Focus on keyboards: The real challenge is 'interfacing' the computer user to the right one

As computer users grow in diversity, interface keyboards are growing in capability, economy and performance to accommodate all of them. Today's keyboards are longer lasting, less expensive and more versatile than keyboards just one year ago. Total specified lifetimes encompass as many as 300-million generated ASCII characters. New keyswitches have alterable and computer-controlled legends. Technologies bordering on the exotic are emerging to go so far as to merge keyboards and CRTs into a single unit. And, if nothing else, a hexadecimal keypad is down to 40 cents.

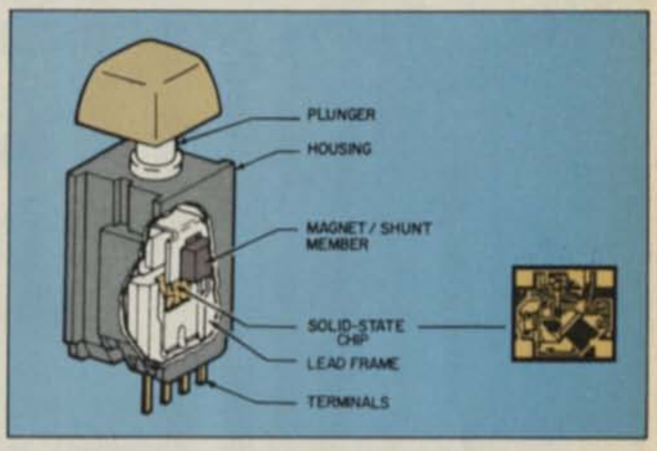
At the same time, this user diversity—coupled with the absence of standards for virtually every keyboard parameter—is also the cause for another situation, one not likely to change: Most OEM keyboards (alphanumeric) and keypads (numeric only) are custom designs, produced on a sole-source basis. And there are several other general facts to be aware of when seeking a keyboard.

Whether it is a full ASCII-encoded, long-life, Hall-effect keyboard or a plastic-membrane panel with graphic legends, the design strategy is the same: Select a keyboard technology whose longevity matches that of the host system, then bring in the keyboard manufacturer to design for utility and lowest cost.

Anticipating a system's volume growth for the first three years is also important. Volume influences selection and design, because the more a keyboard manufacturer can integrate any particular keyboard design with the others he's making, the lower the cost for a given keyboard's lifetime. Some designers, to get a more favorable cost, design-in a less expensive keyboard with excess keys, then mask off the ones they don't need.

In addition, industry studies show little correlation between experienced operators' performance on full-ASCII-encoded keyboards and the type of key feedback they get—tactile, audible or visual. Often a keyboard will combine two of them. Moreover, full-ASCII-encoded keyboards for communications systems may even interface directly to UARTs; they provide protocol-control codes and related keycap legends.

Dick Hackmeister
Field Bureau Editor



1. **Hall-effect keyboard switches** from Honeywell/Microswitch use magnets and custom chips to register key selections. Since no ohmic contacts are used, these keyboards are noted for long life.

To offset fumble-fingered operators, who hit multiple keys and sometimes type with overlapping keystrokes, it is important to be able to sort out their keystrokes electronically. There are three ways to do it, the least expensive being *no-key rollover*. This technique ORs all depressed keys and leaves it to firmware to sort everything out.

With *two-key rollover* (sometimes called *lockout*), depressing a second key kills the keyboard's output strobe, although the second character may be lost if it is released before the first.

The most sophisticated, most expensive and foolproof scheme, *N-key rollover*, captures each keystroke in a FIFO memory, and ignores key releases.

The top of the ladder

The keyboards themselves have a technological pecking order, with Hall-effect keyboards at the top. Their longevity suits them to large, heavy-use data-processing applications, where one faulty keyswitch could cause a $100 service call—or something worse. Since individual Hall-effect keyswitches are sealable, the keyboards are suitable to marine, aerospace and industrial applications, too.

Keyboards featuring a Hall-effect device, magnet and plunger in each keyswitch position (Fig. 1) are available from Honeywell's Microswitch Division,

2. **Microprocessor-based keyboards** with mask-programmable ROM-code generators are available from Cherry for office and communications systems. Keys can be replaced from the top without disassembling any hardware.

which recently introduced a three-terminal Hall-effect module that helps reduce power consumption by a reported 60%. The module's "scan" input shares a pin with the negative power supply, so deselected modules draw no current. An on-board μP activates only eight keys at a time. The modules themselves come individually or in completely built, intelligent keyboards.

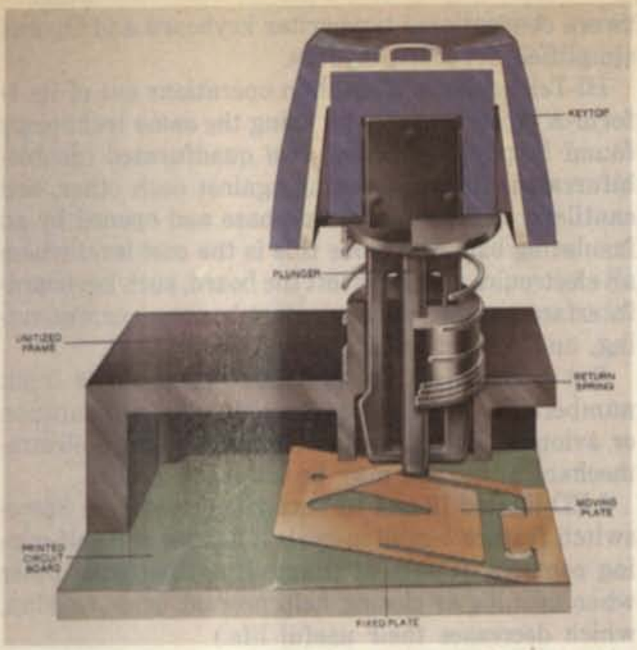
Honeywell's custom μP chip integrates an 8-bit CPU with ROM, RAM and I/O control. Over-all keyboard features include N-key rollover with eight-character FIFO storage, parallel or serial data outputs, timeout repeat for selected keys, audio feedback drive, both programmable strobe-width and data-valid times, and PROM-generated output codes for each key position; any key can generate any 8-bit code. Changing the PROM can make any character assume any keyboard position, thereby allowing a choice between a conventional typewriter keyboard layout or a Dvorak simplified keyboard layout (see "An Incredible Legacy").

For longevity, however, keyboards based on reed switches are right on the heels of the Hall-effects. Hermetically sealed, glass-encapsulated reeds are made to make or break ohmic contact by the influence of an external magnetic field; the magnet is operated by a keycap/plunger assembly.

The mechanics of reed switches usually cause their keyboards to be taller than other types—but not always: The S880 family of low-profile reed switches just introduced by C.P. Clare Co. yield keyboards no larger than any others.

Another long-lifer, the capacitive-based keyboard, generally operates on the principle of an operator-controlled capacitance that, in effect, blocks or passes a low-level signal. Key activation increases the selected key's capacitance, which in turn passes the signal on to detectors, address generators and data latches. Often, capacitance is formed by a small, insulating sponge with ohmic surfaces on both sides—pressing the sponge increases its capacitance.

The longest quoted life for a capacitive keyboard is 300-million operations, claimed by Cherry Electrical



3. **Capacitive keyboards** use operator-controlled capacitance to block or pass a low-level signal. Many styles use a spongy dielectric material, but Digitran's features hinged capacitor plates.

Products for its CB-80 Series (Fig. 2). One version is configured for communications applications, the other for general office work. Both revolve around a custom LSI processor.

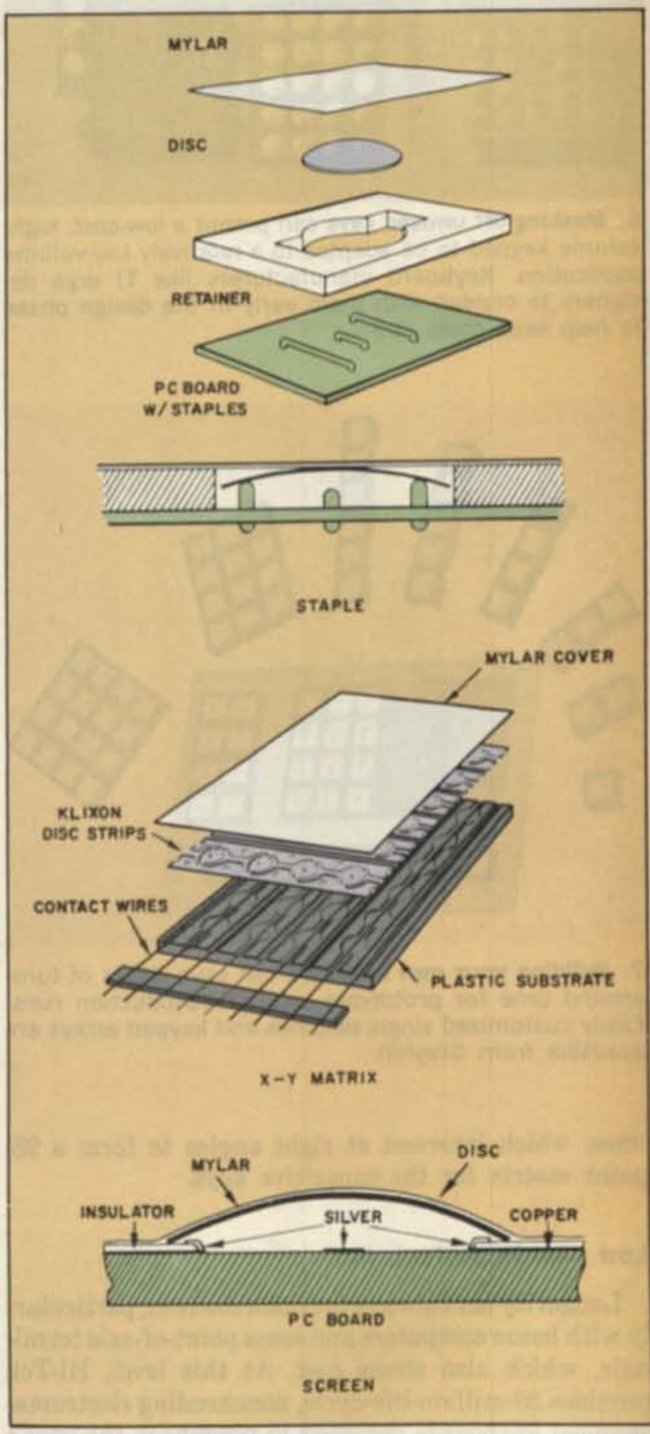
An on-chip, mask-programmable ROM generates each output code. As the keys are scanned, the memory is scanned in synchronism, and any key's operation causes the data at the corresponding ROM address to be latched onto the system data bus. The ROM can be programmed for any key location or code.

For communications systems, the CB-80 provides odd, even or disabled parity, one or two stop bits and a direct UART interface. Both N-key rollover and two-key lockout are pin-selectable, and if a key should ever fail, it can be replaced from the top of the keyboard without disassembling any hardware—an important field-service consideration.

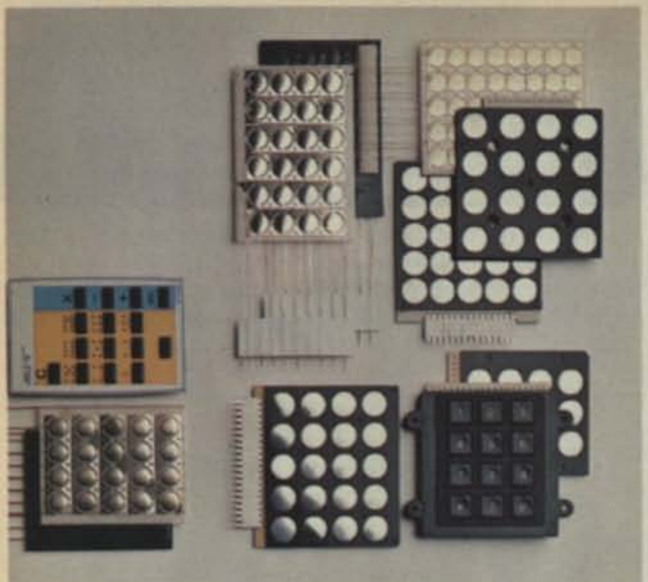
There are alternatives to the spongy capacitor, one of which is a hinged plate, which Digitran now puts on its PC cards to couple the operator's key selection to the sensing circuitry (Fig. 3). The frame of Digitran's Golden Touch keyboard is a single-molded part with guides connecting the keycaps to the hinged plates. As with virtually all other keyboards, Digitran's is completely custom-designed. The firm quotes longevity at 250-million operations.

Instead of hardware, Keytronics recommends that designers emphasize electronics to fight inflation. To this end, the company has introduced a customizable, capacitive keyboard (Fig. 4) with a pair of drive/sense I^2L chips and the capacity for up to 98 keys. It's designed to pace the eroding cost of microprocessors, particularly the 8048. A 20-pin driver and a 20-pin detector provide 12 driver lines and eight receiver

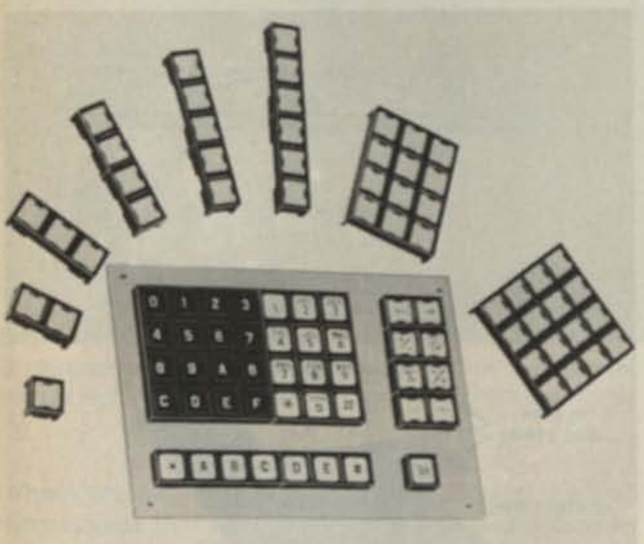
4. **Two custom chips** are all the electronics this Keytronics capacitive keyboard needs; 12 driver lines and eight receiver lines provide 98 possible matrix points for keys. The chips are built with integrated injection logic.



5. **Making keypads with a continuous process** can push the cost down to as low as 2.5 cents per key. Three styles of keyswitches are offered by Texas Instruments, all intended for application in custom designs.



6. **Masking-off unused keys** can permit a low-cost, high-volume keypad to be adapted to a relatively low-volume application. Keyboard manufacturers like TI urge designers to consult with them early in the design phase to help keep costs down.



7. **Building your own keyboard** can save weeks of turnaround time for prototypes and pilot-production runs. Easily customized single switches and keypad arrays are available from Grayhill.

lines, which intersect at right angles to form a 98-point matrix for the capacitive keys.

Low cost important, too

Longevity isn't always the main concern, particularly with home computers and some point-of-sale terminals, which also stress cost. At this level, Hi-Tek provides 20-million-life-cycle, nonencoding electromechanical keyboards designed to piggyback the user's PC card. Keycaps, plungers and switches are all replaceable from the top to hold down field-service complications and provide position scrambling between conventional typewriter keyboard and Dvorak simplified keyboard layouts.

Hi-Tek squeezes 20-million operations out of its 1-form-A (spst) contacts by using the same technology found in pay telephones: two quadfurated (double-bifurcated) fingers pressing against each other, and cantilevered from a common base and opened by an insulating bar. And since this is the cost level where all electronics may have left the board, such keyboard-interface parameters as contact bounce, current rating, and contact resistance, are significant.

But perhaps all the operator has to do is input numbers, as in retail transactions, instrumentation or avionics. Then, a hexadecimal (16-button) electromechanical keypad may be all that's needed.

LED-lighted 12 and 16-button keypads from Stacoswitch feature 5-million-cycle lifetimes and self-wiping contacts. (Contacts that rub against each other when opening or closing help prevent oxide buildup, which decreases their useful life.)

One of the largest suppliers of electromechanical keypads is Texas Instruments. Depending on production volume, required lifetime and end-user application, TI will use any of three different approaches to produce custom-designed keypads (Figs. 5 and 6).

At 10 cents per key position, the company's *staple* technique produces keypads that are best used in control panels for business equipment and computer peripherals. Gold-plated staple contacts resist corrosion, are self-lubricating and have a specified lifetime of 1-million operations. This design results in single-sided boards that leave the other side free for mounting LED indicators or active components.

At 8 cents per key position, TI's middle-of-the-line keypads are produced by a three-pass *silk screen* technique. These keypads are most often used in battery-operated applications such as remote TV controls, where two-pole switches both register the operator's selection and apply intermittent power to the host circuitry. This design, rated at 1-million operations, supports circuitry on both sides of the PC board and allows center-to-center key spacing as close as 0.4 in.

At 2-1/2 cents per key position, TI's least costly keypad technique, called *X-Y matrix*, is aimed at consumer games, hand-held calculators and inventory-taking machines. This technique is the product of a virtually-continuous process; switches made in continuous strips bridge wires imbedded in plastic substrates. A Mylar sheet keeps the dirt out.

Also producing electromechanical keyboards is Grayhill, whose System 87 do-it-yourself keyboard switch modules (Fig. 7) are designed to provide flexibility and save customary turnaround time on prototypes and pilot-production runs. Configurable switches are offered in 16 and 12-position arrays, and single switches in stacks of up to six. All feature 1/2-in. center-to-center spacing and selectable legends for prototyping. Grayhill will hot-stamp the legends for short runs, and, for high enough volume, will even

An incredible legacy

Today's standard keyboard layout—the primary interface between people and computers—is the century-old legacy of one Christopher Latham Sholes, who, by virtue of his U.S. Patent No. 207,559 (issued August 27, 1878) is credited with inventing the typewriter. The problem is, Sholes's keyboard layout is so ill-suited to contemporary uses that even a random scrambling of keys could produce a sharp increase in keyboard-operator throughput.

Fifty-million typists and a growing army of computer-terminal operators still struggle against the Sholes keyboard, which, incredibly, was actually designed to slow operators down. In his original Type-Writing Machine of 1872, Sholes relied on gravity alone to return the embossed letter-blanks to their home positions. The keys were suspended in a circular nest of wires beneath the platen, and too fast an operating speed invariably caused them to jam up.

To solve the problem, a colleague asked his son-in-law, a Pennsylvania school superintendent, to isolate the most-often-used letter combinations in the English language. Sholes then located the combinations as far apart from each other on the keyboard as possible, and assigned their operation to the weakest of human fingers. Success! The Type-Writing Machine operator was compelled to slow down to the primitive machine's pace; key jam-ups were effectively designed out, and Sholes went on to obtain his patent. (It is interesting to note that 52% of all English language is typed on the top row of letter-keys, and the top row (except for an extra Q, U and O) is extracted from none other than the word "typewriter").

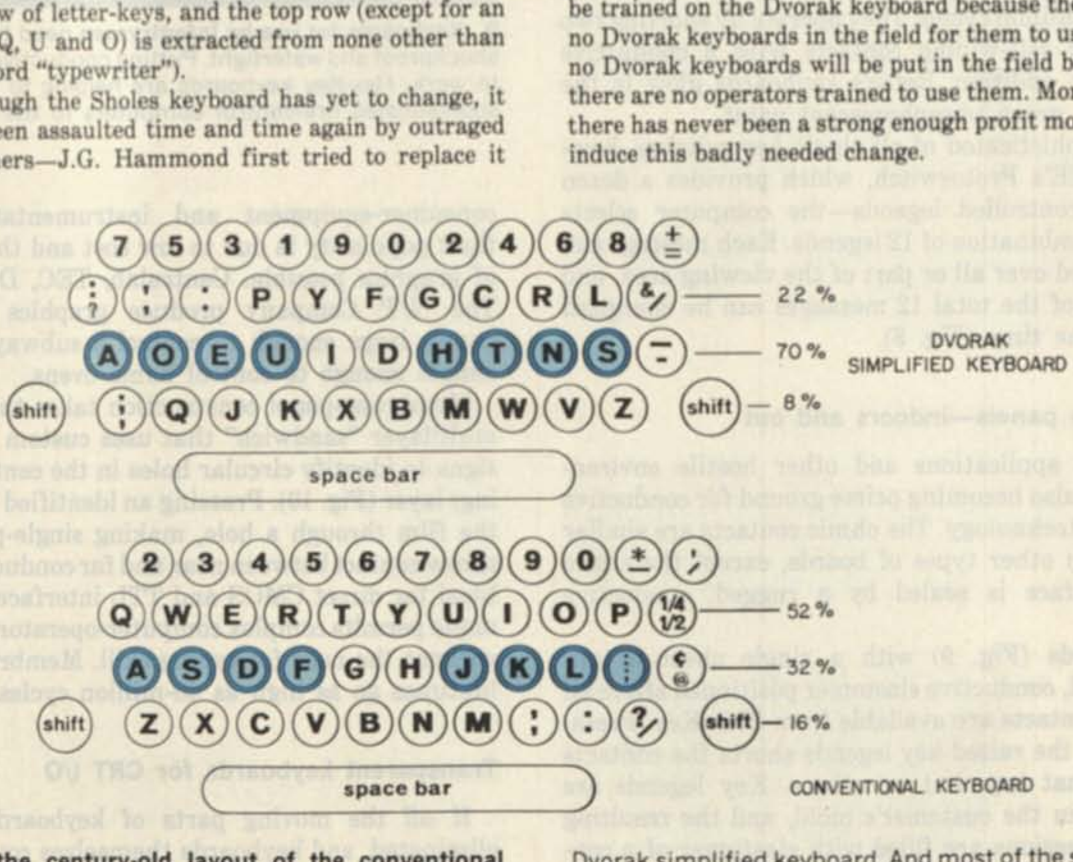
Though the Sholes keyboard has yet to change, it has been assaulted time and time again by outraged designers—J.G. Hammond first tried to replace it with a more humane design in 1893 and failed. Numerous others have tried and failed, too. But of all these attempts, none has come closer to succeeding than the simplified keyboard patented in 1932 by August Dvorak, a professor of education and director of research at the University of Washington. It was the result of a decade of physiological/language research, 250 design iterations and two sizable grants from the Carnegie foundation.

On the Dvorak simplified keyboard, home-row keys put vowels under the left fingers, and major consonants under the right fingers. Odd and even numbers are assigned to left and right hands.

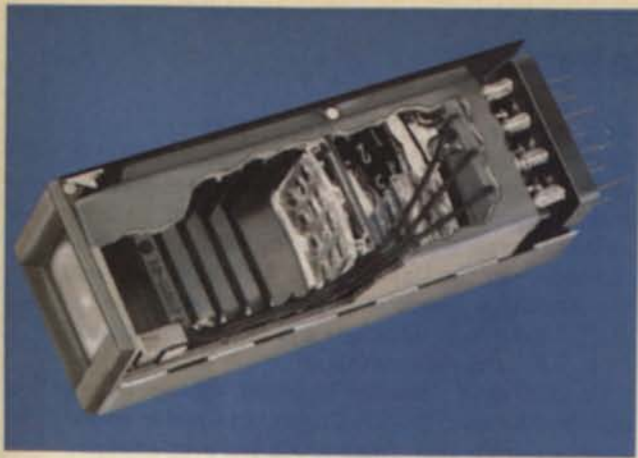
The left hand is loaded with only 44% of the typing, not the 57% the Sholes design awards it by default. What's more, Dvorak distributes the typing workload among the operator's fingers according to their strengths. Awkward strokes are reduced by 90%, while accumulative linear finger motion is cut by 95%.

Sholes's legacy would have a full-time typist move his or her fingers as many as 20 miles during an eight-hour shift, but Dvorak reduces that to just one mile. The implication is that a keyboard operator might produce 20 times the output for a given effort, or produce the same result with only 5% of the work. Less effort and better key placement means fewer errors.

Why does the Sholes keyboard continue to survive when an obviously preferable alternative is there for the taking? It's a Catch-22 dilemma: No students will be trained on the Dvorak keyboard because there are no Dvorak keyboards in the field for them to use; and no Dvorak keyboards will be put in the field because there are no operators trained to use them. Moreover, there has never been a strong enough profit motive to induce this badly needed change.



With the century-old layout of the conventional typewriter keyboard, only 32% of the typing is done on the home-row keys, compared to 70% for the Dvorak simplified keyboard. And most of the special symbols, like $ and % (not shown here), tend to vary in location with the typewriter manufacturer.



8. **Computer-controlled legends** in this new Protoswitch from IEE, Inc., can be projected on all or part of the keycap/viewing screen. Multiple legends can be lit simultaneously. The switch's screen face is hinged, and functions as an SPST key closure.

9. **Keyboards for use by infantrymen** need to be rugged, shockproof and watertight. Putting conductive elastomers to work, Flex-Key keyboards are helping to bring highly sophisticated fire-control computers to the battlefield.

build the keyboards for the customer.

System 87 keyswitches are rated at 3-million-cycle lifetimes and operate on the dome principle—pressing on the dome-shaped keyswitch snaps it inward, where it bridges two wires. Since the dome both moves and clicks, it conveniently provides two modes of operator feedback.

Refac Electronics has a line of keyswitches, the Wild Rovers, that are designed for military applications and rated at 1-million cycles. They operate by shorting two gold-plated self-wiping contacts with a conductive grating. In addition, Refac's keyboards glow in the dark from green phosphorescent paint.

Most sophisticated of all single keyswitches, however, is IEE's Protoswitch, which provides a dozen computer-controlled legends—the computer selects one or a combination of 12 legends. Each message can be projected over all or part of the viewing area, and any three of the total 12 messages can be energized at the same time (Fig. 8).

Membrane panels—indoors and out

Military applications and other hostile environments are also becoming prime ground for conductive elastomer technology. The ohmic contacts are similar to those on other types of boards, except the entire keyboard face is sealed by a rugged, conductive elastomer.

Keyboards (Fig. 9) with a single sheet of unterminated, conductive elastomer positioned above all pairs of contacts are available from Flex-Key. Pressing one of the raised key legends shorts the contacts beneath that key, but no others. Key legends are embossed in the customer's mold, and the resulting mold depressions are filled with elastomer of a contrasting color. Operating life of this switch is in the 10-million-cycle range.

Flat membrane panels are filling a niche in the consumer-equipment and instrumentation fields; their popularity is due to low cost and the high level of graphics possible. Centralab, TEC, Duralith and The N/P Company produce graphics membrane panels large enough to control a subway system or simple enough to control home ovens.

Membrane-panel construction takes the form of a multilayer "sandwich" that uses custom graphic designs to identify circular holes in the center (insulating) layer (Fig. 10). Pressing an identified spot pushes the film through a hole, making single-pole, single-throw contact between near and far conducting layers. Ideal for direct CMOS and TTL interfaces, the technique permits complex computer-operator interaction without the need for typing skill. Membrane-contact lifetimes go as high as 40-million cycles.

Transparent keyboards for CRT I/O

If *all* the moving parts of keyboards could be eliminated, and keyboards themselves could be made transparent, they could overlay CRT screens and provide the most versatile and easy-to-use keyboard design of all. Typing would be eliminated as a prere-

10. **Flexible-membrane switch panels** combine functional graphics and selective backlighting. Such keypads from TEC and Duralith last several million operations; they are spill-proof and easy to clean.

11. **Clear, conductive overlays** make the most versatile keyboard of all. Totally electronic keyboards bypass user languages, typing skills and even language proficiency. Two technologies are emerging—one based on selective antenna loading, the other on acoustic ranging techniques. Both allow host computers to construct a variety of functional commands for operator selection, as illustrated by this Sierracin system.

quisite skill for computer operators, and so could literacy itself. Two technologies have emerged for totally electronic keyboards: One is based on selective-antenna loading; the other uses acoustic ranging techniques.

An antenna-proximity-sensing technique is the heart of TASA's proprietary design, now being marketed as a discrete, 51-key ASCII keyboard. Here, the operator's body mass loads down a sensitive, low-level circuit. Individual keys are driven, sensed, detected and translated within 1 ms into ASCII code.

The other scheme, by TSD, uses piezoelectric transducers to generate acoustic surface (Rayleigh) waves that propagate across a curved piece of glass. When the operator touches a finger to the face of the glass, he interferes with the surface wave (Fig. 11).

An echo-ranging system similar to conventional sonar finds the disturbance and converts it to TTL levels. The data are available to an 8-bit data bus, or to an RS-232 port. Baud rate and parity are selectable.

TSD's standard digitizer is curved to fit a 15-in. CRT, and other shapes are *available on special order*—an indispensable keyboard phrase. ■■

Need more information?

For additional information on keyboards and keyswitches, readers may consult the manufacturers listed here by circling the appropriate numbers on the reader service card. But not every manufacturer makes every type of keyboard. More information on specific vendor lines may be found in ELECTRONIC DESIGN's GOLD BOOK.

Carroll Manufacturing Corp., 1212 Hagan St., Champaign, IL 61820. (217) 352-5438. **Circle No. 527**

Centralab, Inc., 5757 N. Green Bay Ave., Milwaukee, WI 53201. (414) 228-1200. **Circle No. 501**

Cherry Electrical Products, 3600 Sunset Ave., Waukegan, IL 60085. (312) 689-7700. **Circle No. 502**

Chomerics, Inc., 77 Dragon Court, Woburn, MA 01801. (617) 935-4850. **Circle No. 503**

Cortron, Div. of Illinois Tool Works, 6601 W. Irving Park Rd., Chicago, IL 60634. (312) 282-4040. **Circle No. 525**

C.P. Clare, Inc., 2101 W. Pratt Ave., Chicago, IL 60645. (312) 262-7700. **Circle No. 504**

Current Industries, Inc., 3359 Ocean Ave., Oceanside, NY 11572. (516) 678-3444. **Circle No. 526**

Datanetics, Inc., 18065 Euclid St., Fountain Valley, CA 92708. (714) 549-1191. **Circle No. 505**

Digitran Co., 855 S. Arroyo Pkwy., Pasadena, CA 91105. (213) 449-3110. **Circle No. 506**

Duralith Corp., 525 Orange St., Millville, NJ 08332. (609) 825-6900. **Circle No. 507**

Flex-Key Corp., 18 Sargent St., Gloucester, MA 01930. (617) 281-2040. **Circle No. 508**

Grayhill, Inc., 561 Hillgrove Ave., La Grange, IL 60525. (312) 354-1040. **Circle No. 509**

Hi-Tek Corp., 7274 Lampson St., Garden Grove, CA 93641. (714) 898-9511. **Circle No. 510**

Honeywell/Microswitch, 11 W. Spring St., Freeport, IL 61032. (815) 235-6600. **Circle No. 511**

IEE, Inc., 7740 Lemona Ave., Van Nuys, CA 91405. (213) 787-0311. **Circle No. 512**

Keytronic, Inc., Spokane Industrial Park, Spokane, WA 99216. (509) 928-8000. **Circle No. 513**

Maxi-Switch Co., 9697 E. River Rd., Minneapolis, MN 55433. (612) 755-7660. **Circle No. 528**

Mechanical Enterprises, 8000 Forbes Pl., Springfield, VA 22151. (703) 321-8282. **Circle No. 514**

Refac Corp., P.O. Box 809, Winsted, CT 06098. (203) 379-2371. **Circle No. 515**

Sierracin, Inc., 12780 San Fernando Rd., Sylmar, CA 91342. (213) 367-6184. **Circle No. 516**

SMK Corp., 118 E. Savarona Way, Carson, CA 90746. (213) 770-8915. **Circle No. 517**

Stackpole Components Co., P.O. Box 14466, Raleigh, NC 27610. (919) 828-6201. **Circle No. 518**

Stacoswitch Co., 1139 Baker St., Costa Mesa, CA 92626. (714) 549-3041. **Circle No. 519**

TASA, Inc., 2346 Walsh Ave., Santa Clara, CA 95050. (408) 247-2301. **Circle No. 520**

TEC, Inc., 2727 N. Fairview Ave., Tucson, AZ 85075. (602) 792-2230. **Circle No. 521**

Texas Instruments, Data Controls Div., Attleboro, MA 02703. (617) 222-2800. **Circle No. 522**

The N/P Company, Inc., 5620 N. Rosemead Blvd., Temple City, CA 91780. (213) 283-8854. **Circle No. 523**

TSD Products, Inc., 35 Orville Dr., Bohemia, NY 11716. (516) 589-6652. **Circle No. 524**