```
10 !*****************************************************************!
15 !                                                                 !
20 ! This sample program is written for the Fluke 17XXA Instrument  !
25 ! controller. It illustrates the bus operation of the LC77 and   !
30 ! command syntax needed to automatically analyze a capacitors or !
35 ! inductors. Written by Sencore, this program may be used 'as is'!
40 ! or may be modified as needed by any LC77 owner without any     !
45 ! further permission from Sencore, Inc.                          !
50 !                                                                 !
55 ! LC77 is at IEEE address 10                                     !
60 !*****************************************************************!
100 DIM C(10),C$(12)
110 TIMEOUT 0
120 INIT
130 CL$=CHR$(27)+'[2J'
140 PRINT CPOS(0,0)+CL$
1000 ! *** Enter Capacitance Test Data ***
1010 PRINT CL$
1020 PRINT CPOS(5,30)+'1  Aluminum Lytic';
1030 PRINT CPOS(6,30)+'2  Double Layer Lytics';
1040 PRINT CPOS(7,30)+'3  Tantalum caps';
1050 PRINT CPOS(8,30)+'4  Ceramic caps';
1060 PRINT CPOS(9,30)+'5  All other caps';
1070 PRINT CPOS(11,30)+'Enter the capacitor type';\INPUT C(1)
1080 ! C(1)=capacitor type
1090 IF C(1)<>1 AND C(1)<>2 AND C(1)<>3 AND C(1)<>4 AND C(1)<>5 THEN 1010
1100 PRINT CL$+CPOS(8,0)+'Enter the capacitor working voltage';\INPUT C(2)
1110 ! C(2)=capacitor working voltage
1120 PRINT CL$+CPOS(8,0)+'Enter the capacitor value (.01uF)';
1130 INPUT C$(0)
1140 ! C$(0)=capacitor value
1150 PRINT CL$+CPOS(8,0)+'Enter the capacitor tolerance';\INPUT C(4)
1160 ! C(4)=capacitor tolerance
2000 ! *** LC77 Lead Zero ***
2010 LC$=CHR$(27)+'[2K'\C$(5)=LC$\C$(4)=LC$
2020 C$(2)=LC$\C$(3)=LC$
2030 PRINT @10,'CPO'
2040 PRINT CL$+CHR$(7)
2050 PRINT CPOS(8,22)+'Open then leads and touch the screen'
2060 WAIT FOR KEY\K%=KEY
2070 PRINT CL$+CHR$(7%)
2080 PRINT @10,'LDO'
2090 INPUT @10,Z$
3000 ! *** LC77 Test Data Set-up ***
3010 PRINT CL$+CHR$(7%)
3020 PRINT CPOS(8,10);
3030 PRINT 'Hook the leads to the capacitor to test and touch the screen'
3040 WAIT FOR KEY\K%=KEY
3050 PRINT CL$+CHR$(7%)
3060 T1$=MID('ALMDBLTANCERAOC',(C(1)*3%)-2%,3%)
3070 C$(6)=''
3080 FOR J%=1 TO LEN(C$(0))
3090  T2$=MID(C$(0),J%,1%)
3100  IF INSTR(1%,'upfUPF',T2$) THEN C$(6)=C$(6)+T2$
3110  IF INSTR(1%,'.0123456789',T2$) THEN C$(7)=C$(7)+T2$
3120 NEXT J%
3130 PRINT @10,T1$
3140 PRINT @10,C(2);'V'
3150 PRINT @10,VAL(C$(7));C$(6)
3160 PRINT @10,C(4);'+%'
3170 PRINT @10,C(4);'-%'
4000 ! *** Capacitor Value Test Routine ***
4010 PRINT @10,'CAP'
4020 INPUT @10,C$(1)
4030 IF MID(C$(1),15%,1%)='G' THEN C$(8)='Good' ELSE C$(8)='Bad'
4040 IF LEFT(C$(1),3)<>'ERR' THEN C$(1)=MID(C$(1),4%,11%)
4050 Z1$=MID(' FuFpF',(INT(VAL(RIGHT(C$(1),10%))/6%)*2%)+1%,2%)
5000 ! *** Capacitor Leakage Test Routine ***
5010 PRINT @10,'LKI'
5020 INPUT @10,C$(2)
5030 IF LEFT(C$(2),3%)='ERR' THEN C$(2)=CHR$(27)+'[2K'\GOTO 8010
5040 I%=INSTR(1%,C$(2),'-')
5050 IF I%<4% OR I%>10% THEN I%=3%
5060 C$(2)=NUM$(VAL(MID(C$(2),I%+1%,10%-I%)))
5070 PRINT @10,'LKR'
5080 INPUT @10,C$(3)
5090 C$(3)=NUM$(VAL(MID(C$(3),4%,7%)))
5100 IF VAL(C$(3))=8888 THEN C$(3)=CHR$(27)+'[5m8888'+CHR$(27)+'[m'
5110 IF C(1)=2 THEN 6060
6000 ! *** Capacitor Delectric Absorption Test Routine ***
6010 PRINT @10,'D/A'
6020 INPUT @10,C$(4)
6030 IF MID(C$(4),15%,1%)='G' THEN C$(11)='Good' ELSE C$(11)='Bad'
6040 IF LEFT(C$(4),3%)='ERR' THEN C$(4)=LC$\GOTO 6060
6050 C$(4)=NUM$(VAL(MID(C$(4),4%,7%)))
6060 IF C(1)>3 THEN 8010
7000 ! *** Capacitor ESR Test Routine ***
7010 PRINT @10,'ESR'
7020 INPUT @10,C$(5)
7030 IF MID(C$(5),15%,1%)='G' THEN C$(12)='Good' ELSE C$(12)='Bad'
7040 C$(5)=NUM$(VAL(MID(C$(5),4%,7%)))
8000 ! *** Display Results on Screen ***
8010 PRINT CL$
8020 PRINT @10,'CPO'
8030 PRINT CPOS(4,25)+'Value ................. ';VAL(LEFT(C$(1),7%));Z1$;
8040 PRINT CPOS(4,65)+C$(8)
8050 PRINT CPOS(5,25)+'Leakage (current) ..... ';C$(2);
8060 IF C$(2)<>LC$ THEN PRINT 'uA';CPOS(5,65);C$(9)
8070 !PRINT CPOS(5,65)+C$(9)
8080 PRINT CPOS(6,25)+'Leakage (resistance) .. ';C$(3);
8090 IF C$(3)<>LC$ THEN PRINT CHR$(24);!CPOS(6,65);C$(10)
8100 PRINT CPOS(7,25)+'Dielectric Absorption . ';C$(4);
8110 IF C$(4)<>LC$ THEN PRINT '%';CPOS(7,65);C$(11)
8120 PRINT CPOS(8,25)+'ESR ................... ';C$(5);
8130 IF C$(5)<>LC$ THEN PRINT CHR$(24);CPOS(8,65);C$(12)
8140 PRINT CPOS(14,25)+'Touch the screen to rerun the program'
8150 WAIT FOR KEY\K%=KEY
8160 PRINT CHR$(7%)
8170 GOTO 130
```

*Fig. 40 — Sample program using a fluke controller.*

# APPLICATIONS

## Introduction

The procedures explained in the Operation Section of this manual explain how to use the LC77 "Auto-Z". Once you become familiar with the basic operation of the "Auto- Z", you will discover many additional applications of the unit. This section will provide you with further information on using the LC77 features for extended capacitor and inductor tests, as well as other special applications.

## Identifying Capacitor Types

Capacitors are often grouped according to the kind of dielectric that is used to separate the plates, and are named accordingly. For example, an aluminum electrolytic capacitor has an aluminum oxide dielectric. While a mylar capacitor uses mylar dielectric. (Refer to the Appendix for an explanation of dielectric and other capacitor theory).

Many different types of capacitors are used in electronics. Each type has certain properties that make it better suited for particular applications. Properties such as temperature coefficient, ESR, dielectric absorption, leakage, voltage break down, and frequency characteristics are taken into account when selecting the capacitor type to be used. When troubleshooting a circuit, it is not important to know why a certain type of capacitor was selected. It is best to simply replace a bad capacitor with a good capacitor of the same type value and voltage rating. This is especially true when the component is in a "Safety Critical" circuit. Because different capacitor types have different characteristics, it is important that you know what type of capacitor you are testing in order to know if the LC77 test results are acceptable or not.

Capacitors are divided into five different types for testing with the LC77. Each has different parameters which require different good/bad limits. These five capacitor types have different physical characteristics to determine an unknown capacitor type. These characteristics are explained in the following paragraphs and are summarized in Figure 41.

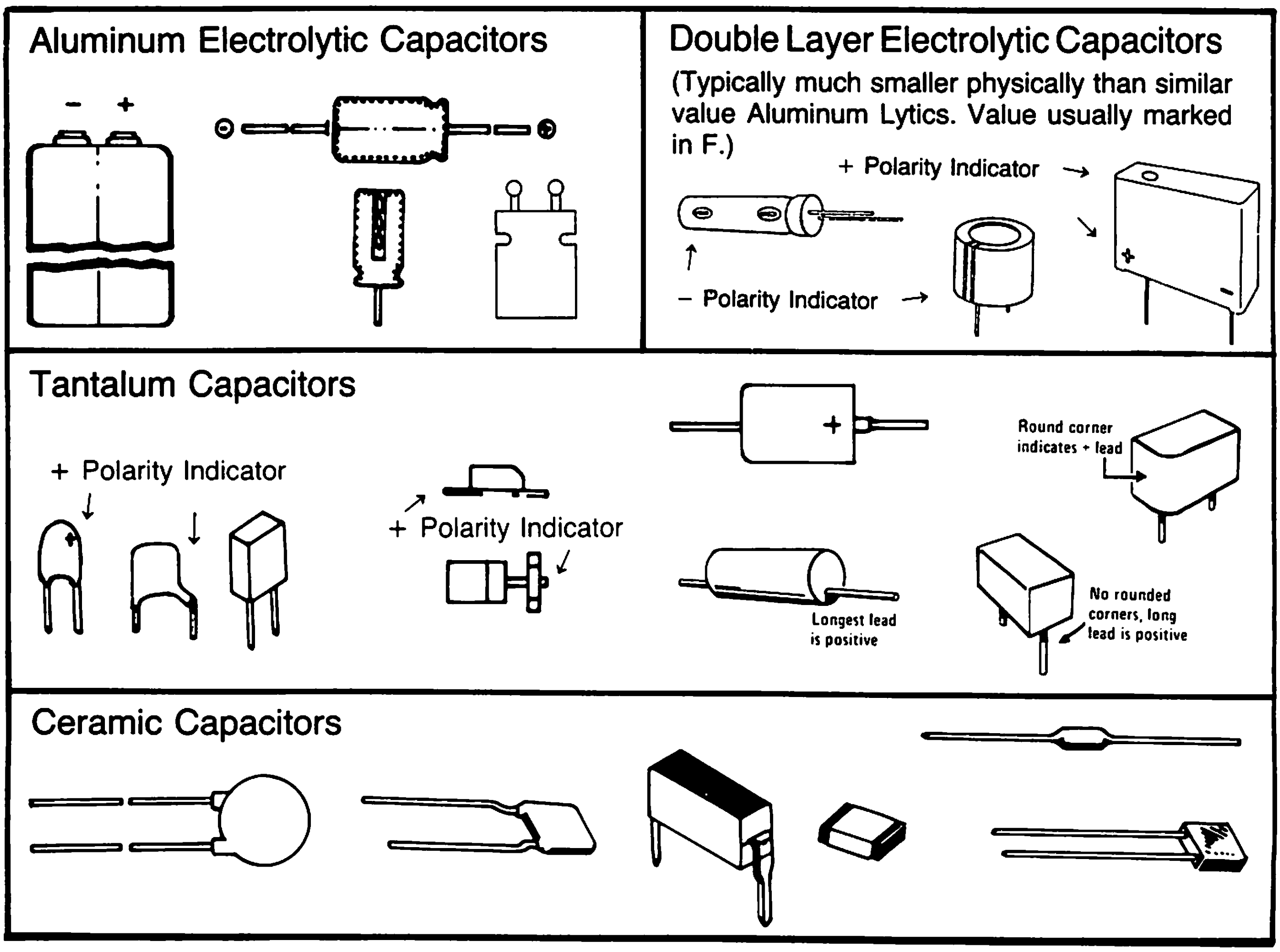



*Fig. 41 — Each capacitor type may be identified by its unique physical characteristics.*

## Aluminum Electrolytics

Aluminum electrolytic capacitors (aluminum lytics) are the easiest capacitor type to identify. They are most commonly cylinder shaped and have radial or axial leads. Large value aluminum lytics often have screw terminals or solder lugs. The case of an aluminum lytic usually is rolled in or formed out near the lead end to hold the end cap and seal. All aluminum lytics have a seal that is soft and rubber like to allow gasses to vent. Depending on the physical size of the case, the soft seal may make up the entire end of the case, or it may be just a small section of a hard end cap. Aluminum lytics have the largest physical size to capacity ratio of all capacitor types. These capacitors may also have several sections, with each section having a different capacitance value but sharing the same negative terminal, usually the case. This is unique to aluminum electrolytics, and whenever you encounter a capacitor having several different capacitance value sections, it will be an aluminum electrolytic.

Because of their unique physical characteristics, most aluminum lytics usually aren't easily confused with other capacitor types. Axial lead aluminum lytics, however, may possibly be mistaken for axial lead tantalum lytics. The lead weld, shown in Figure 43, is an identifying characteristic of the tantalum in electrolytic and is a quick way to differentiate between an axial lead aluminum lytic and a tantalum lytic. Aluminum lytics do not have a lead weld on either terminal.


*Fig. 42 — All aluminum electrolytics have a rubber seal.*

## Tantalum Electrolytics

Dipped tantalum electrolytics are rapidly replacing aluminum lytics in many electronic circuits. They have less leakage and higher value tolerances than aluminum lytics. Tantalum electrolytic capacitors are about one half the size of a similar aluminum electrolytic of the same value and voltage rating.

The most common shapes of tantalum capacitors are illustrated in Figure 41. While they may have many shapes, tantalum capacitors always have polarized leads. Lead polarization is often the only way to distinguish a tantalum lytic from another type of capacitor. Once you become familiar with the polarity markings used, tantalum lytics are not difficult to identify. The polarity markings are not meant to be difficult to notice or understand, although if you are not aware of them, they might be overlooked. Pay careful attention so that you do not overlook the polarity indication and misidentify a tantalum capacitor as another type.

The simplest and most common polarity indicator is a "+" sign near one of the leads. This is often used along with a second type of indicator. Figure 44 shows several examples of lead identification used in tantalum capacitors. In addition to the "+" sign, each capacitor shown has a second indication of the "+" lead: a lead weld, a tapered case, a rounded corner, a line, or an extra ridge near the "+" lead.

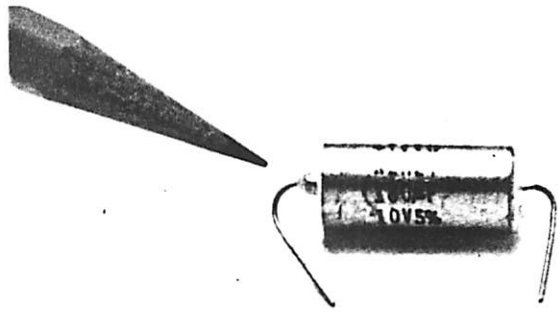


*Fig. 43 — Axial lead tantalum capacitors, like the one shown here, are easily identified from axial lead aluminum electrolytics by a solder weld on one end.*

A "+" indicator is not printed on all tantalum capacitors. In many cases the polarity indicator will simply be the lead weld, a tapered case or rounded corner, a line, or an extra ridge on the case. Several other polarity identifiers are also used. The end or side nearest the plus lead may be painted one color. Also at times, just a dot or a line on the side of the package will be used.

*NOTE: Tantalum capacitors may use dots or stripes to indicate value or tolerance. Do not confuse the value color code for the polarity indicator of a tantalum capacitor. The polarity indicator will be larger and isolated from the color code.*

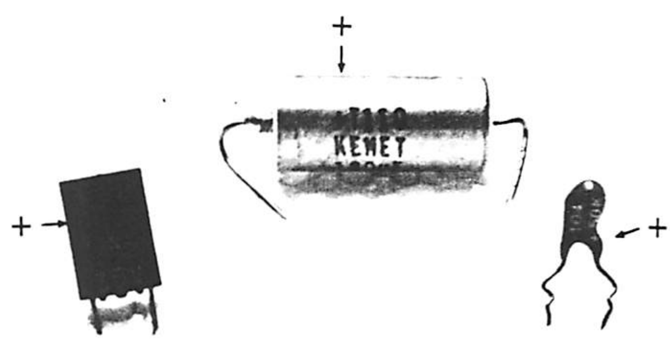



*Fig. 44 — Tantalum electrolytic capacitors always have a polarity indicator.*


***Fig. 45 — A tantalum chip capacitor (left) can be identified from a ceramic chip capacitor by its positive lead.***

Tantalum capacitors are also available in the small surface mount or "chip" type. Tantalum chip caps could be confused with the ceramic chip cap, since they are similar in size and appearance at first glance. But as Figure 45 shows, a tantalum chip capacitor is polarized and has an easily identifiable positive lead. The polarity identification that may give you the most difficulty in identifying a tantalum capacitor is lead length. The only identification of the positive lead on some tantalum capacitors is that it is longer than the other lead. Of course, this presents no problem when the capacitor is new, but once it has been installed into a circuit board, the leads are cut off to the same length. In this situation, use the circuit as the clue to the cap's type and polarity.

## Double Layer Electrolytics

Double layer electrolytic capacitors are commonly known by trade names such as "Supercap" or "Gold Cap". These capacitors are quite easy to identify. Double layer lytics have an extremely large capacitance value for their physical size. They are found in various physical shapes and sizes, as shown in Figure 46. Their value is marked in Farads, rather than in picofarads or microfarads.

The polarity of a double layer lytic is often printed on the case, although a longer lead may also be used to identify the positive terminal. Some double layer lytics use a line next to one lead which may be either " + " or "-". If there is no other marking, the terminal that is part of the metal case is the negative lead.

***Fig. 46 — Double layer lytic capacitors have a very large amount of capacitance for their physical site. their value is usually marked in Farads.***

## Ceramic Capacitors

Ceramic capacitors may be found in many different sizes and shapes. The most common type of ceramic capacitor is the flat, round ceramic disc, as shown in Figure 47. The ceramic disc is unique in its shape, and is easily identifiable from other ceramics, and other types of capacitors. The ceramic disc is also unique from other types of ceramic capacitors in that it may have small amounts of normal leakage.

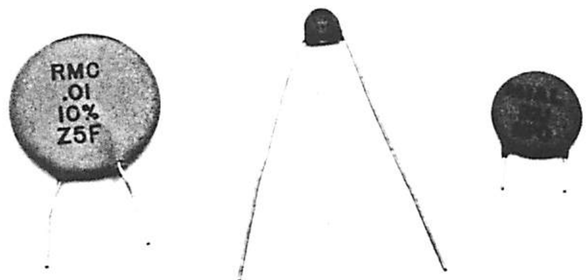



***Fig. 47 — The most common type of ceramic capacitor is the ceramic disc. It has unique parameters which require it to be tested differently than other ceramic, or film capacitors.***

Two other kinds of ceramic capacitors which are easily identified from other capacitor types are the axial lead and chip types. As Figure 48 shows, some axial lead ceramic capacitors may look the same as resistors and inductors which also use the same case type. You can easily determine if the component is a resistor, capacitor or inductor from its location in the circuit. The LC77 can also be used to help identify these unknown components, as explained in a following section, "Identifying Unknown Components", on page 48.

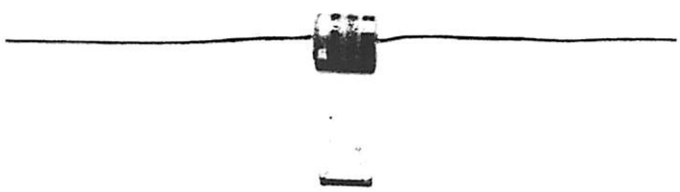


***Fig. 48 — Ceramic capacitors may also include an axial lead and chip-type package. Axial lead ceramics often look like other axial lead components.***

Ceramic chip capacitors are unique in their appearance. Only a tantalum chip capacitor looks somewhat alike. However, as shown in Figure 45, a tantalum chip capacitor has a recognizable polarity indicator. A ceramic chip capacitor does not.

There are a few other kinds of ceramic capacitors besides the three types identified here. These types, such as molded ceramics and encapsulated ceramics, are very similar in appearance to film capacitors, and are difficult to differentiate from films by physical appearance. This presents no problem though, when testing these ceramics with the LC77, since any leakage or D/A in a ceramic capacitor, other than a ceramic disc, is not allowable. If you are unable to identify the capacitor as a ceramic, test it as an "ALL OTHER CAPS" type.

## All Other Capacitors

The final capacitor type capitalized grouping for LC77 "Auto-Z" good/bad testing is "ALL OTHER CAPACITORS". As its name implies, capacitors in this category do not have the electrical (or physical) characteristics to fit into any of the other categories. Capacitors included in this grouping are films, micas, air dielectrics, papers, oil filled capacitors, and other similar types. (There are numerous types of film capacitors such as mylar, polyester, polycarbonate, polystyrene, and polypropylene). Though each of these capacitor types have different dielectrics and somewhat different parameters, they are all similar in that when tested with the LC77, they should have no dielectric absorption or leakage. Also, because of their relatively low capacitance value, ESR is of little importance and is not measurable. If you measure any leakage, or D/A in an "All Other Capacitor" type it is bad.

*NOTE: When replacing any of these capacitors, always replace it with the same type originally used in the circuit. For example, a mylar film capacitor should only be replaced with another mylar film. This is especially important for components in areas of the schematic designated as "Safety Critical".*

# Identifying Inductor Types

Inductors, like capacitors, may be found in many shapes and sizes depending on the application in which they are used. The LC77 will provide an accurate Ringer test on all types of air core and ferrite core inductors, provided the proper INDUCTOR COMPONENT TYPE switch is selected. Each inductor type has a normal range of impedance, and the INDUCTOR COMPONENT TYPE switches match the impedance of the LC77 Ringer circuits to the particular inductor type being tested. With the proper COMPONENT TYPE switch selected, an inductor with just a single shorted turn will produce a "BAD" indication in the Ringer test.

Air and ferrite core inductors break into three, easy to identify types: Yokes and flybacks, switching transformers, and coils. Select one of these three INDUCTOR COMPONENT TYPE switches when performing the Ringer test.

## Yokes And Flybacks

Yokes are used exclusively in video applications to deflect a CRT electron beam. As shown in Figure 49, they can not be easily mistaken for any other type of inductor. Yokes have a ferrite core, surrounded by two pairs of windings, which fits over the CRT neck. It is held in place with a plastic shell attached to the CRT neck.

Flyback transformers are also easy to identify. They too are used exclusively in video applications, and produce high voltage for the CRT. A flyback has several terminals which are often soldered to a PC board chassis. One or two heavily shielded leads exit the flyback to carry high voltage to a tripler, or to the CRT directly.

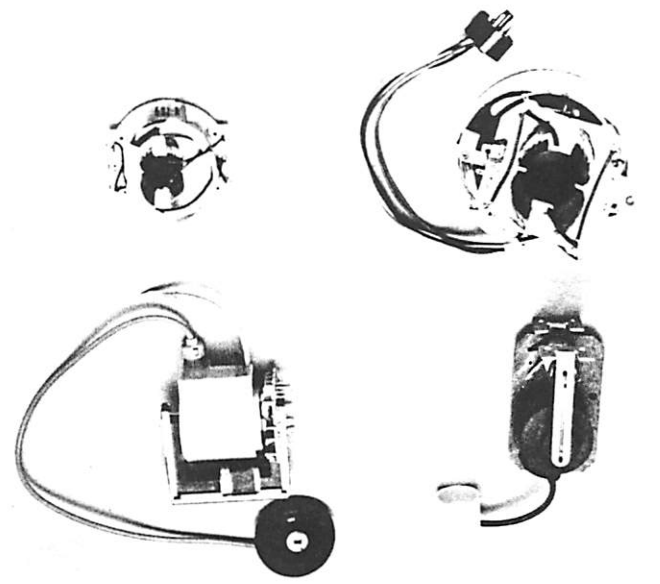


***Fig. 49 — Yokes (top) and flybacks (bottom) are inductor types which are easily identified.***

## Switching Transformers

Switching transformers are used in power supply circuits to step voltages up or down. However, they are much different from conventional power transformers in both appearance and operation, and should not be mistaken for a power transformer. Power transformers usually operate at 60 Hz, and therefore contain a laminated iron core which is often visible. Because the iron core is low Q and absorbs all ringing energy, power transformers cannot be tested with the LC77.

Switching transformers, on the other hand, are much smaller and lighter than power transformers. They are wound around a ferrite core which easily rings when good. Switching transformers operate at much lower currents and much higher frequencies than power transformers. Two common switching transformers, the PC board mount and toroid types, are shown in Figure 50.

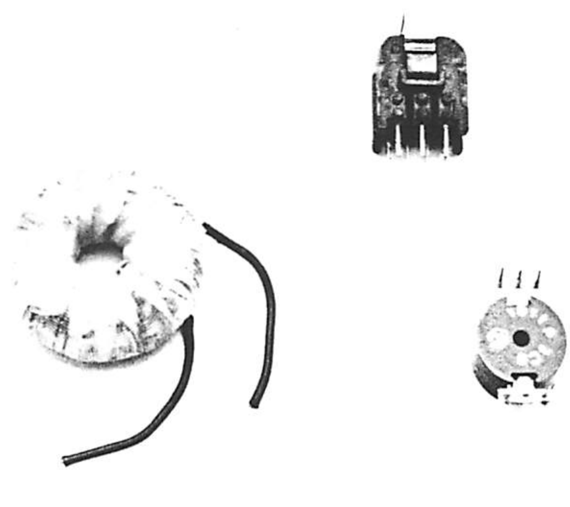


***Fig. 50 — The torriod (left) and PC mount are two common types of switching transformers.***

## Coils

All non-iron core inductors which can not be classified as yokes, flybacks, or switching transformers are tested with the "Coils" INDUCTOR COMPONENT TYPE switch selected. These include RF/IF transformers, RF chokes, postage stamp inductors, axial lead inductors, free form coils, as well as some other types.

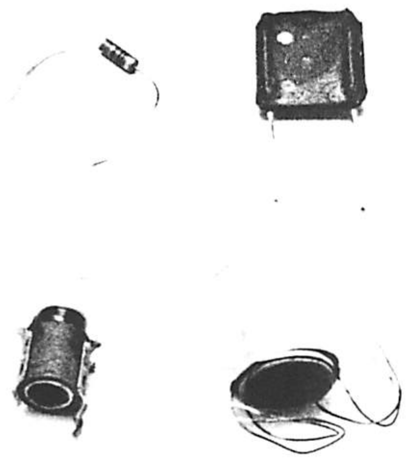


***Fig. 51 — Air and ferrite core inductors are tested with the "coil" component type switch selected.***

## Identifying Unknown Components

Occasionally you may encounter small value inductors and axial lead ceramic capacitors which look like the more common axial lead film resistor. If these components get mixed up in your parts bin, you may have difficulty identifying the component. This may also be a concern with chip capacitors, chip inductors, and a few other axial lead inductors and capacitors on which the markings are difficult to interpret or are not visible.

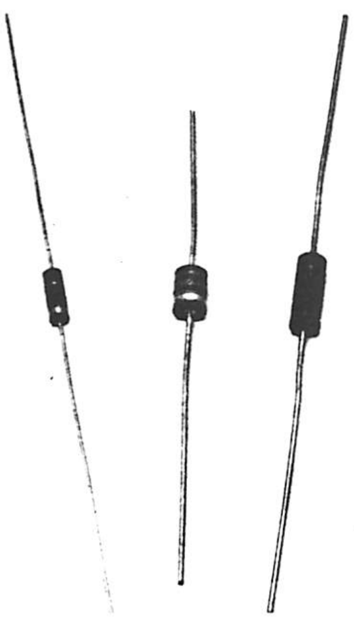


***Fig. 52 — Some small value inductors (left) capacitors (center) and resistors (right) may be hard to tell apart. The LC77 provides a quick test to identify such unknown components.***

You can use the LC77 tests to sort these component types from each other. Figure 53 shows, in flow chart form, the procedure you need to follow. Before beginning the test, zero the test leads in both the "Short" and "Open" position of the LEAD ZERO switch. You begin identifying the component with a capacitor value test. Depending on the reading, you either use the leakage test or inductor value test to further isolate the component. Finally, if the component appears to be an inductor, you use the ringing test as confirmation.

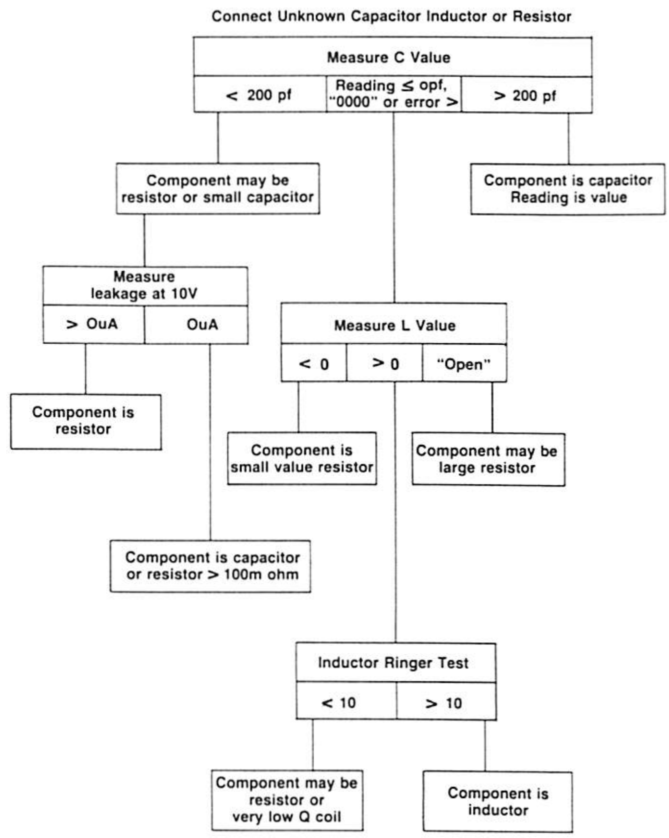



***Fig. 53 — Use this flow chart to help identify small axial lead inductors, capacitors, and resistors from one another.***

**IMPORTANT**

**Do not apply more than 10 volts across an unknown capacitor, resistor or inductor. Most chip, "film" package, and axial lead inductors and capacitors will have voltage ratings greater than 10 volts. If in doubt about an unknown component's voltage rating, use another method to identify it, if possible, or use a lower test voltage.**

*NOTE: This test is only intended to help you sort inductors, capacitors and resistors in "film resistor" type, chip type or small axial lead packages which are difficult to identify by physical appearance or any other means.*

# Capacitor Testing Applications

## Interpreting Capacitor Value Readings

The LC77 "Auto-Z" automatically displays the three most common capacitor values of picofarads (pF), microfarads (uF), and Farads (F). When measuring capacitors with the LC77, you may encounter some capacitors with a value marked without a decimal, such as "25000 pF", but that read ".0250 uF" on the LC77 display. You may also encounter, as an example, a capacitor which is marked "3300 pF" by some manufacturers, yet an identical replacement is marked ".0033 uF" by another manufacturer.

As these examples illustrate, capacitors can be marked in pF, uF or even F. A fourth value multiplier, the nanofarad (nF) is seldom used to mark a capacitor, but is used occasionally in design and industry. Table 12 will help you to easily convert from one reading to another.

## Checking Leakage Between Sections Of A Multi-Section Lytic

Multiple section aluminum electrolytic capacitors are common, especially in many older power supplies. Such capacitors are actually several capacitors, inside one can, sharing the same negative terminal.

Leakage sometimes develops between one or two sections of multi-section lytics. This leakage is especially difficult to troubleshoot without the LC77 leakage test because signals from one section of the capacitor are coupled to another section. This results in multiple symptoms in the operation of the device in which the capacitor is used. An ohmmeter will not show leakage between sections of a multi-layer cap because the leakage only occurs near the capacitor's operating voltage.

To isolate this type of leakage with the LC77 you simply perform the standard leakage test. As you test each section, short each of the remaining sections to ground. Any increase in leakage when a section is shorted to ground indicates leakage between sections.

| Change to<br>From | Farads | Microfarads | Nanofarads | Picofarads |
|---|---|---|---|---|
| Farads | | move decimal 6 places right | move decimal 9 places right | move decimal 12 places to right |
| Microfarads | move decimal 6 places left | | move decimal 3 places right | move decimal 6 places right |
| Nanofarads | move decimal 9 places left | move decimal 3 places left | | move decimal 3 places right |
| Picofarads | move decimal 12 places left | move decimal 6 places left | move decimal 3 places left | |

***Table 12 — Capacitor value conversion chart.***

## Dielectric Stress

Many ceramic capacitors change value when they are DC biased. The applied DC voltage causes physical stress within the ceramic dielectric causing it to decrease in value. This value change is called "dielectric stress". Normally a ceramic capacitor will return to its normal value within several seconds after the voltage is removed.

You will not normally notice dielectric stress when checking a ceramic capacitor with the "Auto-Z", unless you apply a voltage to it with the capacitor leakage test. Then you may find that the capacitance value has decreased by as much as 50% in ceramic capacitors having values 10 pF or smaller. This is a normal characteristic of small value ceramics.

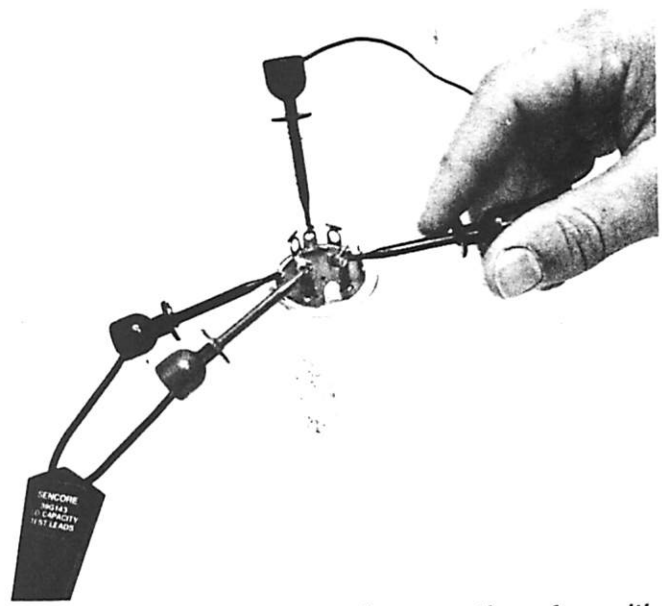


***Fig. 54 — Test the leakage of one section of a multi-section lytic, then short one of the remaining sections to ground. Any increase in leakage current indicates leakage between that section and ground.***

## WARNING

**This test should only be performed by a person who understands the shock hazard of up to 1000 volts applied to the test leads during the capacitor leakage test. DO NOT hold the capacitor in your hand, or touch the test leads or capacitor leads when making this leakage test.**

**To check for leakage between sections of a multi-layer cap:**

1. Connect one section of the capacitor to the LC77 test leads. Be sure to observe proper polarity.

2. Enter the working voltage of the section being tested. Note that a multi-layer lytic may have a different working voltage for each section.

3. Depress the CAPACITOR LEAKAGE button and read the leakage current on the LCD display. It must be within the maximum allowable leakage limits for its value and voltage rating.

4. Connect one end of a short jumper to the common terminal of the capacitor.

5. While depressing the CAPACITOR LEAKAGE button, connect the other end of the jumper to each of the capacitor terminals not already connected to the LC77 test leads.

6. A good multi-section electrolytic will show no increase in the leakage reading as the jumper is connected to each terminal.

## Intermittent Capacitors

Occasionally an electrolytic capacitor may become intermittent. A poor weld of the lead to the internal foil plates or other mechanical problem can cause the capacitor to function randomly. Often such capacitors will also exhibit high ESR when they are working. (The internal construction of an electrolytic capacitor is shown in the Appendix).

If you suspect an intermittent capacitor, move its leads around and pull on them as you perform a capacitor value test. A change in capacitance indicates an intermittent component which should be replaced.

## Checking Ceramic Capacitor Temperature Characteristics

Ceramic capacitors are designed to have a wide range of capacitance value and temperature characteristics, (More details are given in the Appendix.) Replacing a capacitor with one that has the same characteristics is especially important in certain oscillators and other temperature critical circuits. You can quickly determine the basic temperature characteristics of a ceramic using the LC77 and a heat source, such as a heat gun. Simply connect the capacitor to the LC77 and measure its value. Then apply heat to the capacitor while you continue to measure its value. A COG or NPO type capacitor will not change in value, or change very slightly as heat is applied. An N type ceramic will decrease in value, while a P type ceramic will increase in capacitance.

## Checking Capacitance Of Silicon Diodes And Transistors

The capacitance of silicon diodes and transistors, as well as the reverse leakage paths of silicon and germanium transistors can be easily measured using the LC77. Figure 55 shows the connections necessary for these measurements. If the LC77 display shows "0.0 pF" when testing capacitance, or flashing "88.88 mA" when testing leakage, the connections are reversed. No special precautions are necessary when measuring capacitance, however be sure to follow these precautions when testing leakage:

1. Do not apply more than 3 volts to a transistor when testing Ibeo.

2. Set the leakage supply to the maximum voltage rating of the transistor when testing Icbo or Iceo, but do not exceed the rated voltage. Exceeding the rated voltage may cause the transistor to zener, and will damage the junctions.

*NOTE: The capacitance of germanium transistors and diodes can not be measured with the LC77 because of their high leakage. Leakage tests of germanium devices are the same as for silicon devices.*

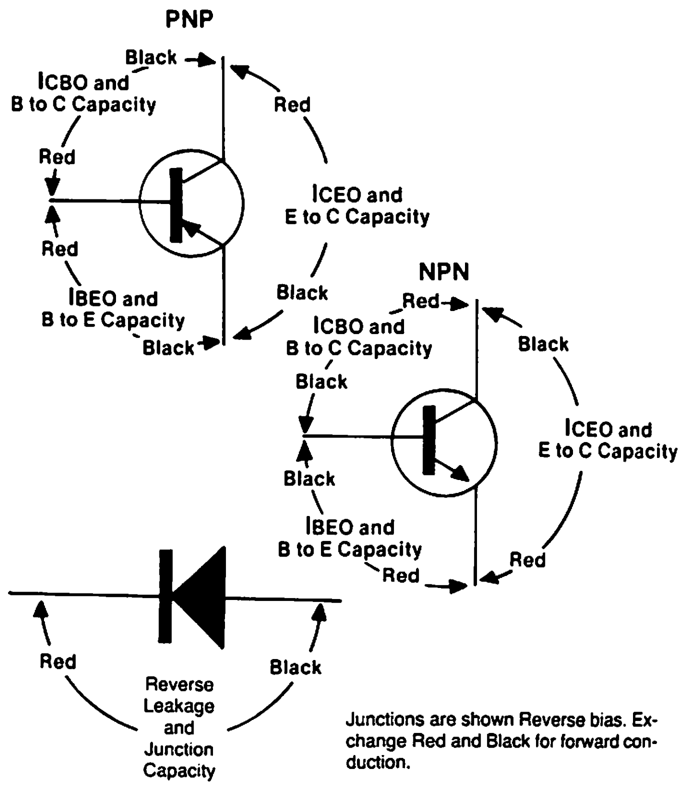



***Fig. 55 — The connection for measuring the capacitance of silicon junctions and leakage paths for silicon and germanium junctions.***

## Testing High Voltage Diodes

High voltage diodes, such as those found in video high voltage and focus voltage sections may require up to 200 volts before they are forward biased and begin to conduct. They cannot be tested with an ohmmeter since, with only a few volts applied, a good high voltage diode will simply indicate "open" no matter how the ohmmeter is connected.

The capacitor leakage test of the LC77 provides sufficient voltage to bias high voltage diodes into conduction and also to test them for reverse breakdown. Test the diode for normal forward conduction first. Then reverse the test leads and check for reverse leakage.

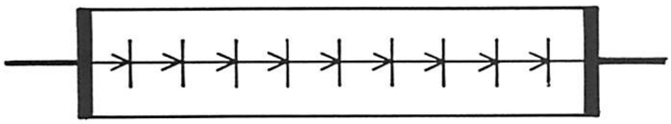


*Fig. 56 — To test a high voltage diode, enough voltage is needed to forward bias all the junctions.*

**WARNING**

**This test should only be performed by a person who understands the shock hazard of up to 1000 volts applied to the test leads when the the CAPACITOR LEAKAGE TEST button is depressed. DO NOT hold the diode in your hand, or touch the test leads or diode leads when making this test.**

**To test a high voltage diode:**

1. Connect the red test lead to the diode anode ("-" end) and the black test lead to the diode cathode (" + " end).

2. Enter 50 volts into the leakage supply and depress the CAPACITOR LEAKAGE TEST button.

3. If the LC77 display shows no leakage, apply more voltage until the diode begins to conduct, as indicated by a leakage current reading of 100 uA or greater.

4. Once the diode begins to conduct, do not apply any higher voltage as this will cause excessive current flow through the diode and damage it.

5. If you apply 999.9 volts to the diode and it still shows no conduction, it is open and you do not need to continue the test.

6. When the diode begins to conduct, release the CAPACITOR LEAKAGE TEST button and reverse the test lead connection to the diode.

7. Set the leakage power supply to the PIV (peak inverse voltage) of the diode shown in a replacement guide. If the PIV is greater than 1000 V (as it will be for most high voltage diodes) set the leakage power supply to 999.9 volts.

8. Depress the CAPACITOR LEAKAGE TEST button and read the leakage current. A good high voltage diode will typically show less than 2 uA of reverse current.

## Reforming Electrolytics

Aluminum electrolytic capacitors often decrease in value and develop leakage if they sit unused for long periods of time. (This is often the case with electrolytics on stockroom shelves or in parts bins). These symptoms are caused by the loss of some of the oxide dielectric. The oxide is formed by a chemical reaction in the electrolyte when voltage is applied to the plates. With time, this oxide deteriorates. In many cases the electrolyte has not dried up and the oxide coating can be reformed by applying a DC voltage to the capacitor for a period of time.

You can use the LC77 leakage test power supply to reform the dielectric. Reforming may take an hour or longer before the capacitor reforms and the leakage drops to a normal amount.

Use the 39G201 Test Button Hold Down Rod supplied with the LC77 to hold the CAPACITOR LEAKAGE TEST button depressed while you are reforming the capacitor. The hold down rod fits between the CAPACITOR LEAKAGE TEST button and the carrying handle, and can be adjusted longer or shorter as needed. A hold down rod rather than a locking button is used as a reminder to you and others that voltage is being applied to the test leads.

**WARNING**

**Use the 39G201 Test Hold Down Rod with extreme caution. Do not touch the test leads or the capacitor leads while the Test Hold Down Rod is being used. Voltage up to 1000 volts is present when the CAPACITOR LEAKAGE TEST button is depressed. Make sure that the capacitor being reformed will not touch or come in contact with any metal object while voltage is applied to it.**

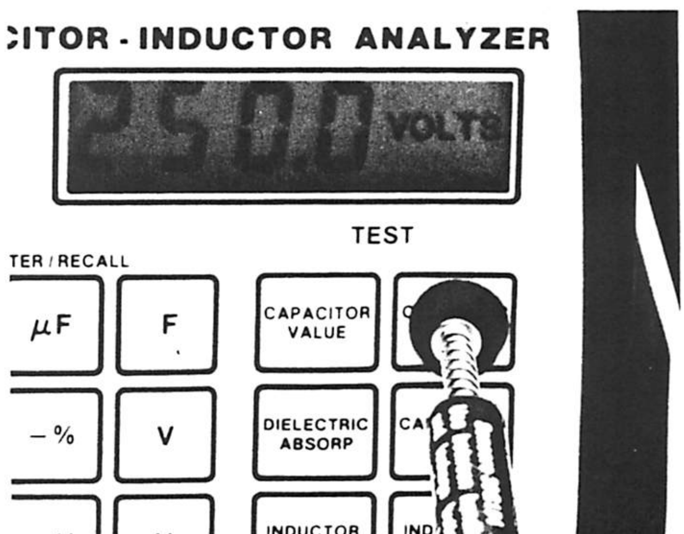



*Fig. 57 — The Test Button Hold Down Red keeps the CAPACITOR LEAKAGE button depressed when reforming capacitors.*

**To reform an electrolytic:**

1. Connect the capacitor to be reformed to the test leads.

2. Enter the rated voltage of the capacitor into the LC77.

3. Depress the CAPACITOR LEAKAGE TEST button, and while holding it in, place the 39G201 Test Button Hold Down Rod between the button and the handle.

4. Adjust the length of the rod by holding one end and turning the other until the hold down rod keeps the CAPACITOR LEAKAGE TEST button depressed.

5. After the capacitor has reformed for at least one hour and the leakage has dropped to a normal amount, allow it to set for 30 minutes. Then recheck the value and leakage to see if reforming has improved the capacitor.

**WARNING**

**NEVER use the Test Button Hold Down Rod to hold in any button except the CAPACITOR LEAKAGE TEST button. Damage to the LC77 may result if it is used to latch another button since the protection circuits inside the LC77 are bypassed when a test button is depressed. The warranty will be voided if the LC77 is damaged by connecting a charged capacitor or any other voltage to it with any of the other buttons held in with the Test Button Hold Down Rod.**

# Inductor Testing Applications

## Testing Inductors In-Circuit

The LC77 "Auto-Z" can be used to measure the inductance of a coil with the component still in circuit. In-circuit inductance measurements, however, may be affected by the impedance of the circuit. Low values of parallel resistance will lower the circuit impedance and cause the LC77 to measure a lower inductance value. Table 13 lists the amount of parallel resistance which will cause a 10% or less change in the measured inductance. Resistances larger than the amounts shown will not have a significant effect on the inductance test.

| Inductor | Value Minimum Parallel Resistance |
|---|---|
| 1 uH to 18 uH | 10 to 100 ohms |
| 18 uH to 180 uH | 25 to 200 ohms |
| 180 uH to 1.8 mH | 50 to 500 ohms |
| 1.8 mH to 18 mH | 150 ohms to 1.3 kilohms |
| 18 mH to 180 mH | 400 ohms to 3 kilohms |
| 180 mH to 1.8 H | 800 ohms to 7 kilohms |
| 1.8 H to 20 H | 5k to 25 kilohms |

***Table 13 — Inductors may be measured in-circuit if the parallel resistance is greater than the amounts listed here.***

*NOTE: Good inductors may not normally ring if connected in-circuit, unless the paralleled impedance is quite high. However, if an inductor does ring in-circuit, it is good.*

Often an inductor mounted in-circuit has leads which are too short to attach the test lead clips to. The (optional) 39G85 Touch Test Probe is especially useful for measuring such coils. It provides 2 needle-sharp points which will pierce through the coating on the foils allowing contact to the coil leads.

***Fig. 58 — Use the optional touch test probe to measure inductors mounted on PC boards.***

## Mutual Inductance

Mutual inductance occurs when two or more coils are wound on the same form and connected together. In such cases, the total inductance measured across the windings will not equal the sum of the measured inductances of the individual coils. This is due to the mutual inductance of the coils. The total measured value may be higher or lower than the individual inductances, depending on whether the coils are aiding or opposing. In addition, the effects of mutual inductance depend on the type of core material, the spacing of the turns, and the type of turns used. The amount of inductance measured by the "Auto-Z" will be the same inductance seen by the circuit.

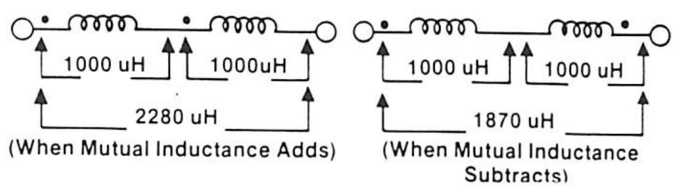



***Fig. 59 — The effects of mutual inductance may add or subtract from the sum of the individual.***

## Ringing Peaking Coils

Peaking coils are often wound around a resistor. The resistor serves to lower the Q of the coil to prevent ringing. For this reason, some good peaking coils will not read good on the Inductor Ringer test. The lower the resistor value, the fewer rings the coil will read.

The best test for peaking coils is to observe the number of rings, rather than the good/bad indication, and compare the coil to an identical known good component.

## Ringing Metal Shielded Coils

Sometimes coils, such as IF transformers, may be placed inside a shield to reduce in-circuit interference. These shielded coils may not ring good when tested with the Inductor Ringer test because the metal shield absorbs some of the ring energy.

A shielded coil is good if it rings ten or more. However, if it rings less than ten, remove the metal shield, if possible, and test the coil again. If it now rings 10 or more, the coil is good. If you are unable to remove the metal shield, make a comparison test using an identical, known good component.

## Ringing Flyback Transformers

A flyback transformer is a special type of transformer which produces the focus and second anode voltages for a CRT. Many flybacks also have several lower voltage, relatively high current windings which power other circuits and the CRT filament. Because of the high voltages present, a flyback transformer may develop an internal shorted turn. A shorted turn reduces the efficiency of the transformer and usually causes severe circuit problems. Inductance measurements are of little value when troubleshooting a flyback, since a shorted turn causes little change in inductance value. In addition, the inductance value is seldom known. The LC77 Inductor Ringer test will detect a shorted turn in any of the primary or secondary windings of a flyback.

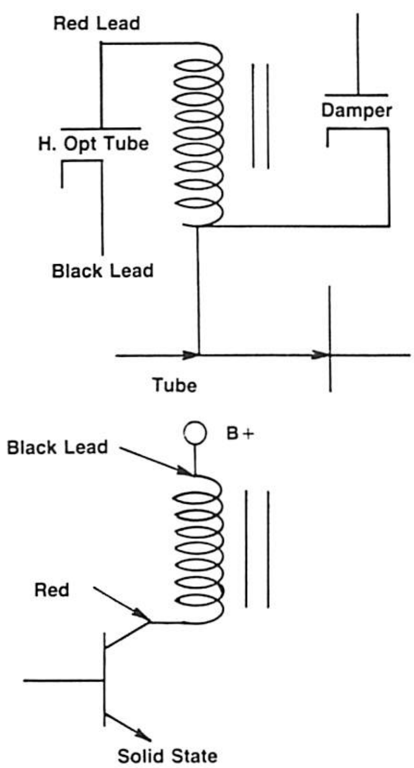



*Fig. 60 — Connect to the primary side of a flyback to do the ringing test.*

A flyback transformer may be tested in or out of circuit with the LC77 Ringer test, although several external loads may need to be disconnected before a good flyback will ring. Connect the LC77 to the primary of the flyback and select the "YOKES & FLYBACKS" COMPONENT TYPE switch. Depress the INDUCTOR RINGER TEST button and read the condition of the flyback as "GOOD" or "BAD" in the LC77 display. If the flyback rings "BAD", disconnect any loads until the display reads "GOOD". If the flyback is completely disconnected and still rings "BAD" the flyback has a shorted turn, or the winding, to which the test leads are connected, is open. In either case, the flyback should be considered bad.

*NOTE: Certain flybacks have removeable cores. The ferrite core must be installed inside the windings in order for the flyback to ring "GOOD".*

A few flybacks used in some small solid state chassis have a low impedance primary which will not ring when good. However, these flybacks will always have a secondary winding which will ring good if the transformer is good. Simply ring the secondary windings. If one rings good the flyback does not have any shorted turns. If no winding rings good the flyback is bad.

A coil in the secondary of a flyback may occasionally open, rather than short. An open coil will not load the other windings as a short does. If the operation of the chassis indicates the possibility of an open winding, leave the LC77 connected to the primary winding and short each of the windings with a jumper. Shorting out a winding will reflect back to the primary and cause the ring test to go from "GOOD" to "BAD". If the ring test does not change, the winding being shorted with the jumper is open.

**WARNING**

**Do not connect the LC77 test leads to a flyback in-circuit until all power to the chassis has be removed, and the AC line cord has been disconnected.**

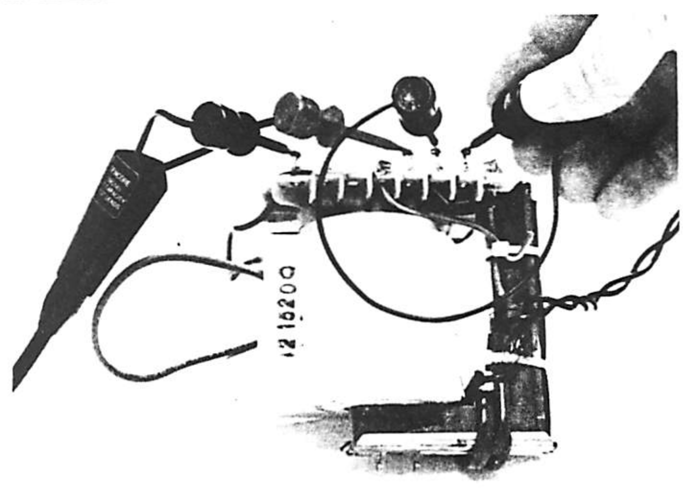


*Fig. 61 — Use a jumper to determine if a flyback winding is open. An open winding will not cause the ringing test to change when a jumper is placed across it.*

**To ring a flyback transformer:**

1. Connect the red test lead to the collector of the horizontal output transistor, or to the plate cap of a horizontal output tube.

2. Connect the black test lead to B+ side of the primary winding. In a tube set connect to the cathode of the damper diode or anode of the boost rectifier.

3. Pull the socket off the CRT (remove the high voltage rectifier tube in a tube chassis) to prevent the filaments from loading the secondary and giving a false ringing indication.

4. Depress the INDUCTOR RINGER TEST button. If the LC77 display reads "GOOD" the flyback is good, and the remaining steps are not necessary.

A "BAD" reading indicates that either the flyback has a shorted turn or that it is being loaded down. The following steps will locate the defect. Continue disconnecting the loads in the following order until the flyback rings "GOOD". If the flyback rings "GOOD" after you disconnect a load, double check that load to make sure it is not defective.

5. Disconnect the horizontal yoke windings and repeat the ringing test.

6. If the ringing test still reads bad, remove one end of the damper diode in the solid state chassis and repeat the test.

7. If the ringing test still reads bad, unplug the convergence coils and repeat the test.

8. If the ringing test still indicates bad, disconnect any remaining low voltage, AGC or other windings one at a time.

9. If all the loads are disconnected and the ringing test still indicates bad, the flyback has a shorted turn.

Many flybacks used in solid state chassis have the high voltage rectifier diodes (tripler) built in to the secondary winding. These flybacks are called Integrated High Voltage Transformers (IHVTs). The Ringing test will locate defective turns in these types of flybacks as well. A problem with the diodes will result in problems with the high voltage, even though the Ringing test indicates "GOOD". If the flyback rings "GOOD" but produces no high voltage, one of the diodes is open. If the high voltage is several thousand volts too low and the flyback rings good, one or more of the diodes is shorted. In either case, the flyback is defective and must be replaced.

## Ringing Deflection Yokes

Video deflection yokes are special inductors which are used to move a CRT electron beam both vertically and horizontally. As with flybacks, the LC77 Ringing test provides a quick and reliable good/bad test. Yokes should be tested while they are still mounted on the CRT, since a shorted winding may be caused by the pressure of the yoke mounting. Relieving the pressure may cause the short to go away.

A deflection yoke has two sets of windings (horizontal and vertical) which must both test good. The yoke leads must be disconnected from the circuit. This is often accomplished by simply pulling the yoke plug from the chassis. The vertical windings may often have damping resistors across them which also must be disconnected. These resistors may be on the chassis, in which case simply pulling the yoke plug will disconnect them.

They may also be soldered right to the yoke, meaning you will need to unsolder one side of the resistor. Test both yoke windings with the "YOKES & FLYBACK" COMPONENT TYPE button selected.

*NOTE: Test the vertical windings individually on yokes that have series connected vertical windings. The vertical windings should read within 3 rings of each other, but may not necessarily ring "GOOD" with 10 or more rings. Any such yoke that has a ring difference greater than 3 rings, or an inductance value difference greater than 10% will give problems in the chassis.*

**WARNING**

**Do not connect the LC77 to the yoke in the chassis until all power has been removed and the AC plug has been disconnected.**

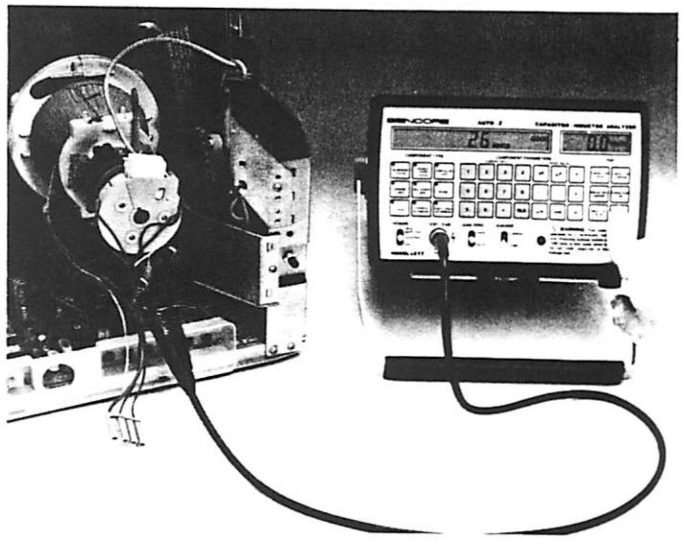


*Fig. 62 — Test deflection yokes with the ringing test while the yoke is still mounted on the CRT.*

**To test horizontal yoke windings:**

1. Disconnect the yoke from the circuit by pulling the yoke plug or unsoldering the wires.

2. Connect the test leads to the horizontal winding.

3. Select the "YOKES & FLYBACKS" COMPONENT TYPE button.

4. Depress the INDUCTOR RINGER TEST button and read the test result in LC77 display.

5. If the horizontal windings test "GOOD", continue on and test the vertical winding. The vertical windings must also test "GOOD" before you consider the yoke good. If the horizontal winding test "BAD" the yoke is defective and there is no need to test the vertical windings.

**To test the vertical windings:**

6. If the yoke has damping resistors across the vertical winding, unsolder one end of the resistor.

7. Connect the test leads to the vertical winding

8. Depress the INDUCTOR RINGER TEST button and read the test result in the LC77 display.

9. If the vertical windings do not test "GOOD", the yoke is defective.

### Special Note On Solid State Yokes And Flybacks:

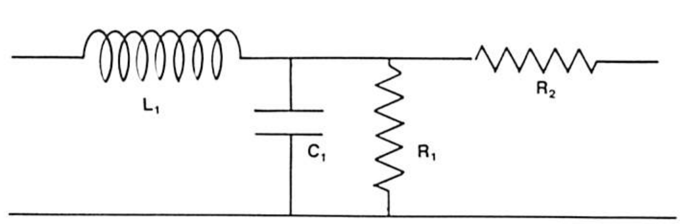
A few yokes and flybacks have very low Q for use in certain solid state chassis. These components may not ring "GOOD" but may rather ring only 8 or 9 times. To determine if they are good or bad simply add a "shorted turn" and again check the number of rings. If the yoke or flyback is good, the number of rings will drop drastically when the short is added. A defective yoke or flyback will not be affected by the shorted turn and the number of rings will change only 1 or 2 counts if at all.

A simple "shorted turn" is a piece of solder or heavy gauge wire formed into a loop. Press the loop close to the windings of the yoke or wrap it around the core or windings of the flyback.

## Cable Testing Applications

### Testing Coaxial Cable

Coaxial cables and transmission lines have characteristics of both an inductor and a capacitor, as illustrated in Figure 63. The LC77 "Auto-Z" can be used to determine the length of a piece of coaxial cable (or the distance to a break) and the distance to a short between the center conductor and shield. Any breakdown in the dielectric can also be detected using the LC77 leakage power supply.




$L_1$ = Series Inductance
$C_1$ = Shunt Capacitance
$R_1$ = Shunt Resistance (dielectric leakage)
$R_2$ = Series Resistance

*Fig. 63 — A length of coaxial cable consists of capacitance and inductance distributed throughout the cable's length.*

DETERMINING THE DISTANCE TO AN OPEN

A length of coaxial cable open at both ends is equivalent to a long capacitor, with the two conductors forming the plates. Every type of coaxial cable has a normal amount of capacitance per foot, specified in picofarads per foot (pF/ft). The capacitance per foot values for some common coaxial cable types are listed in Table 14. The length of a piece of cable, as well as the distance to an open, is found by simply measuring the capacitance between the center and outer conductors and dividing this total capacitance by the cable's capacitance per foot value. If possible, measure from both ends of the cable to more accurately pinpoint the break. In most cases, the length of a cable can be determined within 1-2%.

*Fig. 64 — Use the LC77 to measure the distance to breaks or shorts in buried cable.*

**To measure the length of a cable:**

1. Zero the LC77 test leads.

2. Connect the red test lead to the center conductor and the black test lead to the braided shield outer conductor of an open (unterminated) cable.

3. Press the CAPACITOR VALUE TEST button and read the total capacitance of the cable.

4. Divide the LC77 capacitance reading by the cable's capacitance per foot value. This gives the length of the cable, or the distance to the break in feet.

You can also use this test to determine the length or to pinpoint a break in multiconductor cable that has 3 or more conductors. Due to variations in conductor spacing and noise pickup, however, the accuracy will not be as good as for coaxial cable. Follow the same procedure as above, except tie all but one of the conductors together to form the outer "shield". Measure the capacitance between this "shield" and the remaining single wire. You can determine the capacitance per foot for the cable using the procedure in the section "Determining Capacitance And Inductance Per Foot".

*NOTES: 1. The accuracy of these measurements depends on the cable tolerance. The values listed in Table 14 are nominal amounts which may very slightly (within 2%) with cable manufacturer. 2. Excessive crimping or clamping along the cable will change the total capacitance reading.*

## LOCATING A SHORT IN COAXIAL CABLE

A coaxial cable which has a short between its center conductor and outer conductor is similar to a very long inductor. The LC77 can be used to determine the distance to a short using the Inductor Value test. The amount of inductance per foot of a coaxial cable is not usually published by the cable manufacturer, and the amount for the same type of cable may vary significantly from one manufacturer to another. Therefore, to calculate the distance to a short you must first use a same length of cable to determine the inductance per foot value, as explained in the following section. Record this amount in Table 14 for each type and manufacturer of cable you encounter.

**To determine the distance to a short:**

1. Zero the LC77 test leads.

2. Connect the red test lead to the center conductor and the black test lead to the braided shield outer conductor of a shorted cable.

50-55 Ohm

| | Nominal | Nominal | Nominal |
|---|---|---|---|
| RG/U Cable Type | Impedance | Cap in pF/FT | Inductance |
| 5B/U | 50 | 29.5 | |
| 8U | 52 | 29.5 | |
| 8U Foam | 50 | 26 | |
| 8A/U | 52 | 29.5 | |
| 10A/U | 52 | 29.5 | |
| 18A/U | 52 | 29.5 | |
| 58/U | 53.5 | 28.5 | |
| 58/U Foam | 50 | 26 | |
| 58A/U | 50 | 30.8 | |
| 58C/U | 50 | 29.5 | |
| 58C/U Foam | 50 | 26 | |
| 74A/U | 52 | 29.5 | |
| 174/U | 50 | 30-30.8 | |
| 177/U | 50 | 30 | |
| 212/U | 50 | 29.5 | |
| 213/U | 50 | 30.5 | |
| 214/U | 50 | 30.5 | |
| 215/U | 50 | 30.5 | |
| 219/U | 50 | 30 | |
| 225/U | 50 | 30 | |
| 224/U | 50 | 30 | |

70-75 Ohm

| | Nominal | Nominal | Nominal |
|---|---|---|---|
| RG/U Cable Type | Impedance | Cap in pF | Inductance uH/FT |
| 6A/U | 75 | 20 | |
| 6A/U Foam | 75 | 20 | |
| 11U | 75 | 20.5 | |
| 11U Foam | 75 | 17.3 | |
| 11A/U | 75 | 20.5 | |
| 12A/U | 75 | 20.5 | |
| 13A/U | 74 | 20.5 | |
| 34B/U | 75 | 20 | |
| 35B/U | 75 | 20.5 | |
| 59/U | 73 | 21 | |
| 59/U Foam | 75 | 17.3 | |
| 59/BU | 75 | 20.5 | |
| 164/U | 75 | 20.5 | |
| 216/U | 75 | 20.5 | |

90-125 Ohm

| | Nominal | Nominal | Nominal |
|---|---|---|---|
| RG/U Cable Type | Impedance | Cap in pF | Inductance uH/FT |
| 62/U | 93 | 13.5 | |
| 62A/U | 93 | 13.5 | |
| 63B/U | 125 | 10 | |
| 71B/U | 93 | 13.5 | |
| 79B/U | 125 | 10 | |

***Table 14 — Capacitance per foot values for common coaxial cable types.***

3. Press the INDUCTOR VALUE TEST button and read the total inductance of the cable.

4. Divide the LC77 inductance reading by the cable's inductance per foot value. This gives the distance to the short in feet.

*Note: To help pinpoint the short with greater accuracy, measure the inductance from both ends of the cable.*

### DETERMINING CAPACITANCE AND INDUCTANCE PER FOOT

The capacitance and inductance per foot values for a particular type of coaxial cable can be determined by measuring a sample cable of known length. After measuring the amount of capacitance and inductance with the LC77, divide the total amounts by the length of the sample. Sample lengths of at least 10 feet are recommended for accurate capacitance measurements, and 25 feet for accurate inductance measurements.

**To determine capacitance and inductance per foot:**

1. Zero the LC77 test leads.

2. Connect the red test lead to the center conductor and the black test lead to the braided shield outer conductor at one end of the sample cable.

3. Leave the other end of the cable open to measure capacitance; short together to measure inductance.

4. Press the CAPACITOR VALUE or INDUCTOR VALUE TEST button and read the total capacitance or inductance of the cable.

5. Divide the LC77 reading by the length of the sample cable. Record for future reference.

### USING THE LC77 TO FIND AGING CABLE

All coaxial cables exposed to the elements eventually degrade to the point where they need to be replaced. The LC77 can be used for preventative maintenance checks of coaxial cable to determine if deterioration is beginning to occur. As a cable begins to fail, the dielectric separating the conductors becomes contaminated causing a change in the cable's capacitance and the DC leakage through the dielectric.

All cable has a normal amount of capacitance per foot and any significant change that occurs over a period of time indicates a developing problem. The best check for aging cable is to measure and record the total capacitance of the installation when it is first installed. If the initial value is not known, you can multiply the length of the cable by its nominal capacitance per foot. Then compare periodic capacitance measurements back to the initial amount and look for any changes. As the dielectric becomes contaminated, the LC77 capacitance reading will increase.

The LC77 leakage power supply also provides a good test of a cable's condition. Simply measure the amount of leakage through the dielectric between the conductors. Most cables have a maximum operating voltage of 1000 volts or more and should be tested with the LC77 leakage supply set to 999.9 volts. A few "air space" dielectric types of coaxial cable, such as RG37, RG62, RG71, and RG72 have a maximum operating voltage of 750 volts and should be tested at this lower voltage.

**WARNING**

**This test should only be performed by a qualified person who understands the shock and safety hazards of up to 1000 volts applied to the test leads and open ends on the coaxial cable.**

A good piece of cable should have no leakage when the voltage from the LC77 is applied between the center conductor and outside shield. The length of the cable being tested will make no difference on the leakage reading. Any leakage reading indicates the dielectric is breaking down.

## High Potential Testing

The LC77 "Auto-Z" can be used to locate leakage currents as low as .1 uA, such as the leakage between PC board foils, leakage between windings of a transformer, and leakage between switch contacts and shafts. These leakage currents are much to small to be measured with an ohmmeter, but are measurable when a high voltage potential (Hi Pot) is applied with the LC77 leakage power supply.


*Fig. 65 — Small leakage paths can be detected with the LC77 Hi Pot test.*

## WARNING

**These tests are only to be performed by a person who understands the shock hazard of up to 1000 volts applied to the test leads and to the component under test when the Capacitor Leakage button is depressed. Do not hold the test leads or the component under test in your hands when making any Hi Pot test.**

Traces on a bare printed circuit board should show no leakage when tested at 1000 volts with the LC77. Any leakage indicates contamination on the board, or fine, hair-like projections from the etched traces shorting between the traces. The (optional) 39G85 Touch Test Probe may be used to make easy connection to the foils. It provides needle-sharp points that are adjustable for different trace spacings.

AC power transformers should be tested to make sure they provide proper isolation from the AC line. Transformers should be tested for leakage between the primary and secondary, as well as for leakage between the windings and the metal core or frame. To test for leakage between primary and secondary disconnect all transformer leads from the circuit. Connect one of the LC77 test leads to one of the primary leads and the other LC77 lead to one of the secondary leads. If the transformer has more than one secondary winding, each should be tested for leakage. Most transformers used today have a 1500 volt break down rating and should have 0 microamps of leakage when tested at 1000 volts with the LC77. Any leakage indicates a potential shock and safety hazard.

## Measuring Resistors To 1 Gigohm

Focus and high voltage resistors up to 1 gigohm may be measured using the leakage power supply in the LC77. These resistors are often much too large in value to be measured with any other test. The "Auto-Z" will read the resistance of these resistors without any calculations.

The range of resistance which the LC77 will measure depends on the applied voltage. Table 15 shows the amount of applied voltage needed to produce a usable resistance reading. Simply place the front panel LEAKAGE switch in the "Ohms" position, set the leakage power supply to a voltage just high enough to read the anticipated resistance, and depress the CAPACITOR LEAKAGE TEST button. The "Auto-Z" will display the amount of resistance directly in ohms.

## WARNING

**This test is only intended to measure high voltage resistors. Some resistors have voltage ratings of 200 volts or less and will be damaged by high test voltages. Apply only enough voltage to the resistor (as shown in Table 15) to produce a reading.**

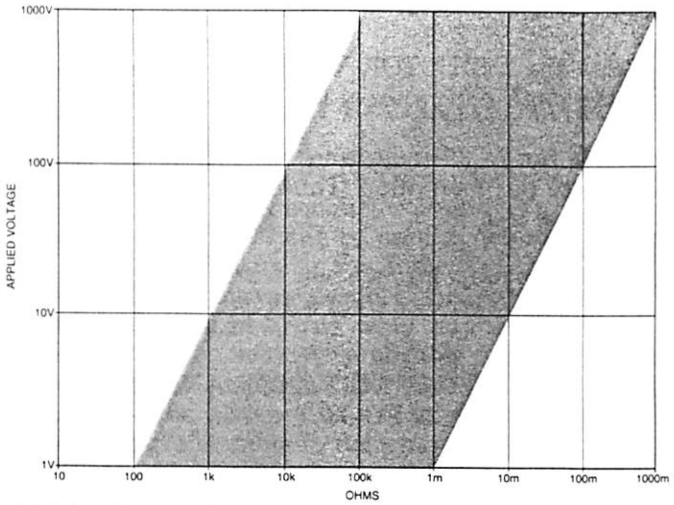



***Table 15 — To measure restance values up to 1 gigohm, enter the necessary leakage voltage amount to place the restance value within the shaded area.***

## Applications Of The Leakage Power Supply

Many times a variable voltage DC power supply is needed in troubleshooting and other applications good as applying a bias voltage or powering a circuit. The LC77 leakage power supply may be used in these applications to provide voltages in 0.1 volt steps from 1.0 to 999.9 volts DC. Simply enter the desired voltage using the COMPONENT PARAMETERS keypad and use the 39G201 Test Button Hold Down Rod to keep the CAPACITOR LEAKAGE button depressed.

The amount of current being drawn by the circuit connected to the LC77 will be displayed in the LCD display up to 19.9 milliamps. (Currents greater than 20 mA will cause the LCD display to overrange). The leakage power supply is current limited and will not be damaged by excessive current draw. When over loaded, the output voltage will drop to a level that will not damage the supply. Table 16 shows the amount of current which the leakage power supply can provide with less than a 10% reduction in output voltage.

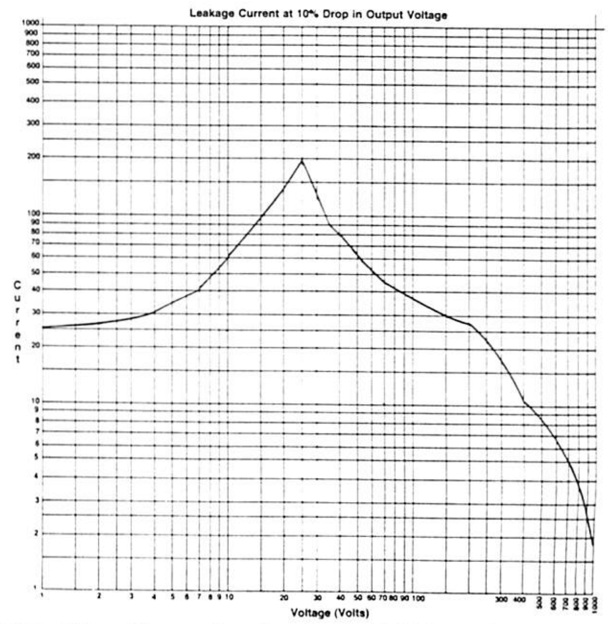



***Table 16 — Current output capabilities of the "Auto-Z" leakage power supply.***

# MAINTENANCE

## Introduction

The LC77 is designed to provide reliable service with very little maintenance. A fully equipped Factory Service Department is ready to back the LC77 should any problems develop. A schematic, parts list, and circuit board layouts are included along with this manual on separate sheets.

## Recalibration And Service

Recalibration of the LC77 is recommended on a yearly basis, or whenever the performance of the unit is noticeably affected. Precise standards are required to insure accurate and National Bureau of Standards (NBS) traceable calibration. For this reason it is recommended that the LC77 be returned to the Sencore Factory Service Department for recalibration. The address of the Service Department is listed below. No return authorization is required to return the LC77 for recalibration or service. In most cases, the unit will be on its way back to you within 3 days after it is received by the Service Department at: Sencore Factory Service
3200 Sencore Drive
Sioux Falls, SD 57107
(605)339-0100.

## Circuit Description And Calibration Procedures

A complete circuit description, and a detailed calibration procedure listing the necessary standards and equipment, are available for the LC77 "AUTO-Z". These items may be purchased separately through the Sencore Factory Service Parts Department at the address and phone number listed below.

## Replacement Leads

The 39G143 Test Leads on the LC77 are made from a special low capacity cable. Replacing the test leads with a cable other than the low capacity test lead will result in measurement errors. Replacement 39G143 Test Leads are available from the Sencore Service Parts Department.

## "Spare" Button

The "SPARE" button on the front panel is provided to keep your LC77 "Auto-Z" from becoming obsolete. If a new or different type of component is introduced in the coming years, your LC77 may be updated by changing the EPROM chip or by changing the EPROM memory itself. Be sure to return the warranty card sent with the LC77 so that you can be notified if an update takes place.

## Blown Fuse Conditions

A 1 amp, Slo-Blo (3AG) fuse is located in the test lead input jack on the front of the "Auto Z". This fuse protects the unit from accidental external voltage or current overloads. The fuse may need replacement if the following conditions exist:

-Display reads "OPEN" during inductor lead zeroing
-Display reads "OPEN" during inductance test
-Ringing test reads "Error 1"
-ESR test reads "Error 7"
-No leakage readings
-Readings do not change with test leads open or shorted

## Fuse Replacement

The fuse for the test lead input is located behind the BNC input jack. Remove the fuse holder by turning the BNC connector counter clockwise and unscrewing the connector until the fuse is free. The BNC connector of the test leads may be used as a "Wrench" to aid in the removal of the fuse holder. When replacing the fuse holder, make sure it is screwed in tightly to prevent the connector from turning when connecting and disconnecting test leads. Replace the fuse with a 1 Amp Slo-Blo (3AG) fuse only.

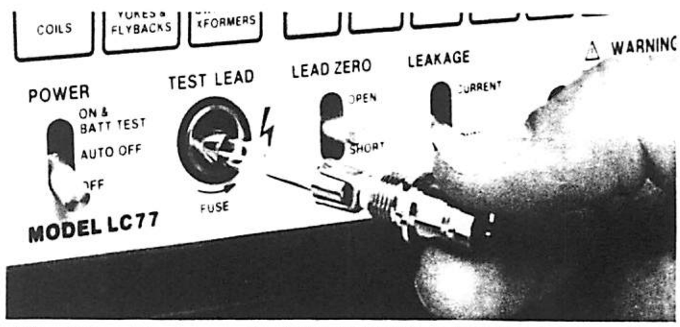



*Fig. 66 — Remove the TEST LEAD BNC jack to replace the input protection fuse.*

## Display Test

The LCD display of the "Auto-Z" LC77 may be tested at any time by performing the battery test and pushing the CLR button at the same time. All the segments of the LCD readout will momentarily turn on followed by a sequential readout of all the numbers and symbols on the display. Any missing segments, symbols, or numbers indicate a defect either in the display itself or an internal circuit. In this case the Sencore Factory Service Department should be called for service instructions.

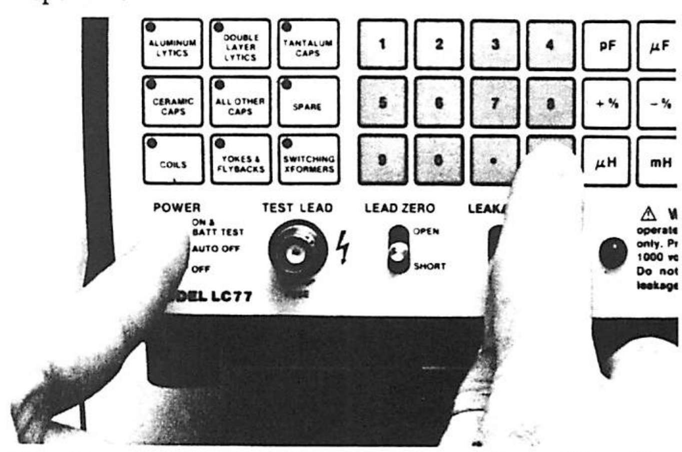



*Fig. 67 — Push the "CLR" button while holding the power switch to "ON & BATT TEST" to check LCD display.*

# APPENDIX

## Introduction

The capacitor is one of the most common components used in electronics, but less is known about it than any component in electronics. The following is a brief explanation of the capacitor, how it works, and how the "Auto-Z" measures the important parameters of the capacitor.

## Capacitor Theory and the "Auto-Z"

The basic capacitor is a pair of metal plates separated by an insulating material called the dielectric. The size of the plates, the type of dielectric, and the thickness of the dielectric determines the capacity. To increase capacity, you can increase the size of the plates, increase the number of plates, use a different dielectric or a thinner dielectric. The closer the plates, or the thinner the dielectric, the larger the capacity for a given size plate. Because flat plates are rather impractical, capacitors are generally made by putting and insulating material (dielectric) between two foil strips and rolling the combination into a tight package or roll.

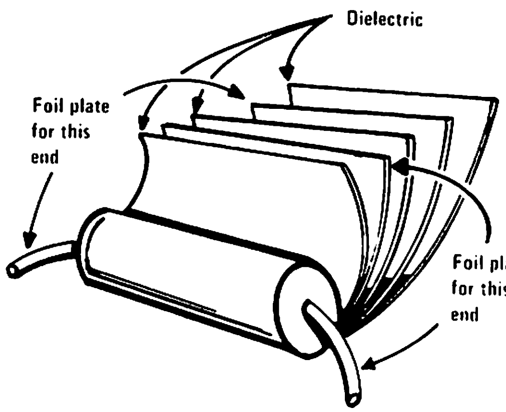



***Fig. A — Many capacitors are made of foil separated by a dielectric and rolled into a tight package.***

The old explanation of how a capacitor works had the electrons piling up on one plate forcing the electrons off of the other to charge a capacitor. This made it difficult to explain other actions of the capacitor. Faraday's theory more closely approaches the way a capacitor really works. He stated that the charge is in the dielectric material and not on the plates of the capacitor. Inside the capacitor's dielectric material, there are tiny electric dipoles. When a voltage is applied to the plates of the capacitor, the dipoles are stressed and forced to line up in rows creating stored energy in the dielectric. The dielectric has undergone a physical change similar to that of soft iron when exposed to current through an inductor when it becomes a magnet. If we were able to remove the dielectric of a charged capacitor, amd then measure the voltage on the plates of the capacitor, we would find no voltage. Reinserting the dielectric and then measuring the plates, we would find the voltage that the capacitor had been charged to before we had removed the dielectric. The charge of the capacitor is actually stored in the dielectric material. When the capacitor is discharged, the electric dipoles become re-oriented in a random fashion, discharging their stored energy.

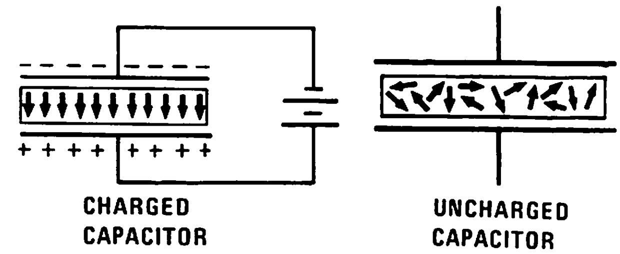



***Fig. B — Applying a potential to a capacitor causes the dipoles in the dielectric to align with the applied potential. When the capacitor discharges the dipoles return to an unaligned, random order.***

When a capacitor is connected to a voltage source, it does not become fully charged instantaneously, but takes a definite amount of time. The time required for the capacitor to charge is determined by the size or capacity of the capacitor, and the resistor in series with the capacitor or its own internal series resistance. This is called the RC time constant. Capacity in Farads multiplied by resistance in Ohms equals the RC time constant in seconds. The curve of the charge of the capacitor is the RC charge curve.

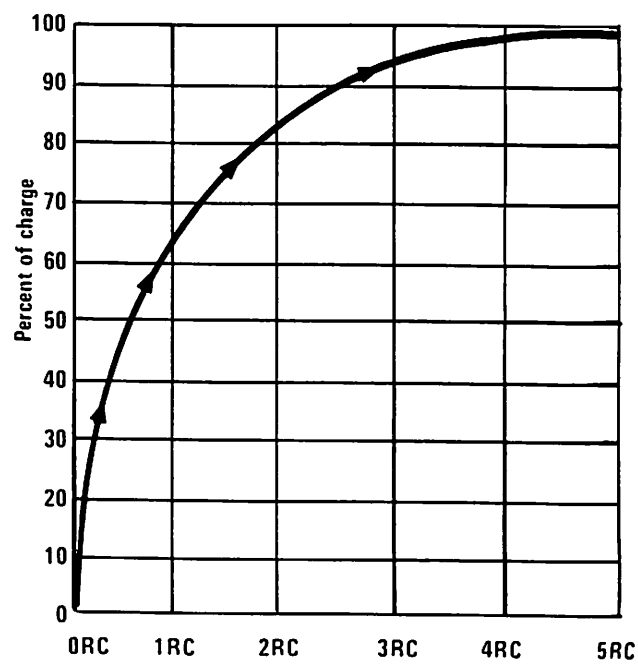



***Fig. C — Capacitors follow an RC charge time as they charge to the applied voltage.***