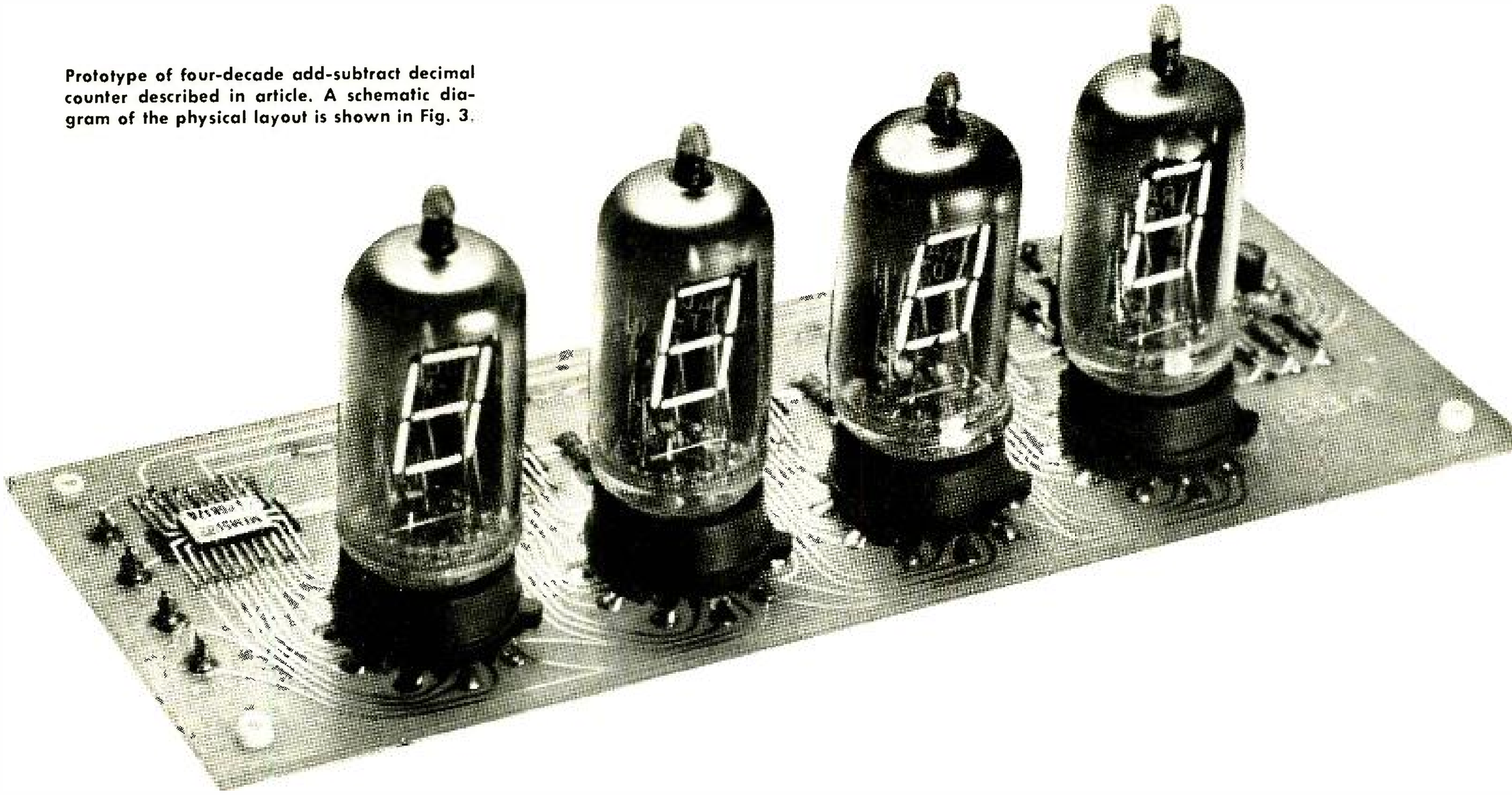
Prototype of four-decade add-subtract decimal counter described in article. A schematic diagram of the physical layout is shown in Fig. 3.



Add-Subtract MOS IC Decimal Counter

By DONALD E. LANCASTER

Use this 0-9999 decimal counter to construct many practical digital instruments. RTL-compatible MOS IC alone performs all functions of counting, storing, decoding, and driving the fluorescent readouts.

A NEW MOS integrated circuit has been introduced which will single-handedly add-subtract decimal count, store a count, decode that count, and drive a fluorescent 7- or 9-bar segmented readout. Besides these features, the same IC may be set to zero or any other count at any time, may be internally gated "on" and "off," and can have its display blanked or unblanked without disturbing the counting or storage actions.

Maximum count rate is 500 kHz and the system is actually cheaper than many competitive counting schemes, particularly when the add-subtract feature is important. One IC and one readout per decade are all the parts required.

Four of these IC's (Type MEM 1056 from *General Instruments Semiconductor*) have been combined with four vacuum fluorescent readouts and some logic translators to produce the 0-9999 add-subtract decimal-counter assembly described here. The assembly has RTL (Resistor-Transistor-Logic), TTL, or DTL (Diode-Transistor-Logic) compatible logic inputs and is easily converted into a calculator, digital voltmeter, digital panel meter, frequency counter, electronic stopwatch, digital servo, or positional control. A number of low-cost RTL module kits are available which can be used to convert the basic assembly into many practical digital instruments.

Features

The counter assembly has five inputs, called In (Clock), Reset, Gate, Blank, and Add-Subtract. The Count input advances or retards assembly one count per input pulse. The Reset input instantly returns the assembly to count 0000. The Gate input conditions the assembly to either accept or ignore input count pulses. You can make a simple frequency counter by connecting a 1-second square wave to the Gate input and working out a Reset scheme. The Blank input either lights or extinguishes the display without affecting the counting or storage section. Finally, the Add-Subtract input "tells" the counter assembly whether the next series of input pulses will be added or subtracted to the tally already in the assembly. In the interests of simplicity, several other features have been omitted from the prototype. As we'll shortly see, these are easily added at the expense of PC board jumpers and extra translator transistors.

Maximum assembly counting speed is 500 kHz with a four-place accurate (0.01%) answer taking a maximum of 20 milliseconds. Input data must, of course, also be equally precise

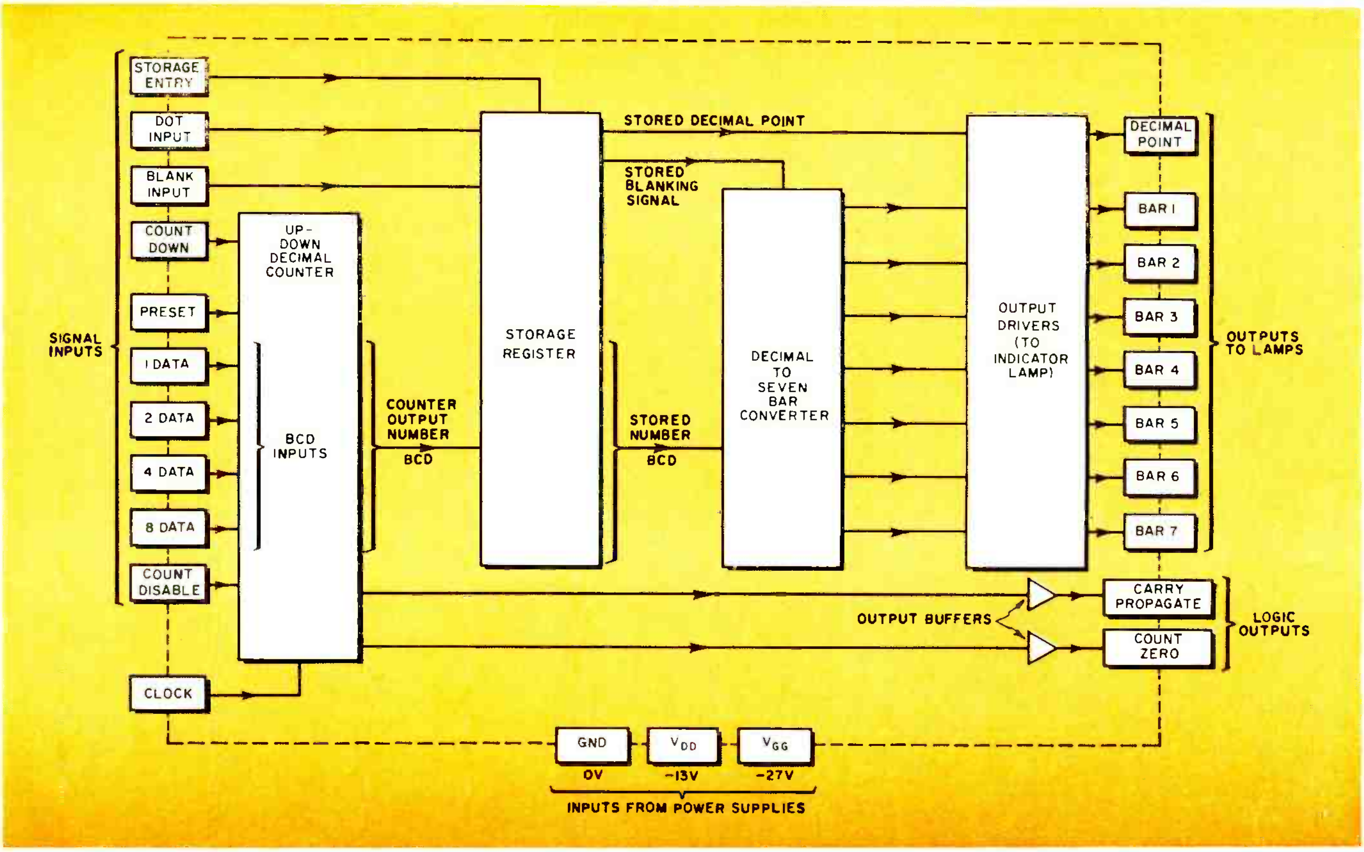
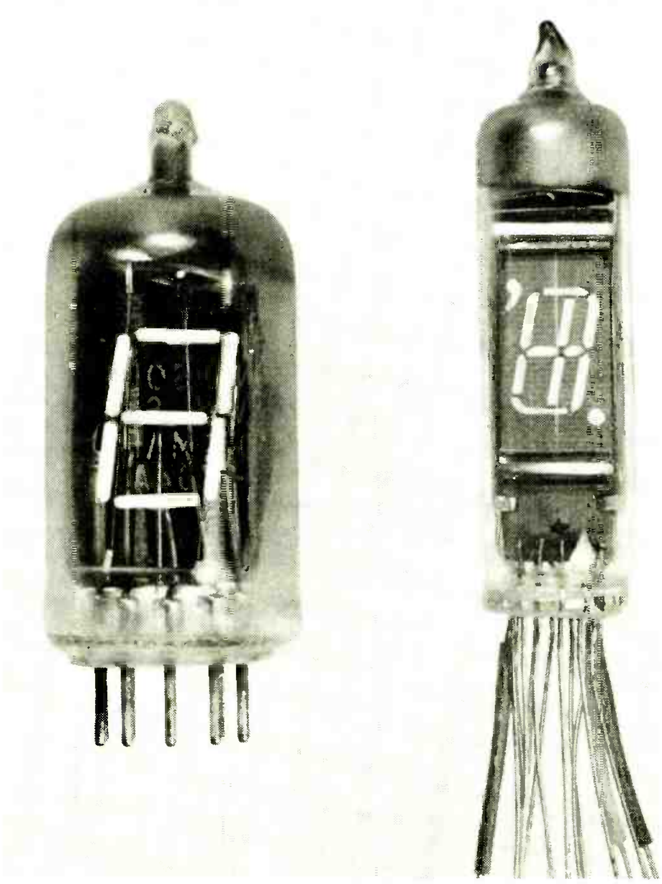


Fig. 1. Block diagram of the MEM1056 MOS integrated circuit used to construct the add-subtract decimal counter. The integrated circuit performs all of the functions represented in the four large blocks of diagram.

Fig. 2. The Tung-Sol DT1704A (left) and Itron DG12C (right) vacuum fluorescent readouts used with the MEM1056 MOS IC.



to achieve this accuracy. Extra stages are easily tacked on the end for more accuracy.

Advantages and Disadvantages

There are many presently popular approaches to decimal counting, decoding, and readout. Irrespective of a manufacturer's claims, no one counting system is "ideal" nor is any one system suitable for all possible counter and display applications. In the case of this system, there are both advantages and disadvantages to its use.

Its greatest advantages are its simplicity and the add-subtract feature. Only two or three parts—an IC, a readout, and possibly a socket are needed per decade. Assembly on a single-sided, multiple-decade PC board with only 13 holes and two jumpers per stage is possible, especially if a slightly wider-than-normal numeral spacing is acceptable.

The Add-Subtract feature is offered on very few competing systems, and then only at considerably higher cost and complexity. On the other hand, the subtract operation is rarely used in digital instruments and is accomplished in a different (parallel) manner in calculators and computers; it is unessential for practically everything but predetermining counters, positional controls, and very simple arithmetic operations.

The display is a pleasing green and is visible over a wide angle. It does not have exceptional brightness and a totally dark area behind the display is recommended, along with a filter. The "boxiness" of the characters is probably objectionable to a "Nixie"-oriented instrument market. A more legitimate objection is the off-center "1" and awkward "4" presented by the display, and the resultant "holes" in a numeric sequence. This may be overcome by using a nine-bar display and an external transistor or two. The output voltages and currents of the IC are only compatible with vacuum fluorescent readouts.

The greatest disadvantages are undoubtedly the rather "weird" supply voltages required: −27 volts, −13 volts, and a 1.6-volt, 45-90-mA filament voltage *referenced* to the −27 volts. Simple translators have been included in the assembly. Each of these consists of a *p-n-p* transistor and two resistors and allows the assembly to be driven from conventional 0- to +3-volt RTL or DTL logic signals.

Other disadvantages include the limited speed which is partially offset by today's low-cost decade scaler circuits. The slower speed does buy better noise performance, particularly in industrial environments. The IC, being a MOS type, can be damaged instantly by reversed supply power, extremely careless handling, or by very large line transients. Protection has been included both inside the IC and on the prototype assembly for normal static, installation, and handling.

The readout has several failure modes, and thus has a limited, but probably quite acceptable life. At least one readout manufacturer has "beefed up" its readouts considerably to make them more immune to vibration. Sockets are probably a worthwhile addition for heavy-use applications.

The readout is also electrostatic-sensitive, with the glow dancing around if you bring a finger near the display. A physical barrier (such as a color filter) and some anti-static spray takes care of this particular problem. A newer *Tung-Sol* readout is available that is smaller, more rugged, and not electrostatically sensitive.

One big objection experimenters and technicians will have is the steep pricing structure of both the IC and the readout. Only in very large quantities can the counter be built for less than $7 per decade. In small quantities (1-99) cost will run around $29 per decade ($24 per IC and $5 per readout). Commercially available competing decimal-counter kits presently range from $10 to $30 per decade in small quantities, depending upon the readout and the speed of operation; none of these is as simple or has the subtract feature.

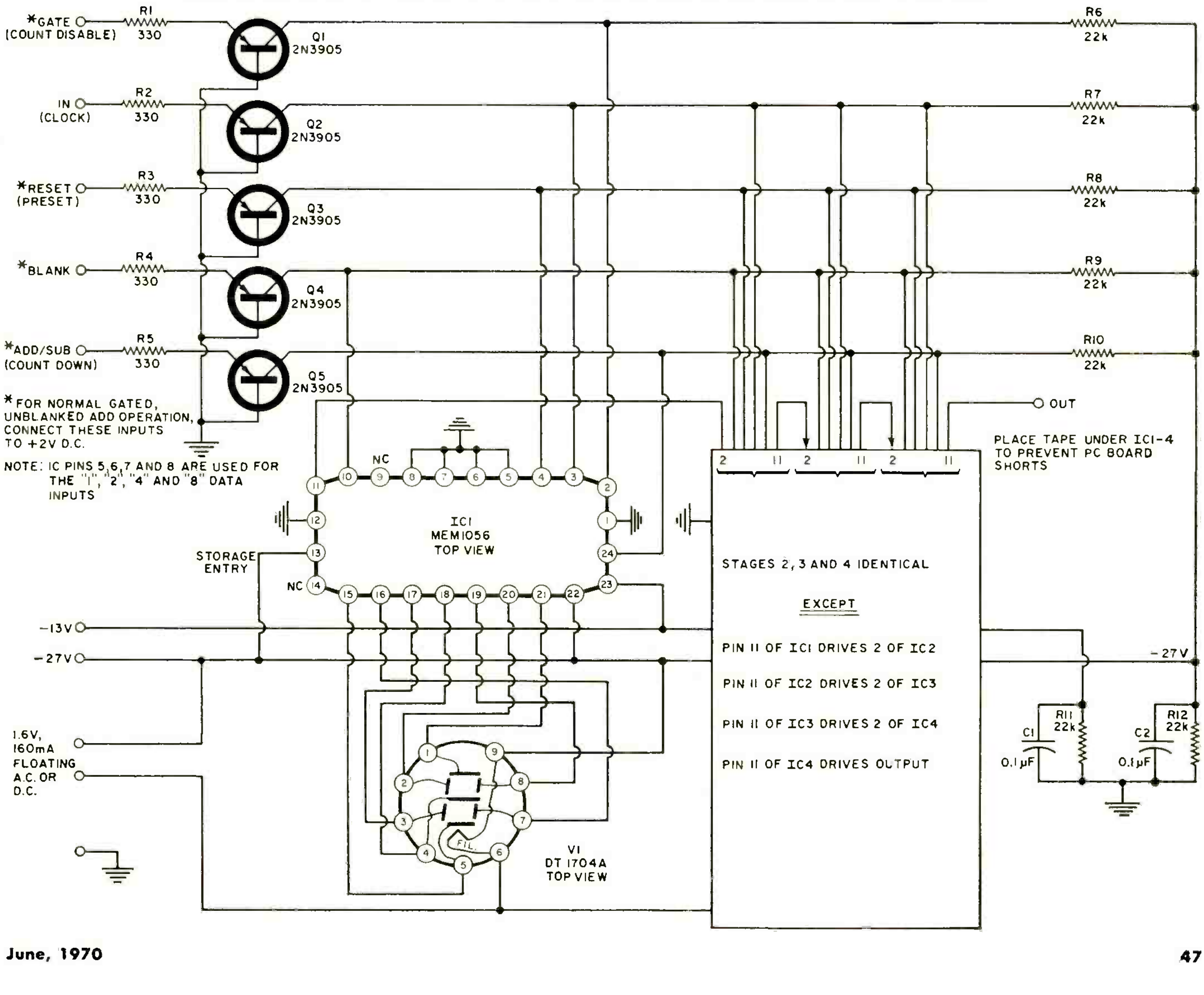
A block diagram of the MEM1056 is shown in Fig. 1. This is a MOS integrated circuit and comes in a 24-lead flat pack that operates off two negative supply voltages of −27 and −13 volts. The input logic swings from 0 volt ("0" or "No") to −27 volts ("1" or "Yes").

There are four main parts to the IC: the up/down decade counter, the storage register, the decimal-to-seven-bar logic converter, and the output drivers. The up/down decimal counter can accept either *series* (a sequential series of count pulses) or *parallel* (simultaneous appearance of count pulses) data.

To count serially, 0- to −27-volt pulses are applied to the Clock input. The clock is a "two-phase" type. The number in the counter changes as the Clock input goes from −27 to ground. Some first-decade conditioning is needed; the Clock input signal must have rise and fall times faster than 20 microseconds, and all mechanical contact or push-button inputs must be made "bounceless" to prevent contact noise from causing erratic operation.

The serial-input clock pulses are controlled by the Count Disable and the Count Down inputs. If the Count Disable input is at −27 volts (logic "1"), all input clock pulses will be ignored. If the Count Disable input is grounded (logic "0") input pulses are accepted. The Count Disable input is used to gate the counter for frequency or period measurement. The readout that is used remains lighted constantly

Fig. 3. Complete schematic of the four-decade counter assembly shown in the lead-in photograph. Complete wiring for one of the IC's and one of the DT1704A seven-segment fluorescent readouts is also included.



***MEM1056 MOS IC**
General Instruments Corp.
Semiconductor Products Group
600 W. John Street
Hicksville, New York

DT1704A and DT1705C 7-Bar Fluorescent Readouts
Tung-Sol Division
Wagner Electric Corporation
One Summer Avenue
Newark, New Jersey 07104

DG19 and DG12C 9-Bar Fluorescent Readouts
Itron Electronics Corp.
Ishimoto Trading Company
3118 W. Jefferson Blvd.
Los Angeles, Calif. 90018

#834 Drilled and Etched PC Board and Accessory Kit
Southwest Technical Products
Box 16297
San Antonio, Texas 78216

*Can be purchased at Terminal-Hudson Electronics, 236 W. 17th Street, New York, N.Y. 10011

Table 1. Sources where the components used in the Add-Subtract MOS Decimal Counter can be purchased.

irrespective of the condition of the Count Disable input.

The Count Down input determines whether the input clock pulses will be added or subtracted from the tally inside the IC; −27 volts ("1") on this input makes the IC subtract and grounding ("0") this input makes the IC add.

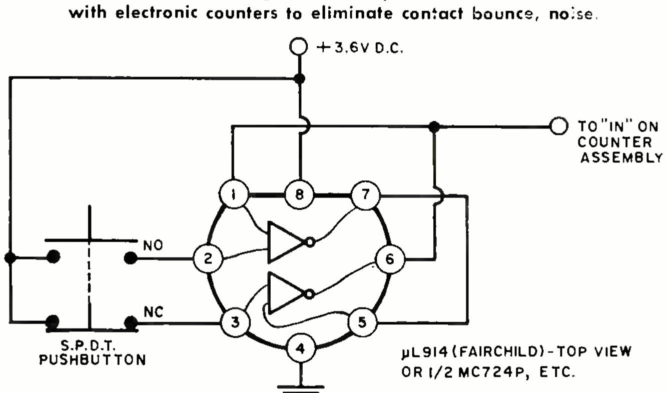
The Preset input forces the counter to the 0 count when −27 volts ("1") is applied, and does nothing when grounded. The "1," "2," "4," and "8" inputs may be used in combination with the Preset input to enter a number in parallel. These inputs are normally left grounded. To enter a "7," the Preset and only the "1," "2," and "4" inputs are lowered to −27 volts ("1"). The proper combination (a BCD word) is used for each required count. In this manner, a keyboard or a selector switch can enter counts without generating a separate series of pulses for each count. The readout will automatically produce an "F" indication if a false count (binary 10 through 15) is entered.

Input Protection

Most IC's are susceptible to damage by static electricity. The MEM1056 has built-in static protection and more is added on the prototype counter assembly. Nevertheless, all inputs to this IC (everything on the left in Fig. 1) must never be left floating or unconnected. All inputs should go either directly to ground, directly to −27 volts, to −27 volts through a 22k-ohm resistor, or to −27 volts through a resistor/transistor RTL-logic translator, depending upon whether control, permanent "1's," or permanent "0's" are desired.

Similarly, no input or power load must ever be allowed

Fig. 4. Schematic diagram of RTL push-button circuit used with electronic counters to eliminate contact bounce, noise.



to go positive by more than +0.3 volt. Permanent damage will result instantly if positive voltage is applied.

Storage

The storage register "keeps" a number for the display. If the Storage Entry input is at −27 volts ("1"), the storage register follows the up/down counter and presents the number in the counter to the readout. If the Storage Entry input is grounded ("0"), the storage register maintains the old number for the display. Storage commands are used to display an old answer while the counter is working on a new count.

The Blank input may be used to turn the display "on" and "off"; −27 volts ("1") turns the display "on"; ground ("0") leaves it "off." Counting action continues even with the display "off."

The Converter and Driver blocks convert the stored number into the proper patterns on a 7- or 9-bar readout. The output swing is 0 (bar lighted) to −27 (bar out) volts with an available current of 1 mA. The Dot Input may be used for optional decimal-point storage.

Two logic outputs are provided, a Carry Propagate and a Count Zero. The Carry Propagate is connected directly to the Count Disable input of the next stage and all decades have their Clock inputs driven in parallel by the input counting signal. This is called a synchronous counter. The Carry Propagate automatically picks the right count for carrying or borrowing (a 9 when adding and a 0 when subtracting) and is inhibited by its own Count Disable input. Thus, gating applied to the first stage will automatically gate all succeeding stages.

The Count Zero output can be used to provide blanking of unused zeros in a display. This takes some external logic.

The Readouts

The MEM1056 will only drive a vacuum fluorescent readout. Suitable versions are the *Tung-Sol* DT1704A (0.6″ numeral, no decimal point) and DT1705C (0.6″ numeral, with decimal point) seven-bar types and the *Itron Electronics Corp.* DG19 (0.7″ numeral, with decimal point) and DG12C (0.5″ numeral, with decimal point) nine-bar types. The DT-1704A and the DG12C are shown in Fig. 2, left and right, respectively. All four readouts cost about the same (around $5 in small quantities to $2 or so in large volume). The *Itron* units have a more pleasing rounded character shape, and by adding external logic to the IC, the off-center "1" and awkward "4" may be eliminated. The logic takes two transistors and two diodes and is based on the fact that the top bar is out only on counts one and four.

Readout Operation

The operating principle of these readouts is similar to the old 6E5 and 6U5 tuning eyes and their more recent tuning-indicator offspring. The devices are basically a 27-volt vacuum tube with a filament, an optional grid (*Itron* units only), and 7 or 9 phosphor-covered, bar-shaped plates. The filament is a low-temperature one and is not normally visible. It is powered by 1.6 volts at 45-90 mA. The filament is referenced to −27 volts and thus one end of a floating supply is tied to this voltage.

If a plate segment is grounded, there is a +27-volt difference between plate and filament. Electrons are emitted, strike the plate and the phosphor, and that segment lights. If a plate is connected to −27 volts, there is no potential between plate and filament, and that segment remains out. By choosing the right combination of grounded and −27-volt plates, any numeral may be obtained. If the readout has a grid, it is normally connected to −7 volts, or around +20 volts with respect to the filament. In other applications, the grid provides an alternate way to blank the display.

The DT1704A is used in the add-subtract counting assembly. It has a 9-pin miniature base, (*Continued on page 65*)

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(*Continued from page* 48)

while the DT1075C uses an identical 10-pin base with the extra pin falling in the normal locating "hole." The *Itron* units have flying leads. Decimal points are simply an extra anode in the shape of a dot rather than a bar-shaped plate.

Prototype Circuit

The four-decade counter assembly is shown in the lead photo and diagrammed in Fig. 3. Grounded-base RTL translators are included on all "active" inputs. The translators convert 0- to +2-volt logic signals from conventional DTL or RTL integrated circuits into the 0 to −27 volts needed for the MEM1056. Four of these IC's are combined with four of the nine-pin, no-decimal-point readouts, using four PC-type tube sockets. A single-sided PC board is used with all parts mounted on the foil side. Insulating tape is placed under the IC's as needed. Four jumpers are used.

Supply power consists of −13 and −27-volt supplies with a floating 1.6 volt (a.c. or either polarity d.c.) tied to one side of the −27-volt line. This voltage is somewhat critical and should range between 1.45 and 1.65 volts. *Be extremely careful when testing.* Even momentarily applying reverse (positive) supply voltages to the IC's will destroy them.

Mechanical contacts and push-buttons must be conditioned to be used with this counter just as they have to in practically all other electronic counters where contact bounce "counts" just as much as keeping the button down for several seconds. A suitable test push-button is shown in Fig. 4. Its output goes to the In (Clock) terminal of the Clock RTL translator (Fig. 3).

More or fewer decades can be used as needed. Remember that in a digital instrument, your answer will be no more accurate than the accuracy of the input data, irrespective of how many decades are in use. So, for best economy, always use the minimum number of decades commensurate with the input accuracy.

Translators are only needed on "active" inputs and may be added or deleted as required. To permanently add, connect the MOS Count Down input (module's Add/Sub input) to ground instead of to its translator; to permanently subtract, connect it to −27 volts. To eliminate display blanking, connect the Blank Input (MOS) to ground rather than to a translator. To eliminate gating, connect the MOS Count Disable input (module's Gate input) permanently to ground.

Features may be added by adding translators. To be able to control the display storage, remove the Storage Entry (MOS) lead (pin 13 of IC) from −27 volts and run it to a new translator. Call the new input Store. Make the RTL Store input positive by 2 volts, and the display will keep the old number even while the counter is working on a new one; grounding this new input will allow the display to follow the counter. Direct input operation (parallel 1-2-4-8 entry) may be picked up in the same way, adding four more translators.

The *Itron* readouts may be connected by their flying leads directly to the PC pattern if desired. If the eighth and ninth bars are to be used to create a centered "1" and a more pleasing "4," external logic will have to be worked out and added.

The DT1705C may be used by drilling out the tenth position on a nine-pin miniature tube socket and adding a new clip; −27 volts extinguishes the decimal point; ground lights it. Internal decimal-point storage and control can also be worked out using the IC.

Some sources for obtaining the components needed to construct the Add-Subtract MOS IC Decimal Counter are listed in Table 1. ▲