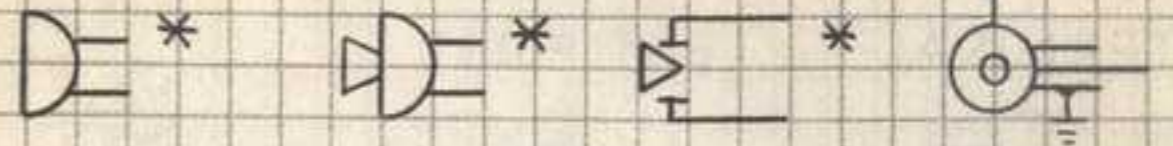
MAGNETIC



TUBE ELEMENTS

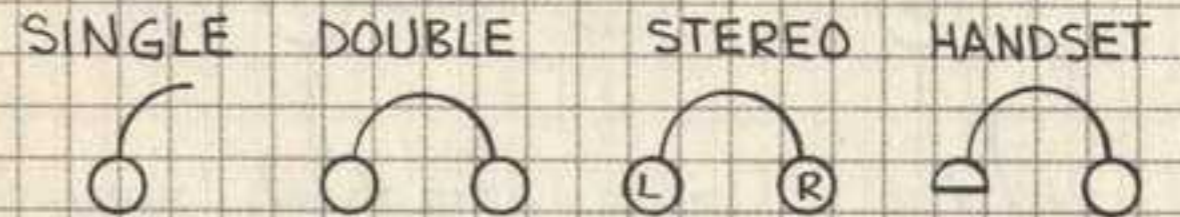
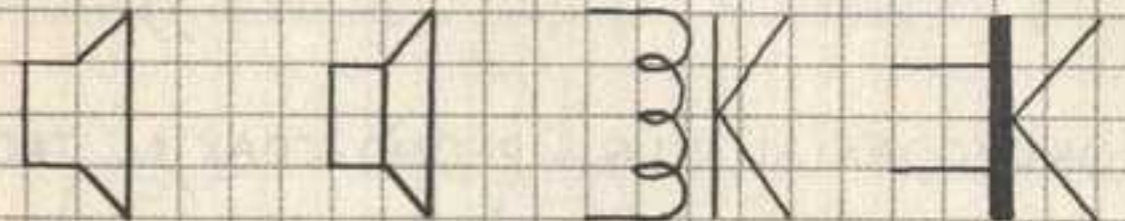


MICROPHONES



* SPECIFY TYPE (CERAMIC, DYNAMIC, CRYSTAL, ETC.)

SPEAKERS AND HEADSETS



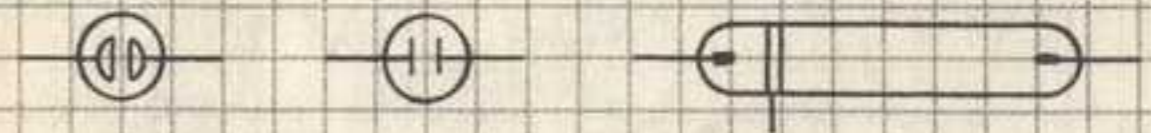
LAMPS

INCANDESCENT



NEON

XENON FLASHLAMP



PIEZOELECTRIC DEVICES

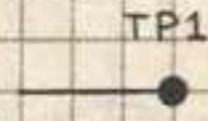
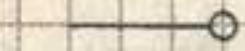
FREQUENCY CONTROL PHONO CARTRIDGES BUZZER
MONO STEREO



CONNECTORS

TERMINAL

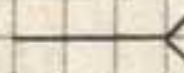
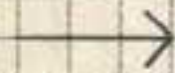
TEST POINT



MALE

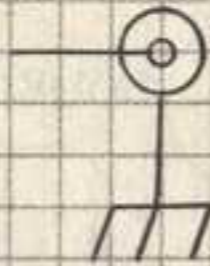
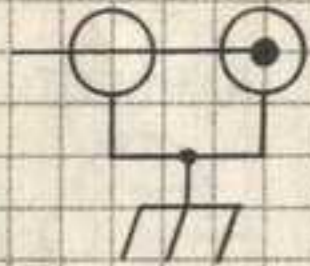
FEMALE

ENGAGED



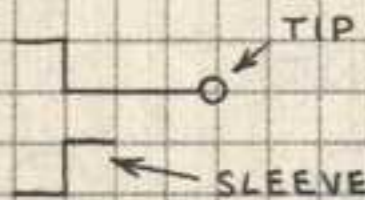
PHONO/COAXIAL PLUG

PHONO/COAXIAL JACK

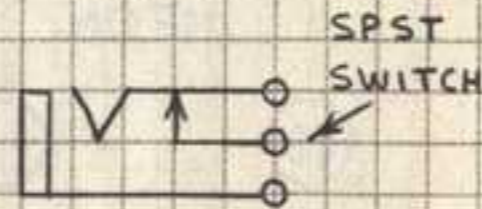
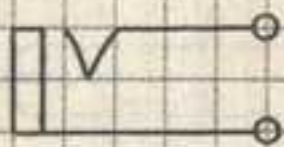


2-CONDUCTOR PLUG

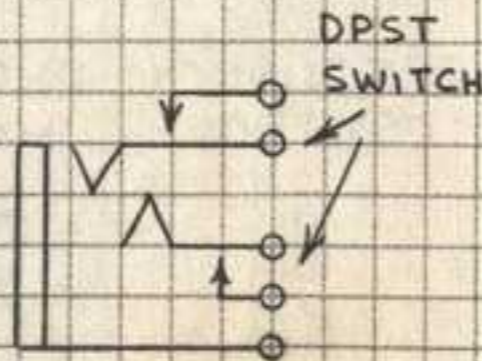
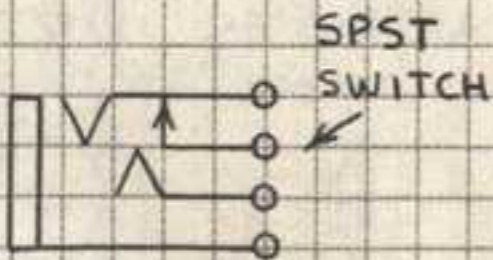
3-CONDUCTOR PLUG



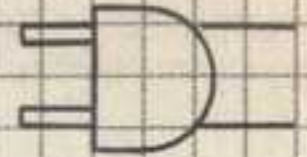
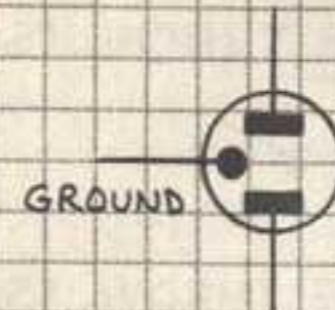
2-CONDUCTOR JACKS



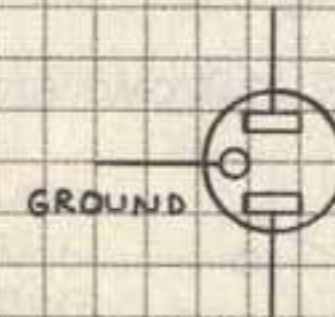
3-CONDUCTOR JACKS



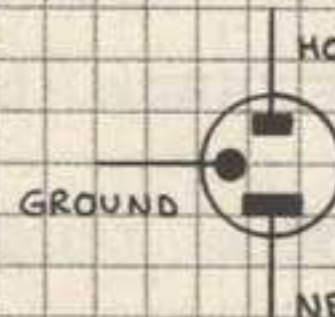
117-VOLT NON-POLARIZED PLUG



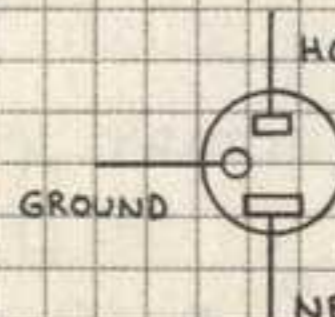
117-VOLT NON-POLARIZED SOCKET



117-VOLT POLARIZED PLUG



117-VOLT POLARIZED SOCKET



234-VOLT PLUG

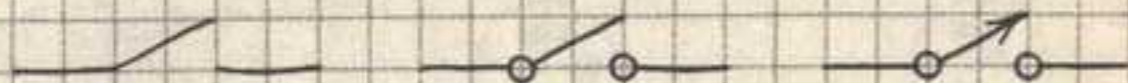


234-VOLT SOCKET

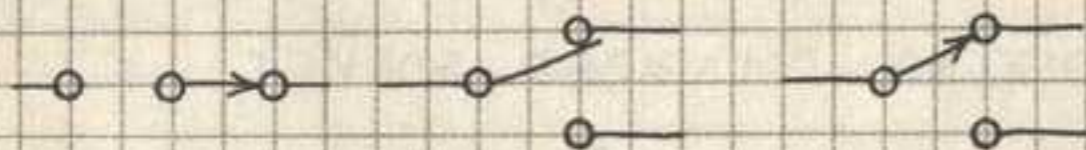


SWITCHES

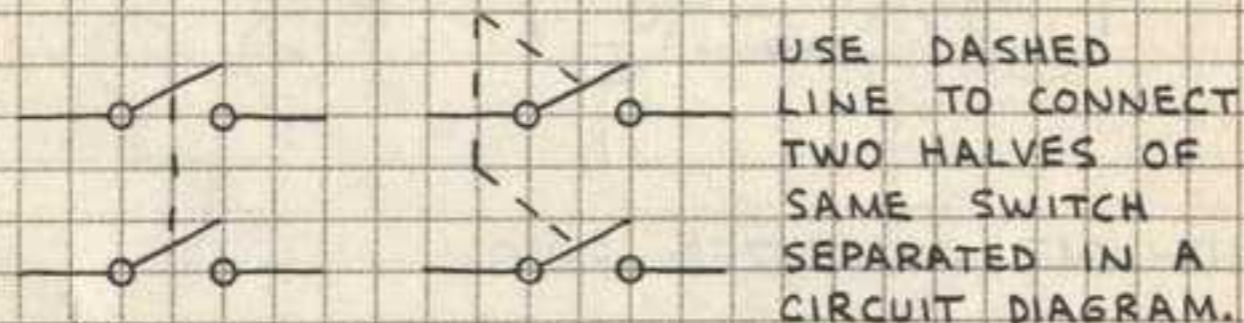
SINGLE POLE SINGLE THROW (SPST)



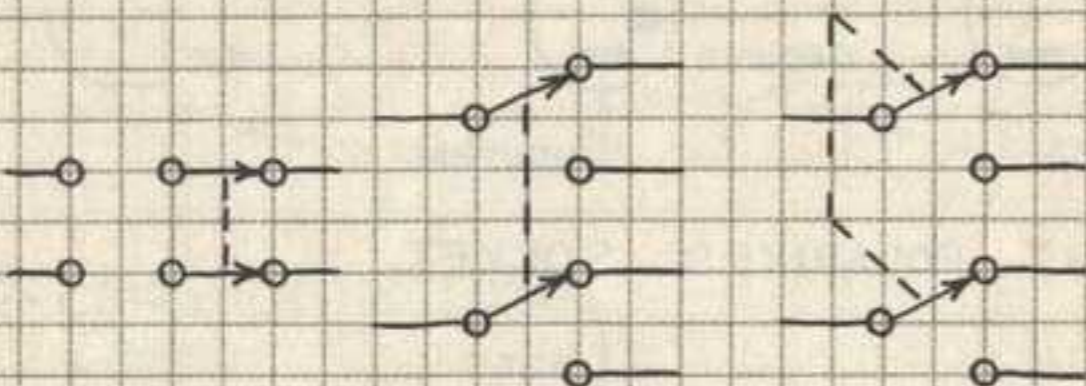
SINGLE POLE DOUBLE THROW (SPDT)



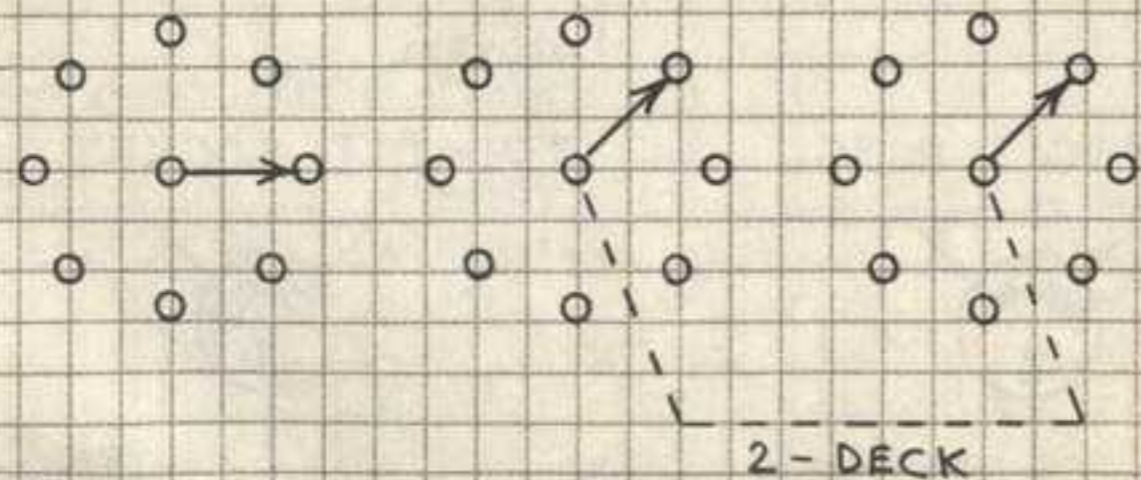
DOUBLE POLE SINGLE THROW (DPST)



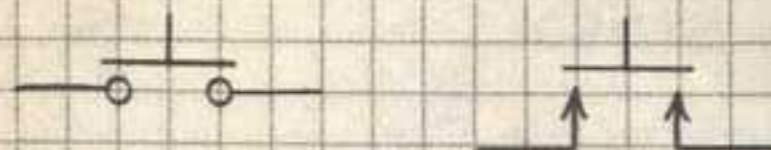
DOUBLE POLE DOUBLE THROW (DPDT)



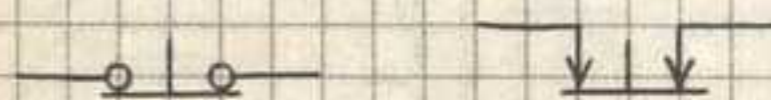
MULTIPLE CONTACT ROTARY



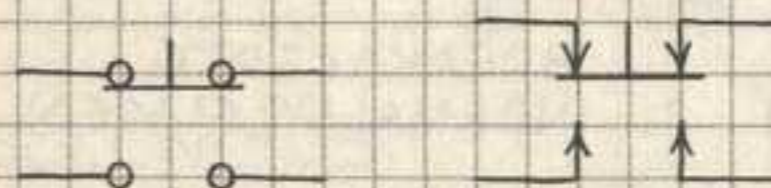
NORMALLY OPEN SPST PUSHBUTTON



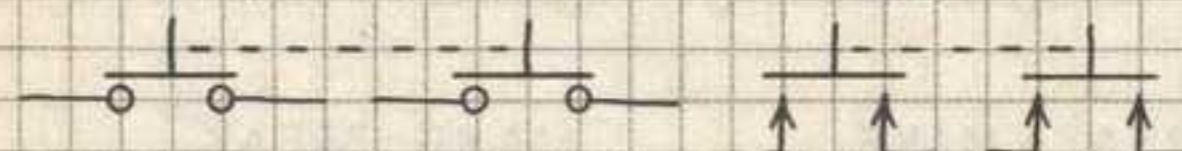
NORMALLY CLOSED SPST PUSHBUTTON



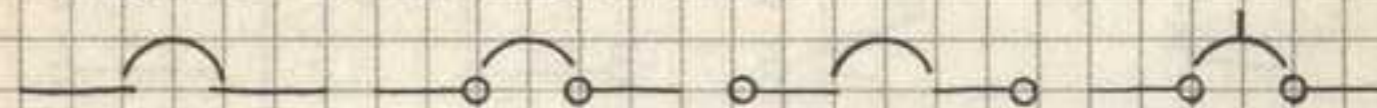
NORMALLY OPEN/CLOSED SPDT PUSHBUTTON



NORMALLY OPEN DPST PUSHBUTTON



MANUAL CIRCUIT BREAKER



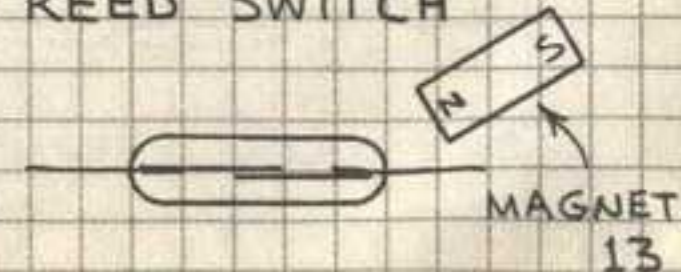
AUTOMATIC CIRCUIT BREAKER



TELEGRAPH KEY

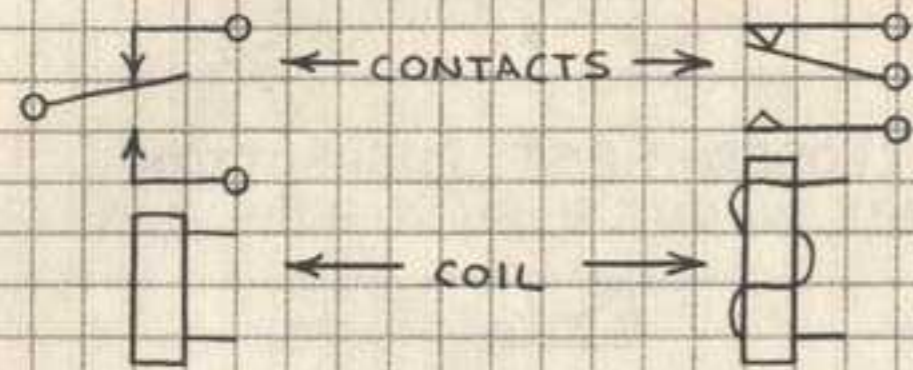


REED SWITCH



RELAYS

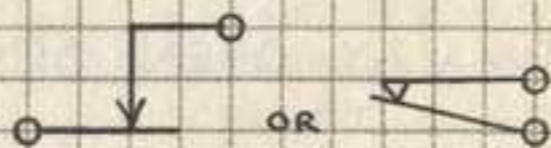
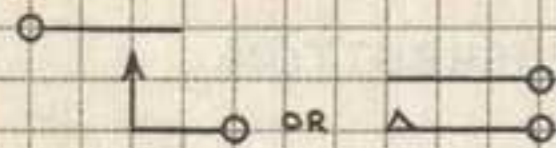
COMPLETE RELAY SYMBOLS



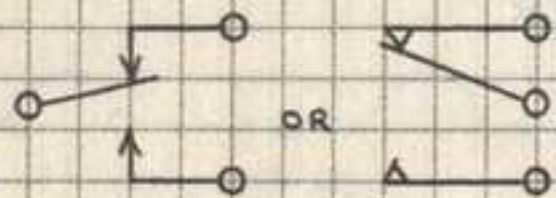
MOST COMMON RELAY CONTACTS:

MAKE (SPST,
NORMALLY OPEN)

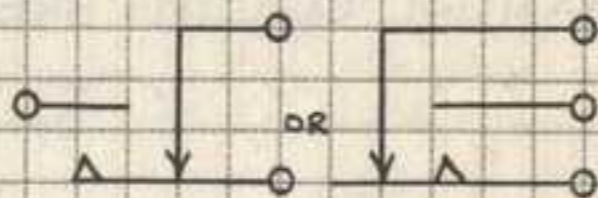
BREAK (SPST,
NORMALLY CLOSED)



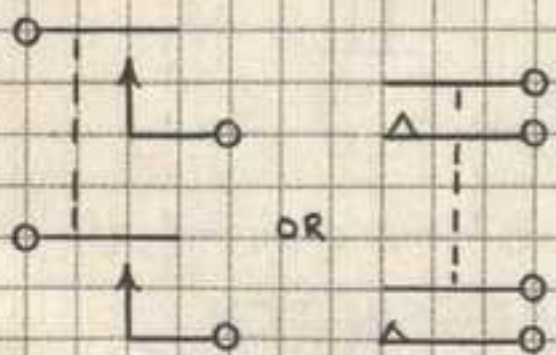
BREAK-MAKE
(SPDT)



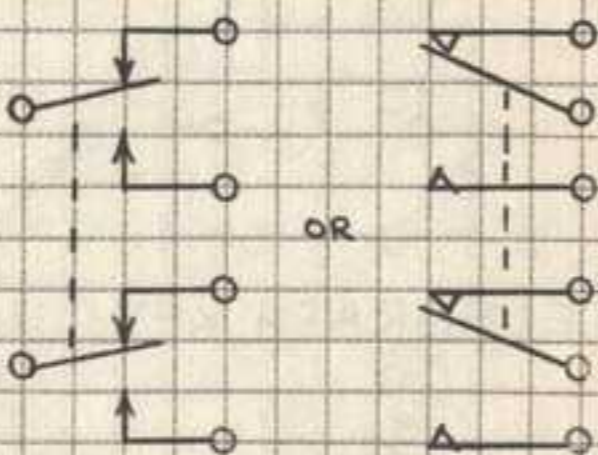
MAKE-BREAK
(SPDT)



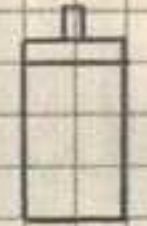
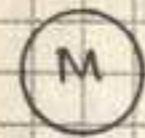
DPST



DPDT



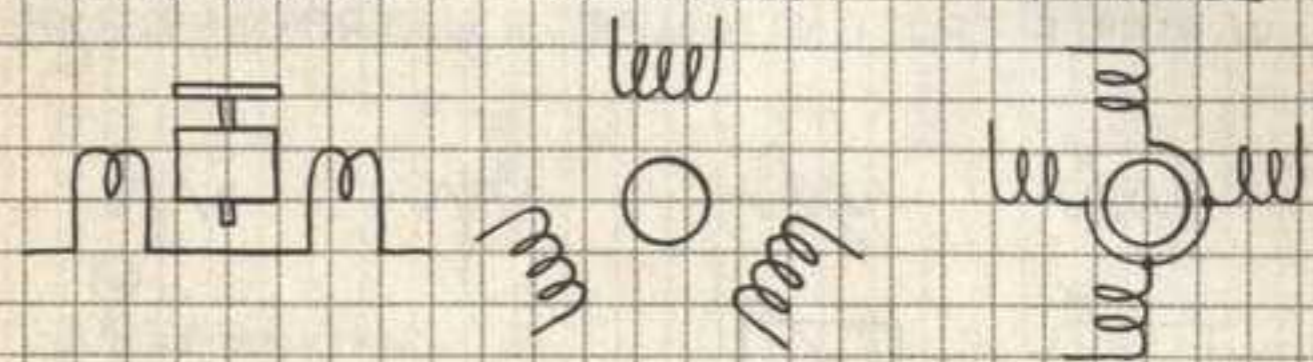
MOTORS



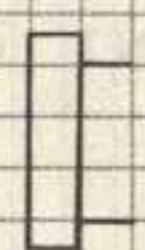
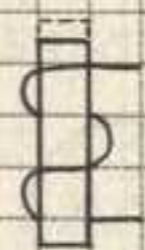
PHONO MOTOR

3-PHASE

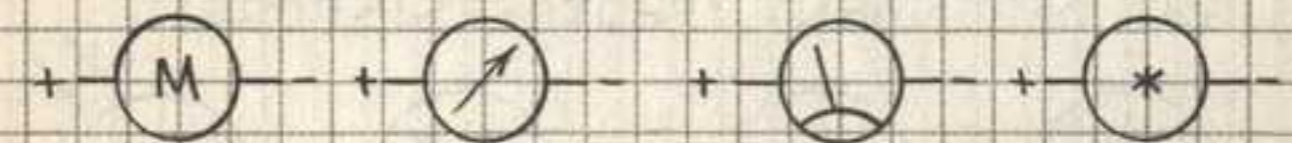
4-PHASE



SOLENOIDS

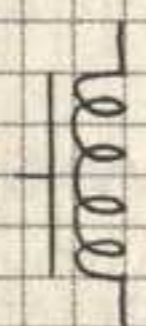


METERS



* INSERT APPROPRIATE DESIGNATION (V=VOLTMETER;
A=AMMETER; mA=MILLIAMMETER; ETC.)

DELAY LINE



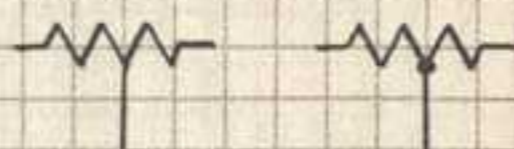
* INSERT DELAY TIME

RESISTORS

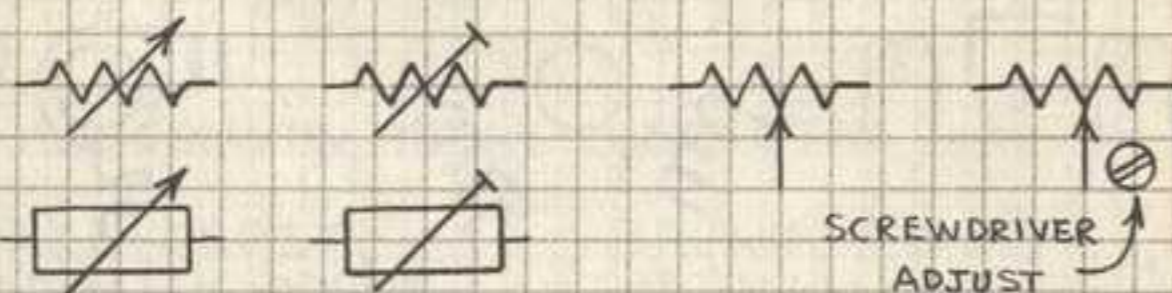
FIXED



TAPPED



VARIABLE (POTENTIOMETERS, TRIMMERS, ETC.)



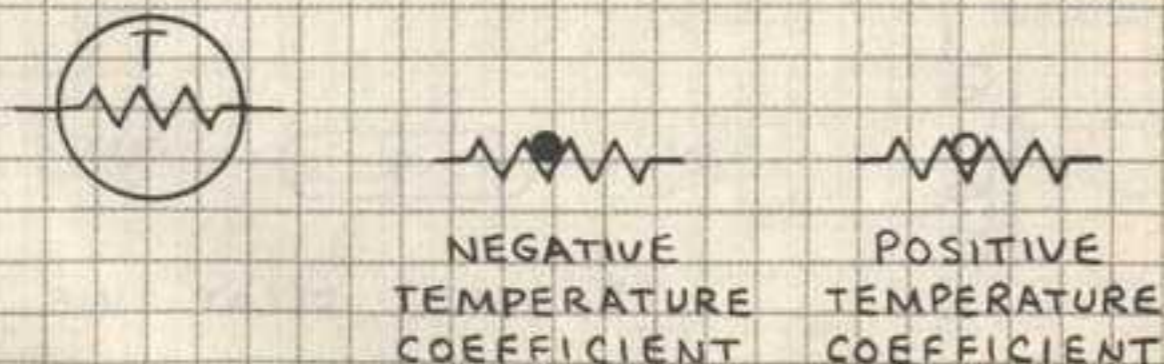
VOLTAGE DEPENDENT CURRENT DEPENDENT



LIGHT DEPENDENT (PHOTORESISTORS)



TEMPERATURE DEPENDENT (THERMISTORS)

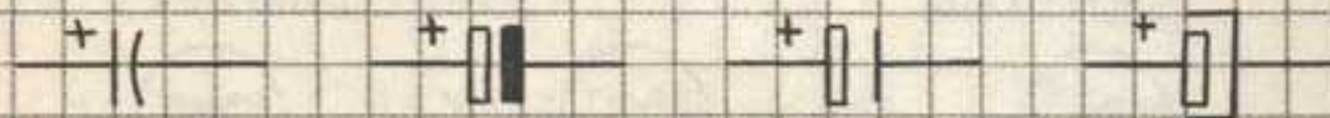


CAPACITORS

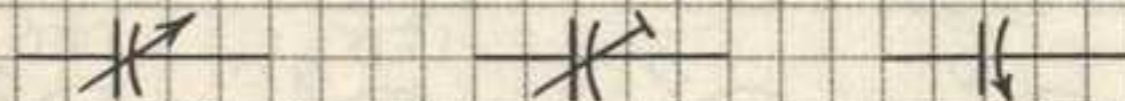
FIXED (NON-POLARIZED)



FIXED (POLARIZED)

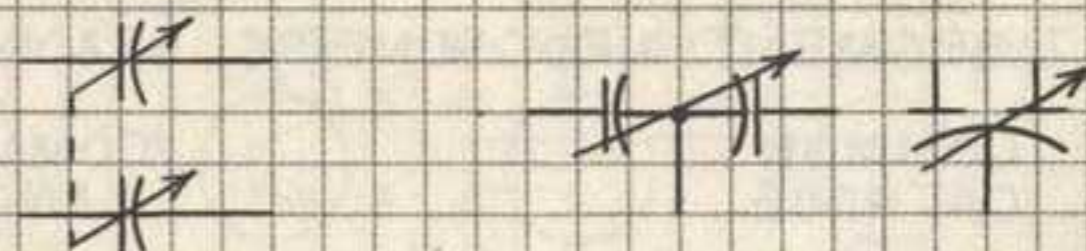


VARIABLE



GANGED VARIABLE

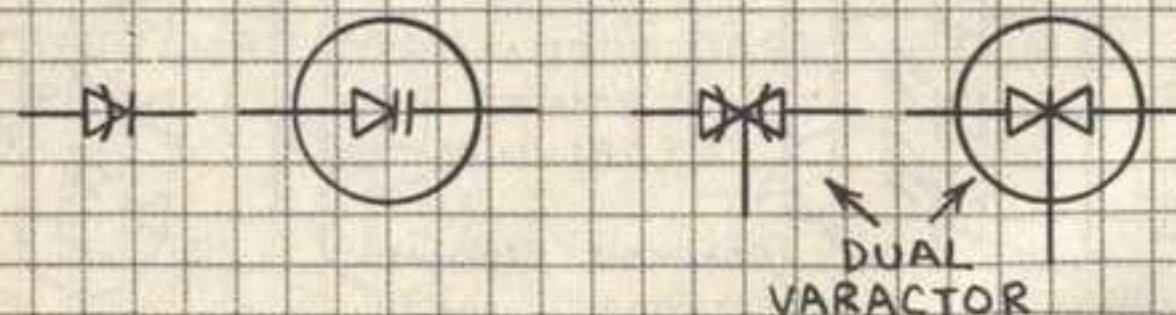
SPLIT STATOR



FEED THROUGH

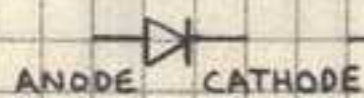


VOLTAGE VARIABLE (VARACTOR)



DIODES

RECTIFIER



ZENER



TUNNEL



TEMPERATURE SENSING



PIN



BIPOLAR VOLTAGE LIMITER



PHOTODIODE



LED



2-COLOR LED

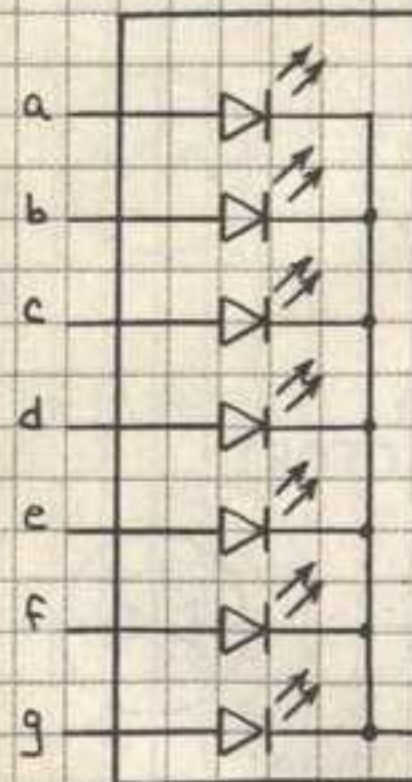


BIPOLAR LED

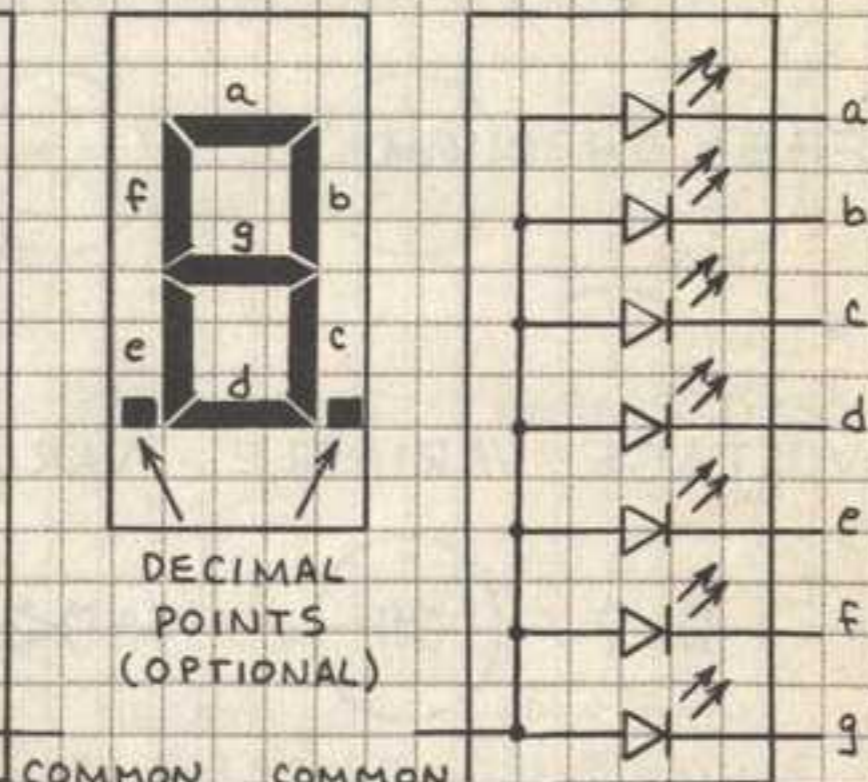


7-SEGMENT LED NUMERIC READOUTS

COMMON CATHODE



COMMON ANODE



DECIMAL POINTS (OPTIONAL)

COMMON CATHODE

COMMON ANODE

3-LAYER SWITCHES (DIACS)

NPN



PNP

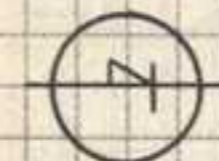


BIDIRECTIONAL



4-LAYER SWITCHES

4-LAYER DIODE



THYRISTORS (SCRs) P-GATE N-GATE



TRIAC



TRANSISTORS

BIPOLAR

PNP



NPN



UNI-JUNCTION

N-CHANNEL



P-CHANNEL



JUNCTION FETS

N-CHANNEL



P-CHANNEL



MOSFETS

N-CHANNEL



P-CHANNEL



PHOTOTRANSISTORS

PNP



NPN

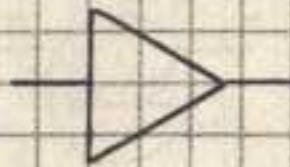


DARLINGTON

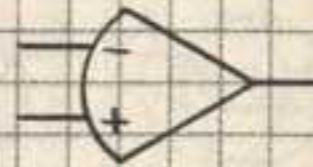
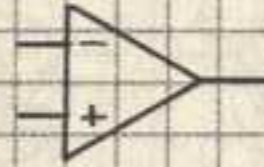


ANALOG CIRCUITS

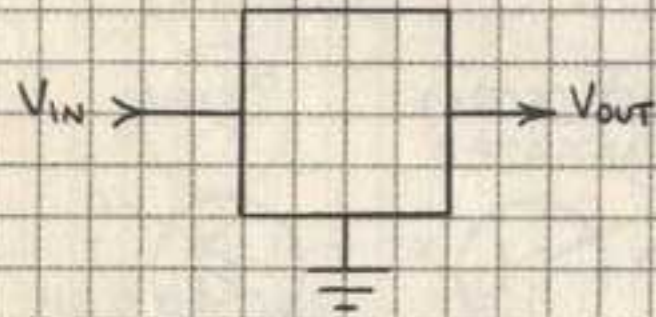
AMPLIFIER



OPERATIONAL AMPLIFIERS



VOLTAGE REGULATOR



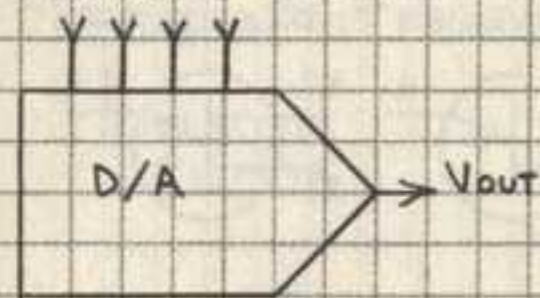
TIMERS, ETC.



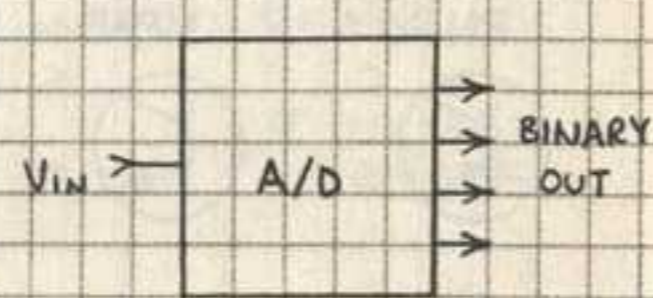
CONVERTER CIRCUITS

DIGITAL-TO-ANALOG

BINARY IN

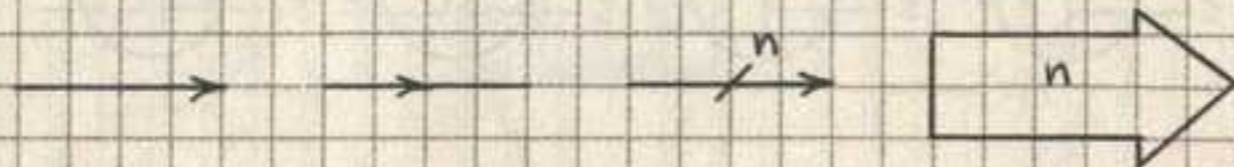


ANALOG-TO-DIGITAL

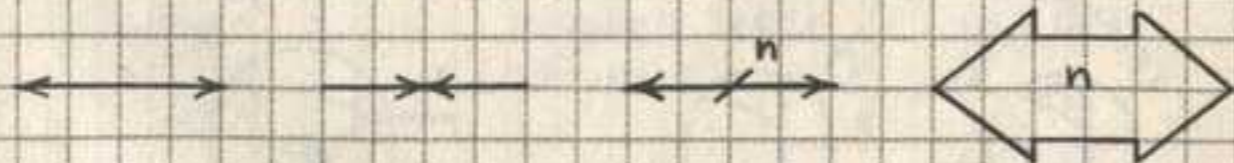


DIGITAL DATA BUSES

UNIDIRECTIONAL



BIDIRECTIONAL

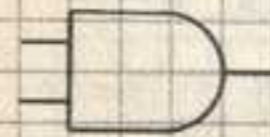


n = NUMBER OF CONDUCTORS

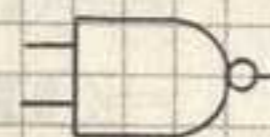
DIGITAL CIRCUITS

LOGIC GATES

AND



NAND



OR



NOR



EXCLUSIVE OR



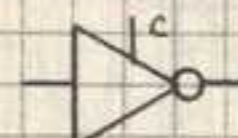
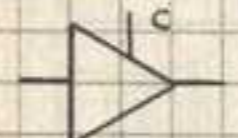
EXCLUSIVE NOR



INVERTERS

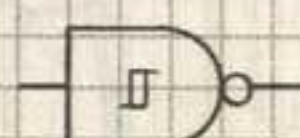
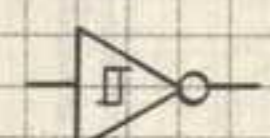


3-STATE BUFFERS



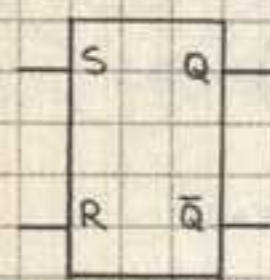
C = CONTROL

SCHMITT TRIGGERS



FLIP-FLOPS

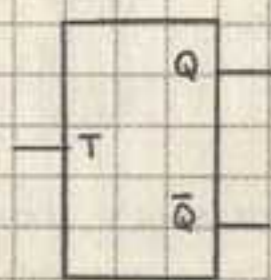
SR



JK

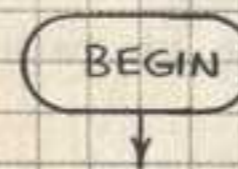


T



COMPUTER FLOWCHART SYMBOLS

BEGIN/IN



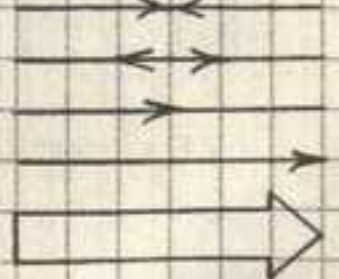
DECISION



OPERATION

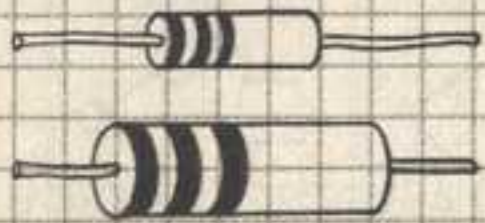


FLOW



2. DEVICE PACKAGES

RESISTORS

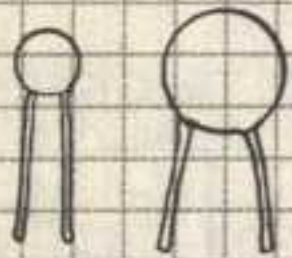


CARBON COMPOSITION

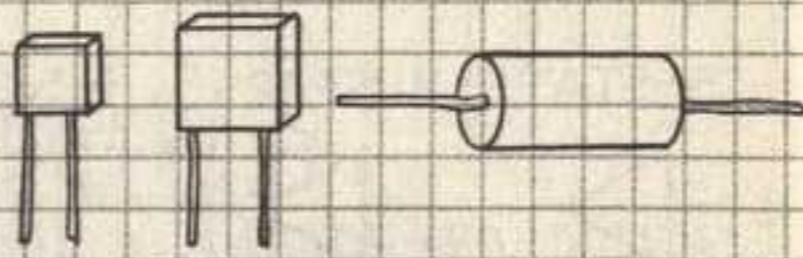


CARBON FILM

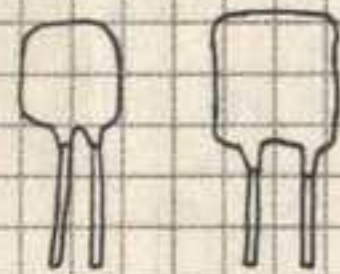
CAPACITORS



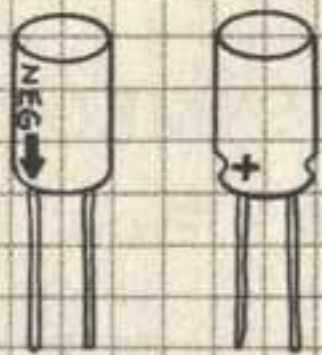
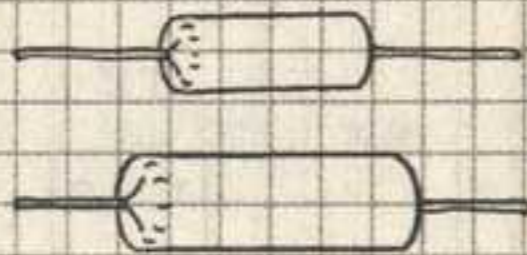
CERAMIC DISK



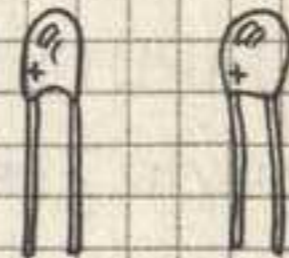
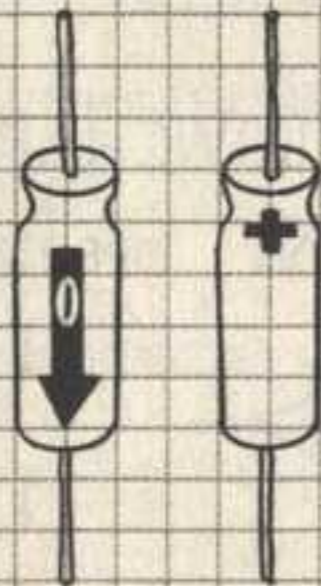
MOLDED MULTILAYER CERAMIC



CONFORMALLY COATED MULTILAYER CERAMIC

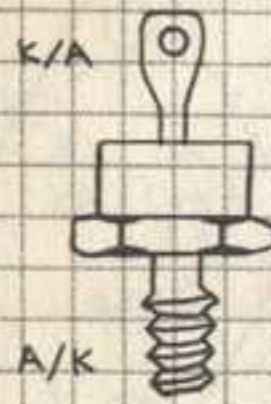


ELECTROLYTIC

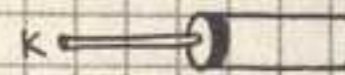


DIPPED TANTALUM

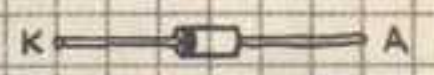
DIODES



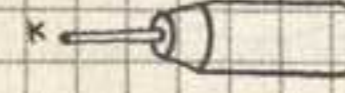
DO-4



DO-7



DO-35

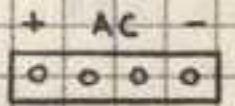
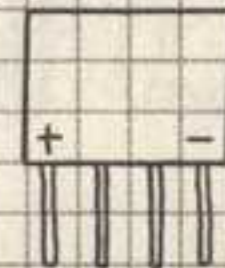
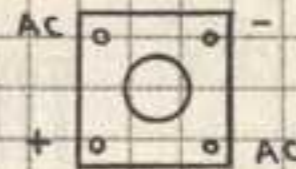
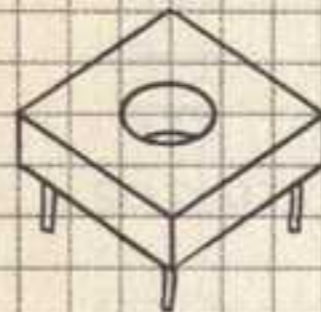
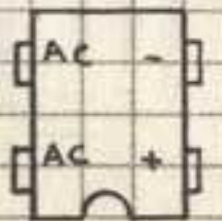
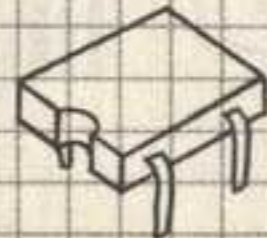
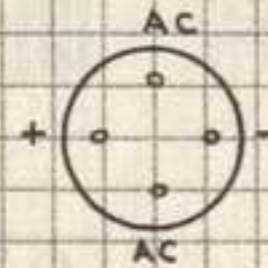
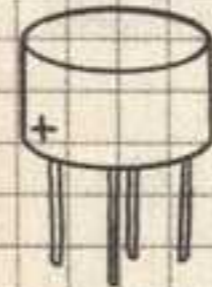


DO-27



DO-41

BRIDGE RECTIFIERS



NOTE: ALWAYS CONSULT DEVICE SPECIFICATIONS TO VERIFY PIN IDENTIFICATION.

LIGHT EMITTING DIODES



COLOR STRIPE
K - CATHODE
A - ANODE

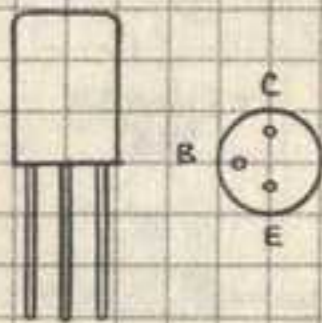


NOTCH

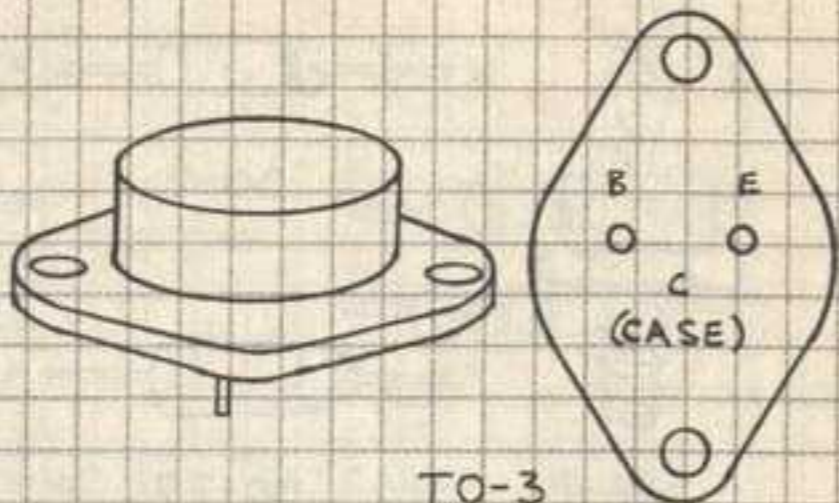


FLAT

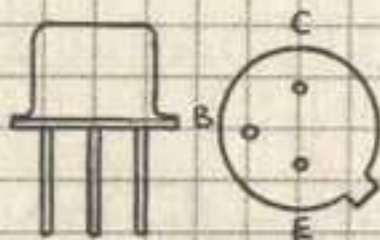
TRANSISTORS (BOTTOM VIEW)



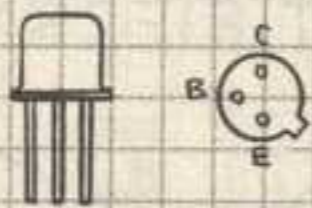
TO-18



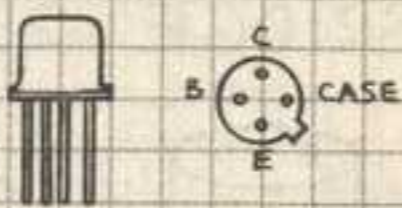
TO-3



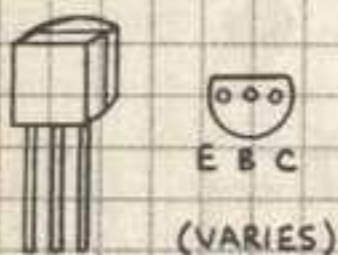
TO-5



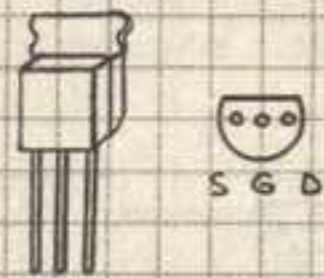
TO-18



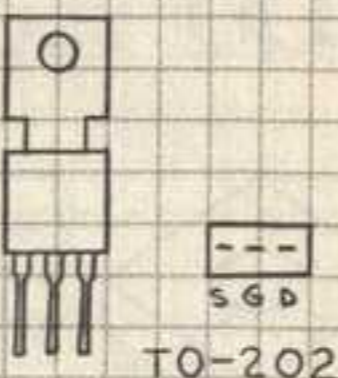
TO-72



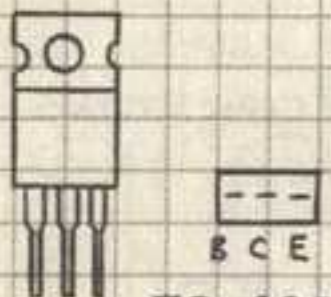
TO-92



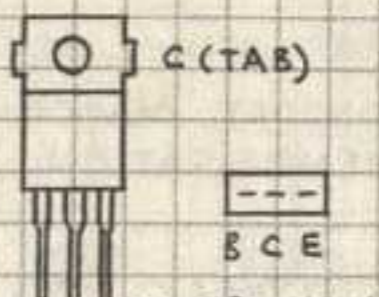
TO-92+



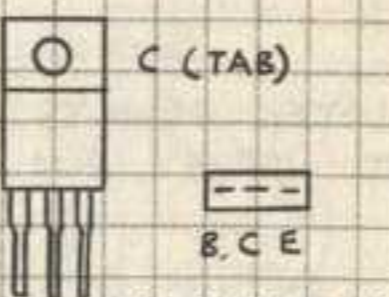
TO-202



TO-220



TO-220AB-1

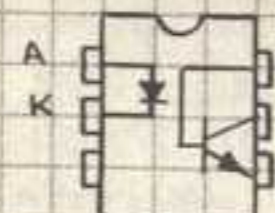


TO-220AB-2

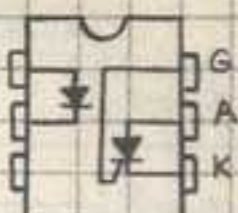
C - COLLECTOR
 B - BASE
 E - EMITTER
 S - SOURCE
 G - GATE
 D - DRAIN

NOTE: CASE STYLES VARY AND MANY OTHERS ARE IN USE. ALWAYS CONSULT DEVICE SPECIFICATIONS TO VERIFY PIN IDENTIFICATION.

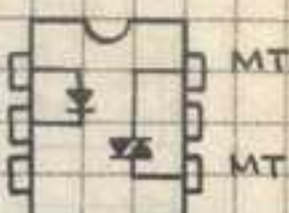
OPTOCOUPLEDERS (TOP VIEW)



TRANSISTOR



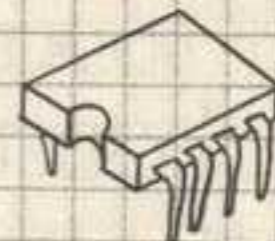
SCR



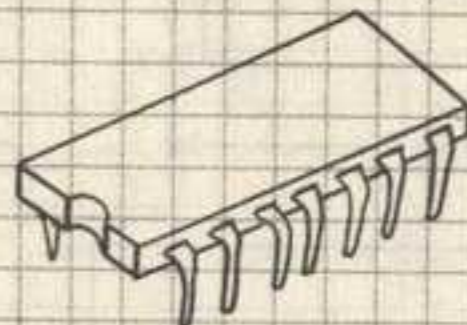
TRIAC

INTEGRATED CIRCUITS (TOP VIEW)

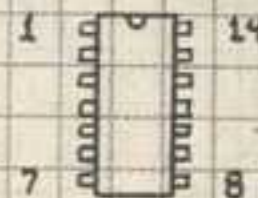
8-PIN MINI-DIP



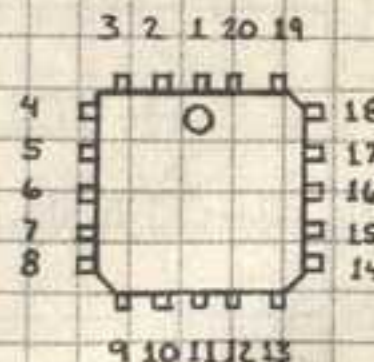
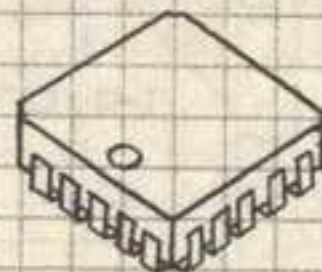
14-PIN DIP



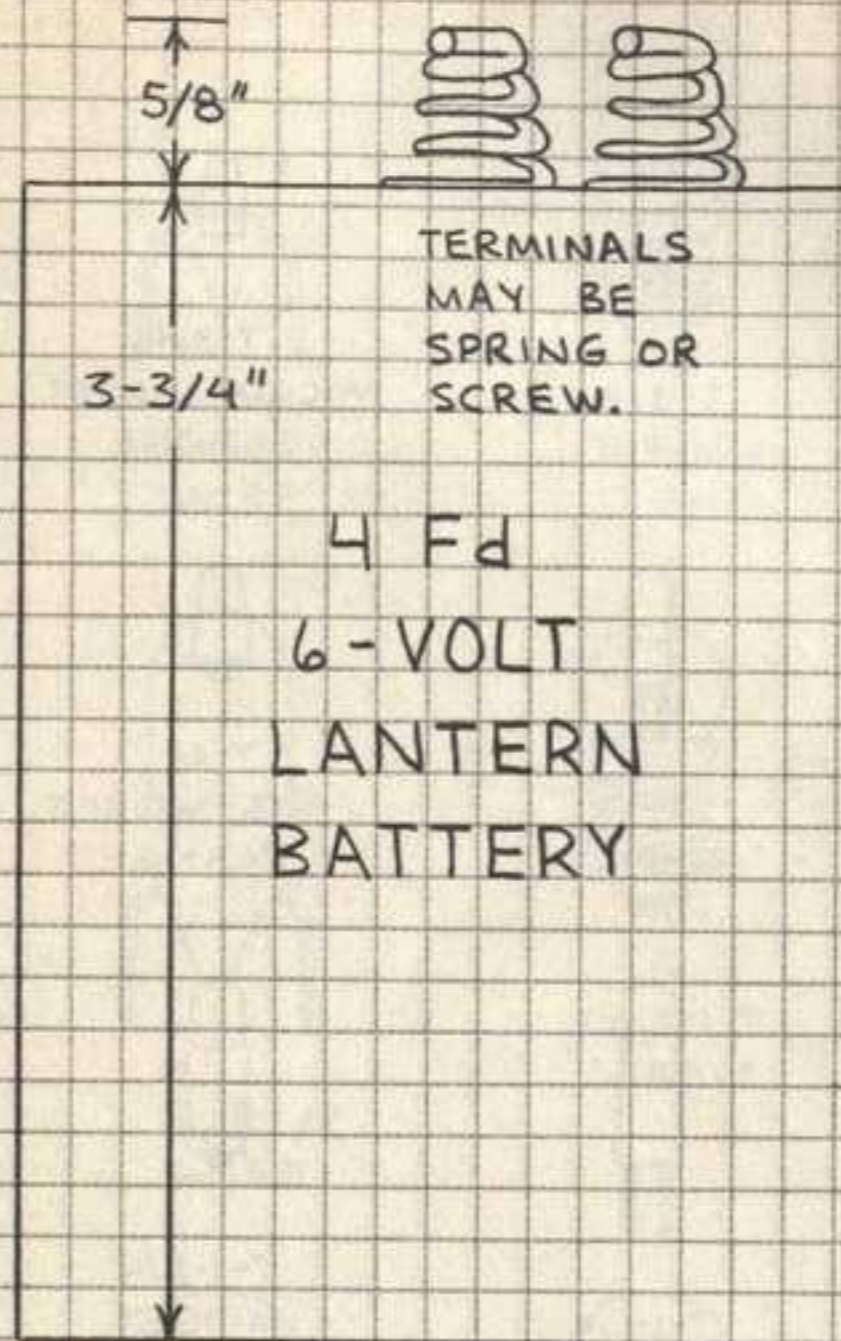
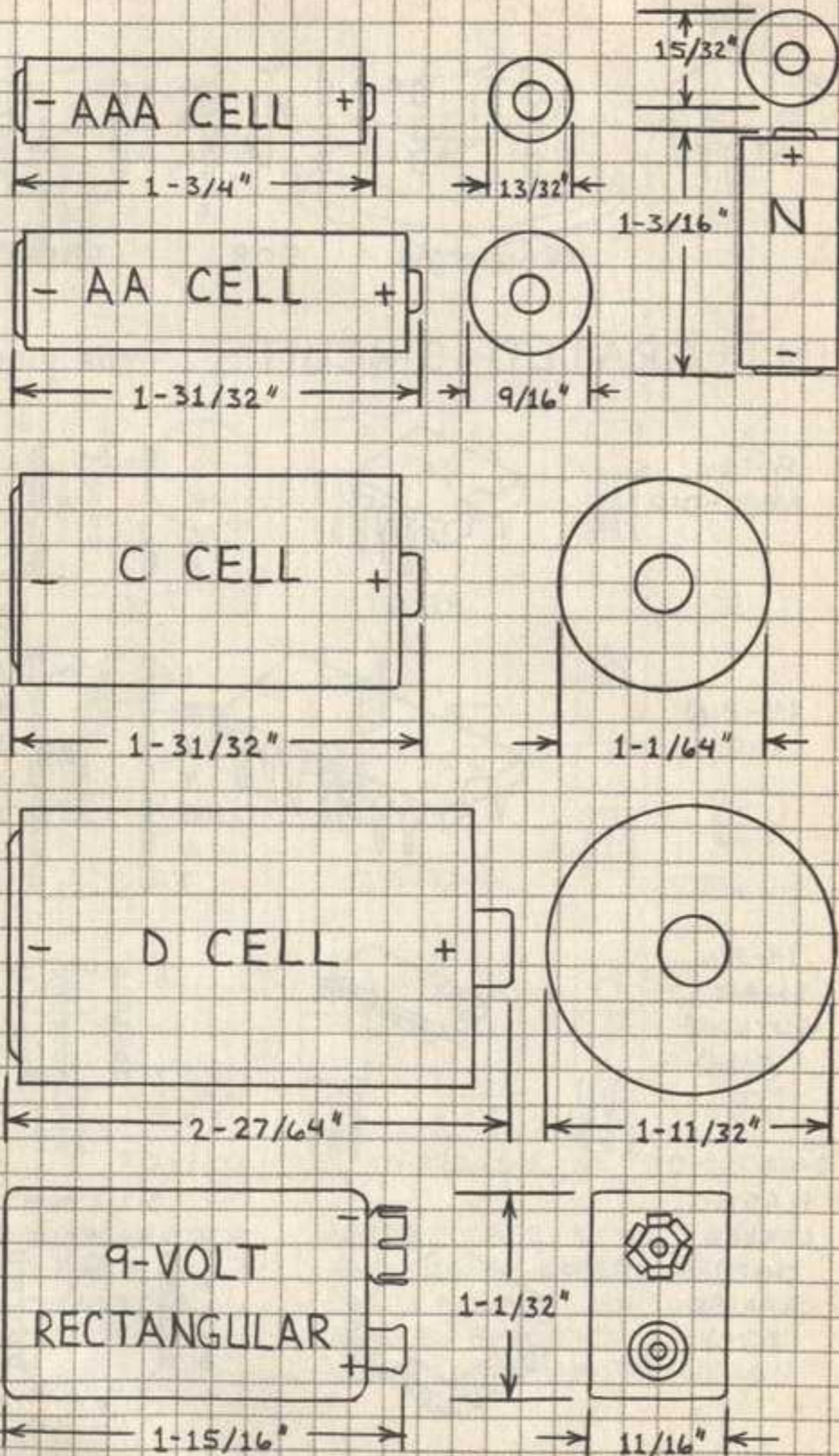
14-PIN SMALL OUTLINE (SO-14)



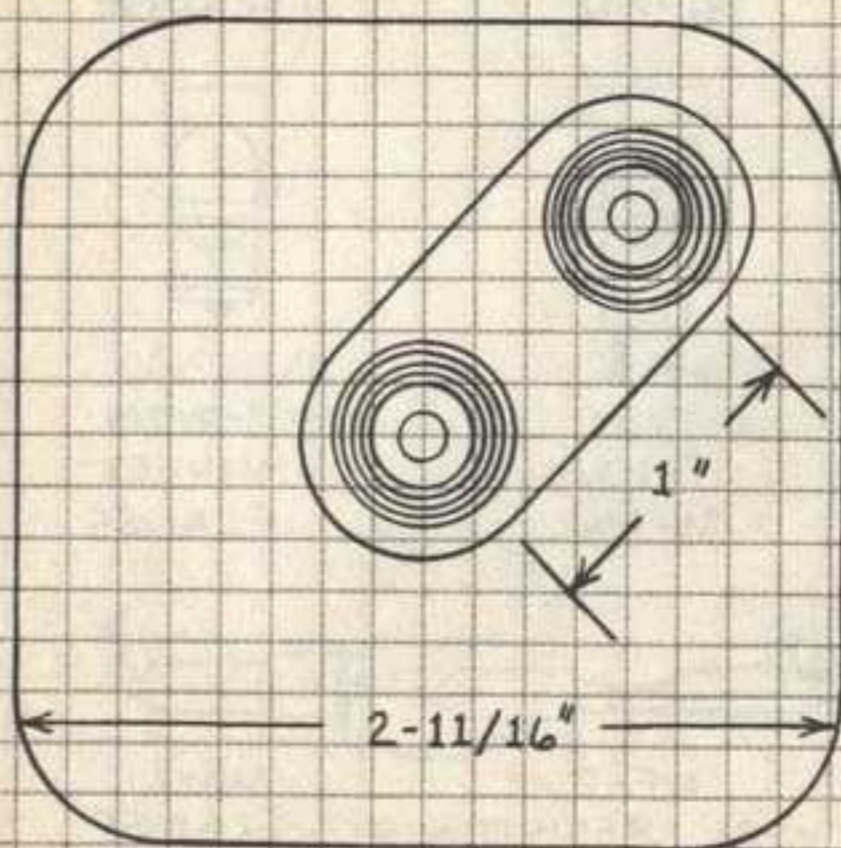
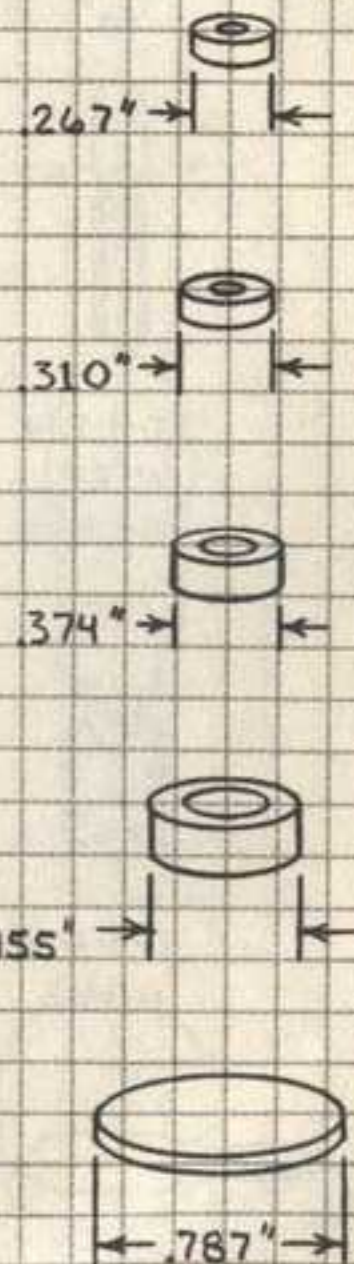
PLASTIC LEADED CHIP CARRIER (PLCC)



BATTERIES



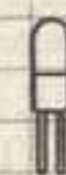
COMMON COIN AND BUTTON CELLS (CELL THICKNESS VARIES WITH TYPE AND CHEMICAL COMPOSITION):



LAMPS



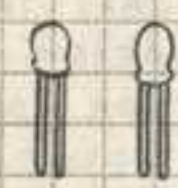
T-3/4
WIRE



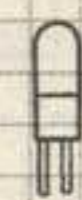
T-3/4
BI-PIN



T-3/4
MICRO-MIDGET
FLANGE



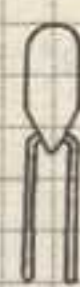
T-1
WIRE



T-1
BI-PIN



T-1
SUB-MIDGET
FLANGE



T-1-1/4
WIRE



T-1-1/4
BI-PIN



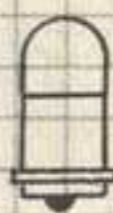
T-1-1/4
MIDGET
FLANGE



T-1-3/4
WIRE



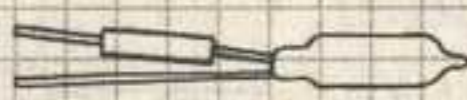
T-1-3/4
BI-PIN



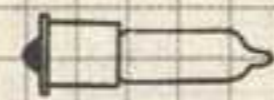
T-1-3/4
MIDGET
FLANGE



NE-2
WIRE



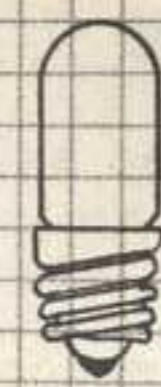
NE-2
WIRE + RESISTOR



NE-2
FLANGE



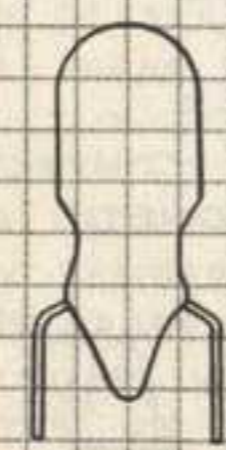
T-3-1/4
WIRE



T-3-1/4
SCREW



T-3-1/4
BAYONET



G-3-1/2
WIRE



G-3-1/2
SCREW



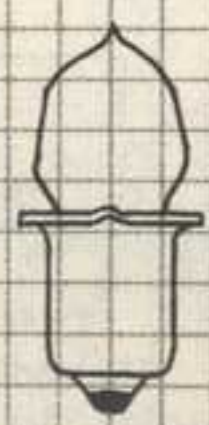
G-3-1/2
BAYONET



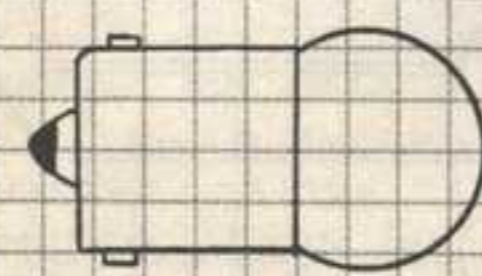
G-4-1/2
BAYONET



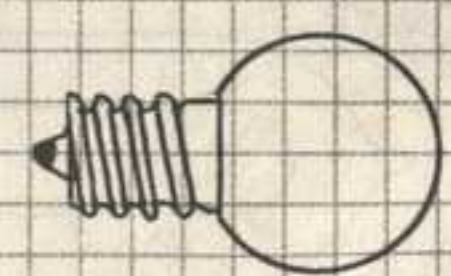
G-4-1/2
SCREW



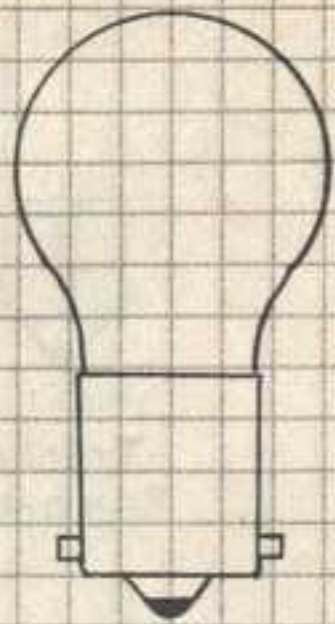
B-3-1/2
FLANGE



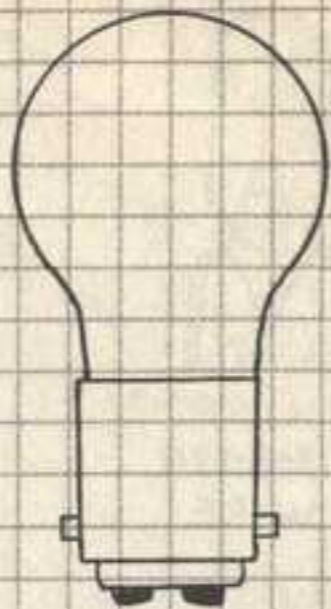
G-6 BAYONET



G-6 SCREW



S-8
SINGLE CONTACT
BAYONET



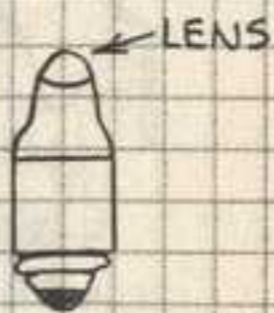
S-8
DOUBLE CONTACT
BAYONET



T-4
HALOGEN

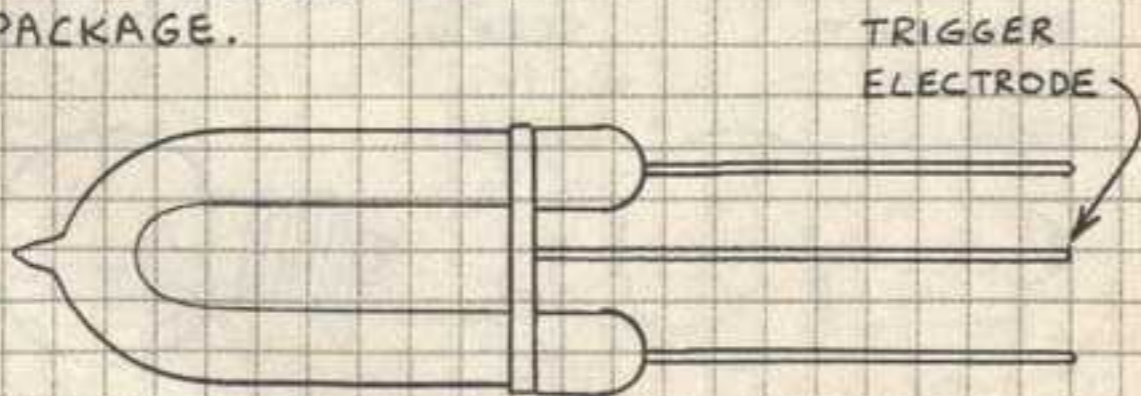


TL-3
SCREW
PRE-FOCUS



TL-2-3/4
SPECIAL
THREAD
PRE-FOCUS

CAUTION: BULB MAY
SHATTER. OBSERVE
SAFETY PRECAUTIONS
ON PACKAGE.



XENON FLASH LAMP

3. COMPONENT HANDLING

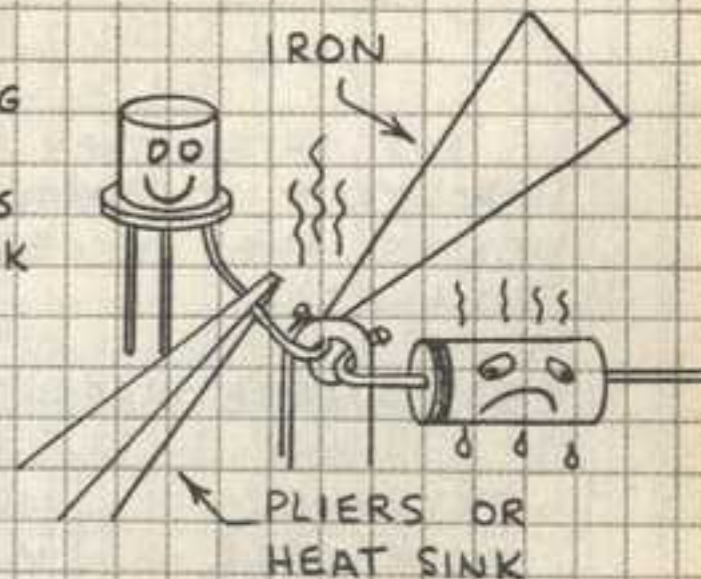
1. STORE COMPONENTS AT ROOM TEMPERATURE IN A DRY, DUST-FREE PLACE, PREFERABLY IN THE ORIGINAL PACKAGE.

2. AVOID DROPPING COMPONENTS. A FALL TO THE FLOOR SUBJECTS EVEN THE SMALLEST DEVICE TO MANY TIMES THE FORCE OF GRAVITY. A DROPPED DEVICE MAY APPEAR UNDAMAGED, BUT THE FORCE OF IMPACT MAY SEPARATE INTERNAL CONNECTIONS AND FORM TINY MICROCRACKS IN THE FUNCTIONAL PART OF THE DEVICE OR ITS PROTECTIVE COVERING OR COATING.

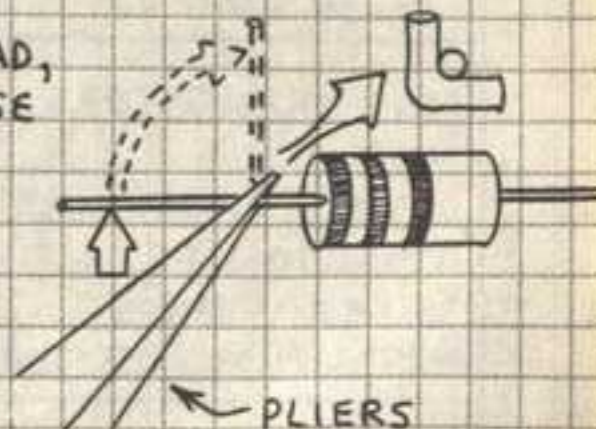


CRACKS IN THE FUNCTIONAL PART OF THE DEVICE MAY RENDER IT USELESS, ALTER ITS SPECIFICATIONS OR DEGRADE ITS PERFORMANCE. CRACKS IN THE COATING WEAKEN THE DEVICE AND PERMIT THE ENTRY OF MOISTURE.

3. AVOID OVERHEATING COMPONENTS WHEN SOLDERING OR DESOLDERING. PROTECT HEAT SENSITIVE COMPONENTS WITH A SOLDERING HEAT SINK OR PLIERS. COOL THESE COMPONENTS BY BLOWING ON THEM, BUT NOT THE CONNECTION, AFTER SOLDERING.



4. TO BEND A COMPONENT LEAD, GRASP THE LEAD WITH LONG NOSE PLIERS NEAR THE DEVICE AND THEN BEND THE LEAD WITH A FINGER. THE RADIUS OF THE BEND SHOULD EXCEED THE DIAMETER OF THE LEAD. BENDING LEADS WITHOUT PLIERS MAY FORM CRACKS BETWEEN LEAD AND DEVICE.



ELECTROSTATIC DISCHARGE

IT IS WELL KNOWN THAT MOS (METAL-OXIDE-SEMICONDUCTOR) COMPONENTS CAN BE DAMAGED BY ELECTROSTATIC DISCHARGE (ESD). WHAT IS LESS WELL KNOWN IS THAT MANY OTHER COMPONENTS CAN ALSO BE DAMAGED BY ESD. COMPONENTS SUSCEPTABLE TO DAMAGE FROM ESD ARE SOMETIMES MARKED WITH A WARNING LABEL...



... BUT OFTEN THEY ARE NOT. THEREFORE IT IS IMPORTANT TO KNOW WHICH KINDS OF COMPONENTS ARE SUSCEPTABLE TO POSSIBLE DAMAGE FROM ESD.

ESD DAMAGE THRESHOLD OF CERTAIN COMPONENTS:

EXTREMELY VULNERABLE (1 TO 1,000 V)	MODERATELY VULNERABLE (1,000 TO 5,000V)	SOMEWHAT VULNERABLE (5,000 TO 15,000V)
MOS TRANSISTORS MOS ICs μWAVE TRANSISTORS JUNCTION FETS LASER DIODES METAL FILM RESISTORS	CMOS ICs LS TTL ICs SCHOTTKY TTL ICs SCHOTTKY DIODES LINEAR ICs	TTL ICs SMALL SIGNAL DIODES AND TRANSISTORS PIEZOELECTRIC CRYSTALS

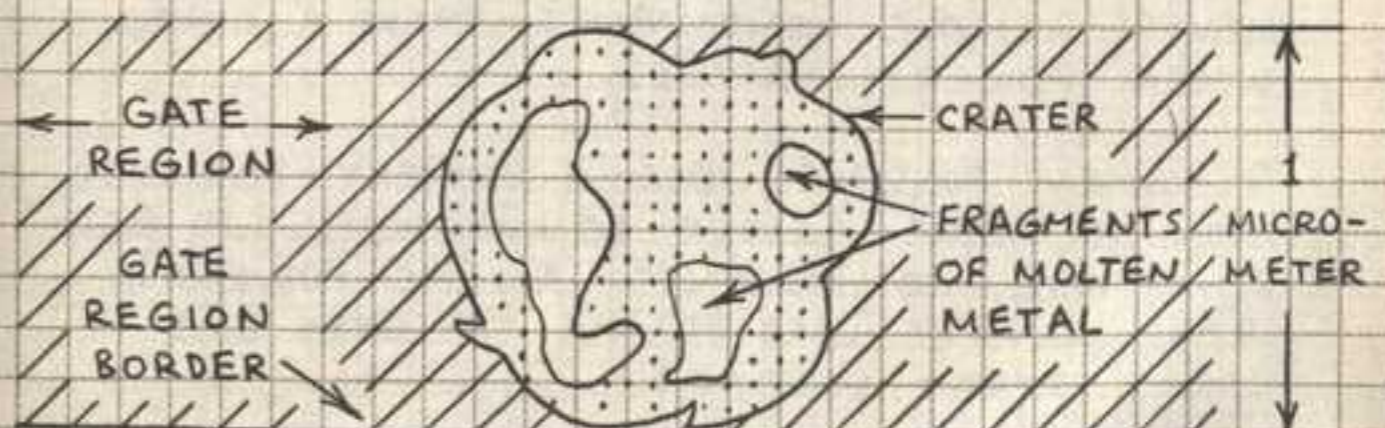
THIS IS ONLY A PARTIAL LISTING. WHEN DOUBT EXISTS, TREAT SUSPECT DEVICES AS ESD SENSITIVE.

TYPICAL ESD VOLTAGE GENERATED BY VARIOUS MATERIALS (75° F., 60% RELATIVE HUMIDITY):

MATERIAL	ACTION	VOLTAGE
RUBBER COMB	STROKE DRY HAIR	-2,500
DESK CHAIR	ROLL ACROSS PLASTIC FLOOR MAT	-2,000
POLYETHYLENE BAG	CRUMPLE IN HAND	-300
TO-92 TRANSISTORS IN POLY BAG	SHAKE BAG SEVERAL TIMES	-200
PENCIL ERASER	RUB ACROSS CIRCUIT BOARD	+100
PLASTIC PARTS BOX	RUB WITH 100% COTTON FABRIC	+100
CLEAN PLASTIC TAPE (2" WIDE)	RAPIDLY UNROLL SEVERAL INCHES	+500
ADULT MALE (RUBBER SOLE SHOES)	WALK ACROSS CARPET	-1,000

THESE MEASUREMENTS MADE WITH COMMERCIAL STATIC METER. ESD VOLTAGE IS FROM 10 TO 50 TIMES HIGHER WHEN RELATIVE HUMIDITY IS 10 TO 20%.

TYPICAL ESD DAMAGE TO GATE OF MOS FET:



ESD HANDLING PRECAUTIONS

OBSERVE THE FOLLOWING PRECAUTIONS WHEN HANDLING COMPONENTS SUSCEPTABLE TO DAMAGE FROM ESD:

1. STORE COMPONENTS IN ORIGINAL PACKAGES, ELECTRICALLY CONDUCTIVE CONTAINERS OR CONDUCTIVE PLASTIC FOAM.
2. DO NOT TOUCH LEADS OR PINS.
3. DISCHARGE THE STATIC CHARGE ON YOUR BODY, BEFORE TOUCHING COMPONENTS, BY TOUCHING A GROUNDED METAL SURFACE (CABINET, APPLIANCE, ETC.).
4. PLACE COMPONENTS ON AN ALUMINUM FOIL SHEET OR TRAY OR ON CONDUCTIVE FOAM AFTER REMOVING THEM FROM THEIR CONTAINERS PRIOR TO INSTALLING THEM.
5. DO NOT SLIDE COMPONENTS ACROSS A WORK BENCH OR OTHER SURFACE.
6. KEEP STATIC-GENERATING MATERIALS (e.g. PLASTIC, CELLOPHANE, CANDY WRAPPERS, PAPER, CARDBOARD, ETC.) AWAY FROM WORK AREA.
7. NEVER ALLOW CLOTHING TO MAKE CONTACT WITH COMPONENTS.
8. NEVER INSTALL ESD-SENSITIVE COMPONENTS IN A CIRCUIT WHEN POWER IS APPLIED, AND NEVER REMOVE COMPONENTS FROM A CIRCUIT WHEN POWER IS APPLIED.
9. WHEN POSSIBLE, USE A BATTERY-POWERED IRON TO MAKE SOLDER CONNECTIONS TO ESD-SENSITIVE COMPONENTS. AN AC-POWERED IRON MAY BE USED IF THE TIP DOES NOT CARRY STRAY VOLTAGE.

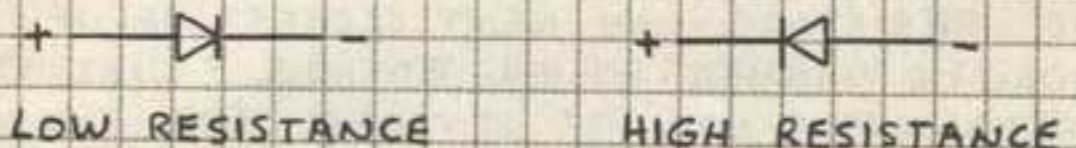
4. COMPONENT TESTING

ALTHOUGH COMPONENTS CONNECTED IN A CIRCUIT CAN BE TESTED, BETTER RESULTS ARE OBTAINED BY TESTING COMPONENTS NOT INSTALLED IN A CIRCUIT. SUGGESTED METHODS INCLUDE:

RESISTORS - MEASURE RESISTANCE WITH A MULTIMETER.

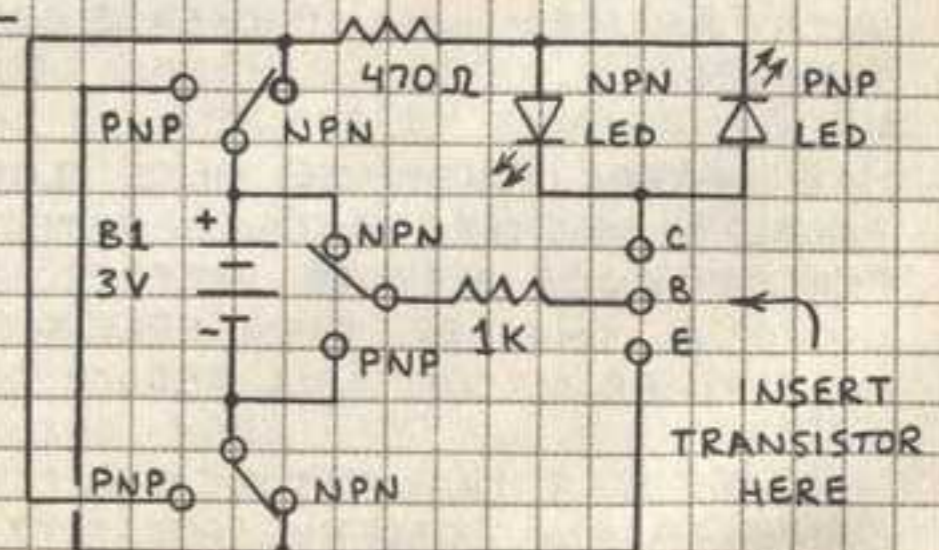
CAPACITORS - DISCHARGE CAPACITOR BY SHORTING LEADS. THEN CONNECT AN ANALOG MULTIMETER SET TO HIGHEST RESISTANCE RANGE ACROSS CAPACITOR. (BE SURE TO OBSERVE POLARITY OF ELECTROLYTIC CAPACITORS.) METER NEEDLE SHOULD MOVE TO RIGHT AND THEN FALL BACK TO INITIAL POINT. NEEDLE WILL MOVE MORE WITH LARGE VALUE CAPACITORS. IT MAY NOT MOVE WHEN VALUE IS BELOW $0.01 \mu\text{F}$. IF NEEDLE REMAINS AT OR NEAR RIGHT SIDE OF METER, THE CAPACITOR IS SHORTED. IF NEEDLE FAILS TO MOVE, VALUE OF CAPACITOR IS BELOW $0.01 \mu\text{F}$ OR CAPACITOR IS OPEN.

DIODES - USE A MULTIMETER. RESISTANCE SHOULD BE LOW IN FORWARD DIRECTION AND HIGH IN REVERSE DIRECTION.



TRANSISTORS -

THIS CIRCUIT PROVIDES A "GO/NO-GO" TEST FOR SWITCHING TRANSISTORS. RESPECTIVE LED GLOWS IF TRANSISTOR IS GOOD.



5. CIRCUIT DESIGN TIPS

1. USE EXISTING CIRCUITS AS BUILDING BLOCKS TO FORM ENTIRELY NEW CIRCUITS.

2. ALWAYS REVIEW THE MANUFACTURER'S SPECIFICATIONS FOR ACTIVE DEVICES (TRANSISTORS, INTEGRATED CIRCUITS, ETC.) BEFORE USING THEM IN A CIRCUIT. PAY PARTICULAR ATTENTION TO OPERATING VOLTAGES, INPUT AND OUTPUT REQUIREMENTS AND POTENTIAL PROBLEMS (SUCH AS OSCILLATION, NOISE, LATCHUP, ETC.).

3. BYPASS CAPACITORS, WHILE NOT ALWAYS REQUIRED, CAN PREVENT NOISE AND OSCILLATION IN ANALOG CIRCUITS AND FALSE TRIGGERING AND MEMORY LOSS IN DIGITAL CIRCUITS. IN ANALOG CIRCUITS PLACE A $0.1\mu\text{F}$ AND $1.0\mu\text{F}$ CAPACITOR ACROSS BATTERY LEADS WHERE THEY ENTER THE CIRCUIT BOARD. USE $0.1\mu\text{F}$ CAPACITORS FROM POWER SUPPLY PINS OF OPERATIONAL AMPLIFIERS TO GROUND. IN DIGITAL CIRCUITS PLACE A $0.1\mu\text{F}$ CAPACITOR ACROSS THE POWER SUPPLY PINS OF EACH CHIP.

4. COMPONENT SUBSTITUTION IS GENERALLY OKAY. HERE ARE SOME GENERAL GUIDELINES:

a. RESISTORS—USE NEXT CLOSEST VALUE. USE EQUAL OR HIGHER POWER RATING. CIRCUIT PERFORMANCE MAY BE ALTERED. FOR EXAMPLE, A SMALLER THAN SPECIFIED RESISTOR IN SERIES WITH AN LED WILL INCREASE CURRENT THROUGH THE LED.

b. CAPACITORS—USE NEXT CLOSEST VALUE. USE EQUAL OR HIGHER VOLTAGE RATING. CIRCUIT PERFORMANCE MAY BE ALTERED. FOR EXAMPLE, USING A SMALLER THAN SPECIFIED CAPACITOR IN A TIMER CIRCUIT WILL REDUCE THE TIMING CYCLE.

c. BIPOLAR TRANSISTORS—SUBSTITUTE WITHIN SAME FAMILY. OBSERVE POLARITY AND POWER.

6. CIRCUIT LAYOUT TIPS

1. CONNECTIONS BETWEEN COMPONENTS SHOULD BE AS SHORT AS POSSIBLE IN HIGH-SPEED DIGITAL CIRCUITS AND HIGH-FREQUENCY ANALOG CIRCUITS.

2. THE INPUT AND OUTPUT SECTIONS OF HIGH-GAIN AMPLIFIERS SHOULD BE PHYSICALLY ISOLATED FROM ONE ANOTHER. OTHERWISE INDUCTANCE BETWEEN THE INPUT AND OUTPUT WIRING MAY CAUSE A PORTION OF THE OUTPUT SIGNAL TO BE FED BACK TO THE INPUT. THE RESULT WILL BE SEVERE OSCILLATION.

3. POWER TRANSISTORS, ICs AND SOME OTHER COMPONENTS THAT BECOME WARM DURING OPERATION OFTEN PERFORM BETTER WITH A HEAT SINK. THEREFORE, LEAVE SPACE AROUND SUCH COMPONENTS FOR A HEAT SINK. AVOID PLACING HEAT SENSITIVE COMPONENTS NEAR COMPONENTS THAT MAY BECOME HOT.

4. USE INSULATED WIRE FOR INTERCONNECTIONS. INSULATE EXPOSED COMPONENT LEADS MOUNTED CLOSE TO OTHER EXPOSED LEADS OR HARDWARE.

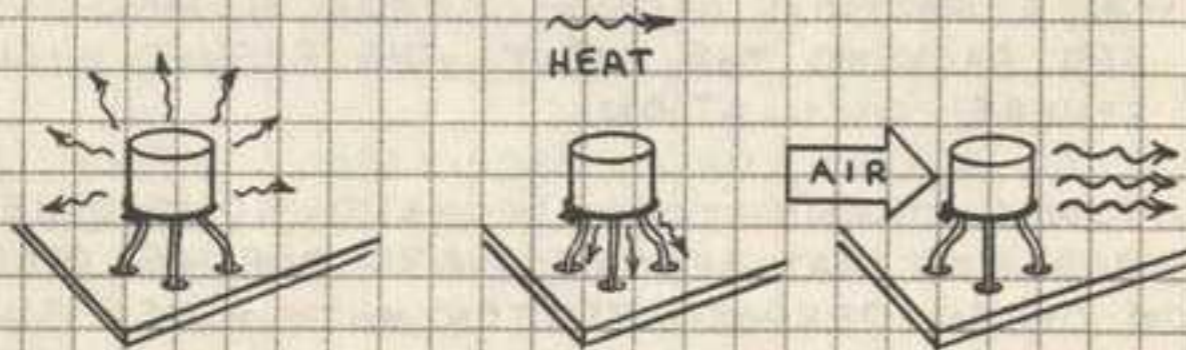
5. ALL LEADS THAT CARRY HOUSEHOLD LINE CURRENT MUST BE INSULATED.

6. CIRCUITS IN WHICH A CURRENT FLOW IS SUDDENLY SWITCHED OFF OR ON MAY EMIT RADIO FREQUENCY RADIATION THAT CAN CAUSE SIGNIFICANT INTERFERENCE IN NEARBY RADIOS AND TELEVISIONS. RADIO FREQUENCY EMISSION CAN BE REDUCED BY ENCLOSING THE ENTIRE CIRCUIT IN A GROUNDED METAL ENCLOSURE. EXTERNAL CONNECTIONS TO OR FROM THE ENCLOSURE SHOULD BE MADE WITH SHIELDED CABLES.

7. USE STRANDED WIRE FOR ALL CONNECTIONS THAT ARE NOT FIXED IN POSITION (BATTERY CLIP LEADS, ETC.). USE SOLID WIRE FOR FIXED CONNECTIONS.

7. HEATSINKING

HEAT IS PRODUCED WHEN AN ELECTRICAL CURRENT FLOWS THROUGH A COMPONENT OR A CONDUCTOR. MOST COMPONENTS ARE SPECIFIED FOR OPERATION WITHIN A GIVEN TEMPERATURE RANGE. A HEATSINK WILL HELP REMOVE EXCESS HEAT FROM A COMPONENT. THERE ARE THREE PRIMARY MEANS BY WHICH HEAT LEAVES A COMPONENT:



RADIATION

HEAT IS RADIATED INTO SPACE AS ELECTROMAGNETIC RADIATION.

CONDUCTION

HEAT IS CONDUCTED AWAY THROUGH DEVICE LEADS.

CONVECTION

HEAT IS CONDUCTED INTO SURROUNDING AIR AND WASTED AWAY.

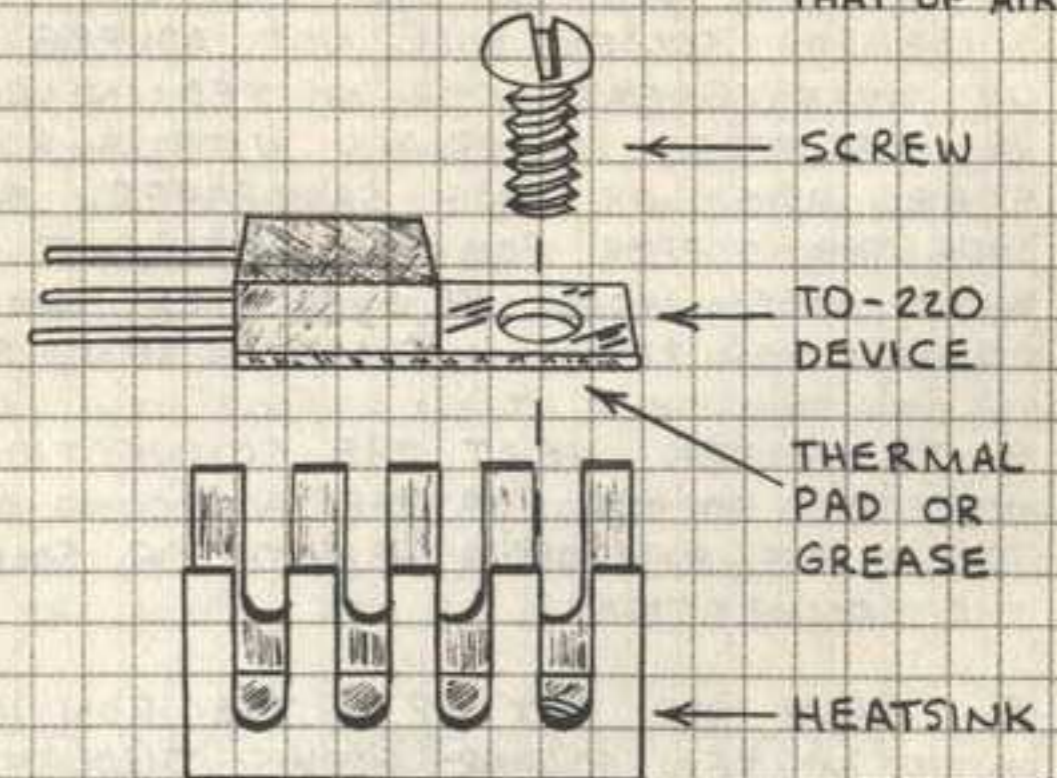
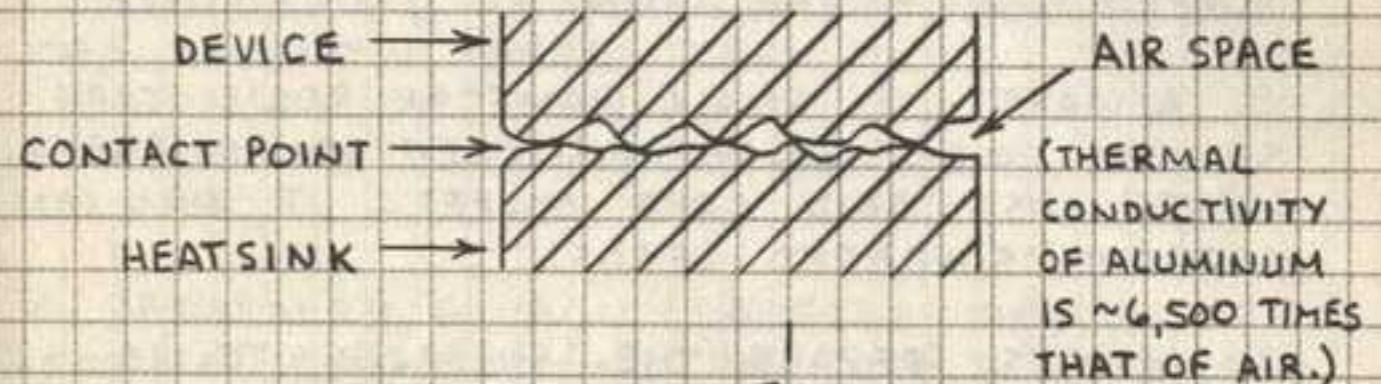
HEATSINKS ARE METAL STRUCTURES THAT IMPROVE THE EFFICIENCY WITH WHICH HEAT LEAVES A COMPONENT. THE THERMAL CONDUCTIVITY OF VARIOUS MATERIALS IS COMPARED BELOW:

MATERIAL	CONDUCTIVITY (RELATIVE TO SILVER)
DIAMOND (II)	5.4
WATER	1.4
SILVER	1.0
COPPER	.93
GOLD	.74
ALUMINUM	.56
NICKEL	.21
IRON	.19
TIN	.16
MICA	.0014
AIR	.000085

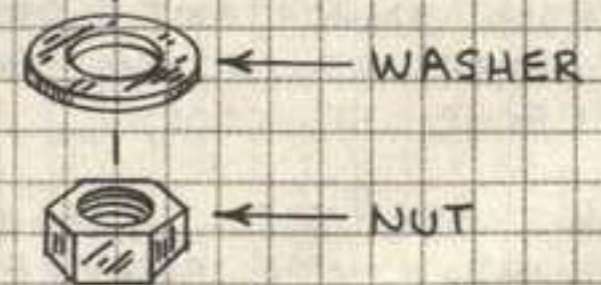
ALUMINUM IS THE MOST COMMON HEAT SINK MATERIAL. NOTE THAT COPPER IS NEARLY AS GOOD AS SILVER.

A HEATSINK WILL PERMIT A DEVICE SUCH AS A POWER SEMICONDUCTOR TO DISSIPATE AS MUCH AS TEN TIMES OR MORE HEAT THAN OTHERWISE. A HEATSINK WILL ALSO INCREASE A DEVICE'S RELIABILITY AND LIFETIME.

THE INTERFACE BETWEEN A HEATSINK AND A COMPONENT IS NOT PERFECTLY FLAT. THEREFORE A THERMALLY CONDUCTIVE PAD OR FILM OF SILICONE GREASE MUST BE PLACED BETWEEN THE HEATSINK AND THE DEVICE:



TYPICAL HEATSINK INSTALLATION



8. SOLDERING

FOLLOW THESE STEPS TO PRODUCE SUCCESSFUL SOLDER CONNECTIONS:

1. ELECTRONIC COMPONENTS AND CIRCUIT BOARDS CAN BE DAMAGED BY EXCESSIVE HEAT. THEREFORE, WHEN SOLDERING COMPONENTS TO A BOARD, ALWAYS USE A LOW-WATTAGE SOLDERING IRON (15 TO 40 WATTS). BE SURE TO TIN THE TIP ACCORDING TO THE INSTRUCTIONS SUPPLIED WITH THE IRON.

2. ALWAYS USE SMALL DIAMETER ROSIN CORE SOLDER WHEN SOLDERING ELECTRONIC PARTS. NEVER USE ACID CORE SOLDER. IT WILL CORRODE SOLDERED LEADS.

3. ALWAYS PREPARE THE SURFACES TO BE SOLDERED. SOLDER WILL NOT ADHERE TO PAINT, OIL, WAX, GREASE OR MELTED INSULATION. REMOVE THESE MATERIALS WITH A SOLVENT, STEEL WOOL OR FINE SANDPAPER. ALWAYS BUFF THE COPPER FOIL OF A CIRCUIT BOARD WITH STEEL WOOL. BE SURE THERE IS A GOOD CONNECTION BETWEEN SURFACES BEING SOLDERED.

4. TO SOLDER, HEAT THE CONNECTION FIRST, NOT THE SOLDER. AFTER A SECOND OR TWO TOUCH THE END OF A LENGTH OF SOLDER TO THE CONNECTION.

5. LEAVE THE HOT TIP OF THE IRON IN PLACE UNTIL MOLTEN SOLDER FLOWS THROUGH AND AROUND THE CONNECTION. THEN REMOVE THE IRON. IMPORTANT: DO NOT APPLY TOO MUCH SOLDER OR ALLOW THE CONNECTION TO MOVE BEFORE IT COOLS.

6. KEEP THE TIP OF THE IRON CLEAN AND SHINY. WIPE AWAY EXCESS SOLDER AND DEBRIS WITH A DAMP SPONGE OR CLOTH.

DESOLDERING

A COMPONENT CAN BE REMOVED FROM A BOARD BY HEATING ITS CONNECTIONS WITH A HOT SOLDERING IRON UNTIL THE SOLDER MELTS AND THEN PULLING ON THE LEADS UNTIL THE COMPONENT IS FREE. UNLESS SPECIALIZED DESOLDERING TIPS ARE USED, THIS METHOD IS SUITABLE ONLY FOR INDIVIDUAL WIRES OR COMPONENTS WITH TWO LEADS. TO REMOVE COMPONENTS WITH MULTIPLE LEADS OR PINS, A DESOLDERING IRON OR TOOL SHOULD BE USED. FOLLOW THESE STEPS:

1. HEAT THE CONNECTION UNTIL THE SOLDER MELTS.

2. DESOLDERING IRON - SQUEEZE BULB BEFORE HEATING CONNECTION; RELEASE BULB WHEN SOLDER MELTS.

DESOLDERING TOOL - SQUEEZE BULB OR ACTUATE PLUNGER. WHEN SOLDER MELTS, TOUCH TIP OF TOOL TO SOLDER AND RELEASE BULB OR PLUNGER. REPEAT IF NECESSARY.

DESOLDERING BRAID - PLACE BRAID OVER SOLDER CONNECTION. PRESS BRAID AGAINST CONNECTION WITH TIP OF IRON UNTIL SOLDER MELTS AND FLOWS INTO BRAID.

3. REPAIR BROKEN AND SEPARATED FOIL PATTERN. SPLICES CAN BE MADE BY SOLDERING SHORT LENGTHS OF WIRE ACROSS BREAKS.

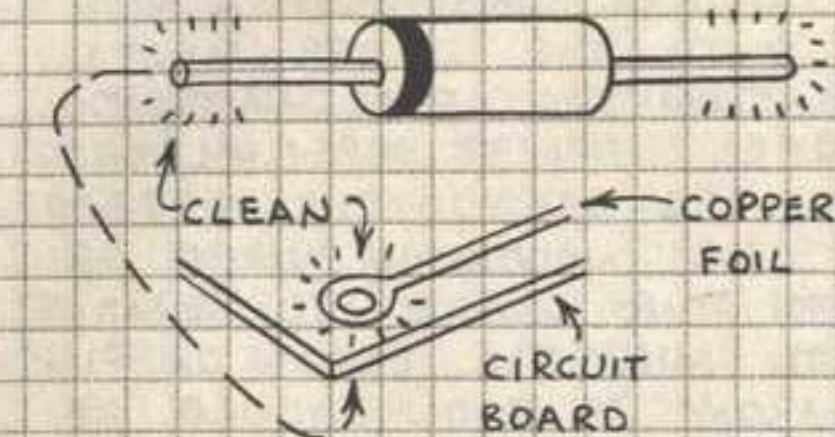
SOLDERING PRECAUTIONS

1. A HOT SOLDERING IRON CAN CAUSE A FIRE OR BURN A FINGER. UNPLUG AN UNUSED SOLDERING IRON!

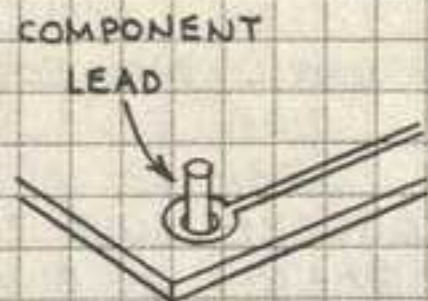
2. AVOID BREATHING SMOKE AND VAPOR FROM HOT SOLDER. SOLDER IN A WELL-VENTILATED AREA.

3. SUPERVISE CHILDREN WHO USE SOLDERING IRONS.

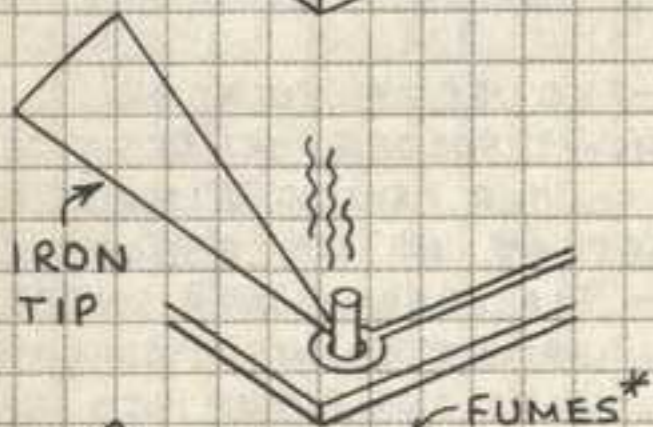
HOW TO SOLDER



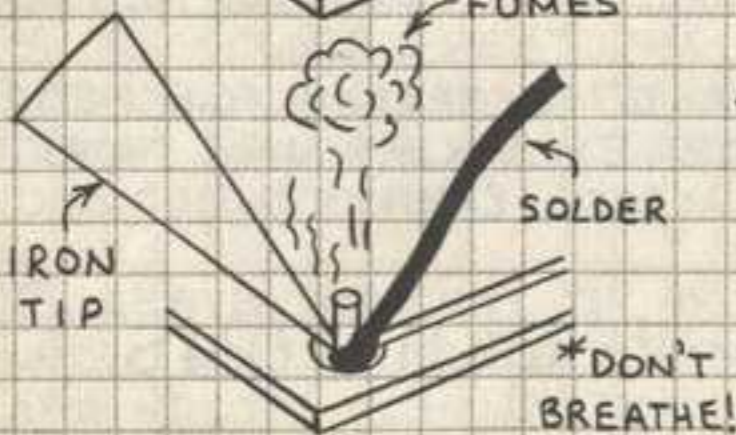
1. PREPARE THE SURFACES TO BE SOLDERED BY REMOVING ALL OXIDATION, GREASE, ADHESIVE AND PARTICLES.



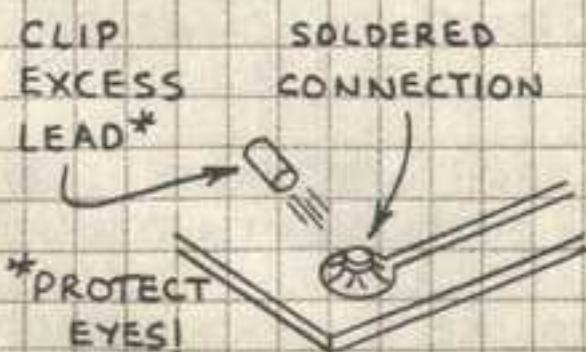
2. SECURE IN FIXED POSITION THE SURFACES TO BE SOLDERED TOGETHER.



3. HEAT THE SURFACES TO BE SOLDERED FOR A FEW SECONDS WITH A HEATED SOLDERING IRON. HOLD THE IRON IN PLACE AND ...

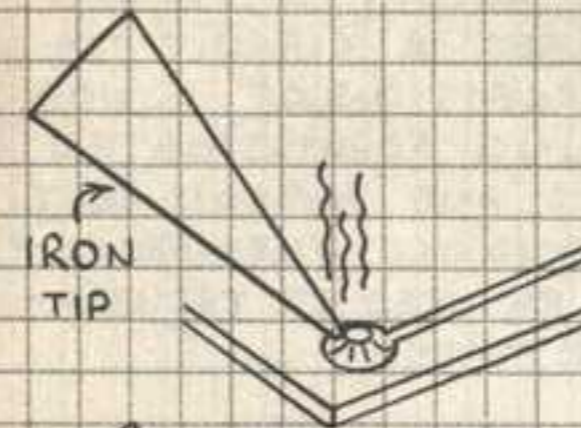


4. ... TOUCH THE END OF A LENGTH OF ROSIN CORE SOLDER TO THE HEATED JUNCTION. ALLOW SOLDER TO MELT AND FLOW THROUGH AND OVER THE JUNCTION.

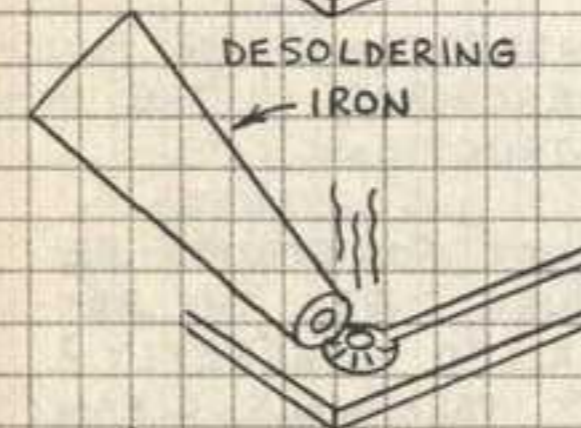


5. REMOVE THE IRON AND SOLDER AND ALLOW THE JUNCTION TO COOL BEFORE MOVING THE BOARD.

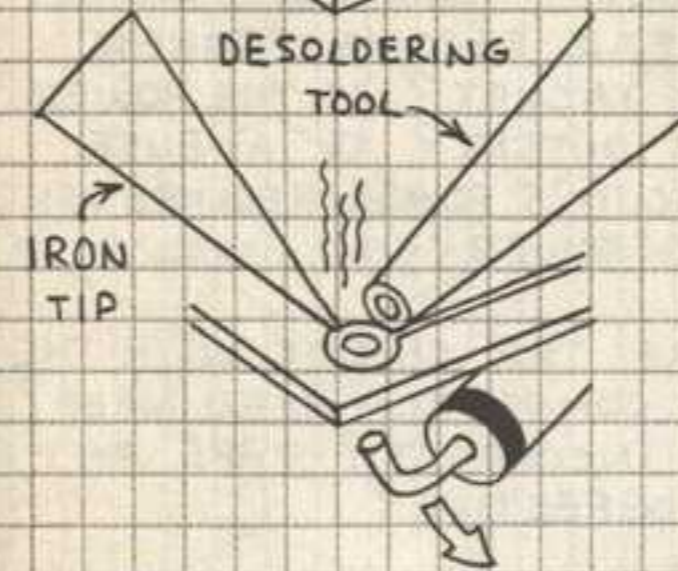
HOW TO DESOLDER



1. HEAT THE JUNCTION TO BE DESOLDERED WITH A HEATED SOLDERING IRON UNTIL THE SOLDER MELTS OR ...



2. ... HEAT THE JUNCTION WITH A HEATED DESOLDERING IRON UNTIL THE SOLDER MELTS.



3. SQUEEZE THE BULB OF A DESOLDERING TOOL (OR IRON), PLACE TIP OF TOOL (OR IRON) AS CLOSE AS POSSIBLE TO SOLDER AND RELEASE BULB. SOLDER WILL BE SLURPED UP INTO TOOL. COMPONENT LEAD CAN NOW BE REMOVED. NOTE THAT LEAD CAN BE REMOVED BY PULLING ON IT WHEN SOLDER IS MOLTEN.



4. CLEAN TERMINAL.



5. REPAIR BROKEN FOIL PATTERN WITH WIRE BRIDGE. SOLDER IN PLACE.

9. TROUBLESHOOTING

TROUBLESHOOTING IS THE PROCESS OF IDENTIFYING THE PROBLEM THAT CAUSES A CIRCUIT TO MALFUNCTION. WITH THE EXCEPTION OF MINOR PROBLEMS, TROUBLESHOOTING SOPHISTICATED SYSTEMS LIKE COMPUTERS AND VCRS IS BEST LEFT TO QUALIFIED TECHNICIANS. THE PROCEDURES LISTED BELOW CAN BE USED TO TROUBLESHOOT DO-IT-YOURSELF PROJECTS:

1. BE SURE YOU FULLY UNDERSTAND THE FUNCTION OF THE CIRCUIT AS DESCRIBED IN THE INSTRUCTIONS FOR ITS CONSTRUCTION.

2. IF THE CIRCUIT DOES NOT FUNCTION, BE SURE IT IS RECEIVING POWER. ARE THE BATTERIES FRESH AND INSTALLED CORRECTLY? ARE THE BATTERY HOLDER'S TERMINALS CLEAN? HAS A BATTERY CLIP LEAD BECOME BROKEN INSIDE ITS INSULATING JACKET? IS THE POWER CORD INSERTED IN AN OUTLET? IS A FUSE BLOWN? DOES THE CIRCUIT'S POWER REQUIREMENT EXCEED THE AVAILABLE POWER?

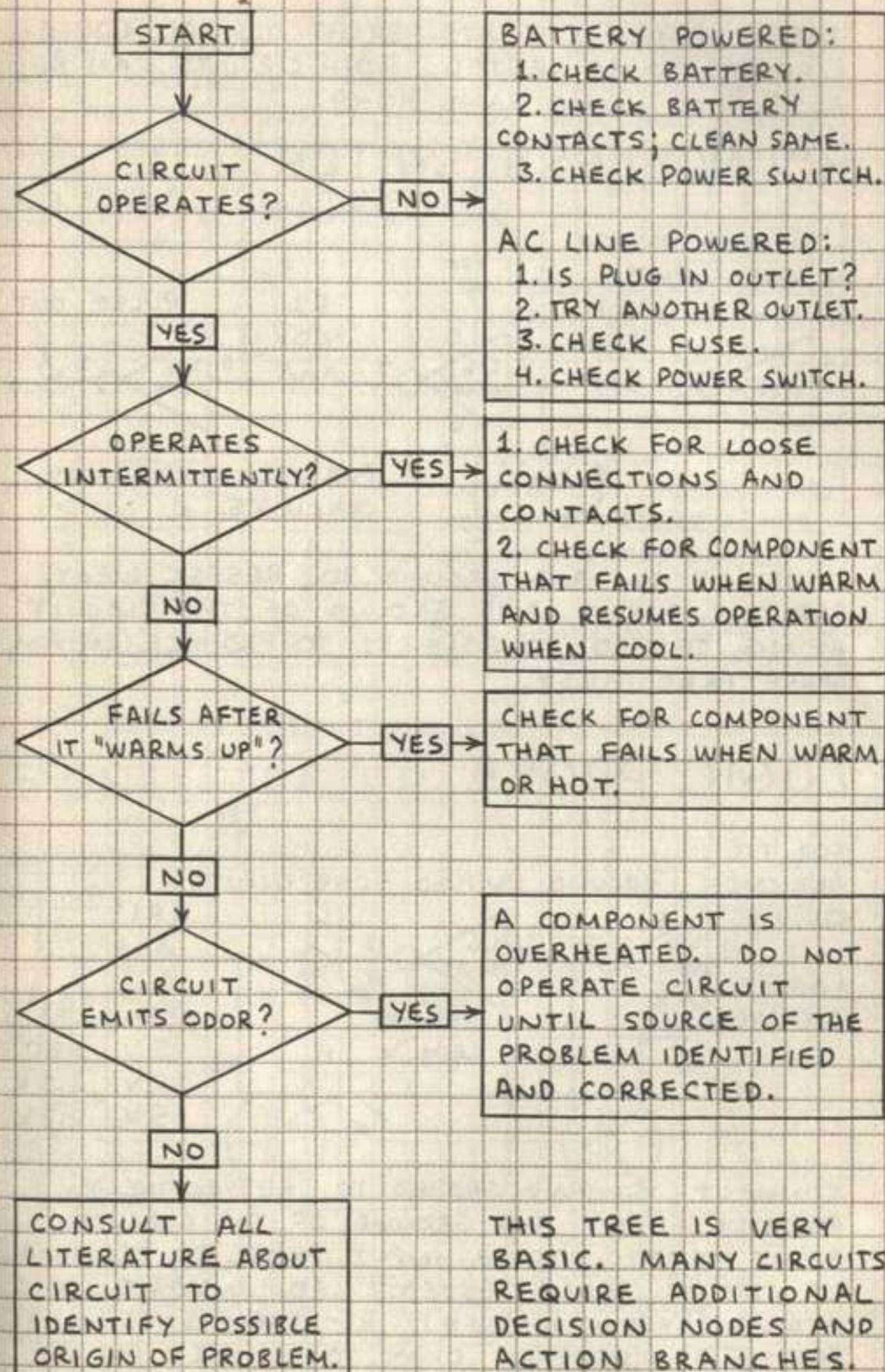
3. CAREFULLY COMPARE THE CIRCUIT WITH THE SCHEMATIC. HAS EVERY CONNECTION BEEN MADE? ARE ANY CONNECTIONS INCORRECT? ARE ANY SOLDER CONNECTIONS DEFECTIVE?

4. ARE POLARITY-SENSITIVE COMPONENTS LIKE ELECTROLYTIC CAPACITORS, DIODES AND TRANSISTORS INSTALLED CORRECTLY? ARE INTEGRATED CIRCUITS INSTALLED CORRECTLY?

5. ARE UNUSED INPUTS OF DIGITAL LOGIC CHIPS CONNECTED TO GROUND OR ONE SIDE OF THE POWER SUPPLY?

6. FOR BEST RESULTS FOLLOW AN ORGANIZED, LOGICAL APPROACH TO TROUBLESHOOTING. THE TROUBLESHOOTING TREE ON THE FACING PAGE ILLUSTRATES THIS APPROACH.

TROUBLESHOOTING TREE

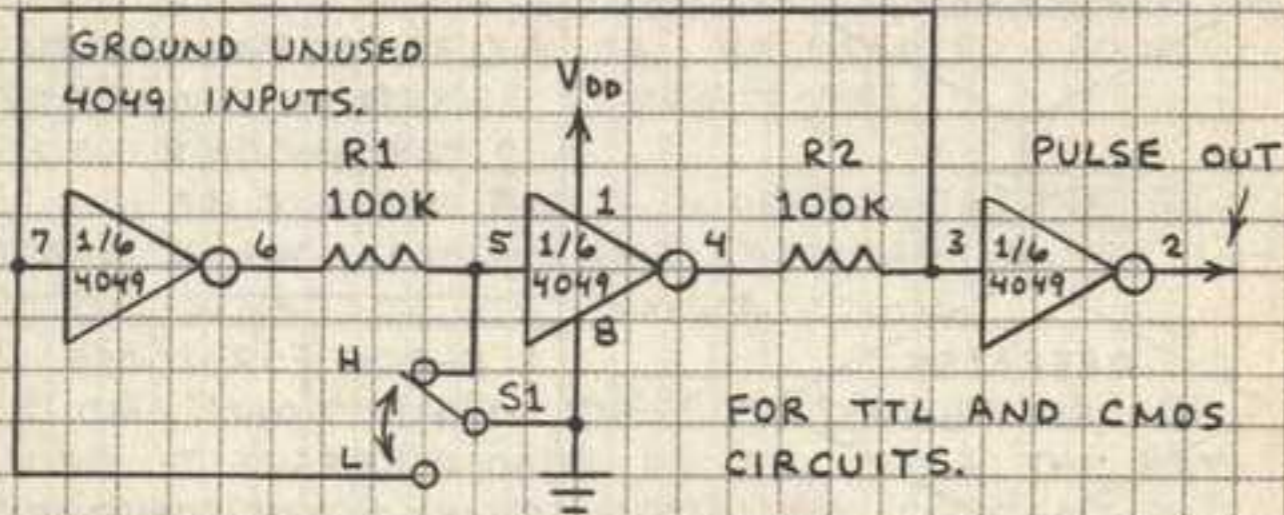


THIS TREE IS VERY BASIC. MANY CIRCUITS REQUIRE ADDITIONAL DECISION NODES AND ACTION BRANCHES.

DIGITAL TROUBLESHOOTING

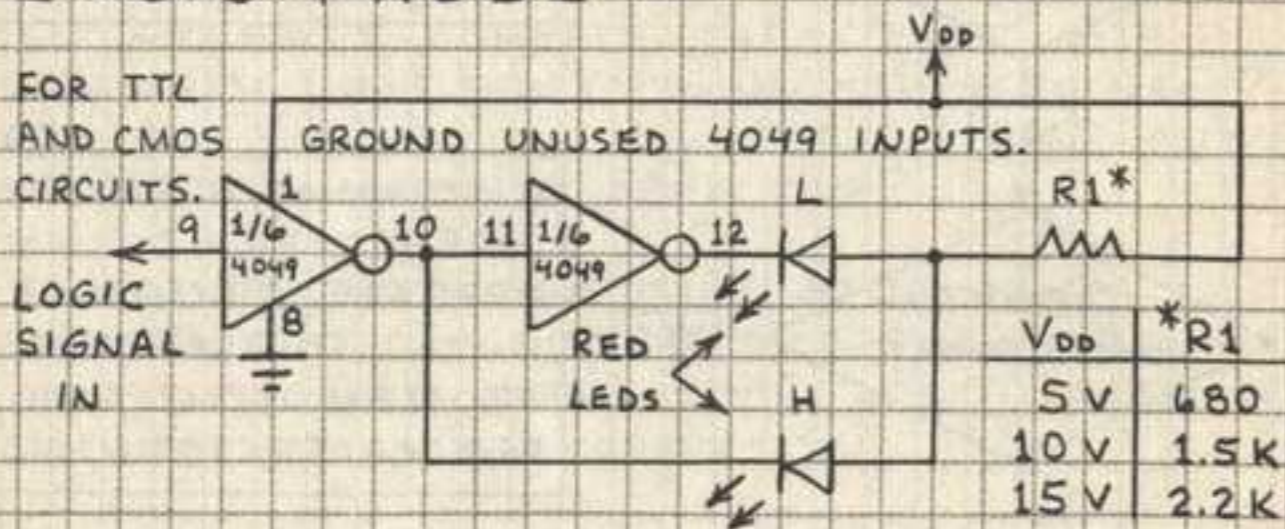
THESE SIMPLE CIRCUITS PERMIT DIGITAL LOGIC CIRCUITS TO BE TESTED. BOTH CIRCUITS CAN BE ASSEMBLED USING SAME 4049.

BOUNCELESS SWITCH



CONNECT V_{DD} AND GROUND TO, RESPECTIVELY, POSITIVE SUPPLY AND GROUND OF THE CIRCUIT BEING TESTED. TOGGLE S_1 TO PRODUCE CLEAN, NOISE-FREE PULSE.

LOGIC PROBE

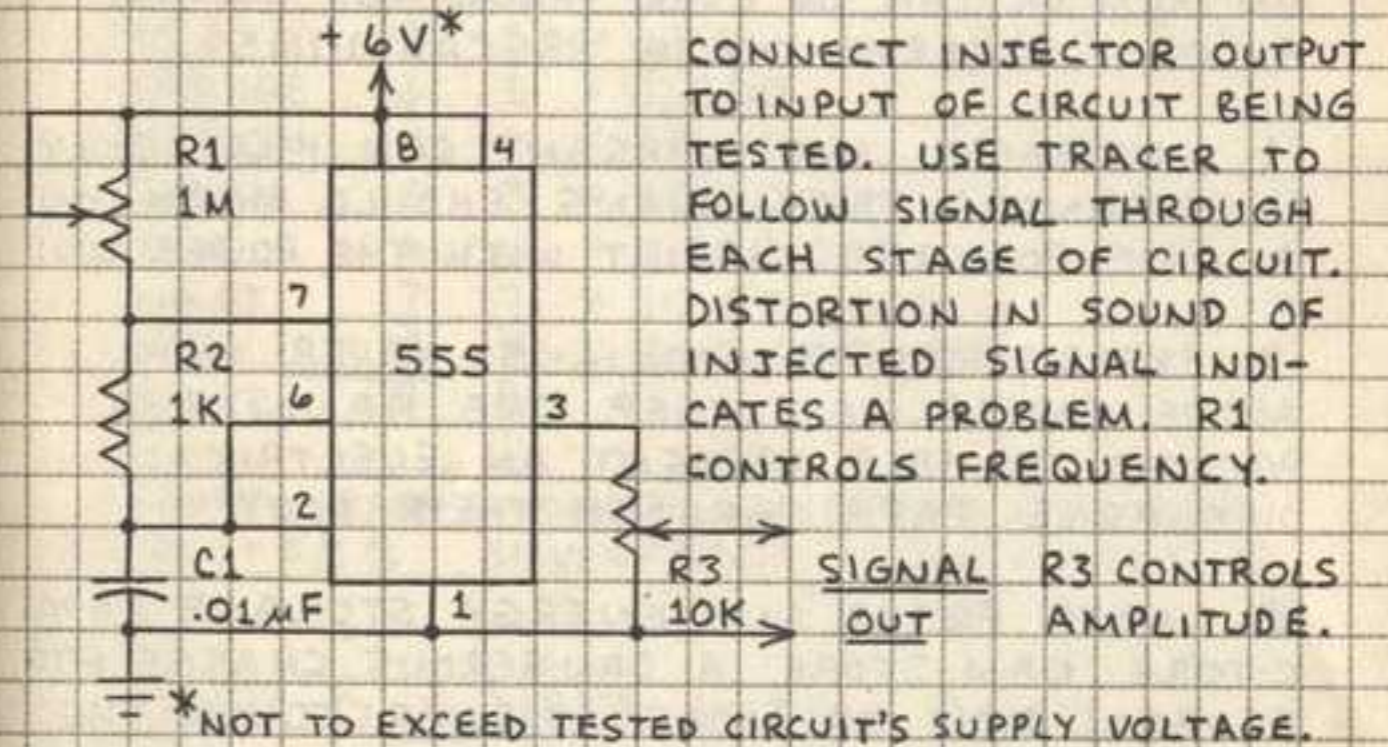


CONNECT V_{DD} AND GROUND TO, RESPECTIVELY, POSITIVE SUPPLY AND GROUND OF THE CIRCUIT BEING TESTED. TOUCH INPUT PROBE TO TERMINAL OF CIRCUIT BEING TESTED. LEDs INDICATE LOGIC STATUS (L=LOW; H=HIGH). R_1 - TABLE GIVES VALUES FOR ~ 5 mA CURRENT. OKAY TO USE 2.2K FOR ALL VALUES OF V_{DD} IF LEDs ARE SUPER-BRIGHT UNITS.

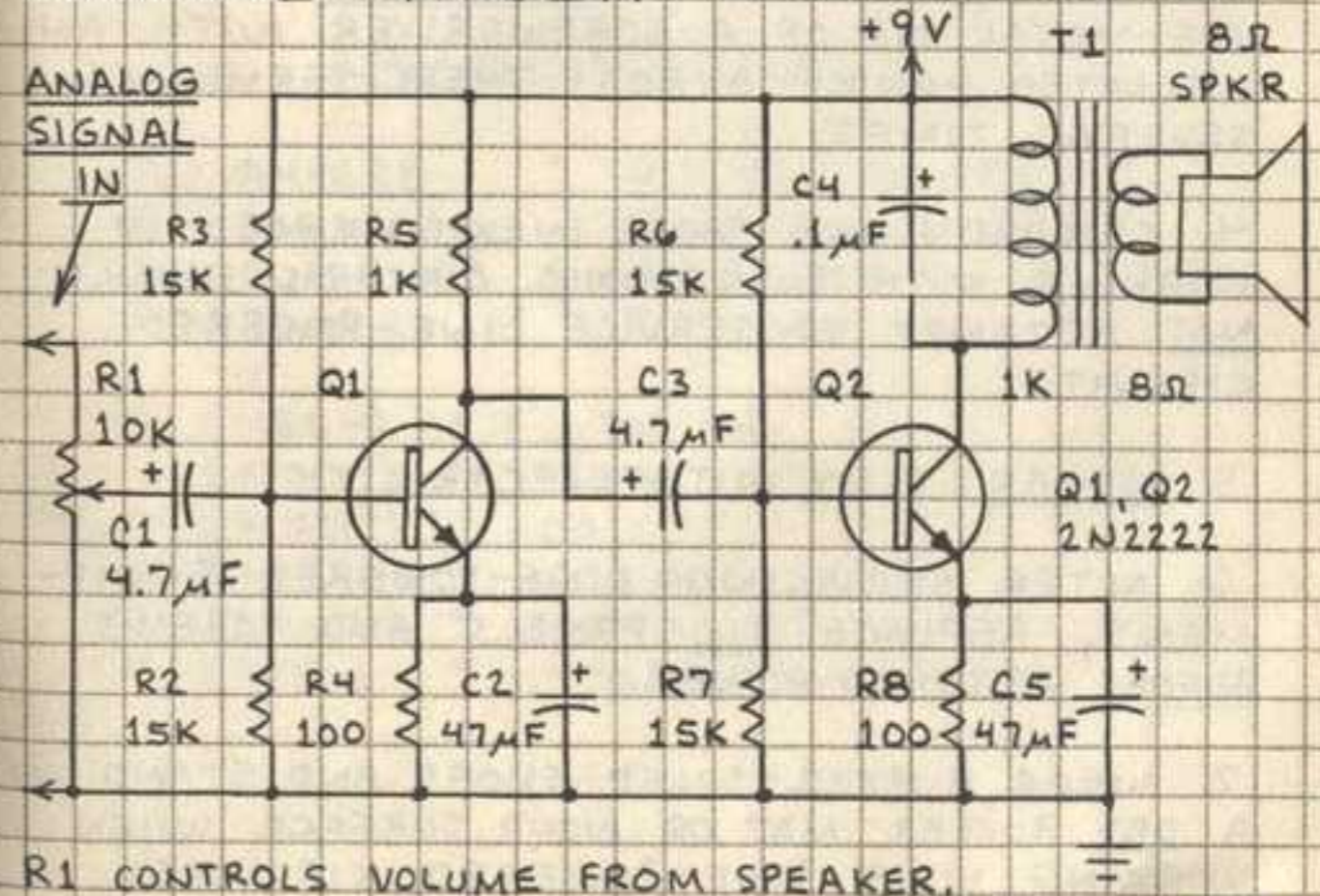
ANALOG TROUBLESHOOTING

THESE CIRCUITS CAN BE USED TO TROUBLESHOOT AUDIO AMPLIFIERS AND TO DETERMINE THE CONTINUITY OF MULTI-CONDUCTOR WIRE AND CABLE. (SEE SAFETY PRECAUTIONS ON FOLLOWING PAGE.)

SIGNAL INJECTOR



SIGNAL TRACER



10. SAFETY PRECAUTIONS

ELECTRONIC CIRCUITS POWERED BY HOUSEHOLD LINE CURRENT AND SOME BATTERY-POWERED CIRCUITS CAN CAUSE DANGEROUS ELECTRICAL SHOCKS. AN ELECTRICAL SHOCK CAN CAUSE HEART FAILURE. A SHOCK CAN ALSO CAUSE A VIOLENT MUSCLE REFLEX THAT MAY INJURE AN ARM OR LEG OR EVEN THROW YOU TO THE FLOOR. OBSERVE THESE PRECAUTIONS:

1. HOUSEHOLD LINE CURRENT CAN KILL! ONLY EXPERIENCED TECHNICIANS SHOULD WORK ON A LINE-POWERED CIRCUIT WITH THE POWER ON!

2. EXPERIENCED TECHNICIANS NEVER WORK ALONE AND ALWAYS KEEP ONE HAND IN A POCKET TO HELP PREVENT AN ELECTRICAL DISCHARGE PATH THROUGH THEIR BODY.

3. LARGE FILTER AND ENERGY STORAGE CAPACITORS CAN STORE A DANGEROUS CHARGE FOR SEVERAL DAYS OR MORE! NEVER TOUCH THE TERMINALS OF SUCH CAPACITORS! CAPACITORS CAN BE DISCHARGED BY CAREFULLY TOUCHING THE METAL TIP OF A SCREWDRIVER WITH AN INSULATED HANDLE ACROSS THEIR TERMINALS SEVERAL TIMES.

4. CHILDREN AND THOSE INEXPERIENCED IN WORKING WITH ELECTRONIC CIRCUITS SHOULD NOT ATTEMPT TO SERVICE LINE-POWERED CIRCUITS!

5. NEVER PLAY WITH ELECTRICITY!

6. AFTER SERVICING LINE-POWERED EQUIPMENT, REPLACE ALL PANELS AND SCREWS BEFORE APPLYING POWER.

7. WEAR RUBBER-SOLED SHOES AND STAND ON A DRY RUBBER MAT OR WOOD SURFACE WHEN WORKING WITH LINE-POWERED CIRCUITS.

RESISTOR COLOR CODE



BLACK	0	0	x 1
BROWN	1	1	x 10
RED	2	2	x 100
ORANGE	3	3	x 1,000
YELLOW	4	4	x 10,000
GREEN	5	5	x 100,000
BLUE	6	6	x 1,000,000
VIOLET	7	7	x 10,000,000
GRAY	8	8	x 100,000,000
WHITE	9	9	—

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

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

ABBREVIATIONS

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

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