Quick LED Displays

How to use National Semiconductors' 4-digit counter/driver ICs for creating easy, low-cost numeric displays for your projects

By J. Daniel Gifford

Liquid-crystal displays (LCDs) have supplanted light-emitting-diode (LED) displays in most commercially made products, mainly because of the LCD's low-power requirements and high visibility under typical lighting conditions. However, there is still a lot of mileage to be gotten out of LED displays, which are still a lot cheaper and easier for the hobbyist and experimenter to use.

If you are like most experimenters, you probably groan at the thought of designing and building projects that require multiple-decade displays because of the multiplicity of components needed—counter and decoder/driver chips, resistors and the LED displays themselves. Fortunately, things are not as bleak as they first appear to be now that National Semiconductor is making a series of 4-digit counter/driver ICs designed to drive LED displays. These relatively new chips reduce the component count, in some cases, to just two: the IC and display. Hence, working with this new series of chips is a breeze.

The series itself consists of four separate devices (numbers 74C925 through 72C928), all of which are nearly identical but differ with some important variations. All four chips are also relatively low in cost and readily available from a number of

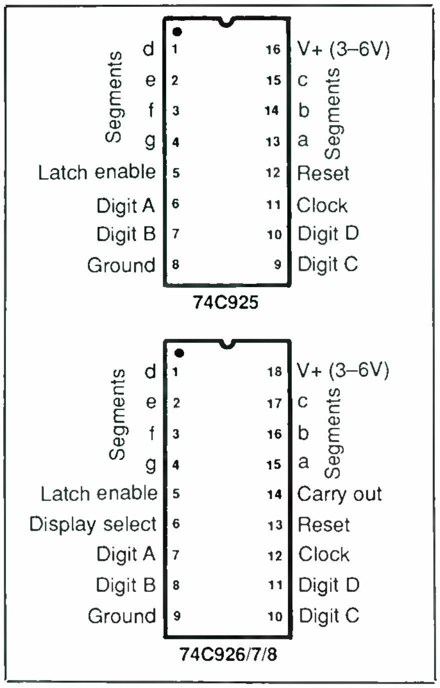

Fig. 1. Pinouts of 16-pin 74C925 and 18-pin 74C926, 74C927 and 74C928. The 74C925 and 74C926 are functionally identical except that the 74C926 lacks carry output and display select input. The 74C927 and 74C928 are identical to the 74C926 except for different counting sequences.

sources traditionally used by hobbyists and experimenters.

Technical Details

The four chips that make up the National series each contain a 4-digit BCD counter, quad 4-bit latch, BCD to 7-segment decoder and segment and digit drivers. The 74C925 is a 16-pin DIP device, while the other three are 18-pin devices (Fig. 1). With any one of these chips, a minimum of outboard components are needed to provide full four-digit decimal counting. The only external components one might need are four common-cathode numeric LED displays, which can be either discrete-digit or a four-digit array, and four bargain-basement npn transistors.

In spite of the many combined on-chip functions, this series of ICs is exceptionally easy to use. Other than the segment and digit outputs, there are only four inputs and one output per chip. Since these chips are CMOS devices, they draw very little power so that any significant power drawn by a 4-decade counter is confined to the LED display, which can consume as much as 100 mA or more.

CMOS construction makes these chips relatively immune to electrical noise and aids in interfacing with almost any kind of circuit that requires a numeric display. Too, there is nothing critical about power-supply requirements, since they are designed to operate over a range of from 3 to 6 volts dc, making operation from 5 volts the easiest design option.

All four ICs in the series feature digit multiplexing. An internal oscillator in each runs the multiplexing circuitry. Hence, the need for even a single external timing capacitor is eliminated. Individual a through g segment-drive outputs can each source up to 40 mA of current, which is sufficient to assure a bright display

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when an IC is called upon to drive even large (0.6- to 0.8-inch) LED numeric digits. Segment resistors should, however, be used when these ICs are powered from a 5- to 6-volt source. though they can be dispensed with when less than 5 volts is used to power the chips.

If very large, bright displays that draw greater current than the counter/driver ICs can safely deliver are to be used, high-current drivers like the CD4050B hex buffer can be included between the combined counter/driver IC's outputs and the displays.

Digit driver outputs A through D are limited to a maximum source current of about 1 mA. This is enough current to drive a general-purpose npn transistor like the 2N2222 or 2N3904 that is then used to sink current from the common cathodes of a single LED decade. The four outputs are switched high in succession, with one and only one being high at any given moment in time. Each output has an on time of 22 percent of a single duty cycle, leaving a 3-percent "dead" time during which no decade is on. This dead time keeps the segment signals from traveling to the wrong display and causing "ghosting" (faint lighting of wrong segments). In severe cases, ghosting can cause the display to faintly light all eight segments continuously.

As each driver output is switched high, the segment drivers switch to the corresponding counter stage's outputs. Actually, the outputs of the 7-segment decoder driver remain connected the same way (to the segment output pins). It is the BCD *inputs* to the decoder that are switched from the outputs of one 4-bit latch to the next.

Each latch is connected to the output of one of the four counter stages and all four latches are controlled by the latch-enable (LE) input. When LE is high, the latches are in flow-through mode, and the outputs of the counters are directly passed to the segment decoder. When LE is brought low, the count in the latches at that point—and the display—is frozen until the input is brought high again. The counters continue to count, however, and their output (instead of the count being held in the latches) can be displayed by bringing the display-select (DS) input high.

When DS is low, the value in the latches is displayed, whether static or changing with the counters. When DS is brought high, the value held in the latches is ignored and the counter outputs drive the decoder.

It is in the counter sections where the only differences between the four ICs lie. The 74C926 has four divide-by-10 counters with BCD outputs. The clock input is connected to the least-significant digit's (LSD's) counter stage. The carry output of

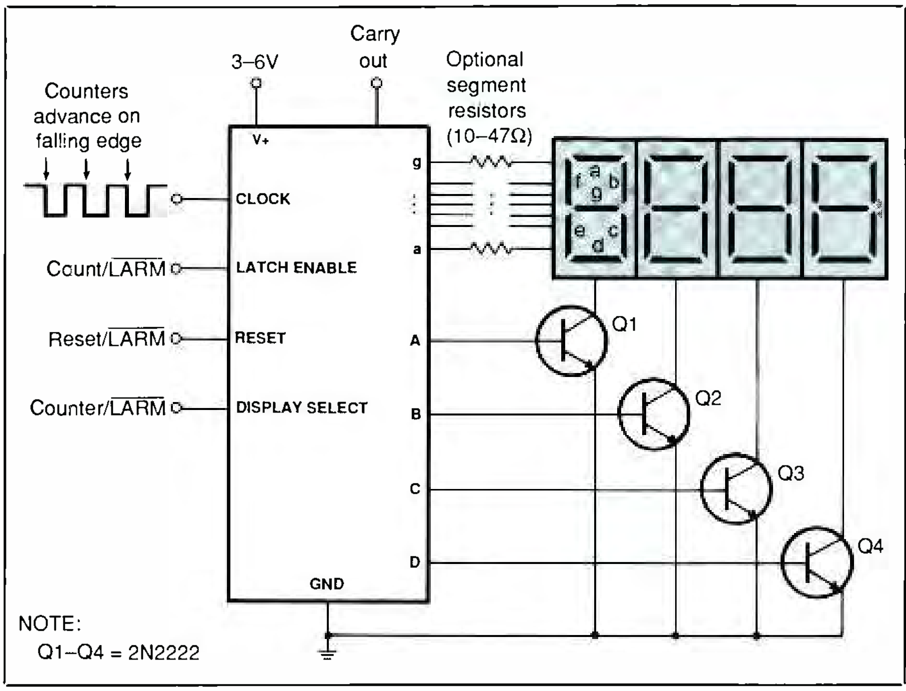

Fig. 2. Basic application circuit for all versions of counter. Segment resistors are optional but should be used whenever power supply delivers 5 volts or more.

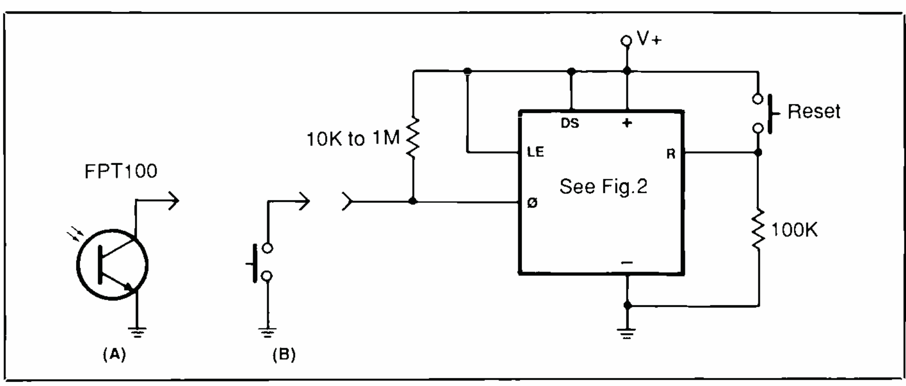

Fig. 3. Basic event counter can use switch (A), phototransistor (B) or any other sensor that can produce a 0-to-5-volt pulse.

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the LSD's counter stage drives the second counter stage, the second counter's carry output drives the third counter stage, and the third counter stage's carry output drives the fourth counter stage. With four counter stages, the 74C926 has a count range of 0000 to 9999. When the count increments by 1 past 9999, the count (and display) roll over to 0000 to begin counting upward again. (All count incrementing occurs on the negative edge of the clock pulse input.)

The fourth counter's carry is brought out to the carry out pin. Hence, two or more of these chips can be cascaded for any desired number of display decades. The chip carry output is low until the display reaches 6000, at which point it drops low again when the counter rolls over to 0000.

With a 5-volt power supply, the maximum clock frequency for all four 4-digit counter/drivers in this series is typically 4 MHz (2 MHz guaranteed), which should be fast enough for most counting applications. If a faster count input is needed, a prescaling counter like the 74HC4017 or 74HC4510 can be used ahead of the display counter/driver to divide the input frequency by any factor of 10. These prescaling counters can be cascaded as needed to obtain the desired divide factor to bring the input signal frequency into a range that can be handled by the display counter/driver.

All four counter/drivers in this series share a common reset input, which is kept low for normal operation and is brought high to force all counter stages to zero and the carry output to its low state. Reset also inhibits counting when it is high.

Being a simple decimal counter, the 74C926 is probably the most useful of the four IC devices. Indeed, it is the most widely available. The 74C925 is an almost identical decimal counter, except that it lacks carry output and display-select pins. Because the output of this counter is always connected to the latches, bringing LE low freezes the display. The only real advantage to the 74C925 is that in OEM quantities (10,000 or

IC Availability

The National Semiconductor LED counter/driver integrated circuits referred to in this article are readily available, but not from all sources traditionally used by electronics hobbyists and experimenters. If you would like to experiment with and use these chips, they can be obtained from the following sources:

Source*	Device No.	Cat. No.	Unit Price
Digi-Key	74C925	74C925N-ND	$8.75
P.O. Box 677	74C926	74C926N-ND	$8.75
Thief River Falls, MN 56701	74C927	74C927N-ND	$8.75
Tel.: 800-344-4539	74C928	74C928N-ND	$8.75
Jameco Electronics	74C925	74C925	$4.95
1355 Shoreway Blvd.	74C926	74C926	$4.95
Belmont, CA 94002			
Tel.: 415-592-8097			

*Digi-Key has no minimum, but service charges may apply; Jameco has a $20 minimum.

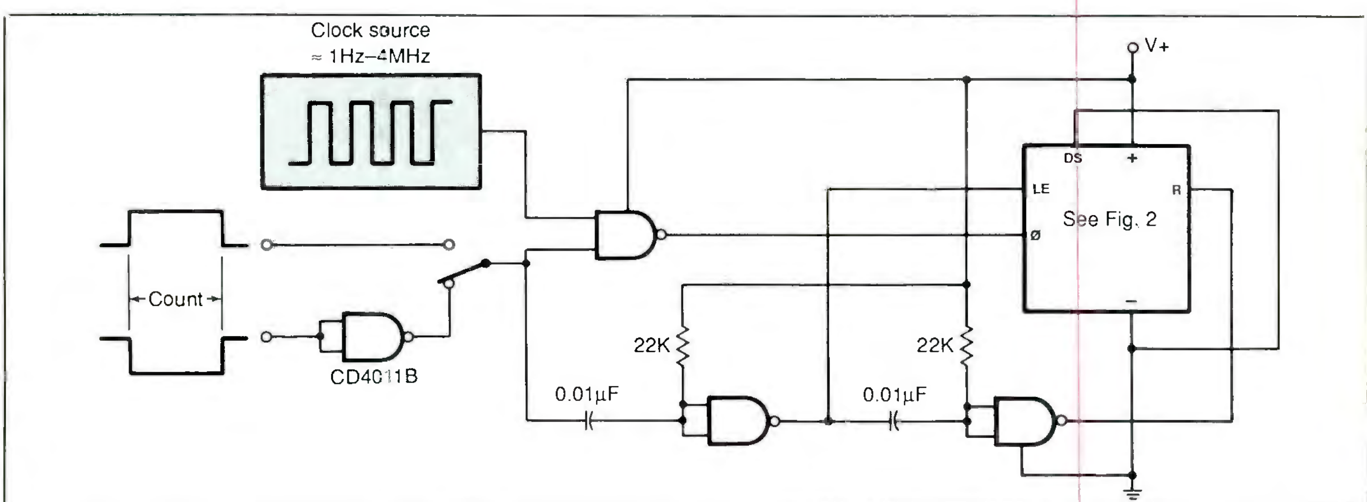

Fig. 4. Basic period-measurement circuit.

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more pieces), it is cheaper than the 74C926. In the small quantities an experimenter usually buys, there is no price advantage worth considering.

The 74C927 is identical to the 74C926 in that it is housed in an 18-pin package and has both reset and carry output pins. The difference is that the second most-significant (hundreds) digit has a maximum count of 6 and rolls over to 0 when it is incremented past 5 (the 6 count is the result of 0 being used as a count digit). This yields a maximum count for the four-digit device of 9599, which is useful for timing and clock applications. (If a 10-Hz clock signal is used with the 74C927, the output would display seconds in tenths up to 10 minutes, which would be displayed as 9:59.9.) The carry output pin follows the same logic as that of the 74C926, going high at 6000 and low at 0000.

Except that its most-significant digit divides by 2, giving a maximum count of 1999, the 74C928 is also identical to the 74C926. The carry output latches high when the count reaches 2000. It returns to low only when the counter is reset. The 74C928 is, thus, a 3½-digit counter, with the carry output acting as an overflow indicator. This counter/driver is suitable for many types of panel-meter circuits.

Applications

All of the application circuits we will be discussing use the basic circuit shown in Fig. 2. This is the circuit implied in later figures by a box with internal callouts. Power supply delivery is assumed to be 5 volts dc. If a lower voltage is used, you might have to make some adjustments in the circuits to be shown.

● *Event Counter.* The resettable event counter circuit shown in Fig. 3 is about as simple an application for the National ICs as you can get. A switch (detail A) or a phototransistor (detail B) are two possible input sensors than can be used to count, say, openings of a door or objects passing on a conveyor belt. Any kind of sensing device that produces a 0-to-5-volt pulse can be used in this circuit in place of the switch or phototransistor.

The Fig. 3 circuit uses a manual reset function, and the display-select and latch-enable inputs are wired high to provide for a continuously updating display. As with all these circuits, you can make any modifications you see fit to suit your particular applications.

● *Gated Timer.* Figure 4 shows a very useful circuit that turns the counting function of the basic circuit into a timing function with a digital display and an adjustable timebase. If the project you incorporate the basic circuit into does not generate countable pulses, you can probably arrange it to produce a variable pulse width to drive this circuit or a variable frequency to drive a frequency counter (see below).

An astable multivibrator or clock source, built around the popular 555 timer or a pair of CMOS gates, is used to provide a timebase frequency for this circuit, the frequency of which can be adjusted to suit the project's needs. The output of the timebase is connected to the clock input of the counter circuit via a gate. The other input of the gate is used to turn on and off the counter.

Two different gating circuits are shown. One counts when the input is high, the other when the input is low. On each, when the output returns to the "don't count" state, the LE input is briefly enabled to store the count, and then the reset input is pulsed high to reset the counters to

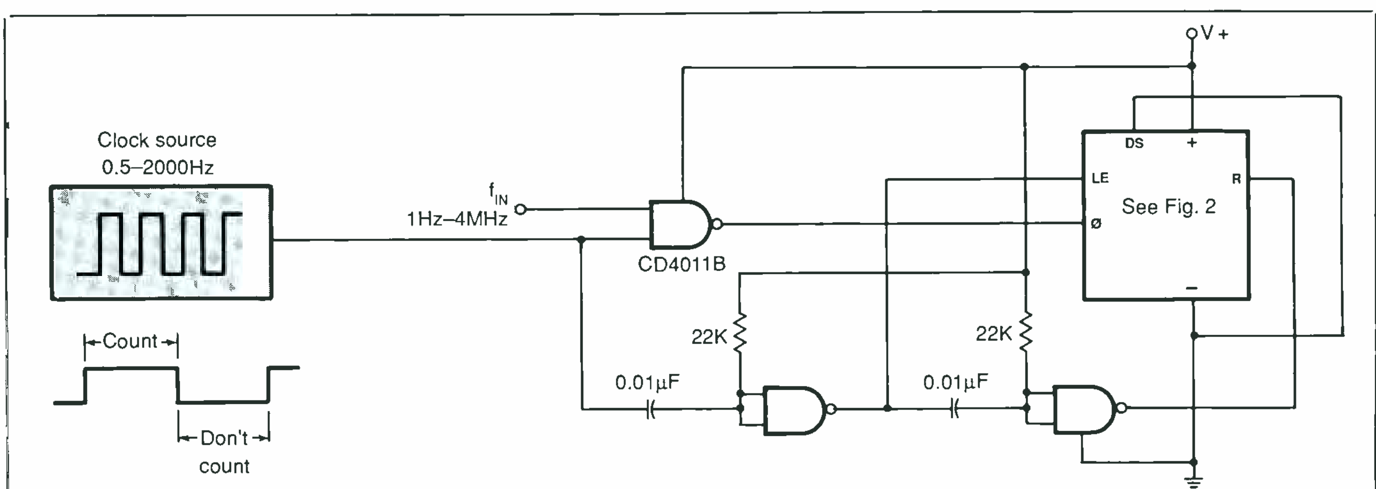

Fig. 5. Basic frequency-counter circuit.

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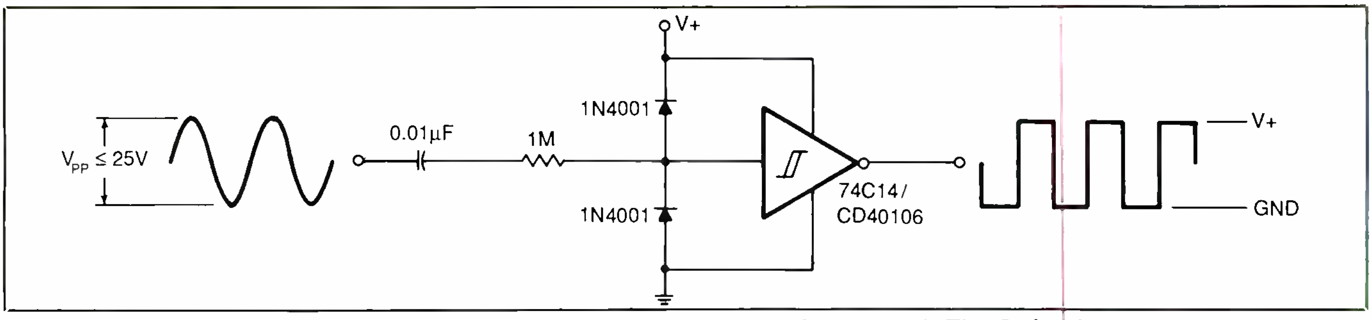

Fig. 6. General-purpose input conditioning circuit for use with Fig. 5 circuit.

await the next counting period. The last count will be displayed until the next counting period is completed.

In general, you will probably want the timebase frequency of the Fig. 4 circuit to be a decade division of 1 second (0.1 second, 0.01 second, and so on), since this will produce a display that tells you how long the high or low pulse was. The timebase frequency can be adjusted to produce other frequencies—to correct for timing factor errors in the main circuit, for example.

- *Frequency Counter*. If your main circuit does not produce countable pulses and cannot be rigged to produce some sort of time-proportional pulses, you might be able to get it to produce a proportionally variable frequency. To produce a readout display from such a frequency, you can use the circuit shown in Fig. 5. If this circuit looks familiar, it is because it is the logical inversion of the Fig. 4 circuit. However, instead of gating on and off a steady frequency with a pulse input, this circuit uses the stable frequency to gate on and off a variable input frequency.

Unless the input frequency is generated by other digital circuitry, it will probably have to be conditioned before it will work properly with the Fig. 5 circuit. Figure 6 illustrates an excellent general-purpose signal conditioner. Because the two diodes clip the input voltage at the ground and V + levels, peak-to-peak inputs of 25 volts or so are safe to apply to the input of the circuit, even though the supply voltage may be as low as 3 volts. Since the main element in this circuit is a Schmitt trigger, the circuit will turn even fairly ragged input signals into clean square waves to drive the counter circuit.

Cascading Counters

In the circuits discussed above, it was assumed that only one counter/driver IC was used. However, with the exception of the 74C925, all of these counters can be cascaded without limit. Although 32 or more decades are possible by cascading, the practical limit is probably more in the range of eight decades, which requires two counter/driver ICs.

Cascading these devices is simply a matter of using the original clock signal—no matter what its source—to drive the clock input of the least-significant digits (units through thousands counter) and then connecting the carry output of that counter to the clock input of the next. In general, the other inputs of each counter (latch enable, display select and reset) should be chained together so that they act simultaneously.

It is difficult to conceive of a circuit in which the lower counter would be anything but a 74C926. The second counter could easily be any of the four counter/drivers in this series—a 75C925 or 74C926 for all-decimal (0 to 9) counting, a 74C928 for 7½-digit counting with an overflow, or even a 74C927 for time counting from 0.00001 second to 10 minutes (with a 100-kHz timebase). If more than two counters are cascaded, all but the highest would be 74C926s.

By choosing the proper counting configuration and correct circuit from those discussed here, you should be able to add a four-or-more-digit LED display to almost any circuit that can benefit from one. **ME**

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