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Application Note

FIVE DIGIT ACCUMULATOR/ ELAPSED TIME INDICATOR

Prepared by:
Al Mouton
Industrial Logic Applications

This application note describes a five digit elapsed time indicator and accumulator system, implemented with CMOS MSI.
Industrial applications are discussed which illustrate the advantages of the CMOS design — low power dissipation, low parts count, etc.

MOTOROLA Semiconductor Products Inc.

FIVE DIGIT ACCUMULATOR/ELAPSED TIME INDICATOR

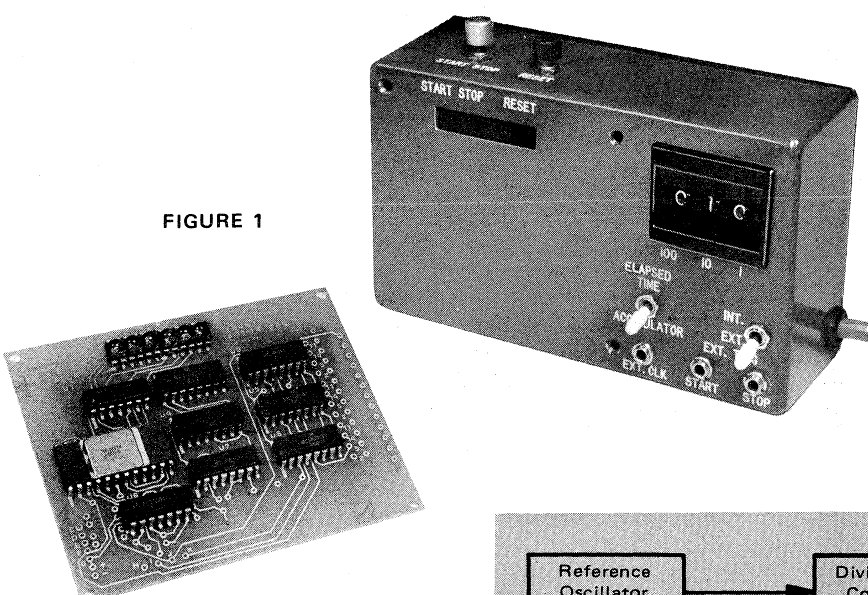
INTRODUCTION

Digital time indicators and digital accumulators are proving to be more valuable because of their accuracy in accumulating data. This article describes briefly a five digit elapsed time indicator and a five digit accumulator with prescaler made possible with Motorola CMOS devices.

The unit in Figure 1 is a combination of the two systems: (1) A five digit elapsed time indicator with a maximum event of 9999.9 seconds, and (2) a five digit accumulator with a maximum counting capability of 99,999 counts x N where N is a prescaler number from 1 to 999. The circuit was designed around the Motorola CMOS real time 5-decade counter (MC14534). This device consists of five ripple-type decade counters whose outputs are time multiplexed using an internal scanner. Until this device was introduced, the same function required a minimum of eight other CMOS devices consisting of counters and multiplexers.

The system block diagram as shown in Figure 2 consists of five basic sections: (1) The Time Base or Oscillator which provides the desired reference frequency for clocking the counters. (2) The Divide-by-N section that provides two functions: a divide-by-1000 in the elapsed time mode for clocking the MC14534 and a prescaling function in the accumulator mode. (3) The MC14534 Real Time Counter section that accumulates the input events and then outputs multiplexed data to the decoder driver. (4) The Display section which decodes the multiplexed information from the counter and routes the information to the correct digit to be displayed. (5) The Control section which consists of circuitry for wave shaping incoming signals to eliminate noisy switch bounce and insure proper clocking. The circuit diagram for the system is shown in Figure 3.

FIGURE 1



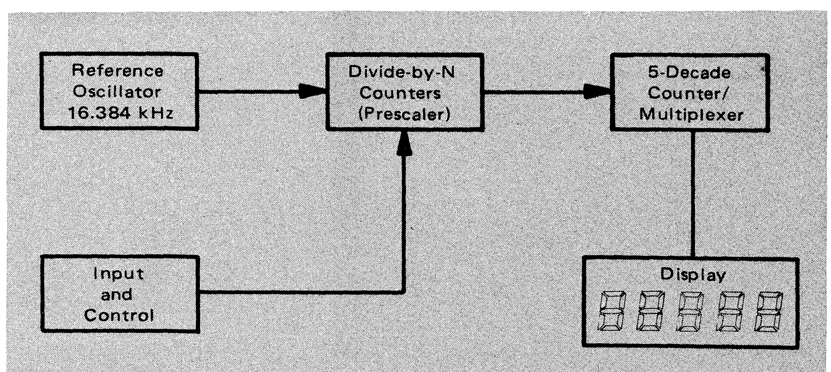
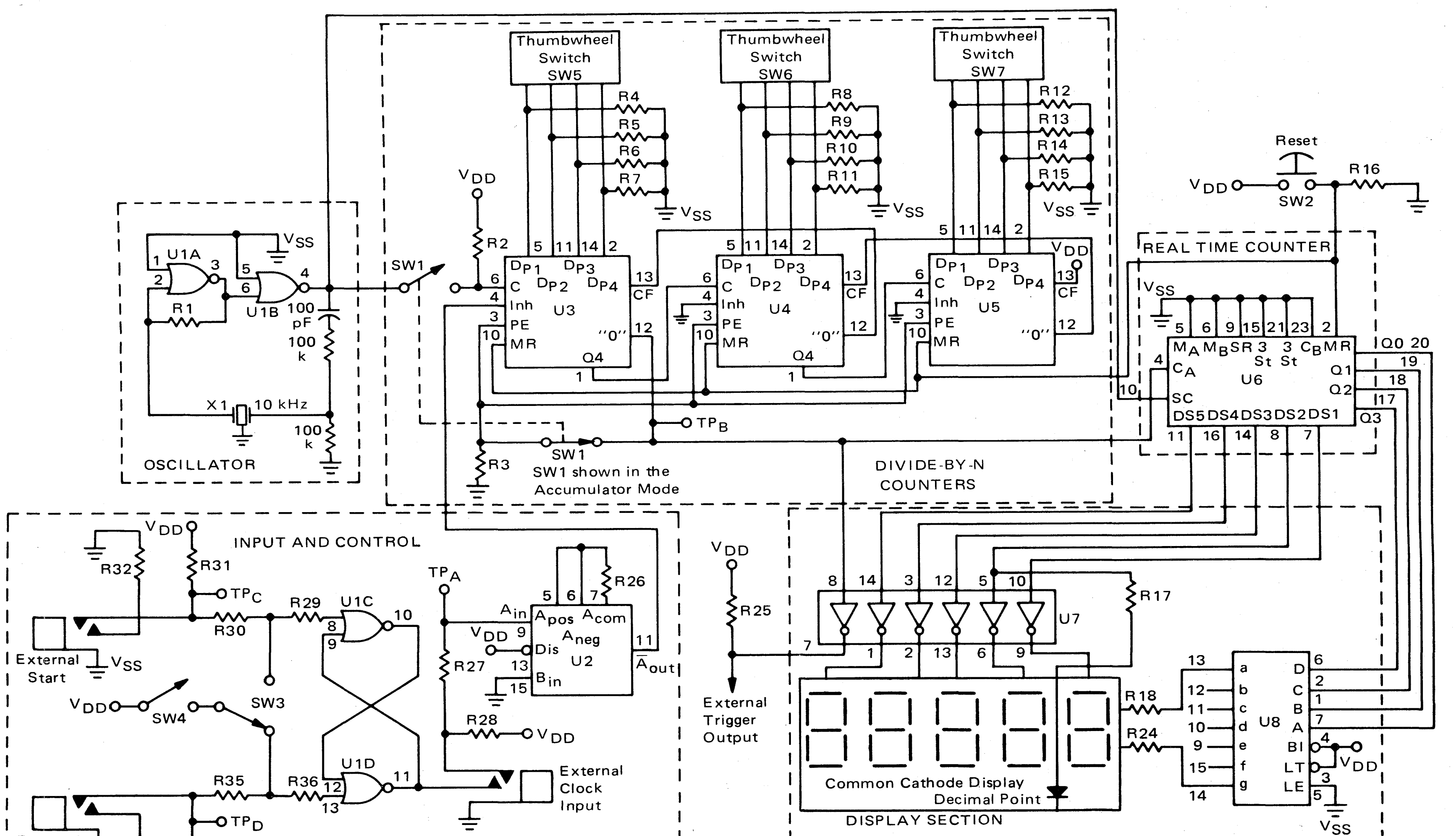
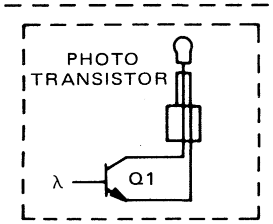


FIGURE 2 – Basic System Block Diagram

Circuit diagrams external to Motorola products are included as a means of illustrating typical semiconductor applications; consequently, complete information sufficient for construction purposes is not necessarily given. The information in this Application Note has been carefully checked and is believed to be entirely reliable. However, no responsibility is assumed for inaccuracies. Furthermore, such information does not convey to the purchaser of the semiconductor devices described any license under the patent rights of Motorola Inc. or others.





Parts List

U1	(1)	MC14001
U2	(1)	MC14583
U3-5	(3)	MC14522
U6	(1)	MC14534
U7	(1)	MC75492
U8	(1)	MC14511
X1	(1)	STATEK Crystal, 10 kHz, SX1H10K

SW1	(1)	DPDT Toggle Switch
SW2	(1)	SPST Pushbutton Switch
SW3	(1)	SPDT Latching Push-button Switch
SW4	(1)	SPST Toggle Switch
SW5-7	(3)	BCD Thumbwheel Switches
Q1	(1)	MRD3055
R1	(1)	5.1 MΩ, ¼W

R2-16,25,26	(17)	10 kΩ, ¼ W
R17	(1)	470 Ω, ¼ W
R18-24	(7)	390 Ω, ¼ W
R27	(1)	1 MΩ, ¼ W
R28,31,33	(3)	10 kΩ, ¼ W
R29,30,35,36	(4)	470 kΩ, ¼ W
R32,34	(2)	560 Ω, ¼ W

1 Display, HP5082-7432
1 Display, HP5082-7433
P.C. Board, DCE Circuits

FIGURE 3 – Circuit Diagram

OPERATION

The Oscillator circuit uses a 10 kHz STATEK crystal with a calibration accuracy of ±0.01% and a low temperature drift of -0.04 ppm/$^{o}C^{2}$. The oscillator is implemented with two NOR Gates (U1A and U1B) to provide the reference time base for operations in the elapsed time mode and also to provide the scanning clock for the data multiplexer of the MC14534 (U6).

The Divide-by-N section consists of three MC14522 BCD divide-by-N down counters (U3 through U5) cascaded in a ripple mode. With switch SW1 in the elapsed time mode, the parallel enable function of the counters is disabled and they do a continuous divide-by-1000. This divides the 10 kHz oscillator signal down to 10 Hz for clocking U6 at a tenth of a second rate. With switch SW1 in the accumulator mode, the thumbwheel switches and parallel load function are enabled and the MC14522s can be programmed to divide or prescale the incoming pulses from an external source by 1 to 999.

The MC14534 Real Time Counter contains five decade counters cascaded together whose outputs are then multiplexed, least significant digit first, through one BCD output. The MC14534 also has five active high digit select lines for indicating which digit data is present on the output. In the elapsed time mode the 10 Hz output from the MC14522 counters is used to clock the input of the MC14534 to a maximum display time of 9999.9 seconds. In the accumulator mode the MC14534 is clocked by external events that were prescaled by the divide-by-N section. Therefore, to determine the actual number of input events that occurred, multiply the number preset on the thumbwheel switches by the number being displayed.

The Display section consists of the BCD to seven-segment latch/decoder/driver (U8), the MC75492 hex LED driver (U7) and the common cathode LED displays (HP5082-7432 and HP5082-7433). The MC14511 is used to decode the BCD word from U6 and then enable the proper anodes of the displays. Because the MC14511 has the ability to source up to 25 mA, interface circuitry is not needed for driving the common cathode LED displays. Due to the low sink capability of the MC14534 digit select outputs, an interface device, the MC75492, is required for sinking the high digit current of the LED displays. The MC75492 has six darlingtons in the package, each having low forward drive current inputs, which can be driven directly with CMOS, and can sink up to 50 mA.

The Control section consists of two parts: the reset function and the gating function. The reset function is generated by one SPST normally open switch, SW2. It is connected to the reset inputs of the MC14534 and the MC14522s. When depressed, the reset line is pulled high, resetting the counters to zero. The gating function is produced by the MC14583 Schmitt trigger, U2, which enables the clocking of the 10 kHz reference by the divide-by-N counters. The Schmitt trigger is used for shaping incoming signals to insure proper gating. With switch SW1 in the elapsed time mode, the external switch or phototransistor Q1, shown in Figure 3, is used for gating the counters via the Schmitt trigger. With SW1 in the accumulator mode, the external pulses are used to clock the counters. Every time the external switch or phototransistor is clocked, the MC14522 is incremented one count. Using the thumbwheel switches, a ratio can be set up between the incoming counts and the actual number displayed, as shown in the timing diagram, Figure 4a. With a 1 dialed in, the ratio is 1:1 as illustrated. That is for every clock pulse the display will advance one count. If a 3 were dialed in, the ratio would be 3:1 and for every three events the display will advance one.

Switch SW3 is used in the circuit as a start/stop switch when operating in the elapsed time indicator mode. This switch is connected to two NOR gates (U1C and U1D) connected as an R-S flip-flop for the elimination of switch bounce. If two separate switches or remote control are desired, one for start and one for stop, the external start and stop inputs are used. The start input sets the flip-flop and the stop input resets it. This is illustrated with the timing diagram in Figure 4b.

The complete system consists of eight ICs and was constructed in a chassis 8 x 4 x 2 inches. The circuit was designed to operate at 5 volts with a total current drain of 65 mA.

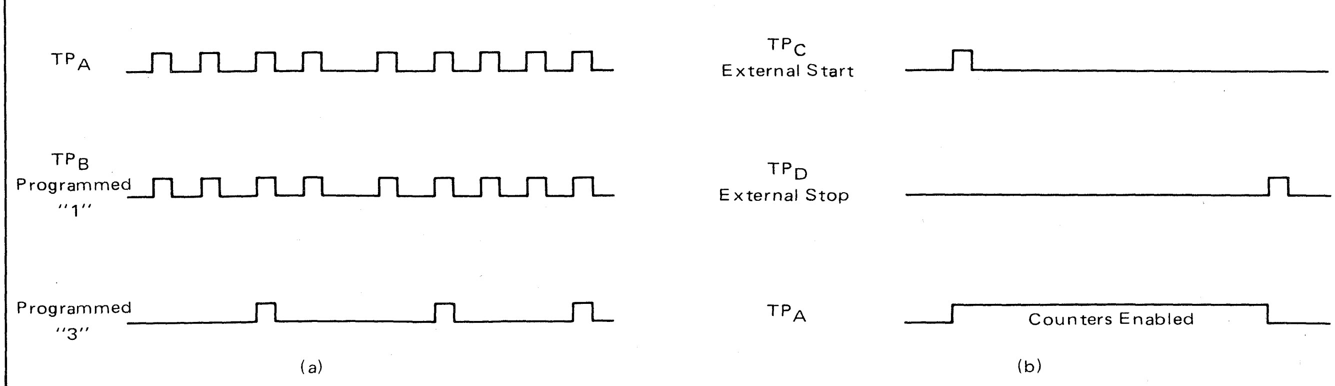


FIGURE 4 — Control Timing

TYPICAL APPLICATIONS

The digital accumulator/elapsed time indicator can be used in numerous applications. In Figure 5, the system is used to control the number of items desired per box and also count the quantity of boxes filled. This is accomplished by using the phototransistor configuration in Figure 3 as a switch and connecting it into the external clock input. The phototransistor is then placed at the end of the conveyor belt so the item will interrupt the light beam causing a count to occur. The external trigger output is then connected to a control mechanism to advance the belt when the desired quantity is reached in each box. Switch SW1 is placed in the accumulator mode and switch SW4 is placed in the external mode. To operate the system, the quantity of items per box is dialed in on the thumbwheel switches. Then by depressing the reset switch the number is loaded into the ÷N counters and the real time counter will go to zero. Now the display will indicate how many boxes have been filled.

In Figure 6 the system is used as a simple accumulator. The system will count every object that passes through the light beam and digitally display the quantity. If the quantity to be counted exceeds 99,999 then the prescaling feature can be used. Simply dial in a multiplying factor from 1 to 999 on the thumbwheel switches, then depress reset to load it in. The resultant quantity will equal the number digitally displayed times the number dialed in. Switch SW1 should be in the accumulator mode and switch SW4 in the external clock mode. The phototransistor circuit should be connected to the external clock input.

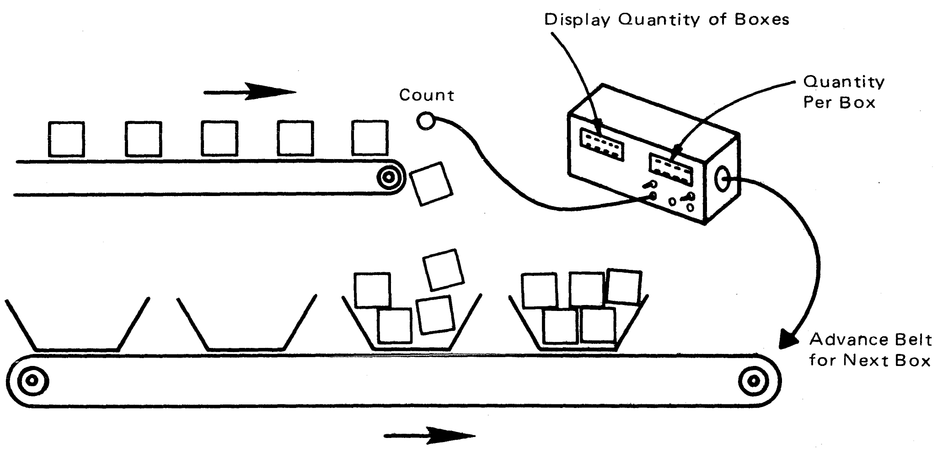


FIGURE 5 – Control and Accumulate

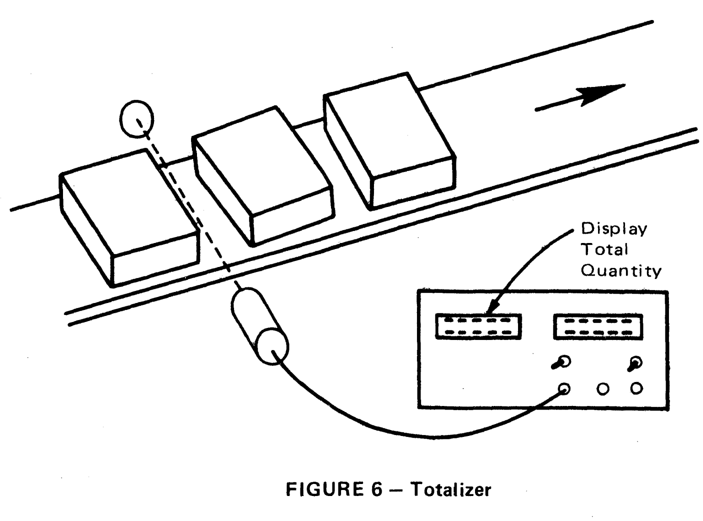


FIGURE 6 – Totalizer

In Figure 7, the system is used to determine the speed of the conveyor belt. This is accomplished with the use of two separate phototransistor circuits – one plugged into the external start, the other into external stop – which are placed some known distance apart. Switch SW1 is set in the elapsed time mode and switch SW4 is left in the external clock mode. The reset switch is then depressed to zero the unit. The speed can now be determined, first by placing on the conveyor belt an object big enough to interrupt the light beams, then turning the belt on. As the object moves through the start light beam, the timer will be initiated. Then as it passes through the stop light beam the time will stop. With the time digitally displayed, the speed can now be calculated:

Speed = Elapsed Time/Distance

In Figure 8, the system is used as a digital ruler. In this application the length of the log can be determined as it moves down the conveyor belt. The phototransistor circuit is again used and is connected to the external clock input. Switch SW1 is placed in the elapsed time mode and switch SW4 in the external mode. The timer will now count as long as the light beam is interrupted, so the length can be determined by knowing the speed of the belt and the time interval the log interrupts the light beam.

Length = (Elapsed time) x (Speed of conveyor belt)

There are numerous ways a system like this can be used to minimize production inaccuracy. Digital equipment is becoming increasingly important as a factor in improving the efficiency of industrial operations to bring about higher profit margin. CMOS helps much of this come true. Today more complex digital systems can be designed in a smaller area, with less power consumed. If you are in a design stage now, become aware of the growing family of CMOS MSI and LSI products.

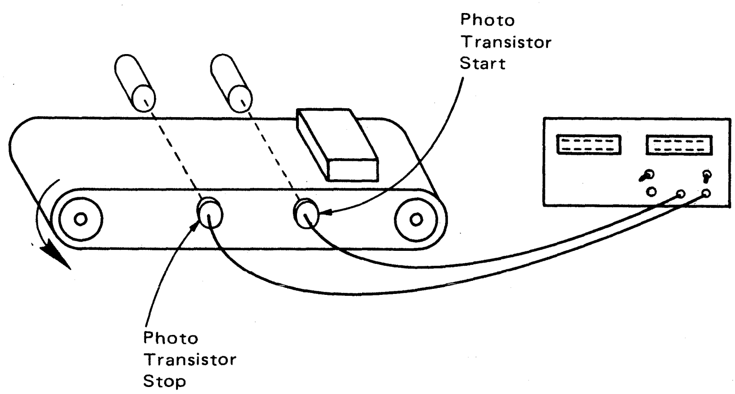


FIGURE 7 — Stop Watch — Measure Speed

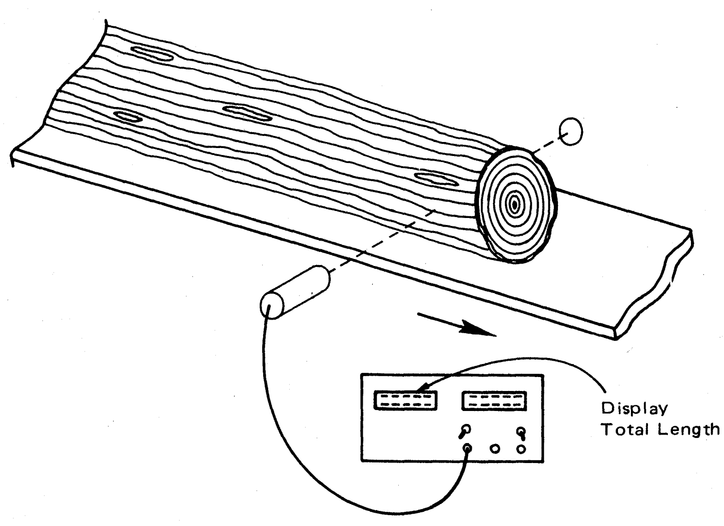


FIGURE 8 — Digital Ruler