Engineer's Mini-Notebook

Schematic Symbols, Device Packages, Design and Testing

Forrest M. Mims III
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
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CONTRIBUTING EDITOR
MODERN ELECTRONICS

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A SILICONCONCEPTS™ BOOK
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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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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

AIR CORE  POWDERED IRON CORE  IRON CORE  VARIABLE CORE

TRANSFORMERS

AIR CORE  IRON CORE  VARIABLE CORE

AUTO  TYPICAL INPUT  TYPICAL OUTPUT

TYPICAL POWER TRANSFORMER (TAPPED)

AC VOLTAGE IN  AC LOW VOLTAGE OUT

AC VOLTAGE OUT  TAP
POWER SUPPLIES

SINGLE CELL  MULTIPLE CELL BATTERY

+———-  +———-

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

FILAMENT CATHODE GRID PLATE
MICROPHONES

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

SPEAKERS AND HEADSETS

SINGLE DOUBLE STEREO HANDSET

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

SPST SWITCH  DPST SWITCH
117-VOLT NON-POLARIZED PLUG

117-VOLT NON-POLARIZED SOCKET

117-VOLT POLARIZED PLUG

117-VOLT POLARIZED SOCKET

234-VOLT PLUG

234-VOLT SOCKET

GROUND

HOT

GROUND

NEUTRAL

NEUTRAL

NEUTRAL
SWITCHES

SINGLE POLE SINGLE THROW (SPST)

SINGLE POLE DOUBLE THROW (SPDT)

DOUBLE POLE SINGLE THROW (DPST)

DOUBLE POLE DOUBLE THROW (DPDT)

USE DASHED LINE TO CONNECT TWO HALVES OF SAME SWITCH SEPARATED IN A CIRCUIT DIAGRAM.

MULTIPLE CONTACT ROTARY

2-DECK
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

MAGNET
RELAYS

COMPLETE RELAY SYMBOLS

CONTACTS

COIL

MOST COMMON RELAY CONTACTS:

MAKE (SPST, NORMALLY OPEN)

BREAK (SPST, NORMALLY CLOSED)

BREAK-MAKE (SPDT)

MAKE-BREAK (SPDT)

DIPST

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)

NEGATIVE TEMPERATURE COEFFICIENT

POSITIVE TEMPERATURE COEFFICIENT
CAPACITORS

FIXED (NON-POLARIZED)

FIXED (POLARIZED)

VARIABLE

GANGED VARIABLE  SPLIT STATOR

FEED THROUGH

VOLTAGE VARIABLE (VARACTOR)

DUAL VARACTOR
3-LAYER SWITCHES (DIACS)

NP/N PNP BIDIRECTIONAL
K A K A T T T

4-LAYER SWITCHES

4-LAYER DIODE

THYRISTORS (SCRs)
P-GATE N-GATE

TRIAC

TRANSISTORS

BIPOLAR
PNP NPN

UNIJUNCTION
N-CHANNEL P-CHANNEL

JUNCTION FETS
N-CHANNEL P-CHANNEL

MOSFETS
N-CHANNEL P-CHANNEL

PHOTOTRANSISTORS
PNP NPN

DARLINGTON

19
ANALOG CIRCUITS
AMPLIFIER OPERATIONAL AMPLIFIERS

VOLTAGE REGULATOR TIMERS, ETC.

CONVERTER CIRCUITS
DIGITAL-TO-ANALOG ANALOG-TO-DIGITAL

BINARY IN

D/A

V_{in} \rightarrow V_{out}

A/D

BINARY OUT

DIGITAL DATA BUSSES
UNIDIRECTIONAL

n

n

BIDIRECTIONAL

n

n

n = NUMBER OF CONDUCTORS
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-27

DO-35

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-1

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.
BATTERIES

AAA CELL
1-3/4" 1-31/32"

AA CELL
1-31/32" 9/16"

C CELL
1-31/32" 1-1/64"

D CELL
2-27/64" 1-11/32"

9-VOLT RECTANGULAR
1-15/16" 1-1/32" 11/16"
4 Fd
6-VOLT
LANTERN
BATTERY

Common coin and button cells (cell thickness varies with type and chemical composition):

- .267"
- .310"
- .374"
- .455"
- .787"
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
S-8 SINGLE CONTACT BAYONET

S-8 DOUBLE CONTACT BAYONET

TL-3 SCREW PRE-FOCUS

TL-2 3/4 SPECIAL THREAD PRE-FOCUS

T-4 HALOGEN

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

XENON FLASH LAMP

TRIGGER ELECTRODE
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.

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 susceptible to damage from ESD are sometimes marked with a warning label...

CAUTION

Contents subject to damage by Static Electricity

...but often they are not. Therefore it is important to know which kinds of components are susceptible to possible damage from ESD.

ESD DAMAGE THRESHOLD OF CERTAIN COMPONENTS:

<table>
<thead>
<tr>
<th>Extremely Vulnerable (1 to 1,000 V)</th>
<th>Moderately Vulnerable (1,000 to 5,000 V)</th>
<th>Somewhat Vulnerable (5,000 to 15,000 V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOS Transistors</td>
<td>CMOS ICs</td>
<td>TTL ICs</td>
</tr>
<tr>
<td>MOS ICs</td>
<td>LS TTL ICs</td>
<td>Small Signal Diodes and Transistors</td>
</tr>
<tr>
<td>Microwave Transistors</td>
<td>Schottky TTL ICs</td>
<td>Piezoelectric Crystals</td>
</tr>
<tr>
<td>Junction FETs</td>
<td>Schottky Diodes</td>
<td></td>
</tr>
<tr>
<td>Laser Diodes</td>
<td>Linear ICs</td>
<td></td>
</tr>
<tr>
<td>Metal Film Resistors</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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):**

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

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

Observe the following precautions when handling components susceptible 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 µF. 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 µF or capacitor is open.

DIODES — Use a multimeter. Resistance should be low in forward direction and high in reverse direction.

LOW RESISTANCE  HIGH RESISTANCE

TRANSISTORS — This circuit provides a "go/no-go" test for switching transistors. Respective LED grows 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\(\mu F\) AND 1.0\(\mu F\) CAPACITOR ACROSS BATTERY LEADS WHERE THEY ENTER THE CIRCUIT BOARD. USE 0.1\(\mu F\) CAPACITORS FROM POWER SUPPLY PINS OF OPERATIONAL AMPLIFIERS TO GROUND. IN DIGITAL CIRCUITS PLACE A 0.1\(\mu F\) 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 wafted away.

Heatsinks are metal structures that improve the efficiency with which heat leaves a component. The thermal conductivity of various materials is compared below:

<table>
<thead>
<tr>
<th>Material</th>
<th>Conductivity (Relative to Silver)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diamond (II)</td>
<td>5.4</td>
</tr>
<tr>
<td>Water</td>
<td>1.4</td>
</tr>
<tr>
<td>Silver</td>
<td>1.0</td>
</tr>
<tr>
<td>Copper</td>
<td>0.93</td>
</tr>
<tr>
<td>Gold</td>
<td>0.74</td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.56</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.21</td>
</tr>
<tr>
<td>Iron</td>
<td>0.19</td>
</tr>
<tr>
<td>Tin</td>
<td>0.16</td>
</tr>
<tr>
<td>Mica</td>
<td>0.0014</td>
</tr>
<tr>
<td>Air</td>
<td>0.000005</td>
</tr>
</tbody>
</table>
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.
DESOLEDERING

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.
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.

*Don't breathe!*

*Protect eyes!*
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

START

CIRCUIT OPERATES?

NO

BATTERY POWERED:
1. CHECK BATTERY.
2. CHECK BATTERY CONTACTS; CLEAN SAME.
3. CHECK POWER SWITCH.

AC LINE POWERED:
1. IS PLUG IN OUTLET?
2. TRY ANOTHER OUTLET.
3. CHECK FUSE.
4. CHECK POWER SWITCH.

YES

OPERATES INTERMITTENTLY?

YES

1. CHECK FOR LOOSE CONNECTIONS AND CONTACTS.
2. CHECK FOR COMPONENT THAT FAILS WHEN WARM AND RESUMES OPERATION WHEN COOL.
3. CHECK FOR COMPONENT THAT FAILS WHEN WARM OR HOT.

NO

FAILS AFTER IT "WARM UP"?

YES

A COMPONENT IS OVERHEATED. DO NOT OPERATE CIRCUIT UNTIL SOURCE OF THE PROBLEM IDENTIFIED AND CORRECTED.

NO

CIRCUIT EMITS ODOR?

YES

CONSULT ALL LITERATURE ABOUT CIRCUIT TO IDENTIFY POSSIBLE ORIGIN OF PROBLEM.

NO

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 VDD and ground to, respectively, positive supply and ground of the circuit being tested. Toggle S1 to produce clean, noise-free pulse.

LOGIC PROBE

Connect VDD 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). R1* table gives values for ~5 mA current. Okay to use 2.2K for all values of VDD 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 **

Connect injector output to input of circuit being tested. Use tracer to follow signal through each stage of circuit. Distortion in sound of injected signal indicates a problem. R1 controls frequency.

R3 controls amplitude.

* * Not to exceed tested circuit's supply voltage.

** SIGNAL TRACER **

R1 controls volume from speaker.
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 = ±5%  SILVER = ±10%  NONE = ±20%

OHM'S LAW:
V = IR
I = V/R
R = V/I
P = VI = I²R

ABBREVIATIONS

A = AMPERE
F = FARAD
I = CURRENT
P = POWER

R = RESISTANCE
V (or E) = VOLT
W = WATT
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