Magnify your CALCULATOR'S DISPLAY

Add a simple multiplexing circuit to your handheld calculator's output so you can use ½-inch digital displays

By Lawrence G. Souder

DO YOUR eyes ache after spending much time with your calculator? Does Granny refuse to take advantage of the usefulness of a calculator because she can't see the digits? Did you ever want to use the calculator as a teaching aid in a math class but couldn't because the people in the back row couldn't see what came up on your display? If you answer yes to any of those questions, you will find this project a useful addition to your calculator. It is a simple circuit that provides a large, easy-to-read display. In addition to being practical, this project demonstrates a principle used in almost every electronic product with two or more seven-segment displays—multiplexing.

What is Multiplexing? Multiplexing is a form of time sharing, a technique that allows more than one signal to occupy the same conductor. It is commonly used in digital circuits, particularly seven-segment displays. Digital clocks, for example, require a separate seven-segment code for each digit. A four-digit clock would need a total of 28 (7 segments times 4 digits) separate lines to feed the digits. However, the same display in a multiplexed configuration could use the same segment code bus for all four digits, with each digit taking its turn using the bus to get its data. Separate digit enable lines tell each digit when to take its turn at the bus. When the seven-segment code for the units value of the minutes is on the segment bus, all four digits get the same code, but only the enabled digit will actually display the code on the bus. Likewise, when the code for the tens value of the minutes is on the segment bus, only the enabled tens digit will display that value. The other three digits remain dark. The cycle continues until all four digits appear to be "on" at the same time because the process of scanning is so rapid.

TI-30 CALCULATOR CHIP

Pin	Function
1	Digit 7
2	Digit 8
3	Digit 9
9	V_{dd}(—)
11	Segment DP
12	Segment B
13	Segment G
14	Segment D
15	Segment A
16	Segment F
17	Segment E
18	Segment C
20	V_{ss}(+)
23	Digit 1
24	Digit 2
25	Digit 3
26	Digit 4
27	Digit 5
28	Digit 6

Handheld calculators use this technique to feed their displays. In the case of the standard nine-digit calculator, multiplexing makes it possible to feed all nine digits with just 17 conductors (eight segment lines and nine digit enable lines). Without multiplexing, a nine-digit display would require 72 signal lines.

Multiplexing also economizes on current demands since only one digit is on (powered) at any one time. This feature is particularly advantageous for battery-powered devices.

About the Circuit. The outboard display circuit shown in Fig. 1 is essentially a copy of the multiplexed display used in most calculators. The important difference is that it uses 0.5-inch digits instead of the usual 0.15-inch digits. All like segments (A through G) of the nine displays are wired in parallel, and each segment line has its own transistor driver (*Q1* through *Q8*). Each display common-cathode lead also has its own transistor driver (*Q9* through *Q16*), the base of which is fed by a digit enable line. The base of every transistor has a series current-limiting resistor to isolate the low impedance of a forward-biased base-emitter junction from the signal line of the calculator chip. Nineteen leads in all run between the outboard display and the calcu-

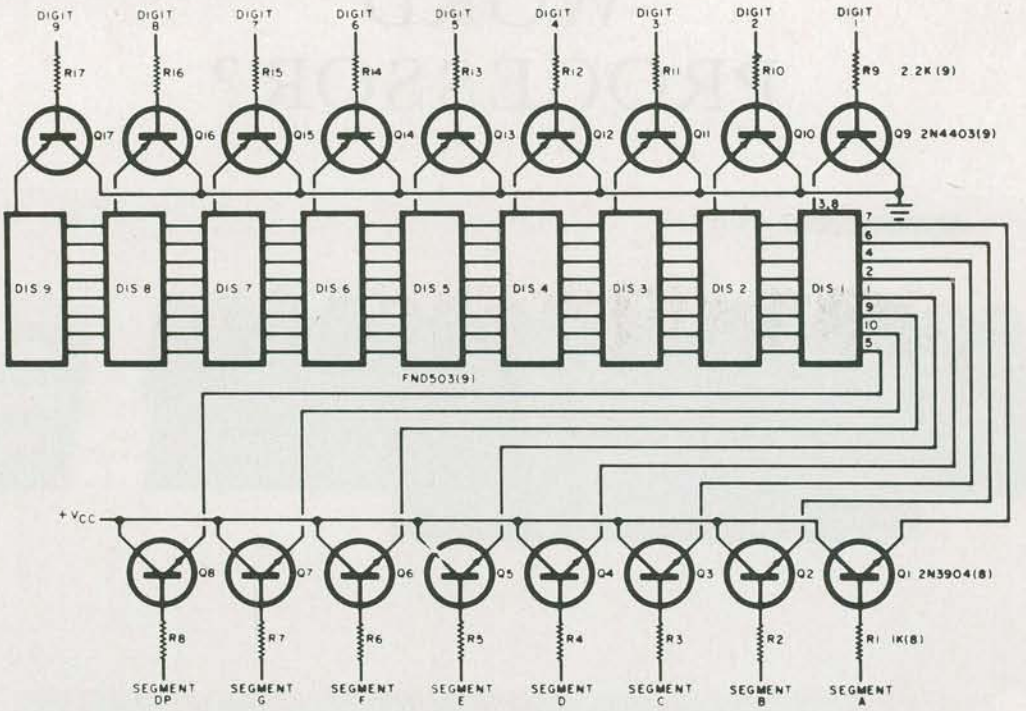

Fig. 1. Nineteen leads connect the outboard display circuit to the calculator itself.

PARTS LIST

D1 through D9—FND 503 0.5 inch, 7-segment display, common-cathode
Q1 through Q8—2N3904 transistor
Q9 through Q17—2N4403
R1 through R8—1-kΩ, ¼-W resistor
R9 through R17—2.2-kΩ, ¼-W resistor

lator: eight for the segment bus (A through G and decimal point), nine for the digit enable lines, one for V_{cc}, and one for ground.

Construction. There is nothing critical about construction. Perforated board is probably the easiest and cheapest way to go, although it does require considerable point-to-point soldering. Multi-conductor ribbon cable will make the interconnection between the display and the calculator easier and neater. Try to use cable having individually colored conductors so that some kind of color-coding scheme can be used (e.g. digit enable one = brown, digit enable two = red, and so forth).

This outboard display was designed for the Texas Instruments TI-30 calculator. The table shows which pins of the calculator chip provide the segment-and digit-enable signals. Since the calculator pc board is crowded, soldering the nineteen wires from the display must be done very carefully using fine solder and a needle-tipped soldering iron. The only additional modification required is to disconnect the digit enable lines of the TI-30's existing display. This is easily done by cutting (with a razor blade) the foil traces from each digit-enable pin of the calculator chip. Cutting them in this way will allow restoring the original display later, simply by bridging the cuts with small blobs of solder.

Adapting Other Calculators. Although the hook-up shown is for a TI-30, this display circuit is easily adapted to other calculators that use a common-cathode display. All you need to do is find out whether your calculator's display is common-cathode or common-anode (common-anode displays are not compatible with the circuit) and what pins of the calculator chip provide the various segment and digit drives. To locate these pins, remove power from the calculator and experimentally apply a low dc voltage (about 5 V) in series with a current-limiting resistor (5000 ohms or so) to various pc traces near the display until at least one segment on the display lights up. When you get two different segments to light, you will know which element is common. Follow those traces back to the chip and record the pin numbers. Eventually, you should be able to track down all digit and segment drive pins.

Operation. Once the outboard display is properly connected, use the calculator as normal. No outside power source is needed since the outboard display "steals" its power from the calculator; the power switch on the calculator will control power to the display as well. The only difference from normal operation is that, since the larger digits draw about three times more current than the original display, it may be best to use the calculator's ac adapter. ◊