

January 1994

### Features

- HOLD Reading Input Allows Indefinite Display Hold
- Guaranteed Zero Reading for 0V Input
- True Polarity at Zero for Precise Null Detection
- 1pA Typical Input Current
- Direct Display Drive
  - LCD ICL7116
  - LED ICL7117
- Low Noise - Less Than 15 $\mu$ Vp-p (Typ)
- On Chip Clock and Reference
- Low Power Dissipation - Typically Less Than 10mW
- No Additional Active Circuits Required
- Small Outline Surface Mount Package Available

### Description

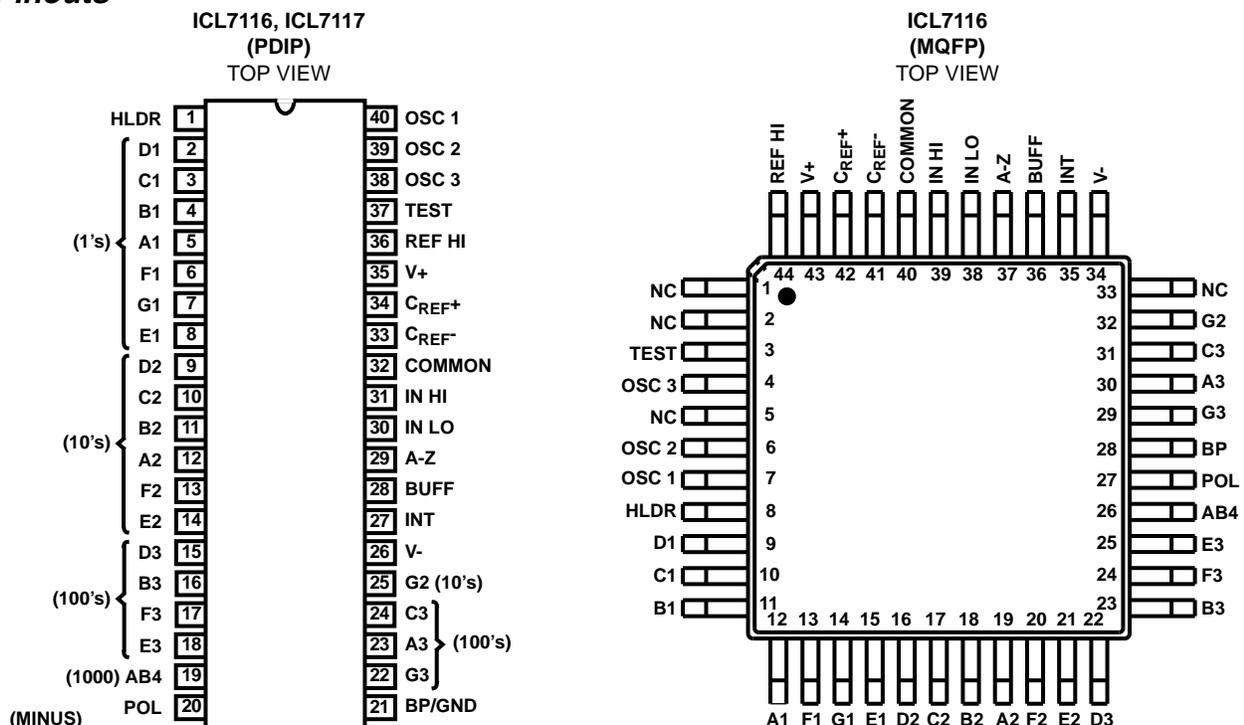
The Harris ICL7116 and ICL7117 are high performance, low power 3<sup>1</sup>/<sub>2</sub> digit A/D converters. Included are seven segment decoders, display drivers, a reference, and a clock. The ICL7116 is designed to interface with a liquid crystal display (LCD) and includes a multiplexed back-plane drive. The ICL7117 will directly drive an instrument size, light emitting diode (LED) display.

The ICL7116 and ICL7117 have all of the features of the ICL7106 and ICL7107 with the addition of a HOLD Reading input. With this input, it is possible to make a measurement and retain the value on the display indefinitely. To make room for this feature the reference low input has been connected to Common internally rather than being fully differential. These circuits retain the accuracy, versatility, and true economy of the ICL7106 and ICL7107. They feature auto-zero to less than 10 $\mu$ V, zero drift of less than 1 $\mu$ V/ $^{\circ}$ C, input bias current of 10pA maximum, and roll over error of less than one count. The versatility of true differential input is of particular advantage when measuring load cells, strain gauges and other bridge-type transducers. And finally, the true economy of single power supply operation (ICL7116) enables a high performance panel meter to be built with the addition of only eleven passive components and a display.

### Ordering Information

PART NUMBER	TEMPERATURE RANGE	PACKAGE
ICL7116CPL	0 $^{\circ}$ C to +70 $^{\circ}$ C	40 Lead Plastic DIP
ICL7116CM44	0 $^{\circ}$ C to +70 $^{\circ}$ C	44 Lead Metric Plastic Quad Flatpack
ICL7117CPL	0 $^{\circ}$ C to +70 $^{\circ}$ C	40 Lead Plastic DIP

### Pinouts



## Specifications ICL7116, ICL7117

### Absolute Maximum Ratings

Supply Voltage	
ICL7116, V+ to V-	15V
ICL7117, V+ to GND	6V
ICL7117, V- to GND	-9V
Analog Input Voltage (Either Input) (Note 1)	V+ to V-
Reference Input Voltage (Either Input)	V+ to V-
Clock Input	
ICL7116	TEST to V+
ICL7117	GND to V+

### Thermal Information

Thermal Resistance (MAX, See Note 1)	$\theta_{JA}$
40 Lead Plastic Package	50°C/W
44 Lead MQFP Package	80°C/W
Maximum Power Dissipation (Note 1)	
ICL7116	1.0W
ICL7117	1.2W
Operating Temperature Range	0°C to +70°C
Storage Temperature Range	-65°C to +150°C
Lead Temperature (Soldering 10s Max)	+300°C
Junction Temperature	+150°C

CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

### Electrical Specifications (Notes 2, 3) $T_A = +25^\circ\text{C}$ , $f_{\text{CLOCK}} = 48\text{kHz}$ , $V_{\text{REF}} = 100\text{mV}$

PARAMETERS	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>SYSTEM PERFORMANCE</b>					
Zero Input Reading	$V_{\text{IN}} = 0.0\text{V}$ , Full-Scale = 200mV	-000.0	±000.0	+000.0	Digital Reading
Ratiometric Reading	$V_{\text{IN}} = V_{\text{REF}}$ , $V_{\text{REF}} = 100\text{mV}$	999	999/ 1000	1000	Digital Reading
Rollover Error	$-V_{\text{IN}} = +V_{\text{IN}} \cong 195\text{mV}$ Difference in Reading for Equal Positive and Negative Inputs Near Full-Scale	-	±0.2	±1	Counts
Linearity	Full-Scale = 200mV or Full-Scale = 2V Maximum Deviation from Best Straight Line Fit (Note 5)	-	±0.2	±1	Counts
Common Mode Rejection Ratio	$V_{\text{CM}} = \pm 1\text{V}$ , $V_{\text{IN}} = 0\text{V}$ , Full-Scale = 200mV (Note 5)	-	50	-	μV/V
Noise	$V_{\text{IN}} = 0\text{V}$ , Full-Scale = 200mV (PK-PK Value Not Exceeded 95% of Time) (Note 5)	-	15	-	μV
Leakage Current Input	$V_{\text{IN}} = 0$ (Note 5)	-	1	10	pA
Zero Reading Drift	$V_{\text{IN}} = 0$ , $0^\circ < T_A < +70^\circ\text{C}$ (Note 5)	-	0.2	1	μV/°C
Scale Factor Temperature Coefficient	$V_{\text{IN}} = 199\text{mV}$ , $0^\circ < T_A < +70^\circ\text{C}$ , (Note 5)	-	1	5	ppm/°C
V+ Supply Current	$V_{\text{IN}} = 0$ (Does Not Include LED Current for ICL7117)	-	0.8	1.8	mA
V- Supply Current	ICL7117 Only	-	0.6	1.8	mA
COMMON Pin Analog Common Voltage	25kΩ Between Common and Positive Supply (With Respect to + Supply)	2.4	2.8	3.2	V
Temperature Coefficient of Analog Common	25kΩ Between Common and Positive Supply (With Respect to + Supply) (Note 5)	-	80	-	ppm/°C
<b>DISPLAY DRIVER ICL7116 ONLY</b>					
Pk-Pk Segment Drive Voltage	$V_{+} = \text{to } V_{-} = 9\text{V}$ , (Note 4)	4	5	6	V
Pk-Pk Backplane Drive Voltage					
<b>ICL7117 ONLY</b>					
Segment Sinking Current	$V_{+} = 5\text{V}$ , Segment Voltage = 3V				
(Except Pin 19 and 20)		5	8	-	mA
Pin 19 Only		10	16	-	mA
Pin 20 Only		4	7	-	mA

#### NOTES:

- Dissipation rating assumes device is mounted with all leads soldered to printed circuit board.
- Input voltages may exceed the supply voltages provided the input current is limited to ±100μA.
- Unless otherwise noted, specifications apply to both the ICL7116 and ICL7117. ICL7116 is tested in the circuit of Figure 1. ICL7117 is tested in the circuit of Figure 2.
- Back plane drive is in phase with segment drive for 'off' segment, 180° out of phase for 'on' segment. Frequency is 20 times conversion rate. Average DC component is less than 50mV.
- Not tested, guaranteed by design.

# ICL7116, ICL7117

## Typical Applications and Test Circuits

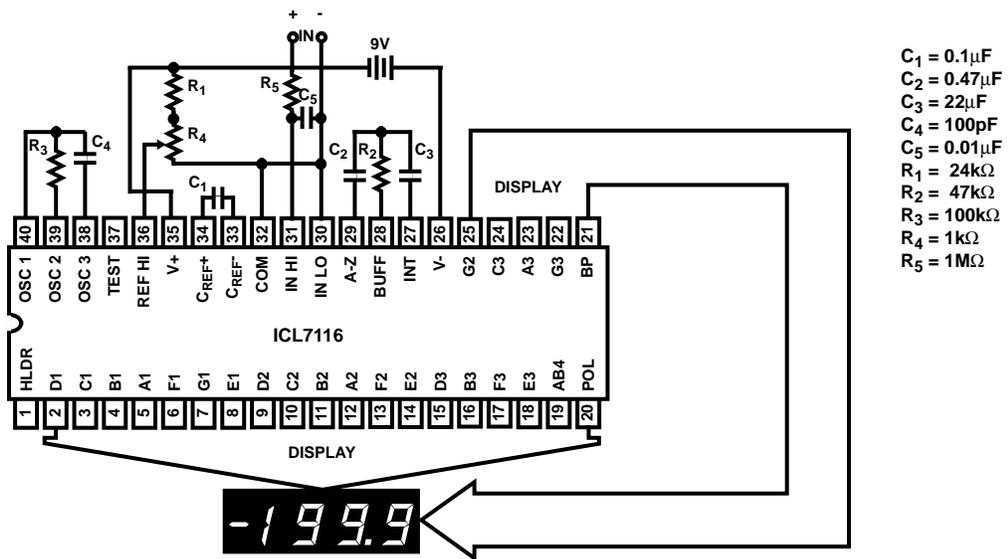


FIGURE 1. ICL7116 TEST CIRCUIT AND TYPICAL APPLICATION WITH LCD DISPLAY COMPONENTS SELECTED FOR 200mV FULL-SCALE

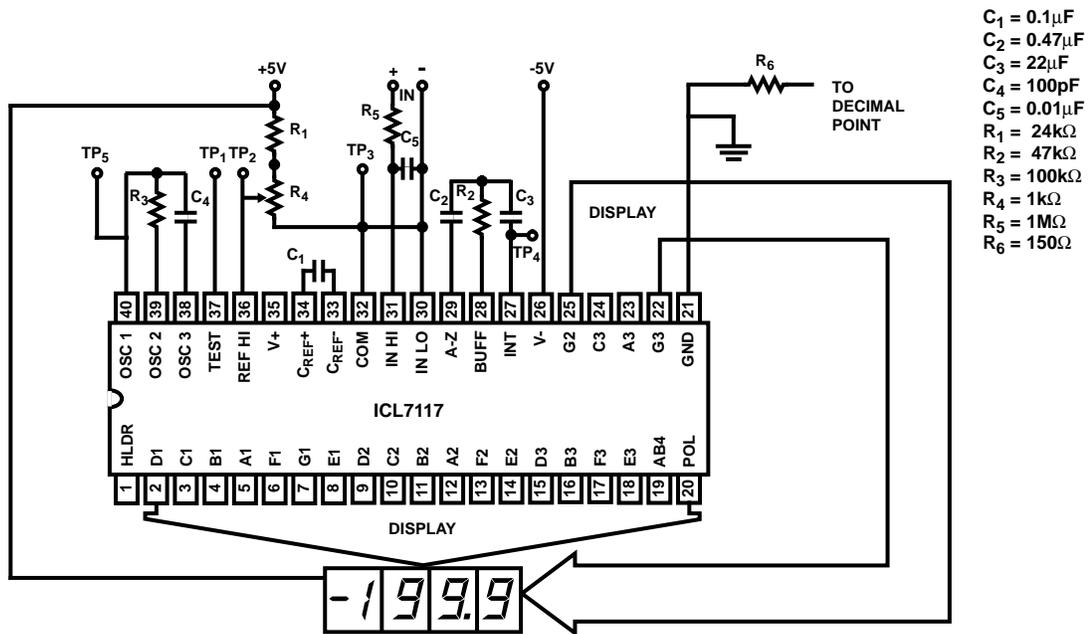


FIGURE 2. ICL7117 TEST CIRCUIT AND TYPICAL APPLICATION WITH LED DISPLAY COMPONENTS SELECTED FOR 200mV FULL-SCALE

**Design Information Summary Sheet**

• **OSCILLATOR FREQUENCY**

$f_{OSC} = 0.45/RC$   
 $C_{OSC} > 50pF$ ;  $R_{OSC} > 50K\Omega$   
 $f_{OSC} \text{ Typ.} = 48KHz$

• **OSCILLATOR PERIOD**

$t_{OSC} = RC/0.45$

• **INTEGRATION CLOCK FREQUENCY**

$f_{CLOCK} = f_{OSC}/4$

• **INTEGRATION PERIOD**

$t_{INT} = 1000 \times (4/f_{OSC})$

• **60/50Hz REJECTION CRITERION**

$t_{INT}/t_{60Hz}$  or  $t_{INT}/t_{50Hz} = \text{Integer}$

• **OPTIMUM INTEGRATION CURRENT**

$I_{INT} = 4.0\mu A$

• **FULL-SCALE ANALOG INPUT VOLTAGE**

$V_{INFS}$  Typically = 200mV or 2.0V

• **INTEGRATE RESISTOR**

$$R_{INT} = \frac{V_{INFS}}{I_{INT}}$$

• **INTEGRATE CAPACITOR**

$$C_{INT} = \frac{(t_{INT})(I_{INT})}{V_{INT}}$$

• **INTEGRATOR OUTPUT VOLTAGE SWING**

$$V_{INT} = \frac{(t_{INT})(I_{INT})}{C_{INT}}$$

•  **$V_{INT}$  MAXIMUM SWING:**

$(V- + 1.0V) < V_{INT} < (V+ - 0.5V)$ ,  $V_{INT}$  typically = 2.0V

• **DISPLAY COUNT**

$$\text{COUNT} = 1000 \times \frac{V_{IN}}{V_{REF}}$$

• **CONVERSION CYCLE**

$t_{CYC} = t_{CLOCK} \times 4000$   
 $t_{CYC} = t_{OSC} \times 16,000$   
 when  $f_{OSC} = 48KHz$ ;  $t_{CYC} = 333ms$

• **COMMON MODE INPUT VOLTAGE**

$(V- + 1.0V) < V_{IN} < (V+ - 0.5V)$

• **AUTO-ZERO CAPACITOR**

$0.01\mu F < C_{AZ} < 1.0\mu F$

• **REFERENCE CAPACITOR**

$0.1\mu F < C_{REF} < 1.0\mu F$

•  **$V_{COM}$**

Biased between  $V+$  and  $V-$ .

•  **$V_{COM} \cong V+ - 2.8V$**

Regulation lost when  $V+$  to  $V- < \cong 6.8V$ .  
 If  $V_{COM}$  is externally pulled down to  $(V+ \text{ to } V-)/2$ ,  
 the  $V_{COM}$  circuit will turn off.

• **ICL7116 POWER SUPPLY: SINGLE 9V**

$V+ - V- = 9V$   
 Digital supply is generated internally  
 $V_{TEST} \cong V+ - 4.5V$

• **ICL7116 DISPLAY: LCD**

Type: Direct drive with digital logic supply amplitude.

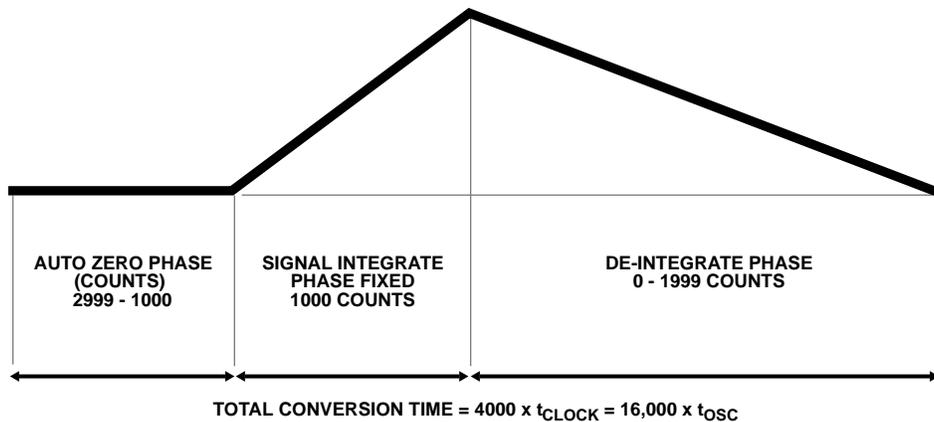
• **ICL7117 POWER SUPPLY: DUAL  $\pm 5.0V$**

$V+ = +5.0V$  to GND  
 $V- = -5.0V$  to GND  
 Digital Logic and LED driver supply  $V+$  to GND

• **ICL7117 DISPLAY: LED**

Type: Non-Multiplexed Common Anode

**Typical Integrator Amplifier Output Waveform (INT Pin)**



## ICL7116, ICL7117

### Pin Description

PIN NUMBER		NAME	FUNCTION	DESCRIPTION
40 PIN DIP	44 PIN FLATPACK			
1	8	HLDR	INPUT	Display Hold Control
2	9	D1	OUTPUT	Driver Pin for Segment "D" of the display units digit
3	10	C1	OUTPUT	Driver Pin for Segment "C" of the display units digit
4	11	B1	OUTPUT	Driver Pin for Segment "B" of the display units digit
5	12	A1	OUTPUT	Driver Pin for Segment "A" of the display units digit
6	13	F1	OUTPUT	Driver Pin for Segment "F" of the display units digit
7	14	G1	OUTPUT	Driver Pin for Segment "G" of the display units digit
8	15	E1	OUTPUT	Driver Pin for Segment "E" of the display units digit
9	16	D2	OUTPUT	Driver Pin for Segment "D" of the display tens digit
10	17	C2	OUTPUT	Driver Pin for Segment "C" of the display tens digit
11	18	B2	OUTPUT	Driver Pin for Segment "B" of the display tens digit
12	19	A2	OUTPUT	Driver Pin for Segment "A" of the display tens digit
13	20	F2	OUTPUT	Driver Pin for Segment "F" of the display tens digit
14	21	E2	OUTPUT	Driver Pin for Segment "E" of the display tens digit
15	22	D3	OUTPUT	Driver pin for segment "D" of the display hundreds digit
16	23	B3	OUTPUT	Driver pin for segment "B" of the display hundreds digit
17	24	F3	OUTPUT	Driver pin for segment "F" of the display hundreds digit
18	25	E3	OUTPUT	Driver pin for segment "E" of the display hundreds digit
19	26	AB4	OUTPUT	Driver pin for both "A" and "B" segments of the display thousands digit
20	27	POL	OUTPUT	Driver pin for the negative sign of the display
21	28	BP/GND	OUTPUT	Driver pin for the LCD backplane/Power Supply Ground
22	29	G3	OUTPUT	Driver pin for segment "G" of the display hundreds digit
23	30	A3	OUTPUT	Driver pin for segment "A" of the display hundreds digit
24	31	C3	OUTPUT	Driver pin for segment "C" of the display hundreds digit
25	32	G2	OUTPUT	Driver pin for segment "G" of the display tens digit
26	34	V-	SUPPLY	Negative power supply
27	35	INT	OUTPUT	Integrator amplifier output. To be connected to integrating capacitor
28	36	BUFF	OUTPUT	Input buffer amplifier output. To be connected to integrating resistor
29	37	A-Z	INPUT	Integrator amplifier input. To be connected to auto-zero capacitor
30 31	38 39	IN LO IN HI	INPUT	Differential inputs. To be connected to input voltage to be measured. LO & HI designators are for reference and do not imply that LO should be connected to lower potential, e.g. for negative inputs IN LO has a higher potential than IN HI.
32	40	COMMON	SUPPLY/ OUTPUT	Internal voltage reference output.
33 34	41 42	C <sub>REF-</sub> C <sub>REF+</sub>		Connection pins for reference capacitor.
35 36	43 44	V+ REF HI	SUPPLY	Power Supply
37	3	TEST	INPUT	Display test. Turns on all segments when tied to V+.
38 39 40	4 6 7	OSC3 OSC2 OSC1	OUTPUT OUTPUT INPUT	Device clock generator circuit connection pins

## Detailed Description

### Analog Section

Figure 3 shows the Analog Section for the ICL7116 and ICL7117. Each measurement cycle is divided into three phases. They are (1) auto-zero (A-Z), (2) signal integrate (INT) and (3) de-integrate (DE).

#### Auto-Zero Phase

During auto-zero three things happen. First, input high and low are disconnected from the pins and internally shorted to analog COMMON. Second, the reference capacitor is charged to the reference voltage. Third, a feedback loop is closed around the system to charge the auto-zero capacitor  $C_{AZ}$  to compensate for offset voltages in the buffer amplifier, integrator, and comparator. Since the comparator is included in the loop, the A-Z accuracy is limited only by the noise of the system. In any case, the offset referred to the input is less than  $10\mu\text{V}$ .

#### Signal Integrate Phase

During signal integrate, the auto-zero loop is opened, the internal short is removed, and the internal input high and low are connected to the external pins. The converter then integrates the differential voltage between IN HI and IN LO for a fixed time. This differential voltage can be within a wide common mode range: up to 1V from either supply. If, on the other hand, the input signal has no return with respect to the converter power supply, IN LO can be tied to analog COMMON to establish the correct common mode voltage. At the end of this phase, the polarity of the integrated signal is determined.

#### De-Integrate Phase

The final phase is de-integrate, or reference integrate. Input low is internally connected to analog COMMON and input high is connected across the previously charged reference

capacitor. Circuitry within the chip ensures that the capacitor will be connected with the correct polarity to cause the integrator output to return to zero. The time required for the output to return to zero is proportional to the input signal. Specifically the digital reading displayed is

$$\text{DISPLAY COUNT} = 1000 \left( \frac{V_{\text{IN}}}{V_{\text{REF}}} \right)$$

#### Differential Input

The input can accept differential voltages anywhere within the common mode range of the input amplifier, or specifically from 0.5V below the positive supply to 1.0V above the negative supply. In this range, the system has a CMRR of 86dB typical. However, care must be exercised to assure the integrator output does not saturate. A worst case condition would be a large positive common mode voltage with a near full-scale negative differential input voltage. The negative input signal drives the integrator positive when most of its swing has been used up by the positive common mode voltage. For these critical applications the integrator output swing can be reduced to less than the recommended 2V full-scale swing with little loss of accuracy. The integrator output can swing to within 0.5V of either supply without loss of linearity.

#### Differential Reference

The reference voltage can be generated anywhere within the power supply voltage of the converter. The main source of common mode error is a roll-over voltage caused by the reference capacitor losing or gaining charge to stray capacity on its nodes. If there is a large common mode voltage, the reference capacitor can gain charge (increase voltage) when called up to de-integrate a positive signal but lose charge (decrease voltage) when called up to de-integrate a negative input signal. This difference in reference for positive or negative input voltage will give a roll-over error. However, by

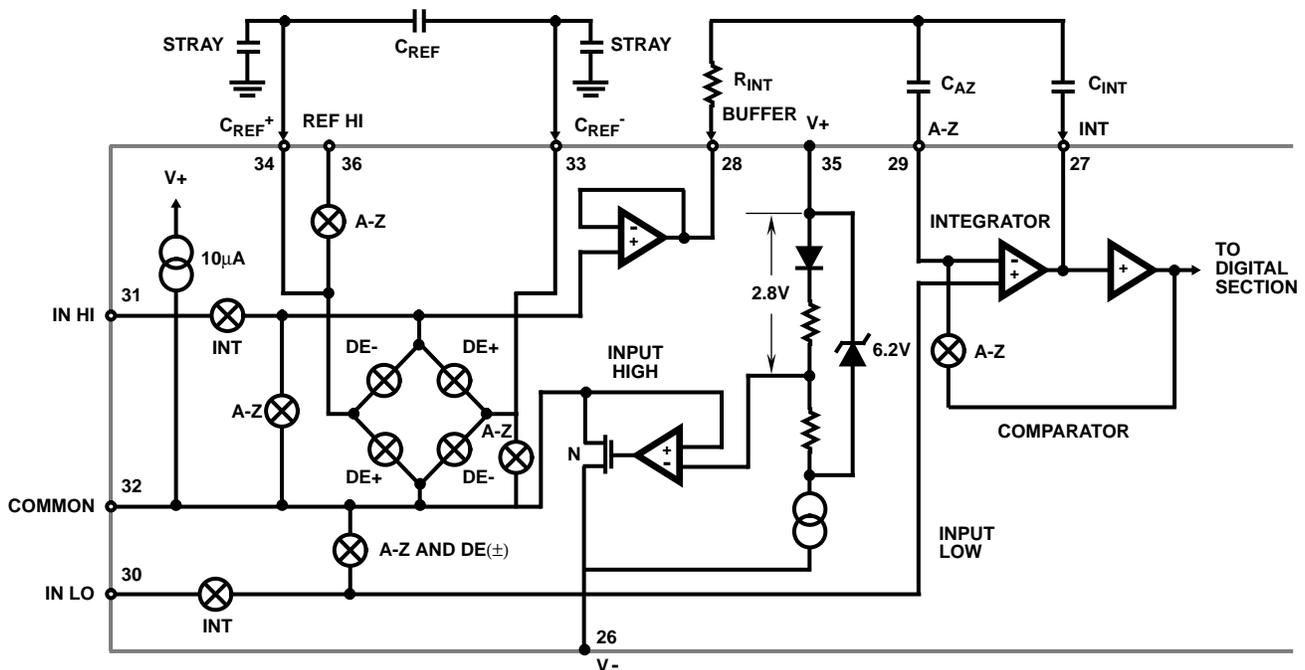


FIGURE 3. ANALOG SECTION OF ICL7116 AND ICL7117

selecting the reference capacitor such that it is large enough in comparison to the stray capacitance, this error can be held to less than 0.5 count worst case. (See Component Value Selection.)

**Analog COMMON**

This pin is included primarily to set the common mode voltage for battery operation (ICL7116) or for any system where the input signals are floating with respect to the power supply. The COMMON pin sets a voltage that is approximately 2.8V less than the positive supply. This is selected to give a minimum end-of-life battery voltage of about 6.8V. However, analog COMMON has some of the attributes of a reference voltage. When the total supply voltage is large enough to cause the zener to regulate (>6.8V), the COMMON voltage will have a low voltage coefficient (0.001%/V), low output impedance ( $\approx 15\Omega$ ), and a temperature coefficient typically less than 80ppm/°C.

The limitations of the on chip reference should also be recognized, however. With the ICL7117, the internal heating which results from the LED drivers can cause some degradation in performance. Due to their higher thermal resistance, plastic parts are poorer in this respect than ceramic. The combination of reference Temperature Coefficient (TC), internal chip dissipation, and package thermal resistance can increase noise near full-scale from 25µV to 80µVp-p. Also the linearity in going from a high dissipation count such as 1000 (20 segments on) to a low dissipation count such as 1111(8 segments on) can suffer by a count or more. Devices with a positive TC reference may require several counts to pull out of an over-range condition. This is because over-range is a low dissipation mode, with the three least significant digits blanked. Similarly, units with a negative TC may cycle between over range and a non-over range count as the die alternately heats and cools. All these problems are of course eliminated if an external reference is used.

The ICL7116, with its negligible dissipation, suffers from none of these problems. In either case, an external reference can easily be added, as shown in Figure 4.

Analog COMMON is also used as the input low return during auto-zero and de-integrate. If IN LO is different from analog COMMON, a common mode voltage exists in the system and is taken care of by the excellent CMRR of the converter. However, in some applications IN LO will be set at a fixed known voltage (power supply common for instance). In this application, analog COMMON should be tied to the same point, thus removing the common mode voltage from the converter. The same holds true for the reference voltage. If reference can be conveniently tied to analog COMMON, it should be since this removes the common mode voltage from the reference system.

Within the IC, analog COMMON is tied to an N channel FET that can sink approximately 30mA of current to hold the voltage 2.8V below the positive supply (when a load is trying to pull the common line positive). However, there is only 10µA of source current, so COMMON may easily be tied to a more negative voltage thus overriding the internal reference.

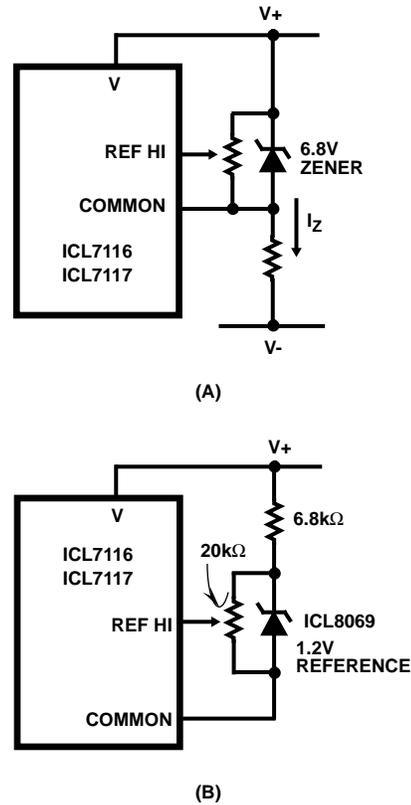


FIGURE 4. USING AN EXTERNAL REFERENCE

**TEST**

The TEST pin serves two functions. On the ICL7116 it is coupled to the internally generated digital supply through a 500Ω resistor. Thus it can be used as the negative supply for externally generated segment drivers such as decimal points or any other annunciator the user may want to include on the LCD display. Figures 5 and 6 show such an application. No more than a 1mA load should be applied.

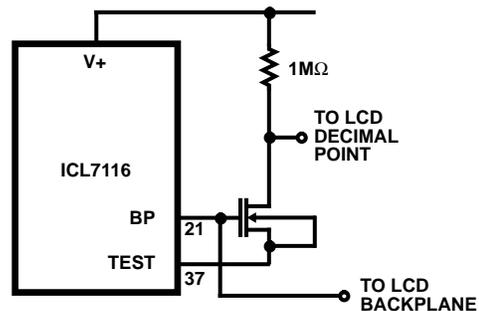


FIGURE 5. SIMPLE INVERTER FOR FIXED DECIMAL POINT

The second function is a “lamp test”. When TEST is pulled high (to V+) all segments will be turned on and the display should read “-1888”. The TEST pin will sink about 5mA under these conditions.

*CAUTION: On the ICL7116, in the lamp test mode, the segments have a constant DC voltage (no square-wave) and may burn the LCD display if left in this mode for several minutes.*



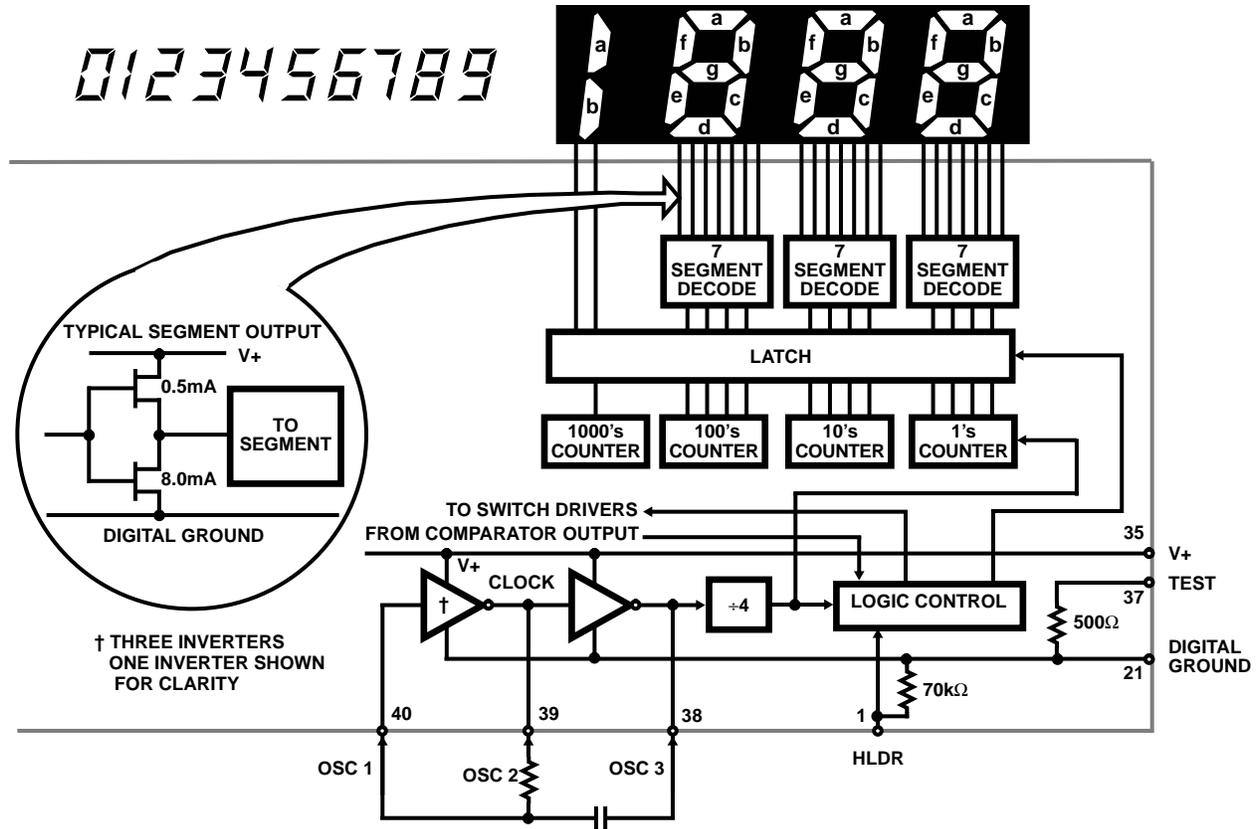


FIGURE 8. ICL7117 DIGITAL SECTION

**System Timing**

Figure 9 shows the clocking arrangement used in the ICL7116 and ICL7117. Two basic clocking arrangements can be used:

1. An external oscillator connected to pin 40.
2. An R-C oscillator using all three pins.

The oscillator frequency is divided by four before it clocks the decade counters. It is then further divided to form the three convert-cycle phases. These are signal integrate (1000 counts), reference de-integrate (0 to 2000 counts) and auto-zero (1000 counts to 3000 counts). For signals less than full-scale, auto-zero gets the unused portion of reference de-integrate. This makes a complete measure cycle of 4,000 counts (16,000 clock pulses) independent of input voltage. For three readings/second, an oscillator frequency of 48kHz would be used.

To achieve maximum rejection of 60Hz pickup, the signal integrate cycle should be a multiple of 60Hz. Oscillator frequencies of 240kHz, 120kHz, 80kHz, 60kHz, 48kHz, 40kHz,  $33\frac{1}{3}$ kHz, etc. should be selected. For 50Hz rejection, Oscillator frequencies of 200kHz, 100kHz,  $66\frac{2}{3}$ kHz, 50kHz, 40kHz, etc. would be suitable. Note that 40kHz (2.5 readings/second) will reject both 50Hz and 60Hz (also 400Hz and 440Hz).

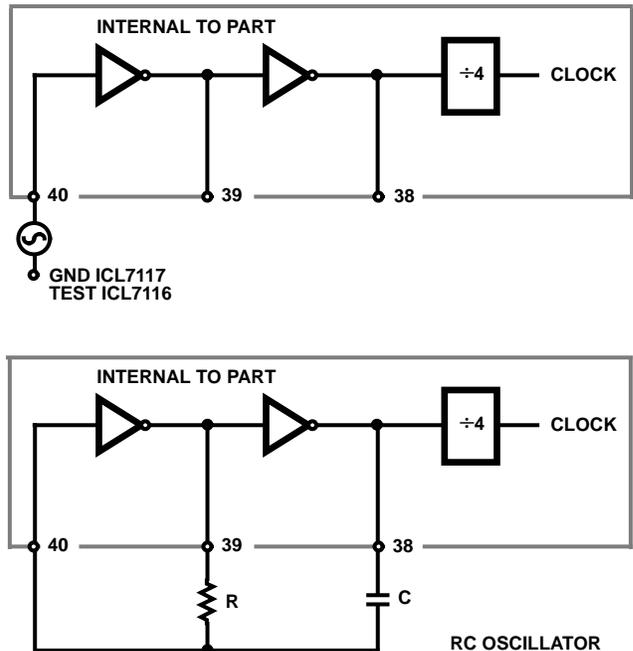


FIGURE 9. CLOCK CIRCUITS

## Component Value Selection

### Integrating Resistor

Both the buffer amplifier and the integrator have a class A output stage with 100 $\mu$ A of quiescent current. They can supply 4 $\mu$ A of drive current with negligible nonlinearity. The integrating resistor should be large enough to remain in this very linear region over the input voltage range, but small enough that undue leakage requirements are not placed on the PC board. For 2V full-scale, 470k $\Omega$  is near optimum and similarly a 47k $\Omega$  for a 200mV scale.

### Integrating Capacitor

The integrating capacitor should be selected to give the maximum voltage swing that ensures tolerance buildup will not saturate the integrator swing (approximately 0.5V from either supply). In the ICL7116 or the ICL7117, when the analog COMMON is used as a reference, a nominal +2V full-scale integrator swing is fine. For the ICL7117 with +5V supplies and analog COMMON tied to supply ground, a  $\pm$ 3.5V to +4V swing is nominal. For three readings/second (48kHz clock) nominal values for  $C_{INT}$  are 0.22 $\mu$ F and 0.10 $\mu$ F, respectively. Of course, if different oscillator frequencies are used, these values should be changed in inverse proportion to maintain the same output swing.

An additional requirement of the integrating capacitor is that it must have a low dielectric absorption to prevent roll-over errors. While other types of capacitors are adequate for this application, polypropylene capacitors give undetectable errors at reasonable cost.

### Auto-Zero Capacitor

The size of the auto-zero capacitor has some influence on the noise of the system. For 200mV full-scale where noise is very important, a 0.47 $\mu$ F capacitor is recommended. On the 2V scale, a 0.047 $\mu$ F capacitor increases the speed of recovery from overload and is adequate for noise on this scale.

### Reference Capacitor

A 0.1 $\mu$ F capacitor gives good results in most applications. Generally 1.0 $\mu$ F will hold the roll-over error to 0.5 counts in this instance.

### Oscillator Components

For all ranges of frequency a 100k $\Omega$  resistor is recommended and the capacitor is selected from the equation

$$f = \frac{0.45}{RC} \text{ For 48kHz Clock (3 Readings/second), } C = 100\text{pF}$$

### Reference Voltage

The analog input required to generate full-scale output (2000 counts) is:  $V_{IN} = 2V_{REF}$ . Thus, for the 200mV and 2V scale,  $V_{REF}$  should equal 100mV and 1V, respectively. However, in

many applications where the A/D is connected to a transducer, there will exist a scale factor other than unity between the input voltage and the digital reading. For instance, in a weighing system, the designer might like to have a full-scale reading when the voltage from the transducer is 0.682V. Instead of dividing the input down to 200mV, the designer should use the input voltage directly and select  $V_{REF} = 0.341V$ . Suitable values for integrating resistor and capacitor would be 120k $\Omega$  and 0.22 $\mu$ F. This makes the system slightly quieter and also avoids a divider network on the input. The ICL7117 with  $\pm$ 5V supplies can accept input signals up to  $\pm$ 4V. Another advantage of this system occurs when a digital reading of zero is desired for  $V_{IN} \neq 0$ . Temperature and weighing systems with a variable fare are examples. This offset reading can be conveniently generated by connecting the voltage transducer between IN HI and COMMON and the variable (or fixed) offset voltage between COMMON and IN LO.

### ICL7117 Power Supplies

3. The ICL7117 is designed to work from  $\pm$ 5V supplies. However, if a negative supply is not available, it can be generated from the clock output with 2 diodes, 2 capacitors, and an inexpensive I.C. Figure 10 shows this application. See ICL7660 data sheet for an alternative.

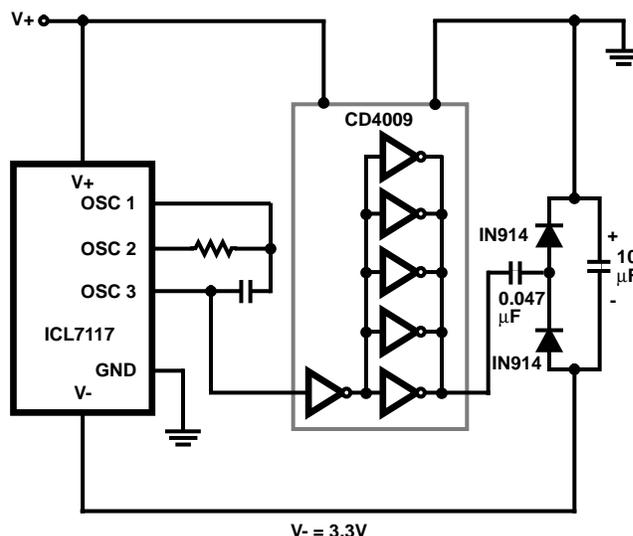


FIGURE 10. GENERATING NEGATIVE SUPPLY FROM +5V

In fact, in selected applications no negative supply is required. The conditions to use a single +5V supply are:

1. The input signal can be referenced to the center of the common mode range of the converter.
2. The signal is less than  $\pm$ 1.5V.
3. An external reference is used.

**Typical Applications**

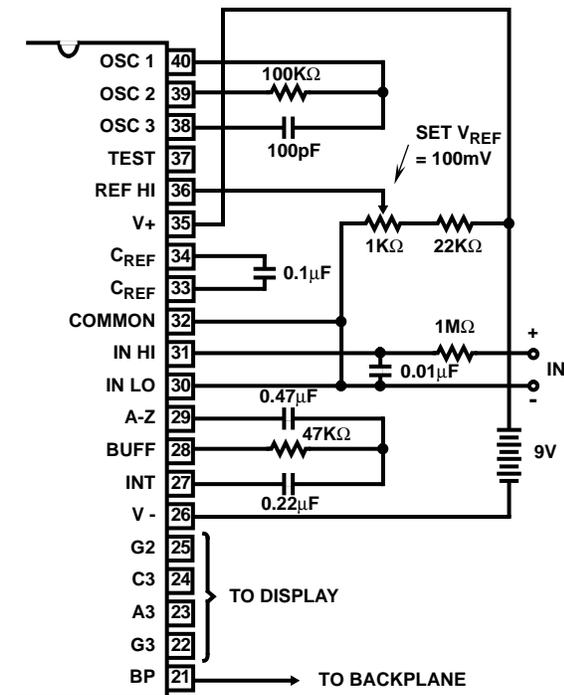
The ICL7116 and ICL7117 may be used in a wide variety of configurations. The circuits which follow show some of the possibilities, and serve to illustrate the exceptional versatility of these A/D converters.

The following application notes contain very useful information on understanding and applying this part and are available from Harris semiconductor.

**Application Notes**

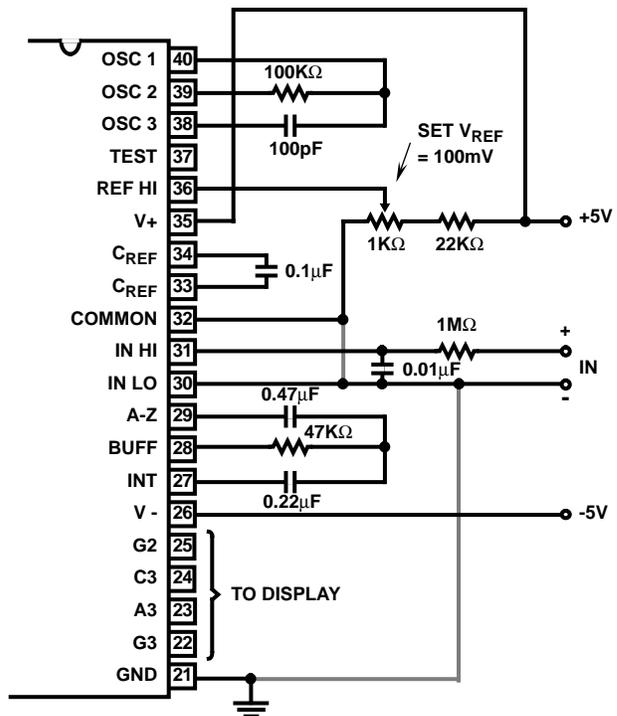
- A016 "Selecting A/D Converters"
- A017 "The Integrating A/D Converter"
- A018 "Do's and Don'ts of Applying A/D Converters"
- A023 "Low Cost Digital Panel Meter Designs"
- A032 "Understanding the Auto-Zero and Common Mode Performance of the ICL7116/7/9 Family"
- A046 "Building a Battery-Operated Auto Ranging DVM with the ICL7116"
- A047 "Games People Play with Harris' A/D Converters," edited by Peter Bradshaw
- A052 "Tips for Using Single Chip 3<sup>1</sup>/<sub>2</sub> Digit A/D Converters"

**Typical Applications**



Values shown are for 200mV full-scale, 3 readings/sec., floating supply voltage (9V battery).

**FIGURE 11. ICL7116 USING THE INTERNAL REFERENCE**



Values shown are for 200mV full-scale, 3 readings/sec. IN LO may be tied to either COMMON for inputs floating with respect to supplies, or GND for single ended inputs. (See discussion under Analog COMMON.)

**FIGURE 12. ICL7117 USING THE INTERNAL REFERENCE**

Typical Applications (Continued)

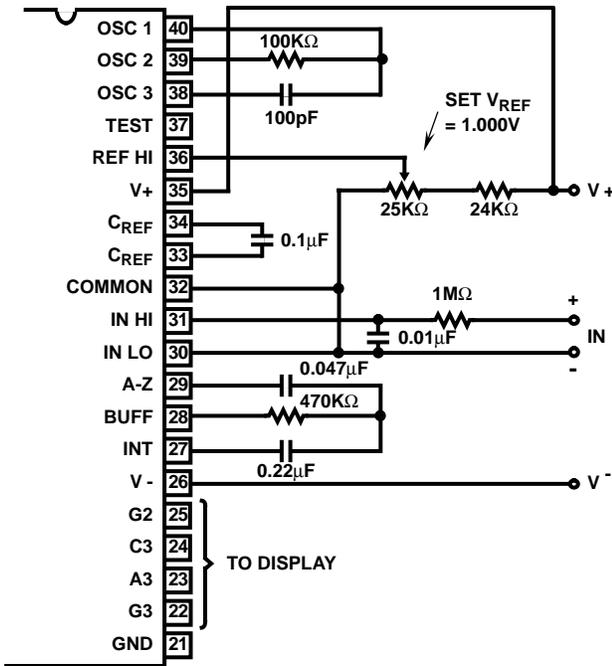
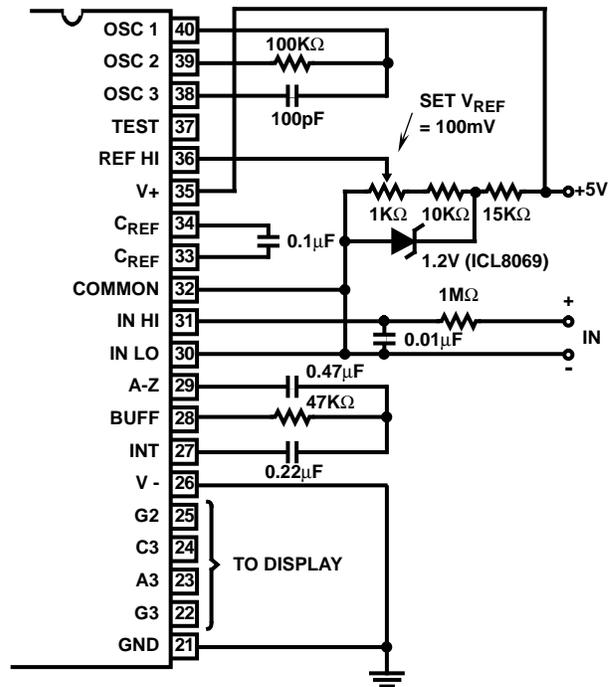
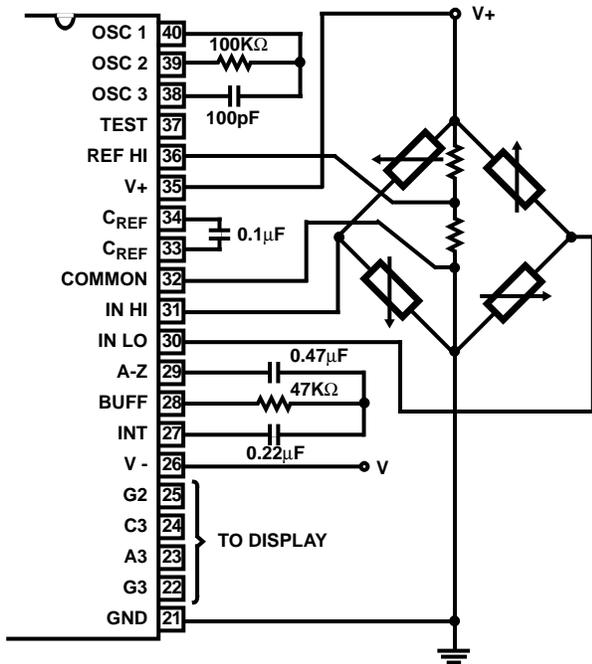


FIGURE 13. ICL7116 AND ICL7117: RECOMMENDED COMPONENT VALUES FOR 2.0V FULL-SCALE



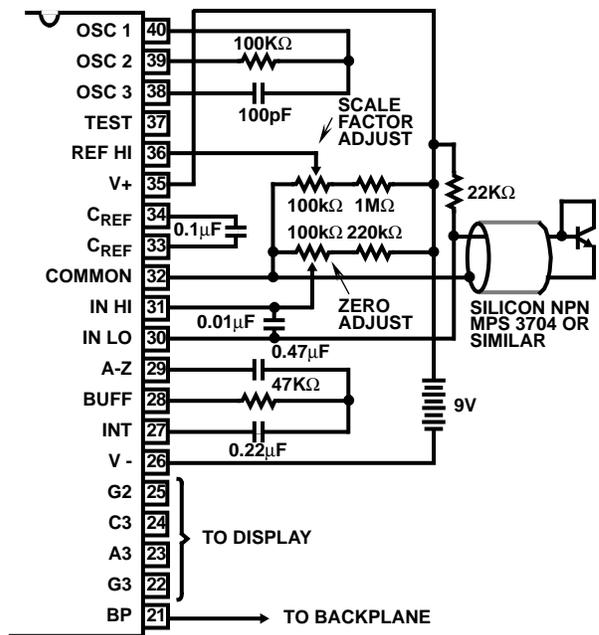
An external reference must be used in this application, since the voltage between V+ and V- is insufficient for correct operation of the internal reference.

FIGURE 14. ICL7117 OPERATED FROM SINGLE +5V SUPPLY



The resistor values within the bridge are determined by the desired sensitivity.

FIGURE 15. ICL7117 MEASURING RATIOMETRIC VALUES OF QUAD LOAD CELL



A silicon diode-connected transistor has a temperature coefficient of about  $-2\text{mV}/^\circ\text{C}$ . Calibration is achieved by placing the sensing transistor in ice water and adjusting the zeroing potentiometer for a 000.0 reading. The sensor should then be placed in boiling water and the scale-factor potentiometer adjusted for a 100.0 reading.

FIGURE 16. ICL7116 USED AS A DIGITAL CENTIGRADE THERMOMETER