

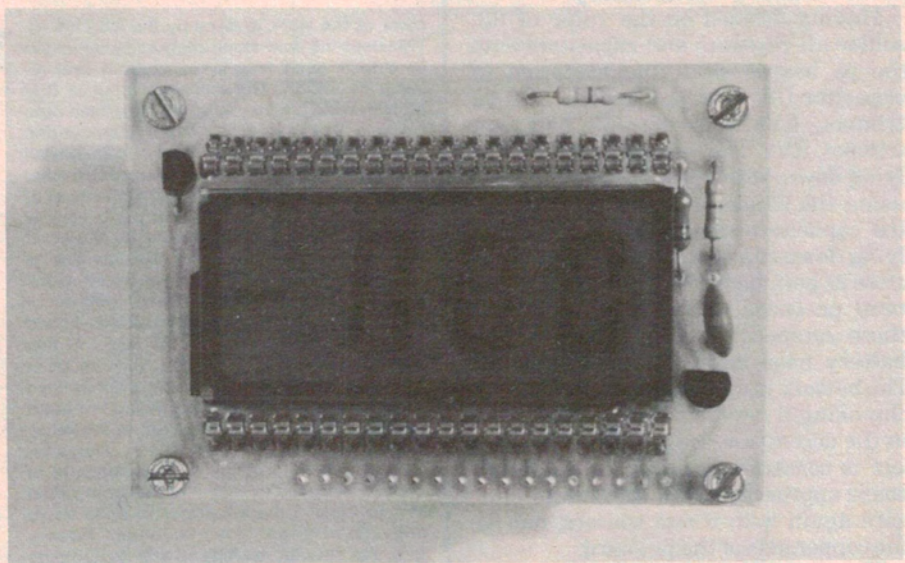
Versatile digital panel meter with liquid crystal display

David Tilbrook

This simple, versatile project can be used as the basis of many test instruments or as a stand-alone meter to measure voltage (as low as 200 mV) or current.

THERE ARE many applications that require a digital readout of dc voltage. To fulfil this requirement we published a digital voltmeter, the ETI-135 digital panel meter in October 1977. It was based around the Intersil ICL7106 digital voltmeter IC, which was at that time available in the form of an evaluation kit. Although the individual ICs are widely distributed now the evaluation kits are becoming scarce. For this reason we have decided to republish the design in a form suitable for commonly available components. The kit was supplied with small rectangular capacitors enabling them to be laid on their side to reduce height and allow the display to be mounted as closely as possible to the front panel. Unfortunately these capacitors are not commonly available. Greencaps work well in this application but their physical size requires a new pc board layout.

We overcame these problems by designing a pc board suitable to be cut in half. The display, the 7106 IC and a few other components mount on one of the pc boards, while all other components, including the battery if required, mount on the other pc board. This enables almost any sized components to be used and by mounting one of the pc boards behind the other, ensures the display occupies as little front panel space as possible. ▶



SPECIFICATIONS

Full scale readout	depends on setup. Full scale sensitivity is 199.9 mV
Resolution	100 μ V
Accuracy	< 1 digit when correctly calibrated
Display	3 1/2-digit LCD
Input Impedance	> 10^{12} ohms
Input bias current	approx. 2 pA
Polarity indication	automatic
Conversion method	dual slope
Reference	internally generated ± 100 ppm
Power supply	9 V @ approx. 1 mA

Project 161

Construction

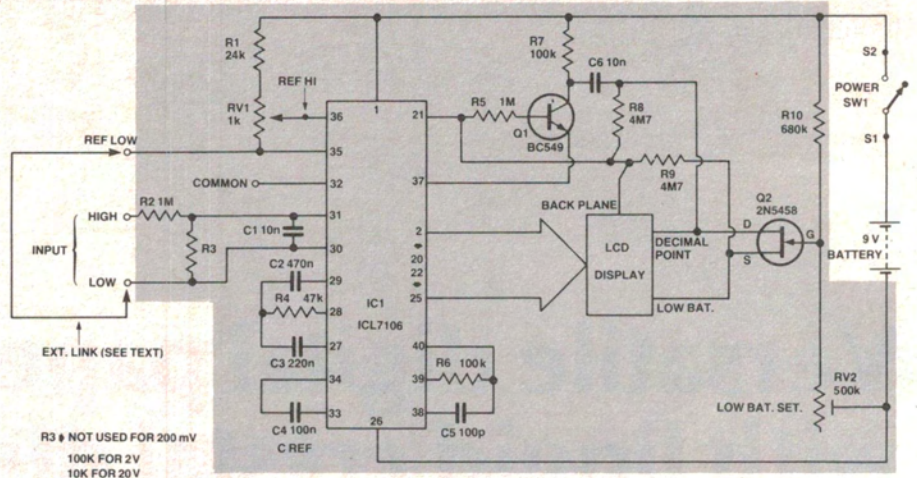
The project can be constructed in two forms, either on a single pc board, or as mentioned above, by cutting the pc board in half and mounting one half behind the other. If your application requires that the pc board be cut, do so before mounting any of the components.

Start construction by deciding on the sensitivity that best suits your requirements. This decides the value of resistor R3. If a 200 mV (199.9 mV) maximum sensitivity is required R3 is omitted. For a 2 V (1.999 V) meter, the required value of R3 is 100k while for a 20 V (19.99 V) meter, use 10k.

If the meter is setup for 200 mV operation it is advisable to solder an additional 1M resistor in parallel with the input, i.e: directly from the low input terminal to the high input terminal. This reduces the input impedance of the meter to 1M and reduces the sensitivity of the instrument to stray static voltages. Without this resistor the display has an input impedance of more than 10^{12} ohms. So the input capacitance can easily become charged by static, prohibiting the meter from zeroing correctly. On the other ranges, a parallel resistor is automatically present so the additional 1M resistor is not necessary.

Having decided on the value of R3, solder all resistors and capacitors onto the pc boards, with the exception of capacitor C6. Next, solder the 10-turn trimpot, RV1, and the 'low batt.' set trimpot, RV2. The latter is best mounted lying down. If the project is constructed using the single pc board approach all the capacitors should also be mounted lying down so that the display can be as close as possible to the front panel. If the twin pc board approach is used only those components mounted under the battery need be mounted lying down. The battery is mounted on a 9 V battery clip using 6 mm long spacers as shown in the accompanying photos. If the project is constructed using the single pc board approach, mount the battery clip, once again with 6 mm spacers, but on the copper side of the pc board.

The main IC and the liquid crystal display can now be mounted. The 7106 is mounted under the LCD display, so if a socket is required ensure that it is a low height type. Otherwise, solder the IC directly to the pc board making sure that the device has been inserted the right way around. Check this against the construction overlay before soldering. The LCD display should be mounted using Molex pins. This spaces the display off the pc board and ensures that the transistors and capacitors around the display are not higher than the dis-



PRINTED CIRCUIT ARTWORK for this project can be obtained by sending a stamped, self-addressed envelope to: ETI-161 ARTWORK, ETI Magazine, 15 Boundary St, Rushcutters Bay NSW 2011.

play itself. It is probably easier to plug in the display before soldering the remaining components. There are no convenient orientation marks on the display so it is necessary to hold it at a slight angle and look for the outline of the digits. The display should be mounted with the decimal points at the bottom and the 'LOW BAT' indicator in the top left hand corner of the display.

Finally, solder the remaining transistors and capacitor C3, being careful to orientate the transistors correctly and not to scratch the front glass of the display.

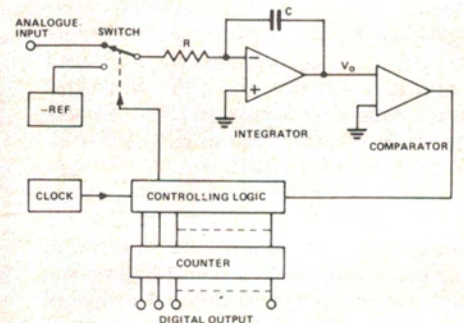
If the single pc board approach has been adopted, construction is complete at this stage. If the twin pc board approach has been used however, it is necessary to solder the 18 wire links

HOW IT WORKS — ETI-161

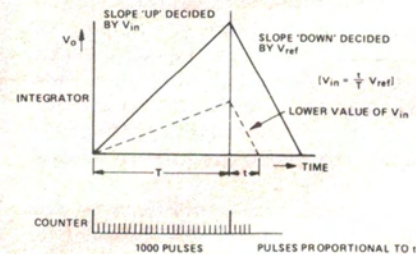
Most of the work is done by the ICL7106 IC. This uses the dual-slope integration technique to ensure good long-term accuracy and reliable operation. The analogue input is first converted to a binary number by a digital counting system. This conversion system is illustrated in the block diagram. When the switch connects the analogue signal input to the input of the integrator, the output from the integrator ramps up at a rate determined by the input voltage. At the same time, the counter is started at zero and begins to count clock pulses. When a predetermined number of pulses has been counted the input is switched to the reference by the control logic. At this time, the integrator capacitor, C, has been charged linearly to some voltage determined by the ramp rate and therefore by the input voltage. As the switch changes to the reference, the counter is reset to zero and commences counting again. The reference is of appropriate polarity to that of the input signal and so causes the integrator to ramp down with a fixed slope. When the output reaches zero, the counter is stopped and its contents displayed on the digital readout. The count displayed is the ratio of the counts during the downward ramp to the counts during the upward ramp.

The value of the integrator capacitor and clock frequency are of little significance, provided they are stable for the duration of the conversion period.

This is a true dual polarity system so the integration direction depends on the polarity of the input voltage. Provided ac ripple on the input averages to zero over the count time it will be rejected. If 50 Hz ripple is to be rejected, for example, a 50 kHz clock rate could be used, giving an 80 ms sampling time (four cycles of 50 Hz). The clock can be adjusted by varying



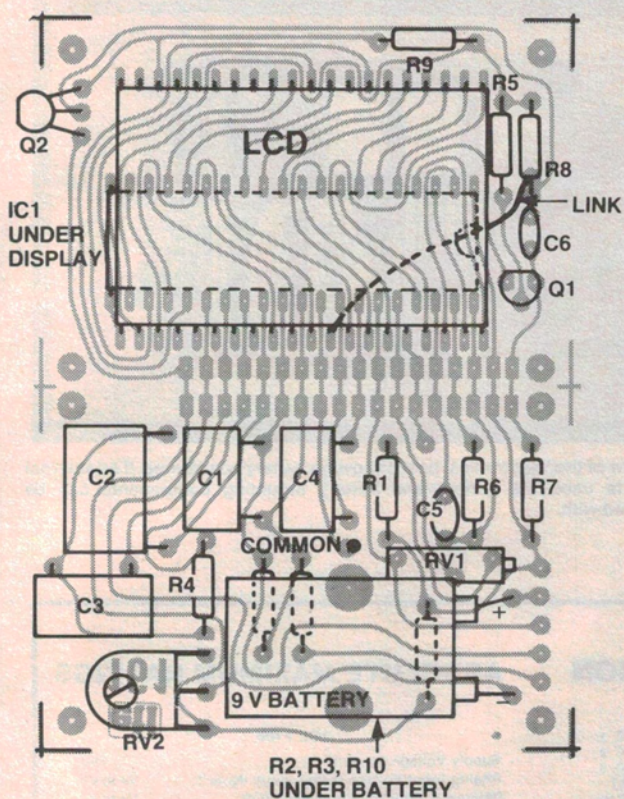
Block diagram of the dual-slope integration technique



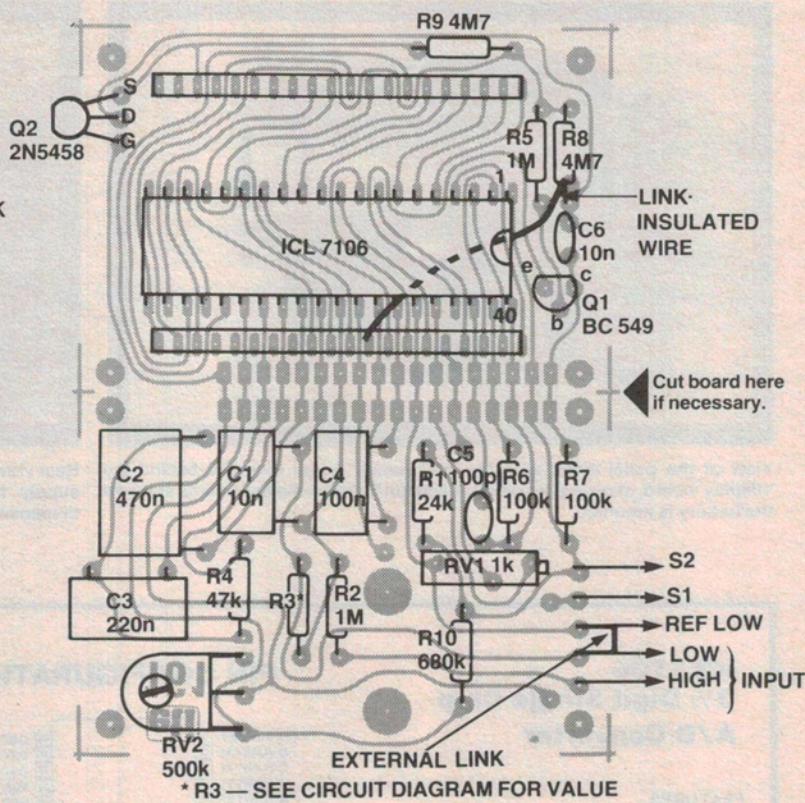
Timing diagram of the dual-slope A/D conversion technique.

the value of R6. We experienced no problem with 50 Hz ripple. Capacitor C1 in conjunction with resistor R2 function as a low pass filter with a -3 dB rolloff point well below 50 Hz.

The 2N5458 JFET (Q2) is used simply as a voltage sensor to monitor the battery voltage and drive the LOW BAT indicator if the voltage falls below that determined during set up.



COMPONENT OVERLAY SHOWING POSITION OF LCD AND BATTERY



COMPONENT OVERLAY WITHOUT LCD OR BATTERY SHOWING POSITION OF IC, R2, R3 AND R10

between the two boards. Before doing this however, solder a lead from the point on the pc board marked 'COM.' It is necessary to connect this point to one of the two input terminals. The usual method is to connect COM to the low input. Also, connect REF LOW to the low input. This configures the meter to a normal absolute reading voltmeter that will display the voltage between the low and high input terminals with normal polarity indication. The module is also capable of ratiometric measurement. For information about this application consult the data sheet included for the ICL7106.

Mount the pc boards, spacing them approximately 20 mm apart, either using spacers or simply an entire set of nuts on the four mounting bolts. Use tinned copper wire to make the links between the pc boards, soldering each one at both ends before proceeding to the next. A fine-tipped soldering iron and fine solder (22g) should be used for this project and is especially important at this stage.

Calibration

Before powering up, ensure that all components have been soldered correctly and have been inserted with the correct orientation. If all is well plug in the battery and connect the points S1 and

S2 to each other. The display should immediately stabilise with all digits reading zero. Use a power supply to generate a test voltage and adjust RV1 so that the panel meter agrees with another voltmeter. Preferably use a digital voltmeter for this, although a good analogue instrument can also be used with decreased accuracy. RV2 is used to adjust the low battery indication on the display. The best way to do this is to run the unit from an adjustable power supply, checking operation against a known voltmeter while decreasing the supply voltage. Set the LOW BAT indicator to come on at a supply voltage just above where the panel meter fails to read accurately. Do not exceed 9 V on the supply leads when doing this test.

Once calibrated correctly this project is capable of very accurate measurement. The 7106 is used in many commercial digital multimeters and the high input impedance enables the module to be used in many applications.

We intend publishing several projects using the display, but even as a general purpose dc voltmeter the module has proved very useful. A 1R shunt resistor can be soldered directly across the input to convert the module into a dc current meter reading in milliamps (i.e: 199.9 mA). Use an OR1 shunt to read dc amps (i.e: 1.999 A). Add an 'absolute

value' generator to enable ac voltage or current to be measured. ▶

PARTS LIST — ETI-161

Resistors	all ¼W, 5%
R1	24k
R2, R5	1M
R3	see note
R4	47k
R6, R7	100k
R8, R9	4M7
R10	680k
RV1	1k 10-turn trimpot
RV2	500k horizontal trimpot

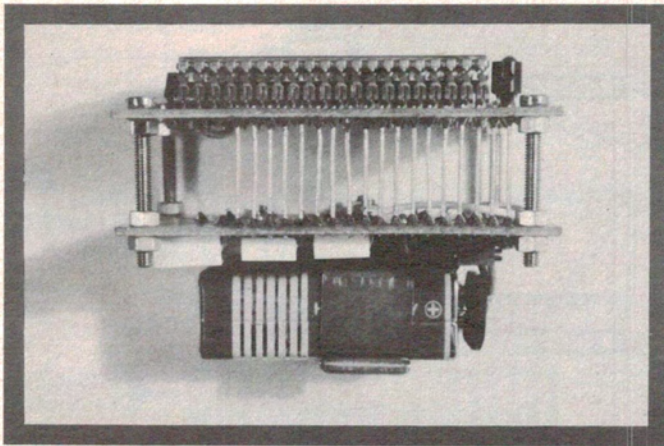
Capacitors	
C1	10n mylar, 50 V
C2	470n mylar, 50 V
C3	220n mylar, 50 V
C4	100n mylar, 50 V
C5	100p NPO ceramic
C6	10n ceramic

Semiconductors	
IC1	ICL7106
Q1	BC549, BC109
Q2	2N5458, MPF106

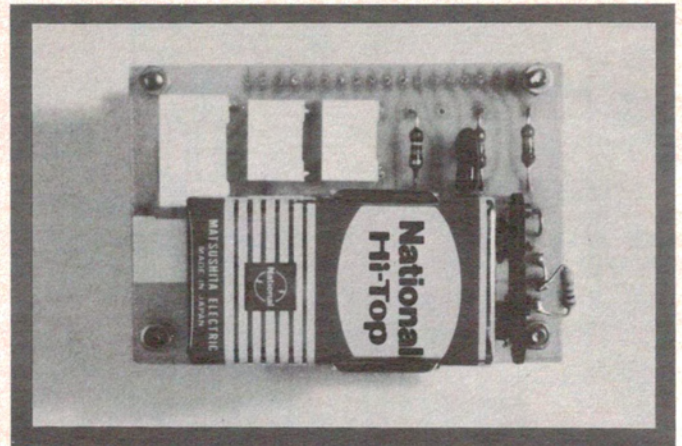
Miscellaneous
ETI-161 pc board; LAD204 liquid crystal display (from Intersil evaluation kit) or similar; battery holder clip for No. 216 battery (if required); SW1 — SPST switch (if required); two 6 mm long spacers; four 20 mm spacers (if required); nuts and bolts to suit assembly; No. 216 9 V battery (if required).

Price estimate **\$30 — \$35**

NOTE: many of these components are available in the Intersil Evaluation kit, particularly the 7106, the display and the capacitors.



View of the panel meter with the 'electronics' board mounted behind the 'display' board, showing the connections run between the two boards and how the battery is mounted.



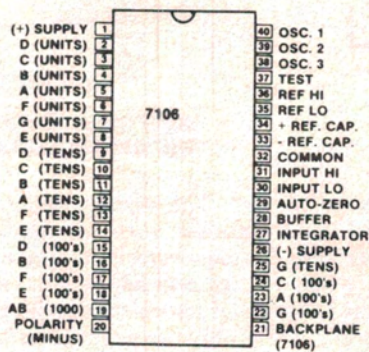
Rear view of the 'electronics' board showing battery positioning. If an external supply is used the battery and battery mounting components can be dispensed with.

ICL7106 3 1/2 Digit Single Chip A/D Converter

FEATURES

- Guaranteed zero reading for 0 volts input on all scales.
- True polarity at zero for precise null detection.
- 1 pA input current typical.
- True differential input and reference.
- Direct display drive - no external components required. — LCD ICL7106
— LED ICL7107
- Low noise - less than 15 μ V pk-pk.
- On-chip clock and reference.
- Low power dissipation - typically less than 10mW.

PIN CONFIGURATION



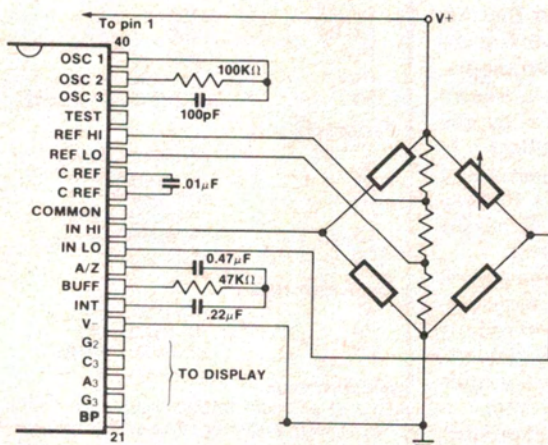
ABSOLUTE MAXIMUM RATINGS

ICL 7106

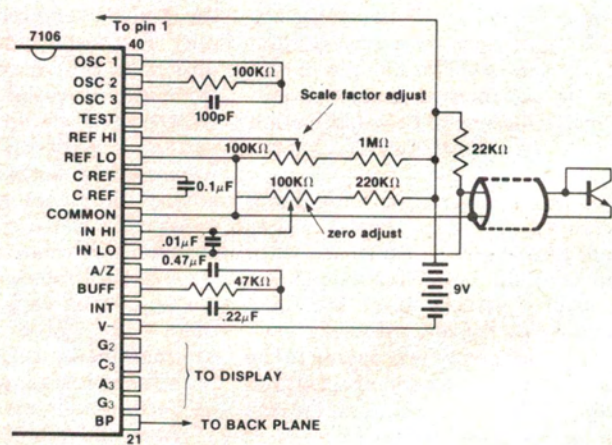
Supply Voltage (V+ to V-)	15V
Analog Input Voltage (either input) (Note 1)	V+ to V-
Reference Input Voltage (either input)	V+ to V-
Clock Input	Test to V+
Power Dissipation (Note 2)	
Ceramic Package	1000 mW
Plastic Package	800 mW
Operating Temperature	0°C to +70°C
Storage Temperature	-65°C to +160°C
Lead Temperature (Soldering, 60 sec)	300°C

Note 1: Input voltages may exceed the supply voltages provided the input current is limited to $\pm 100\mu$ A.

Note 2: Dissipation rating assumes device is mounted with all leads soldered to printed circuit board.



7106 measuring ratiometric values of Quad Load Cell. The resistor values within the bridge are determined by the desired sensitivity.



7106 used as a digital centigrade thermometer. 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 100.0 reading.