Voltage will be applied to the capacitor as long as the CAPACITOR LEAKAGE button remains depressed, and the leakage readings will decrease as the capacitor continues to charge. Some capacitors may take a few seconds to charge up to the applied voltage and may cause the display to overrange with a flashing "88.88 mA" display. Continue to depress the CAPACITOR LEAKAGE button until the leakage reading drops below the maximum allowable amount listed in the Leakage Chart.

When the CAPACITOR LEAKAGE button is released, the LC77 discharges the capacitor through a low value, high wattage resistor. The LC77 contains safety circuits which sense the voltage across the test leads. Therefore, when you release the CAPACITOR LEAKAGE button after checking a large value capacitor, or after applying a high leakage voltage, the display may show "Wait - - - -" until the voltage is gone from the test leads. All data input and test buttons will be locked out until the display returns to "0000".

LEAKAGE IN PAPER, MICA AND FILM CAPACITORS

Paper, mica and film capacitors should have extremely small amounts of leakage. Measuring any leakage when checking these types of capacitors indicates a bad component. The leakage reading may take 1-2 seconds to show an accurate display while the capacitor charges.

LEAKAGE IN CERAMIC CAPACITORS

Leakage in ceramic capacitors is generally very low. Ceramic disc capacitors, however, may have small amounts of normal leakage. Ceramic disc capacitors with voltage ratings above 50 WVDC should have less than 1 uA of leakage. Some discs with working voltages less than 50 WVDC may have a lower insulation resistance, and therefore may show somewhat more leakage, depending upon manufacturer. In general, a 10 WVDC ceramic disc capacitor may show as much as 16 uA of leakage, and 25 WVDC ceramic disc may read up to 2.5 uA of leakage and still be considered good.

LEAKAGE IN ALUMINUM ELECTROLYTICS

Because of their larger value and higher leakage characteristics, aluminum electrolytic capacitors may take several seconds to charge. The LC77 display may overrange (flashing 88.88 mA display) indicating the charging current is greater than 20 mA while the capacitor is charging. Table 2 shows the approximate time that you can expect the LC77 to overrange for a given capacitor value and applied voltage. After the LC77 stops overranging, the current will drop in progressively smaller steps as the capacitor charges. When the cap is fully charged, the leakage readings will change just a few digits up or down. You do not need to wait until an electrolytic capacitor is fully charged to determine if it is good. Simply keep the CAPACITOR LEAKAGE button depressed until the leakage reading falls below the maximum amount shown in the Leakage Charts.

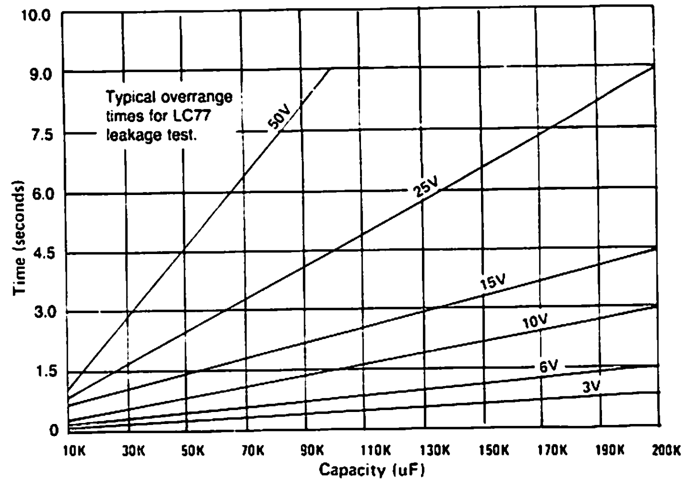


Table 2 — Meter Overrange time versus capacitor value and applied voltage.

LEAKAGE IN TANTALUM ELECTROLYTICS

Tantalum electrolytic capacitors have much lower leakage than aluminum electrolytics of the same size and voltage rating. Therefore, tantalum lytics will give a leakage reading in a much shorter time than an aluminum lytic - typically within 2 to 5 seconds. Compare the measured leakage with the amounts shown in the leakage charts to determine if the capacitor is good or bad.

LEAKAGE IN NON-POLARIZED ELECTROLYTICS

Electrolytic capacitors which are non-polarized should be checked for leakage in both directions. This requires that you measure leakage twice, reversing the LC77 test lead connections for the second test. The maximum allowable leakage for a non-polarized electrolytic in either direction is twice that of a similar polarized electrolytic of similar capacitance value and voltage rating.

Leakage charts

The following leakage charts list the maximum amount of allowable leakage for the most common aluminum electrolytics and dipped soiled tantalum capacitors. These charts are also duplicated on the pull chart below the LC77. Good capacitors (as far as leakage is concerned) will measure lower than the amounts shown in the Leakage Charts. When measuring leakage, you do not need to wait for the readings to drop to zero or to its lowest point. The capacitor is good for any leakage reading which is lower than the amount shown in the chart.

Leakage values shown in Table 3 for aluminum electrolytic capacitors are the worst-case conditions, as specified by the Electronic Industries Association (EIA) standard RS-395. The values are determined by the formulas: L = 0.05 x CV (for CV products less than 1000) or L= 6 x square root of CV (for CV products greater than 1000. (The CV product is equal to the capacitance value multiplied by the voltage rating).

The tantalum capacitor leakage values listed in Table 4 are for the most common type of tantalum capacitors — dipped solid, type 3.3. These values are specified by EIA standard RS-228B, following the formula: L = 0.35 x square root of CV. In a few applications outside of consumer service, tantalum capacitors other than type 3.3 may be encountered. Refer to the manufacturers' specifications for the maximum allowable leakage for these special capacitor types.

Maximum Allowable Leakage (in Microamps)

Standard Aluminum Electrolytic Capacitors

Capacity in uF	1.5V	3.0V	6.0V	10V	15V	20V	25V	35V	50V	100V	200V	300V	400V	500V	600V	1000V
1.0	5	5	5	5	5	5	5	5	5	5	10	15	20	25	30	50
1.5	5	5	5	5	5	5	5	5	5	8	15	23	30	38	45	232
2.2	5	5	5	5	5	5	5	5	6	11	22	33	44	199	218	281
3.3	5	5	5	5	5	5	5	6	8	17	33	50	218	244	267	345
4.7	5	5	5	5	5	5	6	8	12	23	47	225	260	291	319	411
6.8	5	5	5	5	5	7	9	12	17	34	221	271	313	350	383	495
10	5	5	5	5	8	10	13	18	25	50	268	329	379	424	465	600
15	5	5	5	8	11	15	19	26	38	232	329	402	465	520	569	735
22	5	5	7	11	17	22	28	39	199	281	398	487	563	629	689	890
33	5	5	10	17	25	33	41	204	244	345	487	597	689	771	844	1090
47	5	7	14	24	35	47	206	243	291	411	582	712	823	920	1008	1301
68	5	10	20	34	192	221	247	293	350	495	700	857	990	1106	1212	1565
100	8	15	30	50	232	268	300	355	424	600	849	1039	1200	1342	1470	1897
150	11	23	45	232	285	329	367	435	520	735	1039	1273	1470	1643	1800	2324
220	17	33	218	281	345	398	445	526	629	890	1259	1541	1780	1990	2180	2814
330	25	50	267	345	422	487	545	645	771	1090	1541	1888	2180	2437	2670	3447
470	35	225	319	411	504	582	650	770	920	1301	1840	2253	2602	2909	3186	4113
680	192	271	383	495	606	700	782	926	1106	1565	2213	2710	3129	3499	3832	4948
1000	232	329	465	600	735	849	949	1122	1342	1897	2683	3286	3795	4243	4648	6000
1500	285	402	569	735	900	1039	1162	1375	1643	2324	3286	4025	4648	5196	5692	7348
2200	345	487	689	890	1090	1259	1407	1665	1990	2814	3980	4874	5628	6293	6893	8899
3300	422	597	844	1090	1335	1541	1723	2039	2437	3447	4874	5970	6893	7707	8443	
4700	504	712	1008	1301	1593	1840	2057	2434	2909	4113	5817	7125	8227	9198		
6800	606	857	1212	1565	1916	2213	2474	2927	3499	4948	6997	8570	9895			
10000	735	1039	1470	1897	2324	2683	3000	3550	4243	6000	8485					
15000	900	1273	1800	2324	2848	3286	3674	4347	5196	7348						
22000	1090	1541	2180	2814	3447	3980	4450	5265	6293	8899						
33000	1335	1888	2670	3447	4221	4874	5450	6448	7707							
47000	1593	2253	3186	4113	5038	5817	6504	7695	9198							
56000	1739	2459	3478	4490	5499	6350	7099	8400								
68000	1916	2710	3832	4948	6060	6997	7823	9256								
100000	2324	3286	4648	6000	7348	8485	9487									
150000	2846	4025	5692	7348	9000											
220000	3447	4874	6893	8899												

NOTE: No industry standards are available for component values in the shaded areas. These values have been extrapolated from existing standards and manufacturers data. All values not shaded are based on existing EIA industry standards.

Table 3 — Maximum allowable leakage for aluminum electrolytics per EIA standards.

Maximum Allowable Leakage (in Microamps)

Dipped Solid Tantalum Capacitors

Capacity	1.5V	3.0V	6.0V	10V	15V	20V	25V	35V	50V	100V	200V	300V	400V	500V	600V	1000V
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.5	4.9	6.1	7.0	7.8	8.6	11
1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.4	1.0	2.0	4.3	6.1	7.4	8.6	9.6	11	14
2.2	1.0	1.0	1.0	1.0	1.0	1.0	1.8	1.2	2.0	5.2	7.3	9.0	10	12	13	16
3.3	1.0	1.0	1.0	1.0	1.0	1.5	2.2	2.0	3.0	6.4	9.0	11	13	14	16	20
4.7	1.0	1.0	1.0	1.0	1.5	2.0	2.6	2.5	3.5	7.6	11	13	15	17	19	24
6.8	1.0	1.0	1.0	1.5	2.0	2.5	3.0	3.0	6.5	9.1	13	16	18	20	22	29
10	1.6	1.6	1.6	2.0	2.5	3.0	4.0	5.0	7.8	11	16	19	22	25	27	35
15	2.2	2.2	2.2	2.5	3.0	4.0	7.0	5.0	9.6	14	19	23	27	30	33	43
22	2.8	2.8	2.8	3.0	5.0	9.5	10	10	12	16	23	28	33	37	40	52
33	3.4	3.4	3.4	5.0	7.5	15	10	11	14	20	28	35	40	45	49	64
47	4.0	4.0	4.0	10	10	15	15	16	17	24	34	42	48	54	59	76
68	5.0	5.0	5.0	15	15	20	15	17	20	29	41	50	58	65	71	91
100	10	10	10	15	20	20	17	21	25	35	49	61	70	78	86	111
150	15	15	15	20	20	19	21	25	30	43	61	74	86	96	105	136
220	20	20	20	20	20	23	26	31	37	52	73	90	104	116	127	164
330	20	20	20	20	25	28	32	38	45	64	90	110	127	142	156	201
470	24	24	24	24	29	34	38	45	54	76	107	131	152	170	186	240
680	29	29	29	29	35	41	46	54	65	91	129	158	183	204	224	289
1000	35	35	35	35	43	49	55	65	78	111	157	192	221	247	271	350
1500	43	43	43	43	53	61	68	80	96	136	192	235	271	303	332	429
2200	52	52	52	52	64	73	82	97	116	164	232	284	328	367	402	519
3300	64	64	64	64	78	90	101	119	142	201	284	348	402	450	492	636
4700	76	76	76	76	93	107	120	142	170	240	339	416	480	537	588	759
6800	91	91	91	91	112	129	144	171	204	289	408	500	577	645	707	913
10000	111	111	111	111	136	157	175	207	247	350	495	606	700	783	857	1107
15000	136	136	136	136	166	192	214	254	303	429	606	742	857	959	1050	1356
22000	164	164	164	164	201	232	260	307	367	519	734	899	1038	1161	1272	1642
33000	201	201	201	201	246	284	318	376	450	636	899	1101	1272	1422	1557	2011
47000	240	240	240	240	294	339	379	449	537	759	1073	1314	1518	1697	1859	2399
68000	289	289	289	289	353	408	456	540	645	913	1291	1581	1825	2041	2236	2886
100000	350	350	350	350	429	495	553	655	783	1107	1565	1917	2214	2475	2711	3500
150000	429	429	429	429	535	606	678	802	959	1356	1917	2348	2711	3031	3320	4287
200000	495	495	495	495	606	734	783	971	1100	1570	2210	2710	3130	3500	3830	5191

NOTE: No industry standards are available for component values in the shaded areas. These values have been extrapolated from existing standards and manufacturers data. All values not shaded are based on existing EIA industry standards.

Table 4 — Maximum allowable leakage for solid tantalum electrolytics per EIA standards.

Measuring Capacitor Leakage (In Ohms)

At times it is useful to know the amount of capacitor leakage in terms of resistance. For example, it is often easier to visualize what effect a 1 Megohm resistor will have on a high impedance circuit than it is to translate to effect of a capacitor having 1 microamp of leakage. Yet, as far as the circuit is concerned, the DC loading is the same.

The LC77 uses a regulated DC power supply to provide voltages for checking capacitor leakage. Because a DC voltage is used, the leakage currents can easily be converted to a resistance. Placing the front panel LEAKAGE switch in the "Ohms" position allows the LC77 to display leakage current in ohms.

To measure capacitor leakage in ohms:

1. Connect the capacitor to the test leads. If the capacitor is polarized, connect the red test clip to the "+" capacitor terminal and the black test clip to the "-" terminal.

2. Set the LEAKAGE switch to the "Ohms" position to read the leakage current in ohms.

3. Enter the normal working voltage of the capacitor as explained earlier in the section "Entering Component Parameters" on page 16.

WARNING

The LC77 is designed to be operated by a technically trained 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 the capacitor leakage test.

4. Depress the CAPACITOR LEAKAGE button and read the amount of leakage resistance in the LCD display.

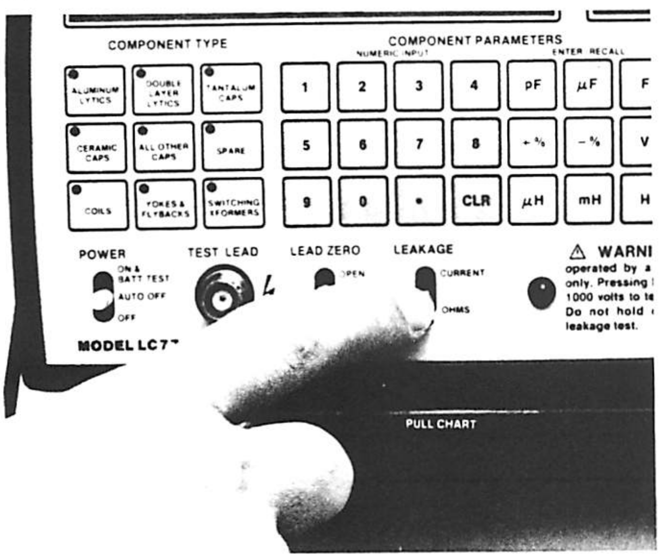


Fig. 17 — Place the LEAKAGE switch in the "ohm" position to measure leakage resistance.

Measuring Capacitor ESR

Equivalent Series Resistance (ESR) occurs when a capacitor develops abnormally high internal resistance. The LC77 tests capacitors for abnormal amounts of internal resistance using a patent pending ESR test.

To test a capacitor for excessive ESR, simply press the CAPACITOR ESR button and compare the measured ESR to the maximum allowable ESR listed in Table 5 for aluminum electrolytic capacitors, and Table 6 for tantalum capacitors. A fully automatic good/bad test may also be used to test capacitors for excessive ESR. This test is explained in a later section of this manual.

Fig. 18 — Depress the ESR button and read the amount of ESR in the LCD display.

To measure capacitor ESR:

1. Zero the test leads, as explained on page 16.

2. Connect the capacitor to the test leads. If the capacitor is polarized, be sure to connect the black test clip to the "-" terminal of the capacitor and the red test clip to the "+" capacitor terminal.

3. Depress the CAPACITOR ESR button and read the amount of ESR in ohms on the digital display.

4. Compare the measured ESR to the value listed in the following ESR tables for the capacitor type, value, and voltage rating of the capacitor you are testing.

NOTE: By entering the component type, working voltage, and value parameters for the capacitor, the LC77 will automatically display the measured ESR along with the same good/bad indication as the ESR tables.

Maximum Allowable ESR (in Ohms)

Standard Aluminum Electrolytic Capacitors

CAPACITY InuF	1.5V	3.0V	6.0V	10V	15V	20V	25V	35V	50V	100V	200V	300V	400V	500V	600V	1000V
1.0	663	663	663	663	464	464	464	464	332	332	265	265	265	265	265	265
1.5	442	442	442	442	310	310	310	221	221	177	177	177	177	177	177	177
2.2	302	302	302	302	211	211	211	151	151	121	121	121	121	121	121	121
3.3	201	201	201	201	141	141	141	101	101	80	80	80	80	80	80	80
4.7	141	141	141	141	99	99	99	71	71	56	56	56	56	56	56	56
6.8	98	98	98	98	68	68	68	49	49	39	39	39	39	39	39	39
10	66	66	66	66	46	46	46	33	33	27	27	27	27	27	27	27
15	44	44	44	44	31	31	31	22	22	18	18	18	18	18	18	18
22	30	30	30	30	21	21	21	15	15	12	12	12	12	12	12	12
33	20	20	20	20	14	14	14	10	10	8.04	8.04	8.04	8.04	8.04	8.04	8.04
47	14	14	14	14	9.88	9.88	9.88	7.06	7.06	5.65	5.65	5.65	5.65	5.65	5.65	5.65
68	9.76	9.76	9.76	9.76	6.83	6.83	6.83	4.88	4.88	3.90	3.90	3.90	3.90	3.90	3.90	3.90
100	6.63	6.63	6.63	6.63	4.64	4.64	4.64	3.32	3.32	2.65	2.65	2.65	2.65	2.65	2.65	2.65
150	4.42	4.42	4.42	4.42	3.10	3.10	3.10	2.21	2.21	1.77	1.77	1.77	1.77	1.77	1.77	1.77
220	3.02	3.02	3.02	3.02	2.11	2.11	2.11	1.51	1.51	1.21	1.21	1.21	1.21	1.21	1.21	1.21
330	2.01	2.01	2.01	2.01	1.41	1.41	1.41	1.01	1.01	.804	.804	.804	.804	.804	.804	.804
470	1.41	1.41	1.41	1.41	.988	.988	.988	.706	.706	.565	.565	.565	.565	.565	.565	.565
680	.976	.976	.976	.976	.683	.683	.683	.488	.488	.390	.390	.390	.390	.390	.390	.390
1000	.663	.663	.663	.663	.464	.464	.464	.332	.332	.265	.265	.265	.265	.265	.265	.265
1500	.442	.442	.442	.442	.310	.310	.310	.221	.221	.177	.177	.177	.177	.177	.177	.177
2200	.302	.302	.302	.302	.211	.211	.211	.151	.151	.121	.121	.121	.121	.121	.121	.121
3300	.201	.201	.201	.201	.141	.141	.141	.101	.101	.080	.080	.080	.080	.080	.080	.080
4700	.141	.141	.141	.141	.099	.099	.099	.071	.071	.056	.056	.056	.056	.056	.056	.056
6800	.098	.098	.098	.098	.068	.068	.068	.049	.049	.039	.039	.039	.039	.039	.039	.039
10000	.066	.066	.066	.066	.046	.048	.046	.033	.033	.027	.027	.027	.027	.027	.027	.027
15000	.044	.044	.044	.044	.031	.031	.031	.022	.022	.018	.018	.018	.018	.018	.018	.018
22000	.030	.030	.030	.030	.021	.021	.021	.015	.015	.012	.012	.012	.012	.012	.012	.012
33000	.020	.020	.020	.020	.014	.014	.014	.010	.010							
47000	.014	.014	.014	.014	.010	.010	.010									
56000	.012	.012	.012	.012												
68000	.010	.010	.010	.010												

NOTE: No industry standards are available for component values in the shaded area. These values have been extrapolated from existing standards and manufacturers data. All values not shaded are based on existing EIA industry standards.

Table 5 — Maximum allowable ESR for aluminum electrolytics per EIA standards.

Capacitor Automatic Good/Bad Testing

The LC77 "Auto-Z" can automatically display a "good/bad" indication for capacitor parameter tests. The automatic tests are much faster than manual parameter tests, since you do not have to look up the result in a chart, or interpolate between listed values. The LC77 compares the measured values of dielectric absorption, leakage, and ESR to tables and formulas stored in its microprocessor memory. The tables and formulas in the "Auto-Z" memory are the same as those printed in this manual, and are based on EIA standards and manufacturers' data. Not every parameter for some capacitor types are specified by EIA standards or manufacturers' data. The LC77 will not produce a "good/bad" display for capacitor parameters not covered by industry accepted standards. The capacitor types and parameters which will produce a "good/bad" indication are listed in Table 7.

Maximum Allowable ESR (in Ohms)

Dipped Solid Tantalum Capacitors

CAPACITY InuF	1.5V	3.0V	6.0V	10V	15V	20V	25V	35V	50V	100V	200V	300V	400V	500V	600V	1000V
1.0	133	133	133	79.6	79.6	79.6	79.6	66.3	66.3	66.3	66.3	66.3	66.3	66.3	66.3	66.3
1.5	88.4	88.4	88.4	53.1	53.1	53.1	53.1	44.2	44.2	44.2	44.2	44.2	44.2	44.2	44.2	44.2
2.2	60.3	60.3	60.3	36.2	36.2	36.2	36.2	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1
3.3	40.2	40.2	40.2	24.1	24.1	24.1	24.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1
4.7	28.2	28.2	28.2	16.9	16.9	16.9	16.9	14.1	14.1	14.1	14.1	14.1	14.1	14.2	14.1	14.1
6.8	19.5	19.5	19.5	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
10	13.3	13.3	13.3	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
15	8.84	8.84	8.84	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31
22	6.03	6.03	6.03	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62
33	4.02	4.02	4.02	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41
47	2.82	2.82	2.82	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69
68	1.95	1.95	1.95	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
100	1.33	1.33	1.33	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
150	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
220	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
330	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
470	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
680	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
1000	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
1500	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
2200	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
3300	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
4700	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
6800	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

NOTE: No industry standards are available for component values in the shaded areas. These values have been extrapolated from existing standards and manufacturers data. All values are based on existing EIA industry standards.

Table 6 — Maximum allowable ESR for dipped solid tantalum electrolytics per EIA standards.

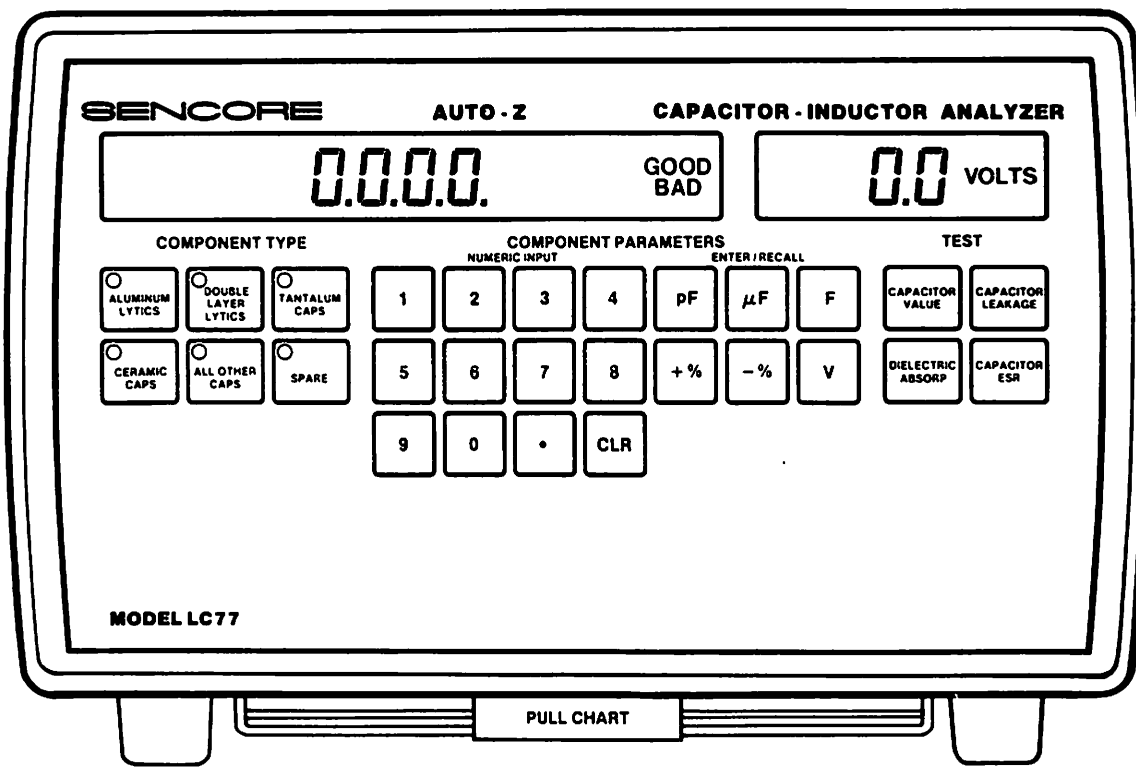


Fig. 19 — Controls used for capacitor good/bad testing.

CAPACITOR TYPE	TESTS TO PERFORM			
	Value	Leakage	D/A	ESR
Aluminum Lytic	X	X	X	X
Double Layer Lytic	X	X		X
Tantalum	X	X	X	X
Ceramic	X	X		
All other caps (paper, film, mylar, etc.)	X	X		

Table 7 — The LC77 will provide an automatic good/bad test of the capacitor parameters shown here.

To perform an automatic good/bad test, you must enter the capacitor type, capacitance value, and voltage rating of the capacitor to be tested so the LC77 can determine the good/bad limits. If you desire to grade capacitors according to value, you must also enter the desired "+" and "-" value tolerances. The value tolerances, however, do not need to be entered for automatic good/bad tests of leakage, ESR, or dielectric absorption.

TEST	CAP VALUE	+%	-%	CAP VOLTAGE	COMPON. TYPE
Cap. Value	X				X
Cap. Leakage	X			X	X
Cap. ESR	X			X	X
Cap. D/A	X			X	X

Table 8 — These parameters must be entered into the "Auto-Z" for a complete good/bad test of a capacitor.

To perform an automatic good/bad capacitor test:

1. Zero the test leads.

2. Connect the capacitor to the test leads.

3. Place the LEAKAGE switch in the "Current" position. The LC77 will not give a good/bad reading with the switch in the "Ohms" position.

4. Enter the component type, value, and voltage rating of the capacitor to be tested. (Refer to the section "Entering Component Data" on page 17.)

5. To grade capacitors according to value, enter the "+" and "-" value tolerance.

6. Push the desired capacitor TEST button.

7. Read the test result in the LCD along with the good/ bad indication.

8. The display must show a "good" reading for all of the tests listed in table 7 under the type of capacitor being tested.

NOTE: The leakage test function may require from 4 to 8 display updates for the leakage value to settle before a good/bad indication is displayed.

Fig. 20 — The LC77 provides an automatic good/bad indication of each capacitor parameter.

Inductor Testing

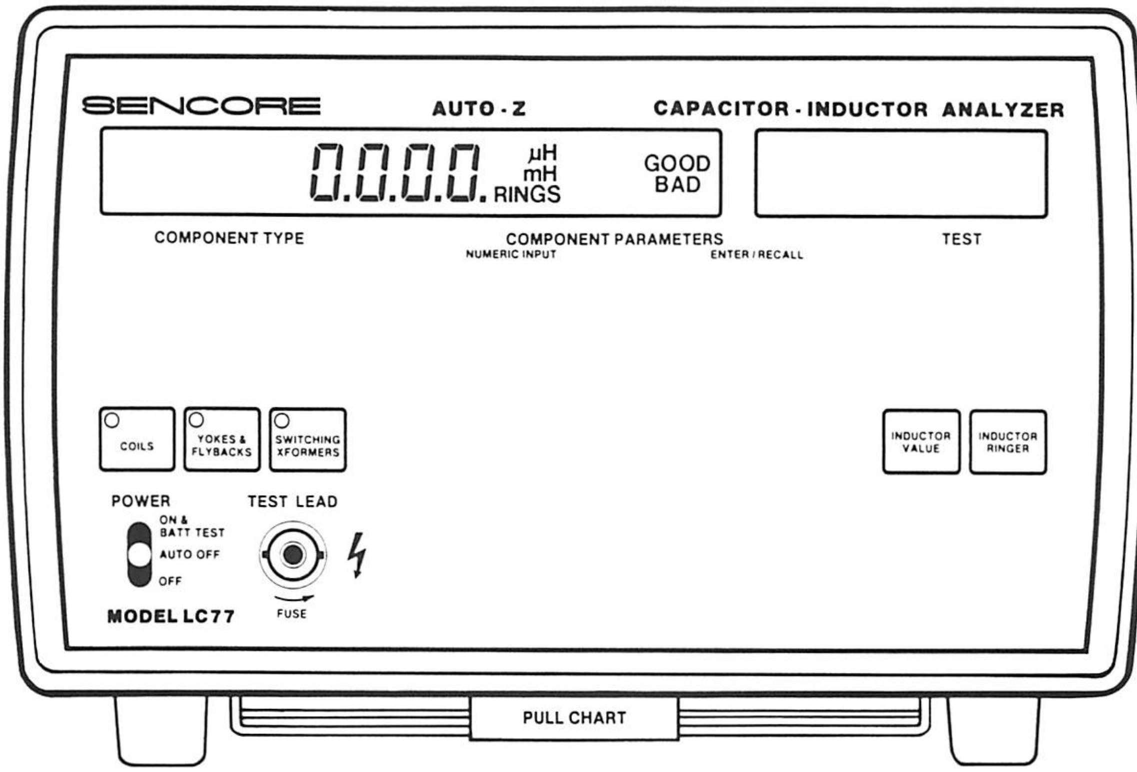


Fig. 21 — Controls used for inductor testing.

The LC77 "Auto-Z" measures the true inductance of coils using a fast, reliable patented test. Coils from .1uH to 19.99 H are automatically measured for value by connecting the test leads and pressing the test button. A patented Ringer test dynamically checks the "Q" of the coil and provides a proven good/bad check.

Balancing Out Lead Inductance

The LC77 test leads have a small amount of inductance which must be balanced out for greater accuracy when measuring inductor values smaller than 1000 uH. This lead inductance is balanced out with the LEAD ZERO switch.

To balance out test lead inductance:

1. Connect the test leads to the TEST LEAD INPUT JACK on the LC77.

2. Connect the red and black test clips together.

3. Move the LEAD ZERO switch to the "Short" position, and release when a "--" begins to move through the display.

4. The test lead inductance will automatically be balanced out for all subsequent inductance tests as long as the "Auto-Z" remains on.

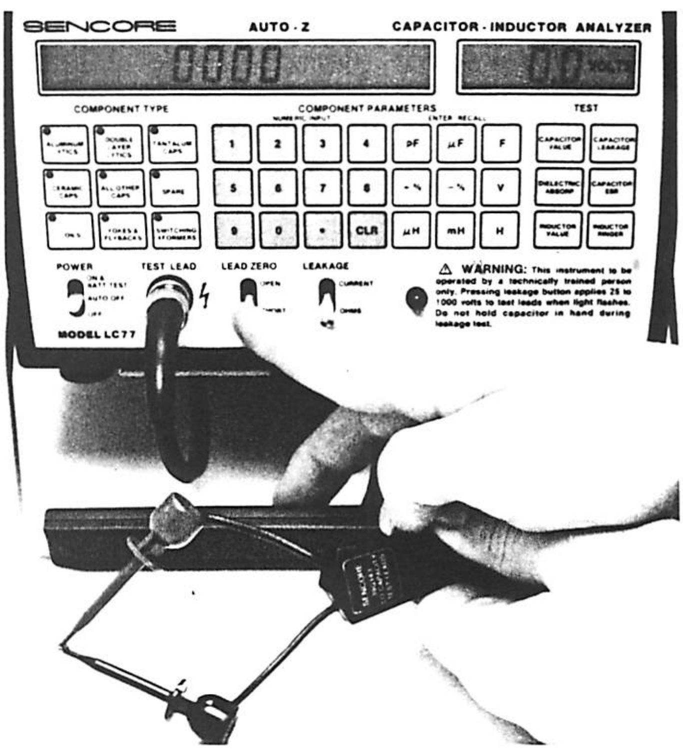


Fig. 22 — Connect the test leads together and push the LEAD ZERO button to "Short" to balance out the test lead impedence when checking small value inductors.

NOTE: Zeroing or not zeroing the test leads will not affect the Ringer test.

Inductor Value Testing

Inductors are tested for value with the LC77 by simply connecting the inductor to the test leads and pushing the INDUCTOR VALUE button. No component type switches need to be selected to measure inductance value. Make sure none of the beige capacitor type buttons are selected, or the LC77 will only display "Error 1" when the inductor test button is pressed.

NOTE: Only the blue color coded LC77 buttons are used for inductor value testing.

To measure inductance value:

1. Zero the test leads.

2. Connect the inductor to the test leads.

3. Push the INDUCTOR VALUE button.

4. Read the inductance value on the LCD display.

NOTE: The LC77 display will read "OPEN" if the component connected to the test leads has more than 20 kilohms of resistance when the INDUCTOR VALUE button is pressed. Check the connections to the inductor. If you are testing a multitap coil or transformer, be sure you are connected to the proper taps. If the connections are good, the inductor has an open winding and is bad.

Inductor Automatic Good/Bad Testing

The LC77 provides two good/bad tests for inductors. The first good/bad test is the patented Ringing test which checks for shorted turns (low Q) in the inductor.

The second LC77 good/bad test compares the actual measured value of an inductor to a user-entered value and tolerances. Both tests will display a good/bad readout along with the measured parameter.

NOTE: The blue color coded TEST and COMPONENT TYPE Select buttons are used for inductor good/bad tests.

Checking Inductors With The Ringer Test

A shorted turn in many coils will go unnoticed with a value test, since the shorted turn changes the inductance value only a small amount. The patented Ringer test, however, provides a fast and accurate good/bad indication of non-iron core coils larger than 10 uH by checking their quality or "Q" factor. The Ringer test is sensitive enough to detect even a single shorted turn on a coil. The "Auto-Z" measures Q by applying a pulse to the coil and counting the number of ringing cycles until the ringing dampens to a preset level. A good coil will indicate "GOOD", and 10 or more rings will be shown in the LC77 LCD display. A shorted turn will lower the Q of the coil, causing the LC77 display to read "BAD" and show less than ten rings.

In addition to air core coils and RF chokes, vertical deflection yokes, horizontal flyback transformers and switching power supply transformers are reliably checked with the Ringer test. The LC77 automatically matches the coil impedance to the necessary testing parameters for the inductor type when the proper inductor COMPONENT TYPE switch is selected. Simply select the component type and press the INDUCTOR RINGER test button to obtain the good/bad indication. Refer to the Applications section of this manual for more details on inductor types.

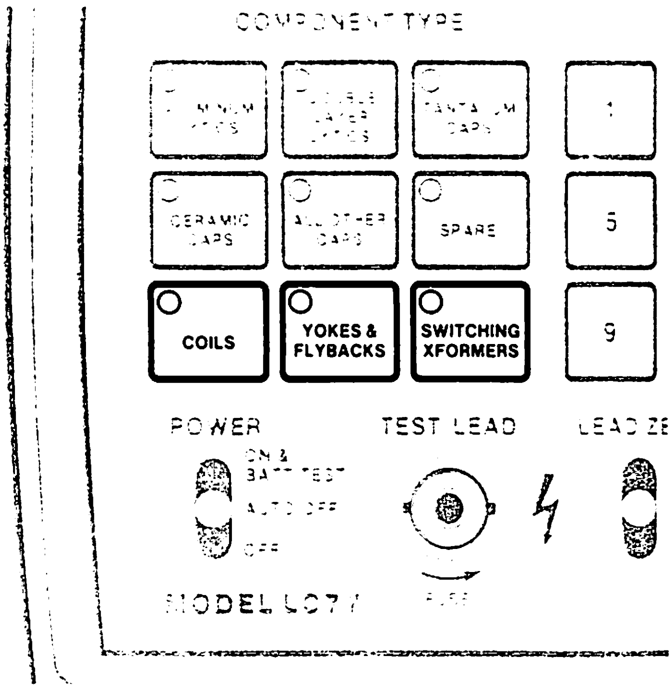


Fig. 23 — The inductor COMPONENT TYPE switches match the Ringer test circuits to the inductor impedance.

To perform the Ringer test:

1. Connect the coil to the LC77 test leads.

2. Select the proper inductor COMPONENT TYPE switch.

3. Push the INDUCTOR RINGER button.

4. Read the condition of the coil as "GOOD" or "BAD" in the LC77 LCD display.

Special Notes On Using The Ringing Test:

1. Do not ring coils and transformers having laminated iron cores, such as power transformers, filter chokes and audio output transformers. The iron core will absorb the ringing energy and produce unreliable test results.

2. Good coils below 10 uH may not read "GOOD" because the small inductance value may not allow the coil to ring. Compare the number of rings to a known good coil.

The patented Sencore Ringing test is based on the Q of the coil. However, the readings on the "Auto-Z" may not agree with the Q readings obtained using a "Q Meter" or bridge. This is because the Ringing test has been simplified to provide a simple good/bad test, rather than a frequency dependent reactance/resistance ratio.

Testing Inductor Values Using The Good/Bad Test

The LC77 will automatically compare the measured value of an inductor to its marked value and display a good or bad result, based on the component being in or out of tolerance. In order for the "Auto-Z" to compare the marked value to the measured value you must program the inductance value and tolerance into the LC77 using the NUMERIC KEYPAD. Then when you push the INDUCTOR VALUE button, the measured inductance value will be displayed along with a good/bad reading based on the programmed tolerance.

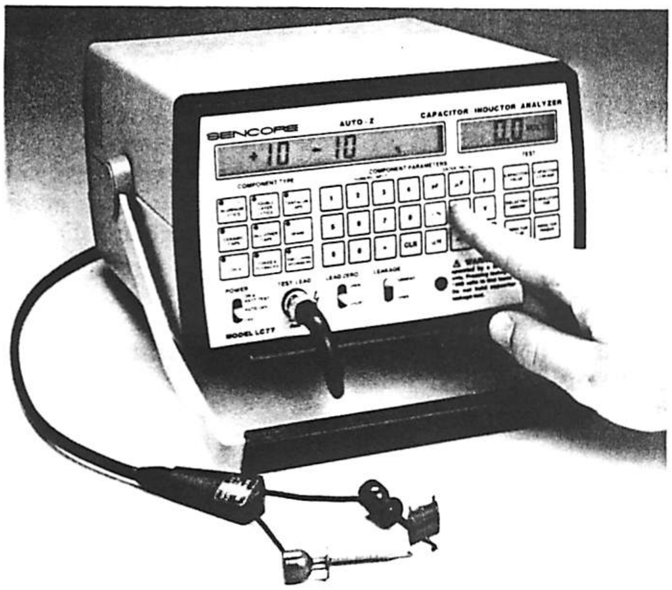


Fig. 24 — The LC77 will provide a good/bad test of inductance value if the marked value and tolerance is programmed in.

To Use The Good/Bad Inductance Test:

1. Zero the test leads.

2. Connect the inductor to the test leads.

3. Enter the marked value, along with the " + " and "-" tolerance of the inductor to be tested. (Refer to the section "Entering Component Data" on page 17.)

4. Push the INDUCTOR VALUE button.

5. If the measured inductance value is within the programmed value tolerance the "GOOD" annunciator will come on.

6. If the measured inductance value is outside the programmed value tolerance, the "BAD" annunciator will come on.

IEEE 488 BUS OPERATION

All of the LC77 "Auto-Z" tests may be totally automated or incorporated into an automated test system through the use of the IEEE 488 General Purpose Interface Bus (GPIB). The LC77 is interfaced to any IEEE system or controller using the (optional) IB72 IEEE 488 Bus Interface accessory. The IB72 makes the "Auto-Z" a fully compatible IEEE instrument.

As an IEEE compatible instrument, the LC77 may have either of two functions. As a "listener" it can receive instructions from the IEEE 488 bus controller to change functions or ranges. The LC77 listener functions provide complete automation, as the controller is able to send any values or tolerances needed for good/bad testing comparisons and the controller can select any of the "Auto-Z" test functions.

As a "talker" the LC77 can send readings back to the IEEE 488 bus controller as the controller requests them.

Connecting The LC77 For IEEE Operation

The IB72 IEEE 488 Bus Interface accessory must be connected to the LC77 "Auto-Z" for IEEE operation. The IB72 acts as a translator between the GPIB signals and the microprocessor inside the LC77 "Auto-Z". The IB72 connects to the INTERFACE ACCESSORY JACK located on the back of the LC77. The standard GPIB cable then connects to the IB72.

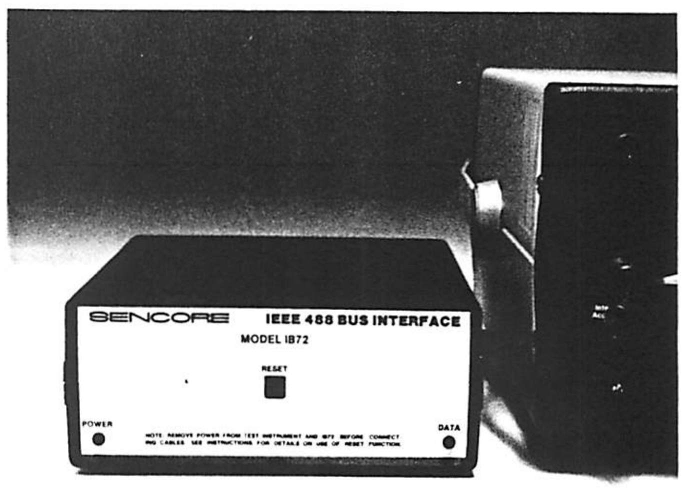


Fig. 25 - The IB72 IEEE 488 Bus Accessory interfaces the LC77 to any GPIB system for automated operation.

When using the LC77 in a Bus system only operate the LC77 from its PA251 AC Adapter/Charger. The PA251 AC Adapter/Charger prevents the auto-off circuits from removing power from the LC77 during an automated test. If the auto-off circuits shut the "Auto-Z" down, the bus controller may become hung up in the middle of its program.

Each instrument in an automated bus system must be assigned its own address in order for the controller to send instructions to or receive readings from one instrument at a time. The address of the LC77 is set with a group of miniature slide switches on the back of the IB72. Refer to the IB72 instruction manual for details about addresses and setting these switches.

To connect the LC77 to an automated GPIB system:

1. Remove power to the LC77 and to the IB72.

2. Set the Bus Address slide switches on the back of the IB72 to the address you have assigned to the LC77.

3. Connect the male DIN connector on the IB72 to the Interface Accessory Jack on the back of the LC77.

4. Connect the AC power adapters to the LC77 and to the IB72 and connect them to AC outlets.

5. Confirm that power has reached the units by checking the power LED on the IB72 and the digital readout on the LC77.

6. Follow the instructions for your controller to load and run the software.

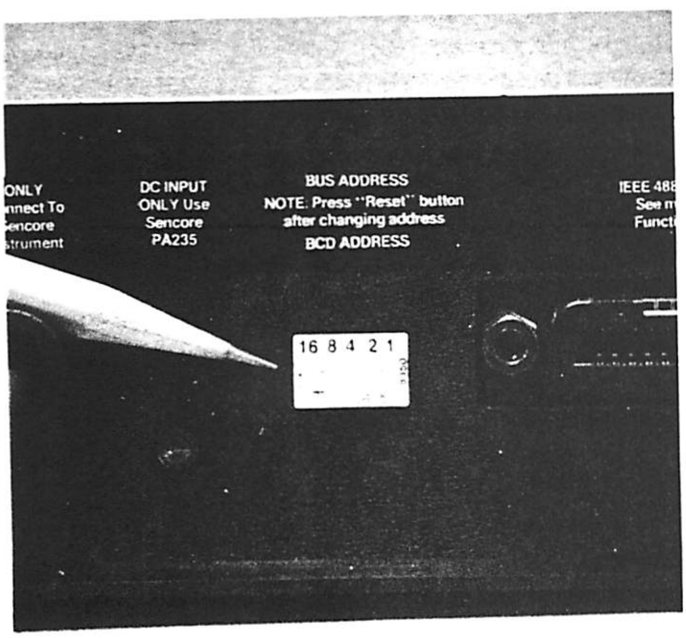


Fig. 26 - The LC77's address is selected by the Bus Address switches located on the rear of the IB72.

Special Note On IEEE Programs

The computer programs or software used to automate a system must be written for the specific application being performed. The amount of programming required depends on the type of IEEE 488 controller used and what you want the automation to accomplish. Most IEEE 488 programming is done in the BASIC computer language, although any other language compatible with your controller can be used as well. The examples covered in this section are written in BASIC, since it is the most commonly used computer language for GPIB applications.

Sending Data To The LC77

As a "listener", the LC77 accepts commands from the controller. These commands can be used to select a function or to send parameters to the LC77 for good/bad comparison testing. The commands sent to the "Auto-Z" during bus operation duplicate the front panel pushbuttons. Follow the same programming sequence and range limits as for manual (non-IEEE) operation.

The listener codes consist of one, two or three characters, and relate to the function being selected or the data being entered. Most listener codes consist only of the code characters. The listener codes used to enter data for good/bad testing consist of a number, followed by the character code.

Most controllers send information over the bus by means of a "print" statement. The information to be sent is usually placed into a variable, and the variable is then printed to the bus, along with the address of the instrument. Study the information with your controller for details about sending information to instruments.

The codes may be sent by the controller as either upper or lower case (capital or small) letters.

All data sent to the LC77 must end with a linefeed character, to be recognized by the LC77. Some controllers automatically add this character to the end of every string of data, while others have a special function which adds the linefeed when activated with a software command. If your controller has neither of these options, you can add a linefeed character by storing the character in a variable and then adding this variable to your data before sending it to the bus.

Fig. 27 shows how the linefeed character can be stored in a string-variable called "LF$". This variable can then be combined with the function stored in "LISTEN$" before being sent to the bus.

```
100 LF$=CHR$(10): REM  CHR$(10) IS A LINEFEED

110 LISTEN$=LISTEN$+LF$: REM ADDS THE LINEFEED TO THE DATA

120 PRINT LISTEN$: REM   SENDS THE STRING TO THE BUS
```

Fig. 27 - Use this routine to add a linefeed character to the end of data statements sent to the LC77.

The data or listener codes sent to the LC77 fall into four groups: 1. **Component Type Commands,** 2. **Value Multipliers,** 3. **Test Function Commands,** and 4. **General Commands.** All listener codes are listed in Table 9. They are also listed in section 12 of the Simplified Operating Instructions on the pull-chart under the unit for ready reference.

Component Type Commands

Aluminum Lytics	ALM
Double Layer Lytics	DBL
Tantalum Caps	TAN
Ceramic Caps	CER
All Other Caps	AOC
Spare	SPR
Coils	COL
Yokes & Flybacks	YFB
Switching Transformers	SWX

Value Multipliers:
(to be preceeded by numeric value)
pF, uF, F, UH, MH, H, +%, −%, V

Test Function Commands

Capacitor Value	CAP
Capacitor Leakage (current)	LKI
Capacitor Leakage (ohms)	LKR
Dielectric Absorption	D/A
Capacitor ESR	ESR
Inductor Value	IND
Inductor Ringer	RIN

General Commands

Lead Zero Open	LDO
Lead Zero Short	LDS
No Function	NFC
Control Panel On	CPO

Table 9 - IEEE control codes for the LC77.

Component Type Commands:

These codes duplicate the front panel COMPONENT TYPE switches and must be sent to the LC77 if you want the test results to be compared to the tables and calculations associated with the LC77 microprocessor. As in non-IEEE operation, the LC77 uses these to establish the good/bad limits for the leakage, ESR, dielectric absorption, and coil ringing tests. The good/bad results may be in error if the wrong Component Type Command is sent.

Note: The LED's on the COMPONENT TYPE switch which indicate if the switch is selected DO NOT light when the LC77 is under IEEE control.

Value Multipliers:

These GPIB listener codes let the controller send component data information to the LC77 including the ideal component value and value tolerance limits. The codes duplicate the non-IEEE operation of the component parameters keypad for entering component data.

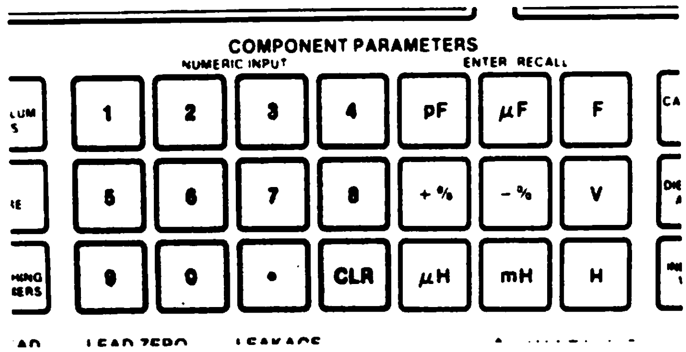


Fig. 28 - During IEEE operation the Value Multiplier Codes allow component data to be entered into the LC77.

As with manual operation each Value Multiplier Command includes a number, followed by the listener code. There are four types of Value Multipliers for IEEE programming: 1. Capacitor value, 2. Inductor Values, 3. Percent tolerance, and 4. Capacitor voltage. The first three are only used for LC77 automatic good/bad comparisons. The capacitor voltage code also sets the LC77 power supply to the selected voltage for the leakage test.

When sending a component value to the LC77 it is not necessary to send long strings of zeros to establish decimal readings. Instead, use the value multipliers uF (microfarads) pF (picofarads), and F (farads) for capacitors and uH (microhenries), mH (millihenries), and H (henries). For inductors the characters may be sent in upper or lower case. For example, "uF", "UF", or even "Uf" will all produce the same results. The LC77 also ignores any blank spaces between listener code characters. This means that "10UF", "10 UF" and even "10 U F" work equally well.

The complete Value Multiplier code consists of the correct numeric value, the Value Multiplier, and the End Terminator. The following examples show valid commands, with the End Terminators not shown:

4.7 uF
(enters capacitor value of 4.7 microfarad)

100 pF
(enters capcacitor value of 100 picofarads)

15 V
(enters leakage voltage of 15 volts)

20+%
(enters value tolerance of +20%)

5H
(enters inductance value of 5 Henrys)

The amount of component data which needs to be entered with the IEEE Value Multiplier codes for a good/bad test depends on the LC77 function. The chart in Table 10 shows the component parameters needed for each good/bad test. Sending additional data to the LC77 will not affect the tests.

TEST	CAP VALUE	IND VALUE	+%	-%	CAP VOLTAGE	COMPON. TYPE
Cap. Value	X		*	*		X
Cap. Leakage	X				X	X
Cap. ESR	X				X	X
Cap. D/A	X				X	X
Ind. Value		X	*	*		X
Ind. Ringing						X

X= Must be entered for good/bad results.
*= Tolerances are set to zero percent at power-up.

Table 10 - These parameters must be entered for the LC77 to produce a good/bad test result.

NOTE: The LC77 will send good/bad indicators back to the controller for each reading if all necessary information has been supplied. To stop the LC77 from sending the "G" or the "B" as part of its returned data, simply send a zero value reading, such as "0pF". The other Value Multipliers (such as percentages or voltage) will remain in the LC77 memory until changed or until power is removed from the unit.

The plus and minus component tolerance limits must be sent in the correct form. First, the number must be a whole number, with no decimal. Then, the percentages must be within the allowable range. The largest negative number allowed is 99 percent (−99%). and the largest positive number allowed is 100 percent (+100%). Numbers that are outside this range, or that contain a decimal, produce an "Error 2" condition.

Setting The Leakage Voltage:

The leakage power supply must be set to the desired voltage before selecting a leakage test with the LKI or the LKR codes. The supply can be set to the nearest tenth of a volt. The listener code simply consists of the desired voltage followed by the letter V and the End Terminator. For example, "100V" sets the supply to produce 100 volts when a leakage function is activated.

The highest voltage which can be programmed into the LC77 is 999.9 volts the lowest is 1 volt. Attempting to enter a voltage higher or lower than this range will produce an "Error 2" condition.

The leakage power supply only applies power to the test leads after one of the two leakage functions have been selected with the LKI or LKR listener code. The power supply automatically removes voltage from the test leads when the controller sends any other listener code, or when any front-panel button is pressed.

WARNING

The warning LED on the front of the LC77 will flash as a reminder that a shock hazard of up to 1000 volts may be applied to the test leads when a leakage test is selected. Use extreme caution when the LED is blinking.

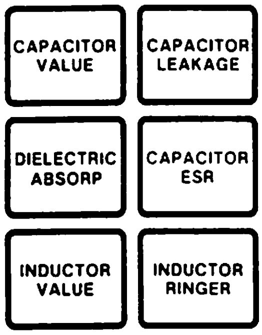
NOTE: When not using a leakage test, send the listener code "0V" to the LC77 to prevent accidentally applying a voltage to the test leads.

Test Function Commands:

One of the seven listener Test Function Codes must be sent to the LC77 before the controller can request a reading. The selected function is cancelled by any other listener code sent to the LC77, meaning that a Test Function Command must be the last listener code sent before a reading is requested.

The LC77 will remain in the last function selected until it receives another test function command or listener code. The controller can select an LC77 test, go on to other instruments on the bus, and then come back to the LC77 at a later time to request a reading. This allows tests which require longer times, such as capacitor leakage, to be used without slowing the operation of other instruments on the bus.

TEST



Test Function	Commands
Capacitor Value	CAP
Capacitor Leakage (current)	LKI
Capacitor Leakage (ohms)	LKR
Dielectric Absorption	D/A
Capacitor ESR	ESR
Inductor Value	IND
Inductor Ringer	RIN

Fig. 29 - The LC77 TEST functions are selected via IEEE using the Test Function Commands.

The LC77 starts a test from its beginning every time it receives another Test Function Code. Therefore, if the LC77 has been preset to a function for a delayed reading, make certain that the controller does not re-send the code just before a reading is taken.

General Codes:

The four general listener codes activate special functions when sent to the LC77. The codes let the controller instruct the LC77 to compensate for the test leads, clear a function, or return control of the LC77 to the front-panel switches.

The LC77 must subtract residual effects of the test leads when testing ESR, and small capacitor or inductor values. The Lead Zero (LDO) and Lead Short (LDS) listener codes duplicate the operation of the front-panel LEAD ZERO button to null out the effects of the residual resistance, capacitance, and inductance of the test leads and test fixture. The leads must be shorted before sending the LDS command and opened before sending the LDO command. If not, the test lead impedance will not be compensated for.

NOTE: The leads can be nulled manually before turning control of the LC77 over to the automated system. Simply follow the procedures for manually nulling the effects of the leads, as explained on page 16. The LC77 will remember the correct compensation until the power is turned off.

The No Function Command (NFC) cancels any test that is in progress and places the LC77 into the standby mode (no button pressed.) You only need to send "NFC" if you want to clear a test. For example, you may wish to turn off the capacitor value test function while you remove one component and replace it with a different one. It is not necessary to send "NFC" when changing functions with a Test Function Command or when changing component parameters with a Value Multiplier Command, since any listener code clears the current function. Sending the "NFC" command when the LC77 is not in a test function has no effect.

IMPORTANT

Do not disconnect or connect any components to the LC77 after performing any capacitor or inductor test without first sending a No Function Command (NFC) or other command first to clear the test function. The LC77 may be damaged if a charged capacitor, or static voltage is connected to it. Also, a severe shock hazard may exist to the user if a capacitor is removed after a leakage test without first being discharged.

The front-panel switches are automatically disabled whenever the LC77 receives its first GPIB command through the IB72. As a reminder of this, any LEDs associated with the COMPONENT TYPE switches will turn off as soon as the LC77 receives a GPIB command. The panel will remain locked out for all functions until the Control Panel On (CPO) code is sent or until power to the LC77 is removed.

NOTE: One exception is the capacitor leakage function. Depressing any of the front-panel switches will unlatch the leakage power supply.

Reading Data From The LC77

The LC77 will send data to the controller through the IB72 IEEE 488 Bus Interface accessory whenever the controller sends the correct talker address and a "Talk" command. The data returned over the bus will be the same as the reading appearing in the LCD display.

Error messages will also be returned over the bus. The error codes will be the same as the codes during manual (non-bus) operation, and are listed on page 37.

NOTE: Most controllers automatically combine the "Talk" command with the instruction containing the address, so there is not a separate step required in the program. Consult the manual for the controller you are using for information on its operation.

Once addressed, the LC77 sends a reading over the bus every time it updates the reading on the LCD display. The softwear in the controller determines how many readings are recorded. Some applications only need a single reading, while other applications may require collecting several readings in a row.

The only difference between collecting a single reading or collecting a series of readings is in the controller software. If only one reading is desired, the controller will trigger the talker function, and then wait until one reading is received. Then the controller sends a bus instruction which causes the LC77 to stop sending readings.

One way to stop the LC77 from sending readings is to simply address a different instrument on the bus with the controller. The LC77 will remain in the test function, but the readings will not be sent to the controller until the LC77's talk address is again selected by the controller.

A second method to stop the LC77 from sending readings is to send any listener code, including the No Function Code (NFC), to the LC77. This will both stop the readings and place the LC77 into its standby mode. Always use this method if a different component is going to be connected to the LC77.

NOTE: The LC77 does not need (nor does it respond to) the special "GET" (group-execute-trigger) command used in some controllers. It will begin sending results as soon as the talk command is complete.

Data Format

All data returned from the LC77 falls into a standard data format. Each data string is 17 characters long and contains information in four data fields. The software can keep the entire string of characters together, or it can separate the data into three parts for calculations or processing.

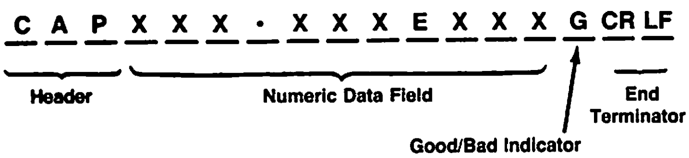


Fig. 30 - The data format returned by the LC77 is a string of 17 characters long.

The four fields of the data string are: 1. Header, 2. Numerical Data Field, 3. Good/Bad Indicator, and 4. End Terminator. Each field has the same number of characters for all test functions, allowing the same subroutines to process any returned data. Here are the details for each field of data.

Header: The first three characters identify the test function which produced the reading. The three characters sent back from the instrument are usually the same as the test function commands used to select a function when the LC77 acts as a listener. These codes let the software identify the source of the data, confirm that the correct function is producing readings, or label the data for future retrieval.

In certain cases, the Header identifies some special conditions, such as errors or shorted or open components. The controller software should test for these conditions before processing readings for accurate test results, as explained in the section "Error Testing" on page 37.

NOTE: The LC77 will return a Control Panel On (CPO) header if it is addressed to talk but has not received a valid listener code. A No Function Command (NFC) is returned if the LC77 has received a valid listener code, but has not been given a Test Function Command.

Numerical Data Field: The 11 spaces following the Header (characters 4 through 14) contain the numerical results of a talker function. The values returned from a test function are in scientific notation, allowing any value to be represented with the same number of characters. Error codes appear as a single digit (from 1 to 7) without the scientific notation.

Good/Bad Indicator: The single space following the Numerical Data Field (the fifteenth character) is reserved for the results of the automatic LC77 good/bad tests. The single letter "G" or "B" appears in this position when the LC77 has sufficient information to determine if the reading is good or bad. If a piece of data (such as the tolerance or ideal value) is missing, the position occupied by the Good/Bad Indicator is left blank.

NOTE: A leakage test function may require from 4 to 8 readings for the leakage to settle before providing a good/bad indication.

End Terminator: All data ends with both a carriage return (ASCII decimal 13) and a linefeed (ASCII decimal 10) character, as recommended by the IEEE 488 standard. Many controllers respond to either character, while others only respond if the linefeed is present. A few controllers, however, may stop accepting data when the carriage return character is sent, leaving the LC77 hung up waiting to send its last (linefeed) character. If this happens, you may need to put an extra GET or INPUT statement into your program to let the LC77 send its last character into an unused variable. Refer to the manual for the specific controller that you are using for information on the end terminator it acts on.

Separating Data Fields

The BASIC commands needed to separate the three fields of information into separate variables are LEFT$ and MID$. The LEFT$ command can collect the three characters of the Header if they need to be compared to information within the program. The MID$ command is used to separate the Numerical Data Field and the Good/Bad Indicator from the other results.

```
2000 REM SUBROUTINE TO SEPARATE DATA INTO 3 PARTS

2010 HEAD$=LEFT$(RESULT$,3): REM FIND HEADER

2020 ANSWER=VAL(MID$(RESULT$,4,11)): REM VALUE

2030 GOOD$=MID$(RESULT$,15,1): REM FIND GOOD/BAD

2040 RETURN: REM JUMP BACK TO MAIN PROGRAM
```

Fig. 31 - The formatted data returned by the LC77 can be easily separated into string-variables using simple BASIC commands.

For example, the controller could place a reading from the LC77 into a string-variable called RESULT$. The subroutine in Figure 31 can then separate the header into the string-variable HEAD$, the Numercial Data into the numerical-variable ANSWER, and the Good/Bad Indicator into the string-variable GOOD$.

Line 2010 moves the first 3 characters into the header variable. Line 2020 selects the 11 characters, starting at the fourth position, and then converts the result to a value (with the VAL statement) before placing it into ANSWER. Line 2030 selects the fifteenth character and moves it to GOOD$. This subroutine can be used to separate data from any reading into the three main parts.

Program languages other than BASIC have similar commands which can separate the data into its different fields.

Advanced Programming Ideas

After the data has been separated, there are many things your program can do to process it. This section explains how to add these refinements to your BASIC programs. In each case, we will refer to the short subroutine listing in Figure 31, with a GOSUB 2000 statement, resulting in the LC77 reading being stored in the variables HEAD$, ANSWER, and GOOD$.

Error Testing

Your controller software should test for error conditions (often called "error trapping") after every reading has been collected from the LC77 to avoid an error from causing unexpected results. The software can either report the error or skip over it, but should do one or the other without crashing the program. If your program is particularly advanced, it may test for the type of error (as indicated by the error number returned in the Numerical Data Field) and then branch to different parts of the program which can take the correct action to compensate for the error.

Error	Description
1	Component Type selection error
2	Entered value beyond range of unit
3	Entered value beyond range of test
4	Value beyond zeroing limit
5	No voltage entered
6	Invalid IEEE command
7	Component out of test range

Table 11 - Error codes returned by the LC77 during IEEE operation.

Most errors cause the LC77 to return a header with the three letters "ERR". A simple test for this header allows the program to be alerted to the error. The value of the Numerical Data Field tells the controller which of seven errors have occurred. The error codes are summarized in Table 11. Refer to the section entitled "Error Codes" for a more detailed explanation of each error condition. The program segment listed in Figure 32 tests for errors and then prints a message which indicates its cause.

```
200  GOSUB 2000: REM  SEPARATE DATA INTO PARTS
210  IF HEAD$<>"ERR" THEN GOTO 300: REM NO ERROR FOUND
220  ON ANSWER GOTO 230,240,250,260,270,280,290
230  PRINT "COMPONENT TYPE SELECTION ERROR": GOTO 300
240  PRINT "VALUE BEYOND RANGE OF UNIT": GOTO 300
250  PRINT "VALUE BEYOND RANGE OF TEST": GOTO 300
260  PRINT "VALUE BEYOND ZEROING LIMIT": GOTO 300
270  PRINT "NO VOLTAGE ENTERED": GOTO 300
280  PRINT "INVALID IEEE COMMAND": GOTO 300
290  PRINT "COMPONENT OUT OF TEST RANGE": GOTO 300
300  ...(Rest of Program)
```

Fig. 32 - A simple BASIC subroutine allows any errors to be identified.

Line 210 in Figure 32 causes the program to jump over the error messages for any header except "ERR". The next line takes advantage of the ON..GOTO function of BASIC which sends the program to line number 230 if ANSWER = 1, to line 240 if ANSWER = 2, etc.

NOTE: Errors detected by the LC77 do not cause a service request (SRQ) on the bus. The LC77 does not respond to serial or parallel polls because errors are sent as part of the normal data string, instead of with a service request.

Good/Bad Results

The string-variable GOOD$ in Figure 31 will contain a single ASCII character, either G or B. The contents of GOOD$ can be tested with simple IF statements and used to produce any desired output. If the Good/Bad Indicator Field is blank, the program can indicate that the result is not available because the LC77 has insufficient data to make a comparison. If the field contains the letter "G" or "B", the controller can print a message concerning the quality of the part. Figure 33 lists a BASIC subroutine which can be used to check the good/bad test result.

```
140  GOSUB 2000: REM SEPARATE DATA INTO PARTS
150  IF GOOD$=" " THEN PRINT "NO GOOD/BAD TEST"
160  IF GOOD$="G" THEN PRINT "THE RESULT IS GOOD"
170  IF GOOD$="B" THEN PRINT "THE RESULT IS BAD"
180  ...(Rest of Program)
```

Fig. 33 - This subroutine can be used to read the result of the LC77 automatic good/bad test.

Shorted Capacitors:

The LC77 automatically senses if a capacitor is shorted before performing a capacitor value test. If a short is detected, the LC77 sends the letters "SHT" as the Header Field of the returned data and displays "Short" in the LCD display. Adding one line of program code will test for this condition. This line should appear before any part of the software program which depends on a value reading, so that the value test will be skipped in case of a shorted capacitor. The program section listed in Figure 34 tests for shorts, prints an error message on the CRT, and jumps to line 400, which handles the error.

```
200  GOSUB 2000: REM SEPARATE DATA INTO PARTS
210  IF HEAD$="SHT" THEN PRINT "CAP IS SHORTED": GOTO 400
220  ...(Rest of Program)...
400  ...(Error Handling Functions)
```

Fig. 34 - The LC77 returns a "SHT" data Header when a shorted capacitor is tested. This sample subroutine checks for the short indication.

Open Inductors:

The LC77 automatically senses if an inductor is open (or if the test leads are not connected to the coil) before performing an inductor value test. If an open is detected, the LC77 sends the letters "OPN" as the header and displays "OPEN" in the LCD display. One additional program line will test for this condition. Place this line before any portion of the program which depends on an inductor value reading, so that the value test will be skipped in case of an open inductor. The program section listed in Figure 35 tests for opens, prints an error message on the CRT, and jumps to line 300, which handles the error.

```
100  GOSUB 2000: REM  SEPARATE DATA INTO PARTS
110  IF HEAD$="OPN" THEN PRINT "COIL IS OPEN: GOTO 300
120  ...(Rest of Program)...
300  ...(Error Handling Functions)
```

Fig. 35 - Open test leads or an open inductor cause the LC77 to return the data header "OPN". This simple subroutine may be used to check for an open condition.

Making Leakage Tests With IEEE:

When testing for leakage on large capacitors, the first reading returned by the LC77 may be outside the normal leakage limits because the capacitor is charging. In the case of electrolytics, several readings may be needed before the capacitor drops to a "good" level, since an electrolytic also goes through a re-forming process every time it is charged from zero. This means that the controller software should ignore the first few readings in order to accept a meaningful reading.

There are several ways to handle this in the software. For example, the program could place the LC77 into the leakage function (with the "LKI" listener code) and then set a softwear timer to insert the correct delay (based on the normal charging time of the capacitor) before reading the leakage value. During this time, the controller could work with other instruments on the bus to keep the delay from slowing down other steps in the automated system. Rather than a fixed time delay, the software can be written to ignore a certain number of readings before recording the one which is to be checked for value.

In either case, the controller can base its decision on whether the capacitor is good or bad by using the Good/Bad Indicator in the returned data. For the automatic good/bad test to function the capacitor's value, voltage, and type must be sent to the LC77 prior to the test. This allows the LC77 microprocessor to compare the leakage readings to the internal formulas and tables. The program steps listed in Figure 36 can be used to report on the capacitor's condition. The program then jumps to line 200 for further testing. If GOOD$ contains neither a "G" nor a "B" then the steps from 140 to 199 take the steps needed to work with a non-good/bad test.

```
100  ...(Program with leakage delay)
110  GOSUB 2000: REM  SEPARATE DATA INTO PARTS
120  IF GOOD$="G" THEN PRINT "LEAKAGE IS OKAY": GOTO 200
130  IF GOOD$="B" THEN PRINT "LEAKAGE IS BAD": GOTO 200
140  ...(Program steps for no G/B test) ...
200  ...(Rest of Program)
```

Fig. 36 - The good/bad indicator Field Returned by the LC77 can be checked to test capacitor leakage.

Making ESR Tests With IEEE:

The capacitor test for Equivalent Series Resistance (ESR) may cause unexpected program errors if your software does not handle the returned data correctly. Remember that ESR tests are only valid on electrolytic capacitors with values larger than 1 microfarad. Also remember that some caspacitors may have such high levels of ESR that the value is above the measuring range of the test. Therefore, make certain that your software tests for the following conditions:

1. An "ERR 1" occurs if any component type other than ALM, DBL, or TAN has been sent to the LC77 in its listener mode.

2. An "ERR 3" occurs if the capacitor under test measures less than 1 microfarad.

3. An "ERR 7" occurs if the amount of ESR is above 2000 ohms.

4. The leads must be zeroed (either manually or by using the "LDS" listener function) before making ESR tests, or the added lead resistance may cause erroneous results.

Programming Examples

It would be impossible to write a program that would work for every LC77 user. First, there are numerous types of bus controllers. Additionally, dozens of personal computers (PC's) can be converted to bus controllers by adding a GPIB control card or expansion device. Each PC could use any of several different GPIB cards. But in addition to hardware differences, the application of the LC77 will be different for each bus system. For example, a Reliability Lab will run different tests than an Incoming Inspection System will.

Several programming hints are provided in this section to help you get your LC77 bus system up and running. The first examples are "building block" programs which allow you to plug the specific details for your controller into an LC77 "Auto-Z" test program. Two complete programs are included at the end of this section. Those programs are ready to run, provided you have the same hardware for which they were written.

Sending Listener Codes

The specific steps needed to send listener codes to instruments on the bus depend on the controller you are using. Some controllers only require the addition of a special code (such as a control character) into a standard PRINT statement. Most, however, require several additional initialization steps to tell the controller's microprocessor which expansion slot or memory location contains the interface card, the address of the instrument being addressed, which method is used to address the talkers or listeners, and so on.

This doesn't have to complicate programming, however, if you use subroutines to take care of all these details. You simply debug these subroutines once, and call them each time you send information over the bus. Your main program places a couple of pieces of information into variables before turning control over to the subroutine which, in turn, handles all the details of communicating with the bus.

Fig. 37 shows an example of a program which uses a subroutine at line 10000 to send information to any instrument on the bus. This subroutine needs two pieces of information: the listener address of the instrument and the data to send to it. The primary address is placed into the variable ADDRESS, and the data into the string-variable CODE$ before calling the subroutine. Once ADDRESS has been loaded, it does not need to be changed unless the controller needs to work with a different instrument. This is the reason line 100 is the only one which uses the variable ADDRESS.

Line 10000 will be unique to each controller. Refer to the manual for the specific controller you are using for details on how it sends data to the IEEE bus.

The steps listed in Figure 37 send all the information needed by the LC77 to test an aluminum electrolytic capacitor with an ideal value of 50 uF, a working voltage of 15 volts and a tolerance of +80% and -20%. The primary address of the LC77 is 8. Each "GOSUB 10000" line sends the data to the unit.

```
100   ADDRESS=8: REM  PRIMARY ADDRESS OF LC77

110   CODE$="50 UF": REM IDEAL VALUE

120   GOSUB 10000: REM SEND VALUE TO LC77

130   CODE$="15V": REM WORKING VOLTAGE

140   GOSUB 10000

150   CODE$="ALM": REM CAPACITOR TYPE

160   GOSUB 10000

170   CODE$="80+%": REM POSITIVE TOLERANCE

180   GOSUB 10000

190   CODE$="20-%": REM NEGATIVE TOLERANCE

200   GOSUB 10000
```

Fig. 37 - This sample program uses a subroutine to simplify sending data over the bus to the LC77. The subroutine called up is unique to each controller.

Sending Talker Codes

As with sending listener codes, all the steps needed to transfer information from the LC77 back to the controller can be done in a subroutine which is called every time the program requests a reading. In the example listed in Figure 38, the subroutine is at line 12000. The listener subroutine is still at line 10000.

Some controllers require a different talker and listener address, but these addresses can be calculated by the program. The subroutine at line 10000 calculates the necessary listener address, while the subroutine at line 12000 calculates the needed talker address from the value already stored in the variable ADDRESS. Thus, it is not necessary to place a new value into the ADDRESS variable.

The last line of the subroutine starting at line 12000 includes an INPUT statement which collects the LC77 reading and places it into the string-variable RESULT$. RESULT$ is then processed through another subroutine to separate the data into its three parts.

```
210   CODE$="CAP": REM LISTENER CODE FOR CAP VALUE

220   GOSUB 10000: REM SEND CODE TO UNIT

230   GOSUB 12000: REM REQUEST READING FROM UNIT

240   CVALUE$=RESULT$: REM TRANSFER FROM SUBROUTINE

250   CODE$="LKI": REM LISTENER CODE FOR LEAKAGE

260   GOSUB 10000: REM SEND CODE TO UNIT

270   GOSUB 12000: REM REQUEST READING FROM UNIT

280   LEAK$=RESULT$: REM TRANSFER FROM SUBROUTINE

290   CODE$="D/A": REM  CODE FOR DIELECTRIC ABSORB.

300   GOSUB 10000: REM  SAME AS BEFORE

310   GOSUB 12000

320   DA$=RESULT$

330   CODE$="ESR": REM CODE FOR ESR TEST

340   GOSUB 10000

350   GOSUB 12000

360   ESR$=RESULT$
```

Fig. 38 - A subroutine can be used to simplify reading the data sent over the bus by the LC77. The subroutine called is unique to each controller.

Sample Programs

The two sample programs which follow are ready to run. However, they will only work for the type of bus controller stated in the open remark section of the program. Use them as a guide for connecting the LC77 into your IEEE bus system.

```
1  REM  THIS PROGRAM ALLOWS THE USER TO ENTER THE
2  REM  STANDARD VALUES FOR ANY CAPACITOR, SENDS THE
3  REM  VALUES TO THE LC77, AND THEN SHOWS THE RESULTS
4  REM  AS GOOD OR BAD. COPYRIGHT (C) SENCORE FIELD
5  REM  APPLICATION DEPARTMENT, 1987. THIS PROGRAM MAY
6  REM  MAY BE USED AS IS OR MODIFIED BY ANY LC77 OWNER
7  REM  WITHOUT FURTHER PERMISION FROM SENCORE, INC.
10  REM
20 D$ =  CHR$ (4): REM   DOS COMMAND CHARACTER
30 Z$ =  CHR$ (26): REM  IEEE CARD COMMAND CHARACTER
40 Q$ =  CHR$ (17): REM  SCREEN TO 40 COLUMNS
50 G$ =  CHR$ (7): REM   RINGS BELL
60  FOR X = 1 TO 19:BL$ = BL$ + " ": NEXT X: REM
   FORMS 20 BLANK SPACES
70  DATA   ALM,DBL,TAN,CER,AOC
80  FOR X = 1 TO 5: READ CT$(X): NEXT X
1000  REM  ******* INPUT DESIRED VALUES *******
1010  HOME : GOSUB 10200: REM   SELECT PRIMARY ADDRESS
1020  REM  ******* BEGIN IDEAL INPUT *******
1030  HOME : VTAB 7: INVERSE : HTAB 6: PRINT "    ENTER
   IDEAL VALUES:   ": NORMAL
1040  PRINT : HTAB 6: INPUT "   VALUE: ";V$
1050 V =  VAL (V$): REM   CONVERT TO NUMERIC VALUE
1060  IF V = 0 GOTO 1020: REM   ZERO VALUE NOT ACCEPTED
1070  VTAB 9: HTAB 16: PRINT V;"                   "
1080  VTAB 11: HTAB 1: INVERSE : PRINT "MULTIPLIER:";:
   NORMAL : PRINT " [1] PF, [2] UF, [3] F  ";: GET K$
1090 MU$ = "F":VM = 1
1100  IF K$ = "1" THEN MU$ = "PF":VM = 1E - 12
1110  IF K$ = "2" THEN MU$ = "UF":VM = 1E - 6
1120  IF K$ < "1" OR K$ > "3" GOTO 1080: REM REPEAT UNTIL
   VALID
1130  VTAB 10: PRINT BL$;BL$: REM  COVER WITH BLANK
   SPACES
1140  VTAB 9: HTAB 25: PRINT MU$: REM  ECHO SELECTION TO
   SCREEN
1150 V$ =  STR$ (V) + MU$: REM  PREPARE STRING TO SEND TO
   METER
1160  HTAB 6: INPUT "      +%: ";PP$
1170 PP =  VAL (PP$): REM   REMOVE NON-NUMERIC CHARACTERS
1180 PP$ =  STR$ (PP) + "+%": REM  PREPARE STRING TO SEND
   TO METER
1190  HTAB 6: INPUT "      -%: ";PN$
1200 PN =  VAL (PN$): REM   REMOVE NON-NUMERIC CHARACTERS
1210 PN$ =  STR$ (PN) + "-%"
1220  HTAB 6: INPUT " VOLTAGE: ";VT$
1230 VT =  VAL (VT$): REM   REMOVE NON-NUMERIC CHARACTERS
1240 VT$ =  STR$ (VT) + "V"
1250  PRINT : PRINT "  ARE THESE VALUES CORRECT? (Y/N)
   ";: GET K$
1260  IF K$ = "y" THEN K$ = "Y"
1270  IF K$ <  > "Y" THEN 1020
1280  HOME : VTAB 7: INVERSE : HTAB 6: PRINT "  SELECT
   CAPACITOR TYPE:  ": NORMAL
1290  PRINT
1300  HTAB 6: PRINT "[1]  ALUMINUM LYTIC"
1310  HTAB 6: PRINT "[2]  DOUBLE LAYER LYTIC"
1320  HTAB 6: PRINT "[3]  TANTALUM LYTIC"
1330  HTAB 6: PRINT "[4]  CERAMIC CAP"
1340  HTAB 6: PRINT "[5]  ALL OTHER CAPS"
1350  PRINT : HTAB 6: PRINT "SELECT NUMBER FOR TYPE: ";:
   GET K$: PRINT K$
1360  IF  ASC (K$) < 49 OR  ASC (K$) > 53 THEN  PRINT
   G$;G$: GOTO 1280: REM   ACCEPT ONLY 1 THROUGH 5
1370 TY$ = CT$( VAL (K$)): REM     SELECT THREE-LETTER
   CODE
1380  VTAB 19: HTAB 6: INVERSE : PRINT "  SENDING VALUES
   TO Z METER  ": NORMAL
1390  GOSUB 10000: REM   TURN ON IEEE CARD
1400  PRINT LA$;Z$;V$: PRINT LA$;Z$;PP$: PRINT
   LA$;Z$;PN$: PRINT LA$;Z$;VT$: PRINT LA$;Z$;TY$
1410  REM ---LA$=LISTEN ADDRESS, Z$=CONTROL-Z
1420  REM  ******* BEGIN TAKING READING *******
1430 FG = 0: REM    RESET 'COMPONENT BAD' FLAG
1440  GOSUB 10100: REM    RETURN COMMUNICATIONS TO
   KEYBOARD
1450  HOME : VTAB 14: HTAB 6: INVERSE : PRINT "  TAKING
   READINGS  ": NORMAL
1460  GOSUB 10000: REM  TURNS ON IEEE CARD
1470 DA$ = "D/A": GOSUB 10500
1480 ZD$ = RZ$
1490 DA$ = "CAP": GOSUB 10500
1500 ZV$ = RZ$
1510 DA$ = "LKI": GOSUB 10500
1520 ZI$ = RZ$
1530 DA$ = "ESR": GOSUB 10500
1540 ZR$ = RZ$
1550 DA$ = "NFC": GOSUB 10500: REM   CANCEL PANEL
1560  GOSUB 10100
1570  REM    ******* PRINT RESULTS *******
1580  HOME : REM   CLEARS SCREEN
1590  PRINT " THE RESULTS OF THIS TEST ARE:": PRINT
1600  PRINT "IDEAL VALUE: ";V$
1610 RE$ = ZV$: REM      LOAD VALUE INTO SUBROUTINE
   VARIABLE
1620  GOSUB 2000: REM   SEPARATE DATA INTO PARTS
1630  IF HE$ = "ERR" THEN  GOSUB 2100: GOTO 1710
1640  IF HE$ = "SHT" THEN  PRINT "CAPACITOR IS SHORTED":
   GOTO 1920
1650  PRINT " MEASURED VALUE: "AN
1660  GOSUB 2200: REM  GET GOOD/BAD RESULT
1670 PC = 100 * (AN - (V * VM)) / (V * VM): REM
   CALCULATE PERCENTAGE
1680 PC =  INT (10 * PC) / 10: REM   SET DECIMAL AT ONE
   PLACE
1690  PRINT " THE VALUE DIFFERED BY "PC"%"
1700  PRINT : PRINT "THE LEAKAGE TESTED AT "VT" VOLTS"
1710 RE$.= ZI$: REM    LOAD LEAKAGE INTO SUBROUTINE
   VARIABLE
1720  GOSUB 2000: REM   SEPARATE DATA INTO PARTS
1730  IF HE$ = "ERR" THEN  GOSUB 2100: GOTO 1770
1740 LK = AN * 1E6
```

```
1750  PRINT "  WAS "LK" MICROAMPERES."
1760  GOSUB 2200: REM    GET GOOD/BAD RESULTS
1770  PRINT : PRINT "D/A TEST:"
1780 RE$ = ZD$: REM    LOAD D/A RESULTS INTO SUBROUTINE
   VARIABLE
1790  GOSUB 2000: REM   SEPARATE DATA INTO PARTS
1800  IF HE$ = "ERR" THEN  GOSUB 2100: GOTO 1840
1810 AN =  INT (10 * AN) / 10: REM   SET DECIMAL TO 1
   PLACE
1820  PRINT " DIELECTRIC ABSORPTION: "AN"%."
1830  GOSUB 2200: REM    GET GOOD/BAD RESULT
1840  PRINT : PRINT "ESR TEST:"
1850 RE$ = ZR$: REM   LOAD ESR VALUE INTO SUBROUTINE
   VARIABLE
1860  GOSUB 2000: REM   SEPARATE INTO PARTS
1870  IF HE$ = "ERR" THEN  GOSUB 2100: GOTO 1900
1880  PRINT " SERIES RESISTANCE: "AN" OHMS."
1890  GOSUB 2200: REM   GET GOOD/BAD RESULTS
1900 GB$ = " GOOD ": IF FG = 1 THEN GB$ = " BAD "
1910  PRINT : PRINT "THE CAPACITOR IS ";: INVERSE : PRINT
   GB$: NORMAL
1920  PRINT : PRINT "END OF RESULTS, PRESS ANY KEY ";:
   GET K$
1930  HOME : VTAB 9: HTAB 6: INVERSE : PRINT " SELECT
   NEXT OPTION: ": NORMAL
1940  PRINT : HTAB 6: PRINT "[1] ENTER NEW VALUE"
1950  HTAB 6: PRINT "[2] MAKE ANOTHER TEST"
1960  HTAB 6: PRINT "[3] REPEAT PRINTOUT"
1970  PRINT : HTAB 6: PRINT "SELECT NUMBER OPTION: ";:
   GET K$
1980  IF K$ < "1" OR K$ > "3" THEN  PRINT G$: GOTO 1930
1990  ON  VAL (K$) GOTO 1020,1420,1570
2000  REM    ###### SUBROUTINE SEPARATES DATA ######
2010 HE$ =  LEFT$ (RE$,3): REM  FIND HEADER
2020 AN =  VAL ( MID$ (RE$,4,11)): REM  FIND NUMERIC
   VALUE
2030 GD$ =  MID$ (RE$,15,1): REM   FIND GOOD/BAD RESULT
2040  RETURN
2100  REM  #######SUBROUTINE FOR ERROR HANDLING#######
2110  PRINT G$;"Z-METER ERROR #"AN" DETECTED:"
2120  ON AN GOTO 2130,2140,2150,2160,2170,2180,2190
2130  PRINT "COMPONENT TYPE SELECTION ERROR": RETURN
2140  PRINT "VALUE BEYOND RANGE OF UNIT": RETURN
2150  PRINT "VALUE BEYOND RANGE OF TEST": RETURN
2160  PRINT "VALUE BEYOND ZEROING LIMIT": RETURN
2170  PRINT "NO VOLTAGE ENTERED": RETURN
2180  PRINT "INVALID IEEE COMMAND": RETURN
2190  PRINT "COMPONENT OUT OF TEST RANGE": RETURN
2200  REM   ###### SUBROUTINE TESTS GOOD/BAD RESULT
   ######
2210  IF GD$ = " " THEN  PRINT "NO GOOD/BAD TEST"
2220  IF GD$ = "G" THEN  PRINT "THE RESULT IS GOOD"
2230  IF GD$ = "B" THEN  PRINT "THE RESULT IS ";: INVERSE
   : PRINT " BAD ": NORMAL :FG = 1
2240  RETURN
9997  REM
   ****************************************************
9998  REM  THE FOLLOWING SUBROUTINES APPLY TO
   ADDRESSING THE APPLE-BRAND IEEE-488 CONTROLLER CARD
   FOR THE APPLE // COMPUTER.
9999  REM
   ****************************************************
10000  REM  ##### SUBROUTINE ENABLES BUS #####
10010  PRINT D$
10015  PRINT D$;"IN#4": REM   CARD IS IN SLOT FOUR
10020  PRINT D$;"PR#4": REM   TURNS ON SLOT FOUR
10030  PRINT "LF1": REM    ENABLES LINEFEED FOR EOF
   CHARACTER
10040  RETURN
10100  REM  ##### SUBROUTINE RETURNS TO KEYBOARD #####
10110  PRINT D$;"PR#0": REM  RETURNS OUTPUT TO CRT
10120  PRINT D$;"IN#0": REM  RETURNS INPUT TO KEYBOARD
10130  RETURN
10200  REM  ##### SUBROUTINE FINDS TALK/LISTEN ADDRESSES
   #####
10210  REM  RETURNS TALK ADDRESS IN VARIABLE TA$
10220  REM  RETURNS LISTEN ADDRESS IN VARIABLE LA$
10230  VTAB 7: HTAB 6: INVERSE : INPUT "  ENTER PRIMARY
   ADDRESS:";K$: NORMAL
10240 AD =  VAL (K$)
10250  IF AD < 1 OR AD > 30 THEN  HOME : VTAB 9: PRINT
   G$;G$;"  ADDRESS MUST BE BETWEEN 1 AND 30": FOR X = 1
   TO 500: NEXT X: GOTO 10230
10260 LA = AD + 32: REM  CALCULATE LISTEN ADDRESS
10270 LA$ = "WT" +  CHR$ (LA)
10280 TA = AD + 64: REM  CALCULATE TALK ADDRESS
10290 TA$ = "RD" +  CHR$ (TA)
10300  RETURN
10500  REM    ##### SUBROUTINE COMMUNICATES WITH BUS
   #####
10510  REM   DATA MUST BE IN DA$ BEFORE CALLING
10520  REM   LISTEN AND TALK ADDRESSES ARE IN LA$ AND TA$
10530 I = 1: REM  SET LOOP COUNTER TO NORMAL
10540  IF DA$ = "LKI" OR DA$ = "LKR" THEN I = 3: REM
   TAKE THIRD LEAKAGE READING
10550  PRINT LA$;Z$;DA$: REM  SEND LISTEN ADDRESS AND
   COMMAND
10560  FOR N = 1 TO I
10570  PRINT TA$;Z$;: REM    SEND TALK ADDRESS
10580  INPUT RZ$: REM  COLLECT READING IN RZ$
10590  NEXT N
10600  RETURN
```

Fig. 39 — Sample program using the Apple IIe as a controller with an Apple IEEE-488 controller card installed. To use the Apple IIe with a different control card change lines 10,000-10,600 accordingly.