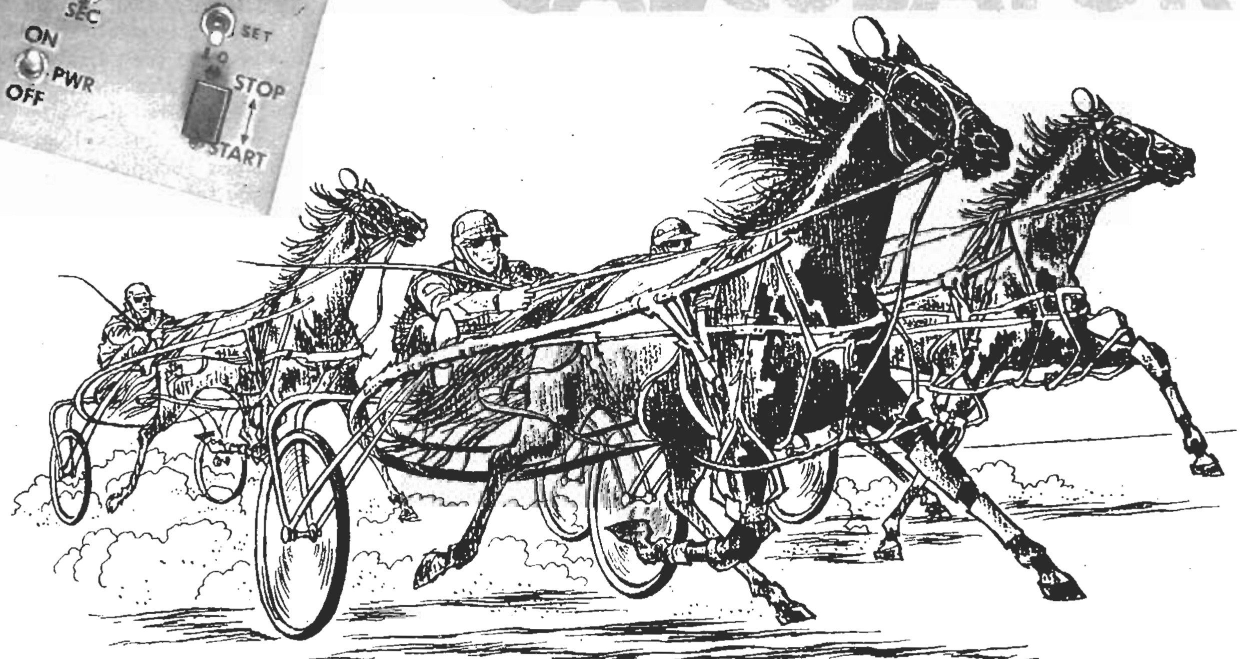
MARK TIME INDICATOR USES YOUR OWN CALCULATOR



Time seconds, minutes, hours, or what have you—or count up or down to 9,999,999—with this inexpensive adaptor for common calculators.

by Robert Way

☐ BUILDING THIS MARK TIME INDICATOR is an easy way to get an event timer using a pocket calculator as the readout device. You can use any low-cost calculator (or a better one) that you happen to own with *Mark Time Indicator* (which we'll call *MTI* from here on). MTI drives the calculator to read minutes, seconds, or half-minutes/seconds, as well as many other intervals you can readily program it to indicate. Your calculator continues to work just as it did before, and is connected to MTI only by a small jack you install in the calculator. When not in use as part of MTI you disconnect the calculator by just pulling out the jack.

In addition to using MTI to clock off seconds or minutes it can be set to a predetermined number of seconds (or minutes) and subtract them one at a time or ½- sec. or ½-min.) until it gets down to zero. Further, it can even work with negative numbers, clocking as many as you want, starting at zero and going toward −9,999,999—one at a time! It can also add in increments of 2, 3, 5, or any other amount you choose, clocking away at any of the four time intervals you desire.

This means your MTI, if set to count minutes, one at a time, could count for 9,444 days, or 190 years—provided the batteries were replaced with an AC-powered supply. Since it's unlikely most readers will want to count such periods of time we've settled for internal batteries as the power source.

MTI's Advantages. A digital interval timer usually costs several dollars per digit to build, and involves assembling a time base, counters, latches, drivers, and the readout (display) device. But it's easy and inexpensive to build MTI if you have a pocket calculator such as the Radio Shack EC-220 which has the auto-constant feature (most calcue/e MARK TIME INDICATOR

lators do). MTI finds many uses in the darkroom, at sporting events, for timing long distance calls, cooking eggs, or even guarding against sunburn at the beach. Some of the advantages and features of MTI are:

- It's portable, and battery-operated.
- It has a capacity that's very large: 9,999,999 seconds, or minutes.
- It counts either up or down.
- The time interval can be interupted and restarted, without going back to zero, plus other operating variations.
- You can choose any of four timing intervals via switches (many more, by internal adjustment).
- Accuracy is close to one percent.
- It's easy to build—only four ICs, six resistors, and two capacitors.

You have to make just one simple modification to the calculator, and that doesn't affect the normal operation of the calculator in any way.

Check Your Calculator. Before making the single modification you need to use your calculator as the readout for MTI, you should double-check that your calculator has the auto-constant feature (most do) which is necessary to let it work as part of your MTI.

To verify the calculator's counting operation, proceed as follows:

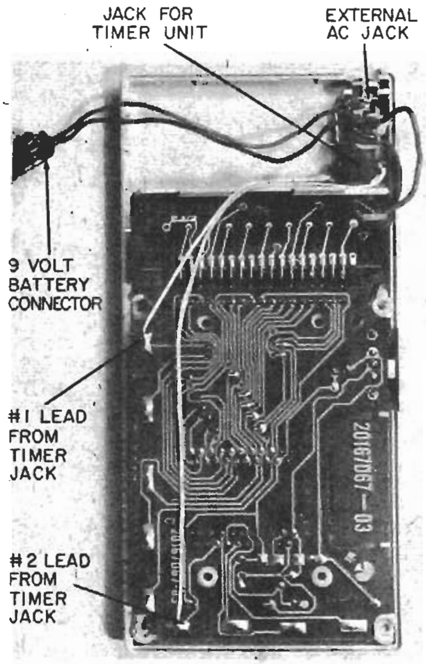
Press the + and 1 keys, and then press the = key several times. After the first time you should get an increase in the number displayed by one each time you press the = key. To read upward starting at zero, enter –, 1, +, 1, = to read 0. Now pressing = will count up by one, but it will start at 0.

To make the calculator count down, enter any number, then press the – and 1 keys. Now each time you press the = key, the calculator display will count down one digit at a time. All of the above steps take less time to perform than to describe, and after playing with your calculator for a few minutes you won't even have to think about the sequence. The timer circuits in the MTI electronically complete the = operation each second, half-second, minute or half-minute.

If the above steps all work out on your calculator you may be assured your calculator will work as the readout for MTI. Go ahead now with the simple modification to your calculator so it can display the time intervals as they are ticked off by MTI.

Calculator Modification. Modification requires merely adding a subminiature phone jack which is connected to two terminals of the circuit board inside the calculator. These are the terminals which connect to the = key on its keyboard.

If you have a Radio Shack EC-220 calculator you can follow these modification steps exactly. If you are adding the jack to some other calculator the steps may be slightly different but the result is the same—to put the terminals of the small phone jack in parallel with



Radio Shack EC-200 calculator, back removed, showing the two leads which are paralleled with = key going to small jack for MTI. Note that IC3 mounts on a smaller board (or DIP mount, with pins bent flat). Main board is Radio Shack's 276-151.

the terminals connecting to the = key of your calculator.

Slide off the battery cover, and remove and disconnect the battery. Unscrew the four Philips screws from the back and remove the back from the main body. Locate the rows of large solder tabs along the left and bottom edges of the circuit board (see photo). There are 5 of these tabs along the left edge, corresponding to the 5 horizontal rows of calculator keys, and 4 tabs along the bottom edge, corresponding to the 4 vertical rows of keys. Solder a 6½-in. length of insulated hookup wire to the left-hand tab along the bottom, and a 4-in. wire to the other top terminal. Be sure to connect these two wires as described, and as shown in the schematic diagram. If they are reversed you won't hurt anything, but MTI won't work. Similarly, if the two wires which go from the MTI to the tiny plug which mates with the jack in your calculator are reversed, it won't work. So be careful with the connections.

Finally, mount the jack to the top cover of the calculator, just beneath the AC power jack (as shown in the top right-hand corner of the photo) by drilling a 5/32-in. hole in the top cover and bolting it on with the nut provided with the jack. This is best done by temporarily dislodging the wires connected to the AC adapter jack, positioning the added jack beneath it to locate the hole to be drilled, and drilling from the circuit board side. Reconnect and replace the battery, and replace the back cover. Solder two 10-in. lengths of insulated wire to the subminiature phone plug, insert it in the jack, and turn on the calculator. Set up the calculator to count, as previously described, and touch the loose ends of the plug wires together; each time the wires make contact, the calculator display will increase by 1. This completes the calculator modification, and the calculator can be set aside until you complete your MTI.

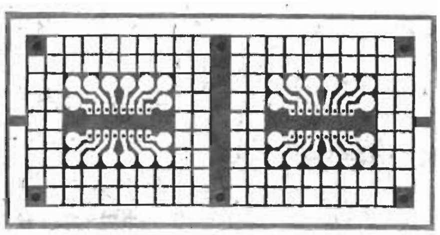
Other Calculators. If you're working with a calculator other than the one shown in our modification, determine which of the two leads from the = key is the more positive (or less negative). Be sure to connect the more positive one to the center connector of the subminiature phone plug.

How MTI Works. The timer circuit starts when capacitor C1 (or C2, depending on the position of switch S2) is discharged, and the output of IC1 (at pin 3) is low. At the beginning of a timing cycle (initiated by pressing S3), the output at pin 3 goes high, and C1 (or C2) starts to charge up toward the battery voltage (6 volts) through R1, R2, and R3 (or R4, R5, and R6). When the charge on C1 equals 2/3 of the battery voltage, pin 7 of IC1 goes to ground and the capacitor discharges through R2 & 3, or R5 & 6. At this instant the voltage at pin 3 goes low. When the charge on C1 has fallen to 1/3 of the battery voltage, the cycle repeats. Hence the timing cycle consists of C1 alternately charging and discharging between 1/3 and 2/3 of the battery voltage. However, at the very first cycle the capacitor is at ground potential and must rise from 0 volts to 2/3 of the battery voltage, while on succeeding cycles C1 only has to charge from 1/3 to 2/3 of the battery voltage.

IC1 Runs Continuously. With switch S2 in the upper position IC1 puts out 120 pulses-per-minute (ppm). These pulses, every half-second, are counted in IC2, a divide-by-ten counter, and also by IC3, a divide-by-12 counter. When 60 pulses are counted, pin 9 of IC3 goes high, and a half-minute pulse is passed through IC4 to the calculator, if S4 is in the lower position a one-minute pulse is fed to IC4 and thence to the calculator.

If switch S2 is in the lower position, R4, R5, and R6 cause IC1 to send out pulses at the rate of 120 pps (pulses-per-second) and half-second pulses occur, after 60 counts, at pin 9 of IC3. One-second pulses appear at pin 9 of IC3 after 120 counts.

Starting and stopping MTI is accomplished by S3, which grounds or ungrounds pins 2 and 3 of IC2 and 6 and 7 of IC3, which are the reset-to-zero terminals of the counters. The counters count when these pins are grounded, and are inhibited from counting (and reset to 0) when these pins are allowed to go high (are ungrounded). Note that S3 is a DPDT switch—since only one set of contacts is needed for the timer circuit, the other contacts are available to switch an external device simultaneously with starting and stopping the time. The author uses this set of contacts to turn his enlarger on and off precisely when the timer is started and stopped.



Experimenter's printed circuit board from Radio Shack is convenient mount for MTI's parts, which go on the blank, (non-foil side of board. When you mount the components trace all connections carefully, referring frequently to schematic diagram.

Since both terminals of J1 (at the calculator) are above ground potential during switching, connecting either of them directly to the output of IC3 would interfere with the counting action. IC4 provides the necessary electrical isolation between the calculator and IC3.

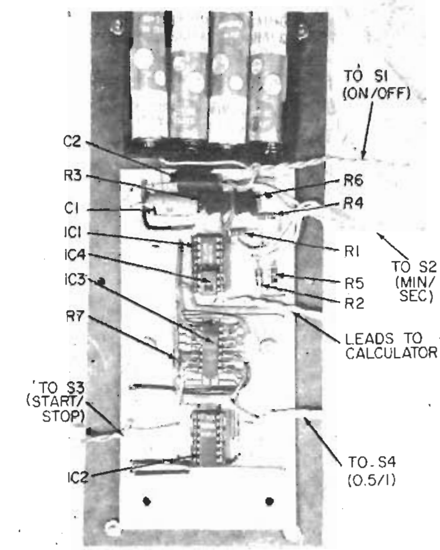
Opto-Isolator. IC4 is an opto-isolating device consisting of two parts. First there is a light-emitting diode (LED) which produces light pulses when it is driven by pulses of current from terminal 8 or 9 of IC3. These light pulses fall on the base of a light-sensitive transistor in IC4, whose output is taken from terminals 4 and 5 of IC4. Actually there is no "output" from 4 and 5 of IC4. It is built so that light rays from the LED in it fall on the base of the transistor, biasing it *On* or *Off*. When the LED is *Off* (or dark), the emitter-to-collector resistance of the transistor is extremely high (effectively an open circuit). When the LED is energized, the emitter-collector junction resistance drops to a moderately low value (around 1000 ohms). This emitter-collector junction acts like a diode, and if voltages of the proper polarity are applied to the emitter and collector, current will flow through the junction. In other words, it will act like a closed switch. Since the transistor in the opto-isolator is NPN, a positive voltage must be applied to the collector and a negative voltage to the emitter. In the case of the Radio Shack EC-220 calculator = key leads, both of the voltages are negative (as measured with respect to the battery + terminals, which is the ground for this calculator). However, one of these voltages is less negative (more positive) than the other, and that one is connected, through the plug, to the collector of the isolator transistor, and the other, more negative, voltage goes to the emitter.

Other Calculators. The MTI output circuit as shown (using Opto-isolator IC4) works well with the Radio Shack calculator and others with = keys having similar voltages. However, some calculators have been found to require a small relay in place of IC4. If this should be the case (checking first to be sure that the Opto-isolator is clocking signals out properly) you can substitute either of two relays for IC4, as shown in the Parts List.

One is a standard mechanical relay sold by Radio Shack. The other is smaller, and costs less, but is not as readily available. It's a low-voltage, low-current relay made in the shape of a little cylinder about 1-in. long by 3/8-in. in diameter, and has stiff wire leads, about 3/4-in. long projecting from either end—these are the SPST contact connections of the relay. At one end of the cylinder, one white and one black stranded wire, about 2 3/4-in. long protrude—these are the relay coil connections. Assemble the relay and diode in place of IC4, using the IC socket for convenience. R7 is eliminated, too.

Construction. The circuit of MTI is built on a Radio Shack experimenter's circuit board, with the parts placed as shown. The etched side of this board, in addition to solder tabs for the IC pins, has several rows of large square solder tabs, and 2 bus strips for power Vcc) and ground. The various components in MTI are connected by being soldered to the same square tab, or via jumper wires soldered between the tabs. These jumpers are visible in the photo. All the ICs are oriented so that pin 1 is at the upper left as viewed in the photo.

The connections between pins 2 and 6, and between 4 and 8 of IC1 were made by burning the insulation off the



The four ICs, two capacitors, and six resistors mount easily on the non-foil side of circuit board. Trace out connecting leads between the parts carefully.

ends of short lengths of varnish-insulated #28 wire, bending them into a "U" shape and inserting the ends of the "U" into the appropriate holes from the top of the board before soldering in the IC socket. IC3 is mounted to a separate mini-board, which has an adhesive backing, permitting it to be stuck to the main board. If the Calectro board shown in the prototype is not available you may substitute the Radio Shack printed circuit board listed.

It's a good idea to use stranded hookup wire to connect the switches and the phone plug to the printed circuit board because it's much less likely to break from the flexing and handling it must take during construction and adjustment. Also note that switch S4 must have a middle position which is Off.

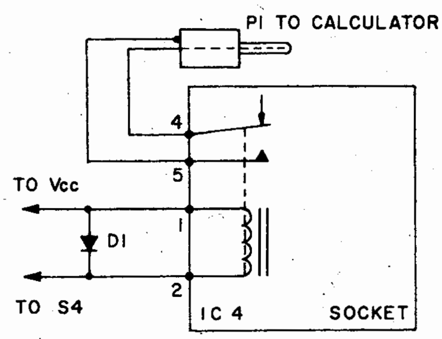
The timer case was made of light sheet aluminum, pop-riveted to short lengths of aluminum angle iron. The bottom of the case was a piece of masonite, and the circuit board, battery case, and a set of rubber feet mounted to it with size 4-40 hardware. However, the case is not essential. You can build the circuit on the printed circuit board listed in the Parts List, or even breadboard it if desired, and place the calculator on the bench beside it for connecting it to MTI.

Calibration. When construction is finished plug in the batteries and plug the subminiature phone plug into the calculator's jack. Press the + and 1 keys of the calculator and the *Start* button on MTI. R3 and R6 must be adjusted so the IC1 produces output pulses at intervals of 0.5 second and 1/120 second, respectively. The divider chain (IC2-

e/e MARK TIME INDICATOR

IC3) will function if it is wired correctly. The best way to adjust R3 and R6 is with a frequency counter, but another method will suffice if no counter is available. To adjust R3 without a frequency counter, place S2 in the upper (min.) position and temporarily connect a jumper wire between pin 3 of IC1 and the center terminal of S4, thus bypassing IC2 and IC3. MTI will now count by half-seconds, and you can use the following method of calibration.

You'll need a clock or watch with a sweep-second hand, and some patience. Set R3 to its midrange and start the timer. With the calculator display and the sweep-second hand both within your field of view, note the calculator readings at the beginning and end of 30 seconds (60 counts). Better to let



Some calculators may require a small relay in place of IC4. Assemble relay and diode right in socket otherwise used for IC4.

the timer run continuously than to try to start and stop it for a 30-second period because your own reaction times will add some definite fractions of a second to the interval you're trying to time. Note whether the timer is running fast or slow, and rotate R3 no more than a quarter of an inch, and time another 30 seconds. It will take several tries to determine which way R3 must be turned to slow down or speed up MTI. When you find the R3 position that makes your timepiece and MTI agree pretty well, try several more adjustments at a one-minute period.

After something like a dozen adjustments my MTI gained less than 1 second in 2 minutes, an error of under 1 part in 120. In a subsequent check with a frequency counter, the period measured 0.994 seconds (frequency of 1.006 Hz). This reading varied ±1 count about every 30 seconds.

When R3 has been adjusted and the jumper wire is removed, half-minute and one-minute pulses are obtained, according to the position of S4. Now you can proceed with the adjustment of R6.

Place S2 in the lower (sec.) position and use the sweep-second hand proced-

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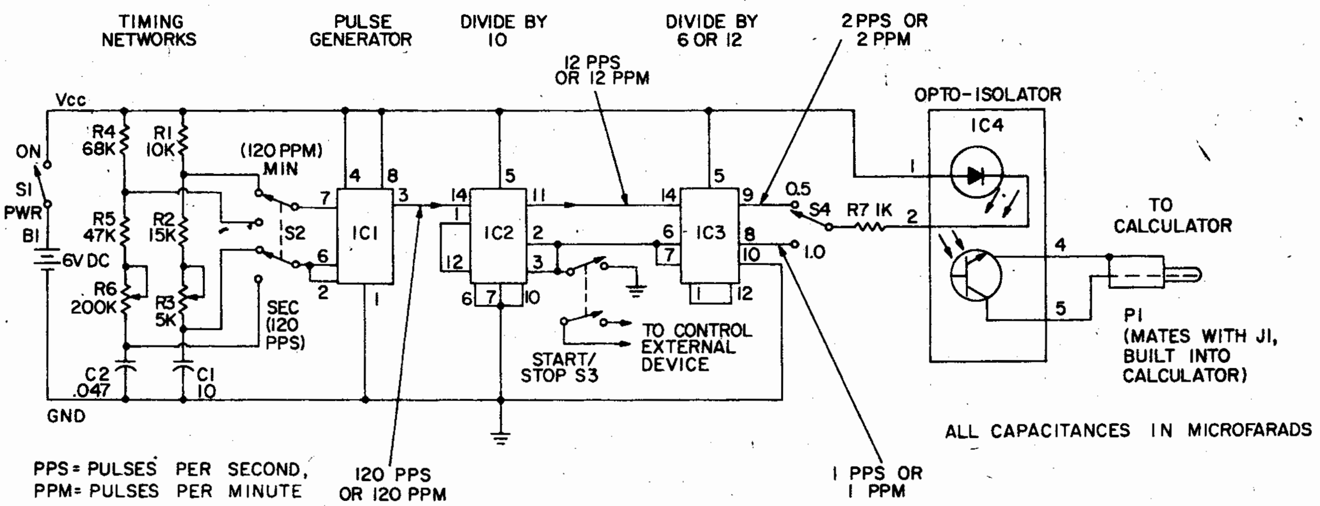

NOTES:
PPS = PULSES PER SECOND,
PPM = PULSES PER MINUTE
ALL CAPACITANCES IN MICROFARADS

PARTS LIST FOR MARK TIME INDICATOR

C1—10-uF, 15-V or more electrolytic capacitor (Radio Shack 272-1002 or equiv.)
C2—0.047-uF, 50-V or more disc capacitor (Radio Shack 272-1052 or equiv.)
IC1—555 Timer chip, TTL (Radio Shack 276-1723 or equiv.)
IC2—7490 divide-by-10 counter chip, TTL (Radio Shack 276-1808 or equiv.)
IC3—7492 divide-by-12 counter chip, TTL (Radio Shack 276-1819 or equiv.)
IC4—Opto-isolator chip, TTL (Radio Shack 276-1723 or equiv.)
D1—General purpose diode for shunting coil or relay. (Radio Shack 276-1620 or equiv.)
R1—10,000-ohm, ½-watt resistor (Radio Shack 271-000 or equiv.)
R2—15,000-ohm, ½-watt resistor (Radio Shack 271-000 or equiv.)
R3—5000-ohm miniature potentiometer (Radio Shack 271-217, Allied Electronics 854-6127, or equiv.)
R4—68,000-ohm, ½-watt resistor (Radio Shack 271-000 or equiv.)
R5—47,000-ohm, ½-watt resistor (Radio Shack 271-000 or equiv.)
R6—500,000-ohm potentiometer (Radio Shack 271-221, Allied Electronics 854-6180, if 200K not available)
R7—1000-ohm, ½-watt resistor (Radio Shack 217-000 or equiv.)
RY1—SPST electromagnetic relay, 6-9 VDC coil, resistance 500 ohms, current 8-12 mA, (Radio Shack 275-004 or equiv.), or miniature reed relay SP-37A, available from Meshna Electronics, Box 62, E. Lynn, MA 01904.
S1—SPST toggle switch (Radio Shack 275-324 or equiv.)
S2—DPDT toggle switch (Radio Shack 275-1546 or equiv.)
S3—Push-on, push-off DPDT switch (Radio Shack 275-1561 or equiv.)
S4—SPST, center-off switch (Radio Shack 275-325 or equiv.)

Misc.—Experimenter's printed circuit board (Radio Shack 276-151 or equiv.), miniature phone plug (Radio Shack 274-289 or equiv.), miniature phone jack (Radio Shack 274-275 or equiv.), 16-pin DIP socket (Radio Shack 276-1998 or equiv.), 14-pin DIP socket (Radio Shack 276-1999 or equiv.), mini-mount IC board (Calectro J4-784 or equiv.), battery holder for four AA cells (Radio Shack 270-391 or equiv.), AA cells (four required—Radio Shack 23-468 or equiv.)

M r Time Indicator

(Continued from page 46)

ure to obtain 0.5-second and one-second pulses.

If an oscilloscope is available, R6 can be adjusted very quickly and accurately. Set up the scope to display one cycle of the 60-Hz line frequency, either by means of the scope's own test jack if it has one, or by connecting it to the secondary of a low-voltage transformer. Carefully note where the beginning and end of this sine wave trace are on the scope face. Then, without readjusting the scope's horizontal gain or sweep controls, connect it to pins no. 1 and 3 of IC1. Vary the scope's positioning controls to center the trace, and the vertical gain and sync controls as appropriate. Now adjust R6 until two square waves of the IC1 output occupy exactly the same distance on the scope face as the sine wave did. R6 is now adjusted. While this method is not as exact as using a frequency counter, it will get you within half a cycle.

Programming Your MTI. To program the calculator to count, proceed as follows:

To Count Up:

1. Place S4 in the *Set* (center, off) position.
2. Press −, 1, +, and 1 (or −, 0.5, +, and 0.5, if desired).
3. Place S4 in the desired position.

Step 3 will cause the calculator readout to go to 0, and MTI is now ready to count as soon as S3 is pressed.

To Count Down:

1. Place S4 in the *Set* position.
2. Press the calculator keys for a number one digit higher than the timing period desired. That is, to time 15 seconds, enter the number 16.
3. Press −, 1, (or −, 0.5).
4. Place S4 to 0.5 or 1.0.

Step 4 will cause the calculator to display the desired number (15 in our example), and the calculator is ready.

Since the calculator display does not automatically clear when the timer is stopped, any timed interval can be interrupted and restarted. This is convenient if you are part way through a timed operation and have to stop (to answer the telephone, maybe) and want to pick up where you left off.

Timing Variations. Several operating variations are possible. Timing ranges can be changed during a timed interval. For instance, if 20 seconds is to be timed, the first 15 seconds could be timed with the timer in the 1-second position, and the last 5 seconds in the 0.5-second position.

Since the calculator will count by negative numbers as well as by positive numbers, it is possible to time two intervals consecutively without having to re-initialize the calculator. For example, if you want to time one event for 10 seconds, and then another event for 20 seconds, you can enter −10, and count up from −10 to 0 for the first event, and from 0 to 20 for the second. Or, you can enter 10, and count down from 10 to 0 for the first event, and from 0 to −20 for the second event.

Still another possibility is counting by numbers other than 0.5 and 1. The calculator will count by 5s, 10s, 100s, or any other number, although the time period between any two counts will always be one of the ranges determined by timer switches S2 and C4 . ■