SOLID-STATE DEVELOPMENTS

By Forrest M. Mims

Reflections on the Pocket Calculator

WHILE visiting a department store recently, I noticed a special sale on Unisonic® 940 pocket calculators. This calculator, about the size of a bar of soap, has a highly visible, 8-digit, electrofluorescent display. It also has a fully addressable memory and both square root and percent keys.

The sale price for this calculator was an incredible $2.97! I bought some for my family and a few extras to be modified into counters and timers.

It's hard to believe how a calculator can be profitably manufactured and retailed for less than three dollars. Perhaps the models I bought were obsolete because of more attractive liquid crystal versions that use much less power. In any event, the $3 calculator is light years away from the first pocket calculators, which cost several hundred dollars about a decade ago.

I remember those early calculators very well. Their high prices kept them beyond the reach of most experimenters and hobbyists until November 1971 when Popular Electronics featured on its cover an 8-digit, 4-function calculator which was available in kit form from MITS, Inc. for the price of "only" $179. A digital calculator for under $200 was a real breakthrough.

Introduced before the availability of microprocessor-like calculator chips, the Model 816 used six LSI chips. MITS eventually introduced a line of single-chip calculators, several of which were featured as construction articles in Popular Electronics. Back then, LEDs were the most popular display medium, and the management at MITS eagerly awaited the day readouts would cost them "only" a dollar per digit in very large production quantities. Today one can buy surplus LED calculator displays for as little as a nickel per digit!

The calculator industry made a giant step forward with the introduction by Hewlett-Packard in 1972 of the first *scientific* calculator, the famous HP-35. For $395, the HP-35 provided keys for trigonometric, exponential, and logarithmic functions, as well as square root, pi, reciprocal, and memory. In short, the HP-35 provided an electronic replacement for the venerable slide rule. Not only was the HP-35 much faster than the slide rule, it was more accurate.

In the decade since the introduction of the HP-35, dozens of scientific calculators have become available for ever decreasing prices. Sharp's EL-5813, for example, is a slim, liquid-crystal display model with more functions than the HP-35, plus 30 steps of programming. Priced at about $35, its inflation corrected cost is only about 5 percent of the original price for the HP-35!

Only a few American manufacturers of scientific calculators have survived the increasing competition of Japanese calculator firms. One is Texas Instruments. Its most advanced scientific calculator is the TI Programmable 59, a programmable model that sports a built-in magnetic card reader and a receptacle that accepts any of a wide range of ROM modules that have been factory loaded with preprogrammed software.

A decade after the HP-35, Hewlett-Packard still makes the most advanced scientific calculator, the HP-41C. The HP-41CV is an identical model with five times the memory.

The HP-41 has an alphanumeric, liquid-crystal display and four receptacles for various kinds of plug-in modules. External peripherals such as a printer, bar-code reader, a mass storage unit, and a versatile interface link can be connected to the HP-41 by means of the receptacles. There's even a miniaturized magnetic card reader that attaches to the top end of the calculator. The HP-41C can accept up to 400 program lines before an external memory cartridge is needed. The HP-41CV can accept 2000 program lines.

All these advanced features notwithstanding, perhaps the most unique aspect of the HP-41 is its remarkable user-definable, alphanumeric keyboard. Briefly, nearly any of its 35 keys and their secondary functions can be reassigned the function of any other key when the calculator is switched to a special USER mode. You can even assign programs you have written to various keys for single-key execution.

Plastic keyboard overlays and self-adhesive labels allow HP-41 owners to custom design their own calculators! Thanks to the alphanumeric display, the calculator can provide visual prompts for information after a key is pressed, thereby negating the need for a special list of program operating instructions.

When my HP-41 is placed in USER mode, it becomes a highly specialized machine that can quickly solve problems in lightwave communications and optical radar. It can also tell me the series resistance required to bias a light-emitting diode at a given current level for a particular forward voltage. Here's the program listing:

```
01 LBL "LEDR"
02 "FORWARD V?"
03 PROMPT
04 ENTER
05 "LED V?"
06 PROMPT
07 -
08 "LED I?"
09 PROMPT
10 /
11 "LED R="
12 ACRL X
13 AVIEW
14 BEEP
15 PSE
16 PSE
17 GTO "LEDR"
18 END
```

This program is assigned to the RTN key on my HP-41. Here's a typical exchange after the new LEDR key (RTN in USER mode) has been pressed:

HP-41: FORWARD V?
USER: 5 (press R/S)
HP-41: LED V? (LED voltage drop)
USER: 1.7 (press R/S)
HP-41: LED I? (desired LED forward current in amperes)
USER: 0.020 (press R/S)
HP-41: (BEEP) LED R = 165.00 (ohms)

After a second or so, the answer is replaced by the FORWARD V? prompt. The program can be adapted for use with a printer by replacing the PSE (pause) statements with a single PRX (print X register) instruction. Many other variations are also possible since editing HP-41 programs is exceptionally easy. The calculator can even be programmed to turn itself off after it has processed a program. The results can be printed, or stored in the machine's continuous memory for later readout.

Is the HP-41 an advanced programmable calculator or a handheld computer? Though the HP-41 doesn't understand BASIC or other higher level languages, it does have many features characteristic of computers. I like to think of it as a hand-held computer with an advanced calculator-style language.

Of course, for those who prefer BASIC, true handheld computers are now available. If it took only a decade for the first scientific calculator to evolve into the handheld computer, think what the next decade might bring. It doesn't take much imagination to envision pocket computers with large-area liquid-crystal displays that show several program lines or graphics. Of course, large amounts of self-contained memory will be a standard feature.

The New Solid-State Relays. SCR and triac circuits billed as solid-state relays have never managed to match the very low contact resistance of conventional electromagnetic relays. However, a new kind of solid-state relay is going to rectify this situation.

The new relays use power FETs in their output stages having an on resistance as low as 0.3 Ω. This ultra-low resistance is made possible by the incorporation of many thousands of identical, parallel-connected FETs onto the surface of a single silicon chip.

A development of Teledyne Relays (12525 Daphne Ave., Hawthorne, CA 90250), the new relays are far more than simple FET switches. They also include a CMOS compatible input Schmitt trigger that increases noise immunity. An optoisolator protects the input from output transients of up to 1,000 V. The relays also incorporate circuitry to eliminate or greatly reduce the noise spikes that are characteristic of conventional SCR and triac relays. This is accomplished by controlling the switching time of the output FET.

The circuits which provide these features are hybridized on a tiny pair of stacked boards and housed in a hermetically sealed, square can that measures only 0.37 x 0.37 x 0.23 inch. An alternate, DIP compatible package option measures 0.5 x 0.9 x 0.2 inch.

Don't expect to rush out and buy one of these new solid-state relays just yet. The cost of one model, the 690-1, is $41 each in lots of 100.

The good news, of course, is that the availabity of low on-resistance, power FETS means budget-minded experimenters, technicians and engineers can design and make their own FET solid-state relays.

High Speed Logic. Emitter-coupled logic (ECL) is considerably faster than standard transistor-transistor logic (TTL). Motorola (Box 20912, Phoenix, AZ 85036) has recently added an even faster line of ICs to its MECL family.

Designated the MECL 10KH series, the new chips provide a 100% improvement in propagation delay over the standard MECL family, with no increase in power consumption

The gate propagation delay for the MECL 10KH series is only one nanosecond. The improvement in rise and fall times over the standard MECL 10K line is shown clearly in scope photographs reproduced on the data sheets for the new chips. For example, here are the rise and fall times for the NOR outputs of the 10K and 10KH versions of Motorola's MECL triple line receiver:

	MC10K116	MC10KH116
Rise Time	1.86	1.12
Fall Time	1.74	1.08

(Times shown are in nanoseconds.)

Other chips in this new family include the MC10KH104 quad two-input AND gate, the MC10KH107 triple two-input Exclusive OR/NOR gate, the MC10KH109 dual four-five input OR/NOR gate and the MC10KH131 dual D Master-Slave flip-flop.

Because of their ultra-fast switching times, ECL chips require special attention to lead dress. For some basic operating tips about how to use ECL chips, see "Experimenter's Corner" in the October, 1981 issue of this magazine. ◊