FOCUS on Keyboards

If you're not now using a keyboard in your electronic system, chances are you soon will. Expect a tough time when making a choice. You'll have mountains of claims to climb over as each manufacturer insists that his switching technique is best.

"But for 90% of the applications, it makes little difference which switching method is used," claims Harry Meyer, senior vice president and keyboard expert at Cherry Electric. Most methods, when well executed and properly interfaced, can probably do your job. Many manufacturers elect to go with a particular switching technique merely because it's different.

Only for very particular needs—extreme environmental conditions, exceptionally long life, very-high-speed operation, and situations requiring special keys, codes or functions, to name a few—are certain switching techniques possibly better than others.

Despite volumes of claims that tend to focus attention on switching techniques, the most important keyboard specification is reliability. Cost in most industrial, communications, military or other critical applications should be secondary, because a cheap switch that isn't reliable is useless.

Reliability specs: Are they reliable?

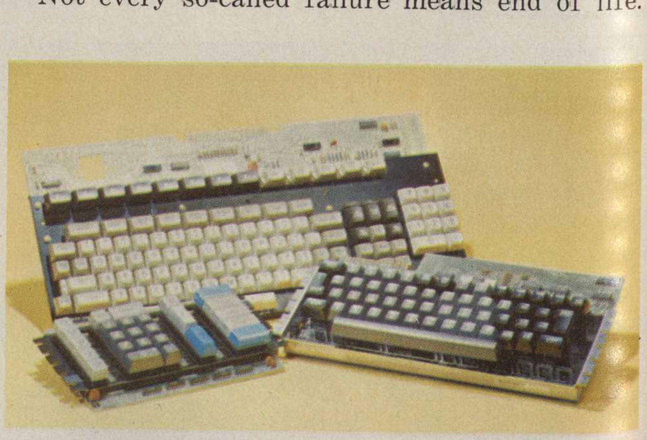
With reliability such an important spec, you would be justified in assuming that keyboard vendors and users have developed some uniform, dependable way to measure and specify reliability. Not so!

Every manufacturer claims long life and high reliability for his product. But every manufacturer tends to run tests that make his product look good. And every manufacturer claims that he has the best cost-effectiveness ratios. For the design engineer, there are no hard standards even now, despite the lengthy existence of this industry. And even high cost doesn't guarantee good reliability.

An engineer can best protect himself by understanding the nature of keyboard reliability specs. Unfortunately, few manufacturers freely publish any "true" measure of reliability. What you usually get is a so-called life value in terms of the number of strokes each key (or the total keyboard—make sure which) can be expected to withstand.

But life figures are not true measures of reliability. Worse, life figures are not even very useful, unless the end-of-life criteria are also given. Too often, even when given, such criteria are vague.

Not every so-called failure means end of life.



Advanced solid-state switching techniques, such as used in these Hall-effect Micro Switch keyboards, solve the problems of contact wear, bounce and contamination by doing away with contacts. But, of course, the price for longevity is paid in circuitry and in the use of power.

Morris Grossman
Associate Editor

Some switches are repairable, and the switch's life can continue for many failures. And some failures are merely temporary random "misses."

In a teletypewriter communications system, an occasional miss is not critical. But financial data keyed into a bank-record storage device could present very serious problems, if the data aren't error-free.

Accordingly, keyboard-life specifications in millions, even billions, of cycles are no criterion of reliability. One keyboard may last much longer than another, but may also generate an excessive number of misses. Or, during its lifetime, the keyboard may need a lot of servicing: application engineers of one manufacturer believe that a reliable keyboard should need less than one service call a year.

The construction of each keyboard must be carefully evaluated for serviceability. In some keyboards, individual keyswitches are easily replaced; in others, the entire keyboard must be replaced. Most of the low-cost, flat-keyboard units, as used in pocket calculators, are not repairable. Some manufacturers may even supply you with a measure of serviceability—MTTR (mean time to repair). But this is a figure difficult to standardize for comparison purposes and check out.

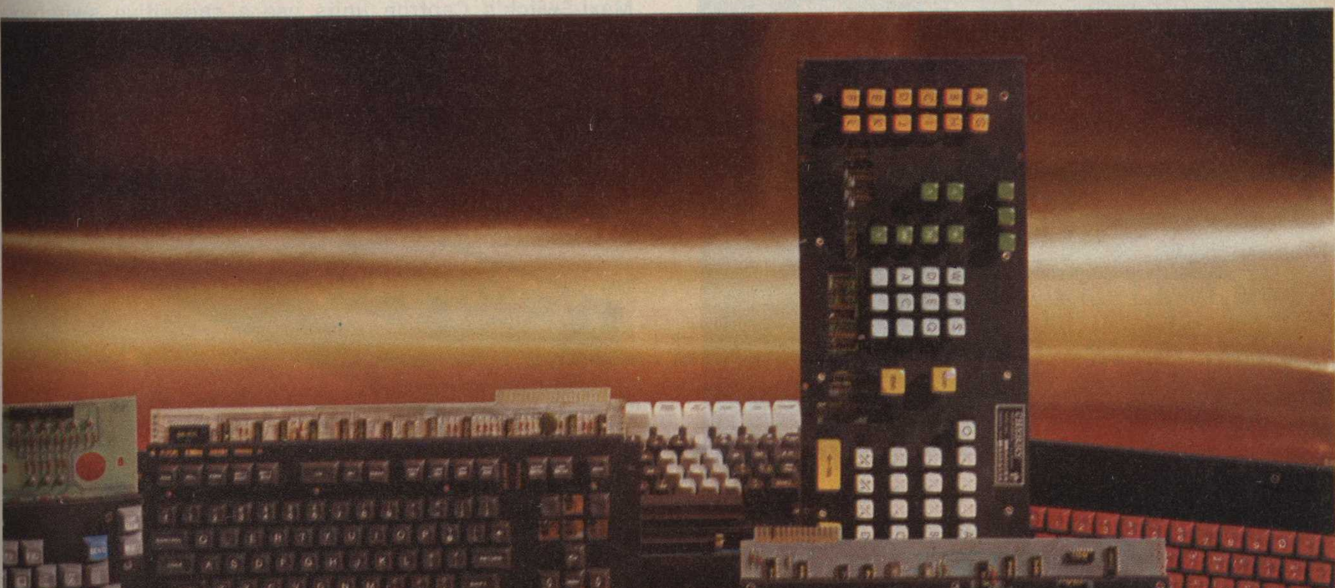
How many strokes in a lifetime?

Though stroke lifetime may not be a good measure of reliability, it still is a valuable specification, assuming the keyboard is adequately reliable for your needs.

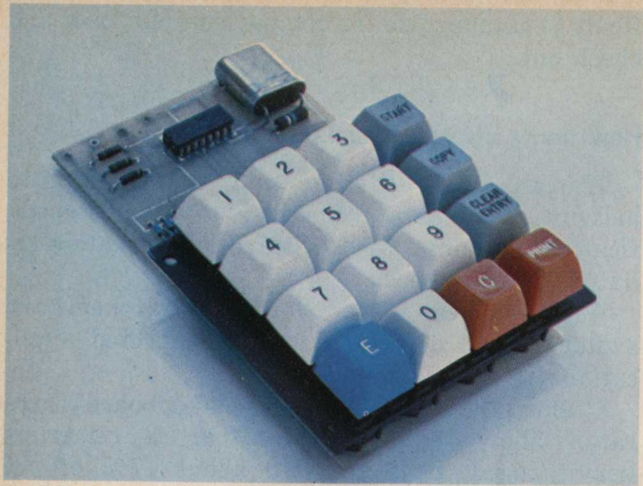
What's a reasonable lifetime for a keyboard switch? It all depends upon the expected application.

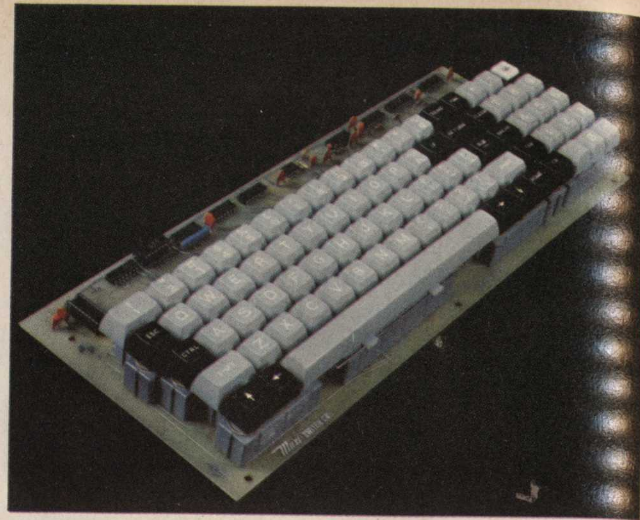
Studies of English-language, keyboard-usage ratios show that the space bar is relatively heavily used. It is actuated about 17% of the time. If expected use is relatively heavy—say, 6 hr/day, 200 days/yr at an average rate of 30 words/min. (5-letter words)—then in one year about 1.84-million strokes will be accumulated on the space bar. Thus, a switch with a 10-million-stroke operating life could last for about 5 years.

Lifetimes of 50 or 100 million strokes probably wouldn't be worth much of a cost premium in today's fast moving technology—electronic-equipment half lives run closer to 3 to 5 years than to 30 to 50 years. But this is a value judg-



The popularity of metal-to-metal-contact keyswitches, as used in Cherry keyboards, results from being able to get good reliability at low cost. Unless very long life is needed, contact switches can meet most needs.





Each of the many keyboard manufacturers tends to specialize in one or two different switching methods for its keyboards. All claim high reliability, and most manufacturers can deliver on their promises. But reliability results mostly from quality manufacturing procedures and processes: the switching method, generally, is secondary. As examples of the methods (from lower left, clockwise), Cortron uses a magnetic saturation method; Key Tronic's keyboard designed for Boeing's police-station data-entry system uses reed switches; GRT's Touch-Tone keyboard uses low-priced gold-contact switches; Maxi-Switch's Captron units use a capacitive switching method; and Collimation uses an optical-coding approach.

ment the engineer and his marketing department must make.

Pocket-calculator keyboards generally don't get anywhere near the use cited in the previous example. Thus, a life of 0.3 to 1-million actuations may be sufficient life expectancy. But for a desk-model calculator in a busy accounting department, a 10-million-stroke keyswitch life would be more reasonable.

So what's reliability?

If a keyboard's lifetime is not a measure of reliability—what is?

Reliability is the probability that a device will perform its function under given conditions, without failure, for a specific number of hours. It is usually specified as MTBF (mean time before failure) or in cycles as MCBF (mean cycles before failure).

In evaluating keyboards, you'll probably find a statement such as: "Minimum MTBF exceeds 25,000 hours."

That statement appears to be very definite and precise, but it really isn't.

In common with establishing lifetime values for a keyboard, to determine MTBF (or MCBF), the meaning of failure for this purpose also must be clearly defined. Obviously, the definitions of failure for measuring keyboard life and "failure" for measuring reliability are generally different. For MTBF, a single miss can be a "failure" in some applications; in other cases, ten or more misses are allowed before a failure is indicated. Lifetime may end only when the unit is no longer repairable.

Other failure criteria might be based on arbitrary levels of contact resistance, contact bounce, mechanical force needed to depress a key and output voltage levels in coded units.

Perhaps the most meaningful definition of reliability for keyboards is the mean time before first failure (MTBFF)—the expected time between the installation of a new keyboard and its first failure. After the first repair, the mean time to the second failure is theoretically less than the initial MTBF because of the accumulated use of components that didn't fail the first time.

But no matter how you specify or define reliability, you should measure it under clearly defined test procedures and conditions. The methods should be standardized for "normal" conditions to allow easy comparison of different manufacturers. Environmental and operator hazards other than normal use should not be included in the standard procedure. For special applications, however, tests that include these hazards should be conducted to separate the effects and allow the engineer to decide if his application needs the extra ruggedness.

Most manufacturers publish bare reliability figures, or will supply them upon request. But the figures are generally interpretations of test results, not the real data. View such figures with caution: They may be totally irrelevant to your system. You may be forced to do your own reliability analysis and testing to obtain a meaningful evaluation.

Keyboard layouts resist standardization

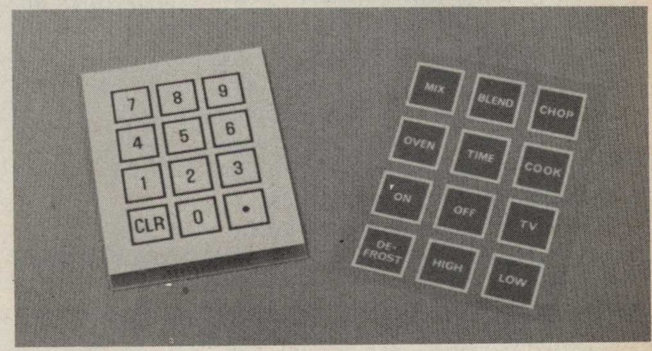
"Keyboards tend to be far more customized than is generally realized," reports a spokesman for Micro Switch. "The idea of an off-the-shelf keyboard is somewhat of a fallacy," he contends. "Standardization of board layout, key placement, key quantity or board shape is neither desirable nor feasible at this time," he concludes. Most users and manufacturers agree.

A prime reason for this, but seldom expressed, is that every manufacturer scrambles to corner a specific niche for his product with some distinctive design. Adding to this pressure for diversity, computer and peripheral-device OEMs also seek individuality in their equipment, with keyboard makers only too eager to comply—for a price, of course.

Nevertheless, your best interests are served by selecting a layout common to several keyboard makers, whenever possible. "The most serious mistake a design engineer can make is to finalize a system design before surveying the market to find out what is available," application engineers at Stackpole point out. "By adapting designs to a manufacturer's "standard" keyboards, engineers not only can reduce the cost substantially, but in some cases can even allow second sourcing, although this is usually rare."

Almost every keyboard manufacturer urges a consultation early in the system design. This is good advice. At an early stage, you have the greatest flexibility to adapt and, therefore, not require a special design; perhaps you can use a so-called standard design and save money. If left to the last minute, your choice of vendors narrows, and then you must settle for what you can get.

Major keyboard manufacturers provide boilerplate specs to help guide your design. They also provide free advice for the selection of options to customize the unit to your needs. Of course, tight specs and overspecification are to be avoided—they only increase the price needlessly.



Flat, often waterproofed keyboards, with no cracks to collect contaminants, are easy to clean. Datanetics Series 700 units are now popular for both appliance and industrial-control applications.

If you expect to use a large number of keyboards, manufacturers will be most cooperative. Then you needn't worry when the "standard" model doesn't exactly fit your needs: Most manufacturers will bend over backwards to remodel a standard design—frequently at no extra cost. But get the manufacturer involved early.

Quantities over 1000 pieces drive those who make medium and high-priced keyboards ecstatic and ensure the fullest cooperation: 100-piece orders are the more usual quantities.

One area that is at least partially standardized is keyboard coding.

Coded or uncoded—it's your choice

Some keyboards produce codes; some don't. The noncoded types often have a single common lead and a separate lead for each keyswitch. Another popular arrangement uses an XY matrix: Each key, when pressed, connects an X line to a Y line.

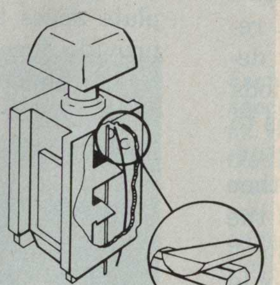
Noncoded keyboards may deliver either a logic

Keyswitch techniques abound

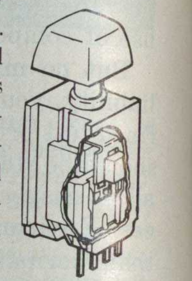
When choosing a switching technique for your keyboard, consider your objective first, not the alleged reputation of a specific switching method. A technique is not necessarily reliable merely because it is a so-called solid-state method. Nor is the over-all result cheap, when you have to provide considerable electronic circuitry to make the switch work in your system. The switching technique you choose can often be the last item to consider. Nevertheless, consider it you must!

Here are thumbnail sketches of most of the popular switching methods:

Mechanical contacts with open construction are simple and low priced. Contacts can either be slow make or have snap action. But open construction is subject to contact contaminations. Also, bounce is an inherent problem; thus, direct coding is rarely provided. With "bounce-eliminator" circuits and a logic-encoder system, an effective and reliable system can be built. Cherry, for example, uses knife-edge keyswitch contacts made of gold alloy and experiences no difficulty handling any bounce problems. Life estimates of mechanical-contact keyswitches run from 5-to-10-million operations.

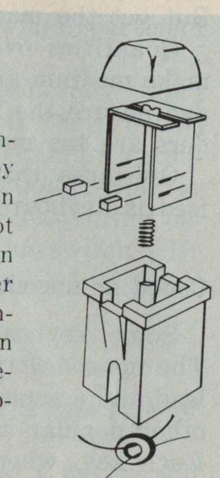


Hall-effect keyswitches move a magnet on a plunger assembly near a sensitive Hall transducer. In Micro Switch's design, the Hall unit provides two isolated outputs to reduce encoding-logic complexily. Though an oscillator or amplifiers are not required, the Hall transducer does require a substantial dc-current source that's always in a standby ON condition. Reliability is very good and lifetime to 100-million operations is reported.



Reed switch contacts in enclosed packages eliminate the problems of contact contamination. Also, the high resonant frequency of reeds produces short bounce times. Except for occasional misses, keyboards with reeds—a Key Tronic's specialty—offer high reliability with life estimates in the 50-to-100-million operation range.

Saturable-core keyswitches unsaturate a toroidal transformer by displacing permanent magnets when the key cap is pressed. When not saturated, a local hf oscillator can couple through the transformer and provide an output. This method, mainly used by Cortron, can provide good reliability with lifetimes in the 50-to-100-million operation range.



level or a contact closure. If it's a contact closure with metal-to-metal contacts, question the bounce characteristics of the switch, and make sure your circuit design can handle the bounce. Bounce time on make may be quite different from break bounce time. Bounce may worsen as the contacts age. Such data are seldom volunteered, so be sure to ask.

For logic-level outputs, the keyboard's power requirements should be checked. Though seldom a problem in fixed installations, a portable application that works on batteries usually needs special attention to power demands. And, of course, the output-level tolerances and drive capabilities should be examined.

Coded keyboards may have special cycling, or timing, requirements. Study the keyboard's sequence carefully and make sure it can properly interface with your system.

Old codes persist

Although the ASCII code is used most frequently IBM's EBCDIC code has a good percentage of the market, and the old Baudot teletypewriter code is still very much alive. ASCII (American National Standard Code for Information Interchange) is a Federal standard, uses seven bits and separates the letters from the numerals and symbols on the keys. ASCII is also known as ANSI, or more correctly, USASCII.

Elastomeric contact switching is usually used in low-cost, low-profile keyboards, like those for pocket calculators. A "soft" contact eliminates problems of contact bounce. And the relatively high contact resistance is no problem with MOS circuits found in many calculator chips and μPs.

Capacitive keyswitches are perhaps mechanically the simplest of all the methods. Movement of a plate couples a signal from an oscillator to an amplifier, whose output is then encoded. Electronic complexity is similar to that of the saturable-core approach. Companies such as Maxi-Switch and Key Tronic build capacitive keyboards. Reliability is high, and life over 100-million operations is claimed by most manufacturers.

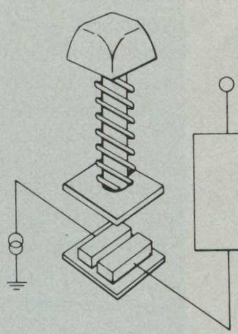
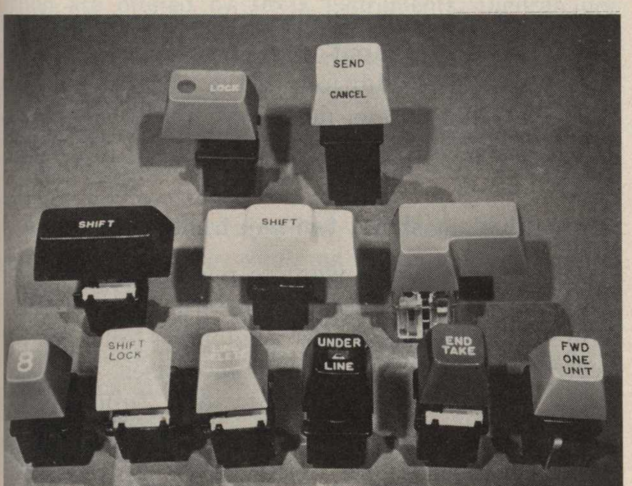


Photo-optic coupled keyboards, such as those made by Collimation, use an array of LEDs (or a single distributed light source) directed through a matrix of notched steel masks, that are controlled by the "keyswitches." The code in each notched mask selectively interrupts the light beams to provide a coded output for each key. Since there are no electrical contacts, contact bounce, wear and resistance are eliminated. But mechanical complexity takes their place. With a good design, reliability can be good. Lifetime values are difficult to estimate, but a 5-to-10-million operation range is reasonable to expect.

EBCDIC (Extended Binary Coded Decimal Interchange Code), the so-called data-separation keyboard widely used on IBM systems, uses eight bits (plus parity) and, unlike ASCII, assigns both numerals and symbols to alpha-character keys.

The keyboard industry would love to standardize on ASCII. With ASCII, lower-to-upper-case shifts are handled by inverting only one bit and the logical separation of numbers and letters



Key caps can be obtained in many shapes and styles as illustrated by this small selection from Cortron's repertoire. Some companies also offer a large selection of legends. The use of standards will save you money.

(and symbols) facilitates the processing of the data.

But the common use of a single key for two characters—or one character and a function, such as shift, unshift and various special controls —prevents any rigid code standards. Specialized codes will continue to be needed for a long time.

However, code standardization is an ongoing, if neglected, activity. The small degree of standardization found in today's keyboards can be traced back to the American National Standard —ANSI X4.14-1971—"Alphanumeric Keyboard Arrangements Accommodating the Character Sets of ASCII and ASCSOCR." Keypunch, key-to-disc, key-to-tape and other data-entry equipment codes are more or less standardized.

Many manufacturers would like to remove the burden of keyboard encoding from the keyboard. The manufacturers of calculator-type keyboards, in particular, argue that the advent of microprocessors makes letting the data system do the encoding more economical. However, those manufacturers whose designs inherently supply coded outputs (optical and some mechanical-matrix units) naturally insist that letting their keyboards do the encoding is still cheaper.

Keyboard manufacturers who advocate uncoded units point to the great flexibility a system designer achieves when only key-location or address codes are obtained from the keyboard. Then, with a ROM or logic circuit, the designer

Keyboard options fill every need

In addition to their "standard" keyboard assemblies, many manufacturers offer a list of options. Some of the more popular options—which need little explanation—include lighted indicators, lighted switches, selection of keyswitch operating forces and travel lengths, and tactile or nontactile feel. Also, various mechanical keyswitch actions are available. They include alternate and shift-lock actions and switches with locks.

Other, more complex options, such as the choice of one of the many possible rollover versions and other electronic features need some explanation. Several of the available rollover variations include:

- **Second-key inhibit.** All keys must be released between keystrokes. The second key doesn't work on a rollover. This option is used mainly in calculators; point-of-sale devices and numerical controls, where single-finger operation is normal.

- **Two-key rollover.** Available in a number of forms—some with undesirable side effects—so this feature must be carefully examined. One popular form puts out the first code immediately, and the second code only when the first key is released. If properly designed, this approach can avoid the many undesirable characteristics some versions exhibit.

- **Two-key rollover, N-key lockout.** The keyboard locks out until only one key remains pressed. Only then is the pressed key's code put out.

- **N-key rollover.** A so-called true key-rollover version puts out a code as soon as a key is pressed, without regard to the release of any other key. Some versions include a variety of provisions for simultaneously struck keys, such as a priority or other form of selectivity. Such a system, of course, must include a circuit that defines simultaneity. Key actuations occurring within a certain narrow time interval, are usually considered to be simultaneous.

- **Staggered N-key rollover.** For terminals that are slower than the operator, the first pressed key locks out the rest of the keyboard. After the terminal recognizes the first code, the keyboard puts out the code for the second key pressed, and so on, on a staggered basis. This is a less expensive approach than true-key rollover, which requires a large first-in/first-out buffer.

Other electronic options include:

- **Code inhibit.** Provides lockout of particular unwanted or nonmeaningful sets of codes, under such conditions as shift or external control. Or the inhibit can inactivate some keys, when desired, such as the Screen Erase.

- **Repeat key.** Allows repeat of the last character hit. But many versions are available, such as the alternate repeat of two or more keys with the repeat key pressed, or repeating characters only, such as for an upper-case X.

- **Special function keys.** Includes such functions as Scroll-up, Scroll-down, Cursor-control, Right-cursor keys, etc.

- **Multiple-function keys.** Combines such functions as carriage-return and line-feed keys.

And, of course, an endless variety of interface arrangements—TTL, MOS, special line drivers and serial or parallel outputs in many formats—are available.

can generate any code he wants for use inside his system. Some key-location addresses are determined by row/column contact-closure arrays. Many keyboards use a high-speed scanning circuit to spot the actuated key. Others use a diode matrix. And in still others, the switch itself provides an intermediate code to address a ROM.

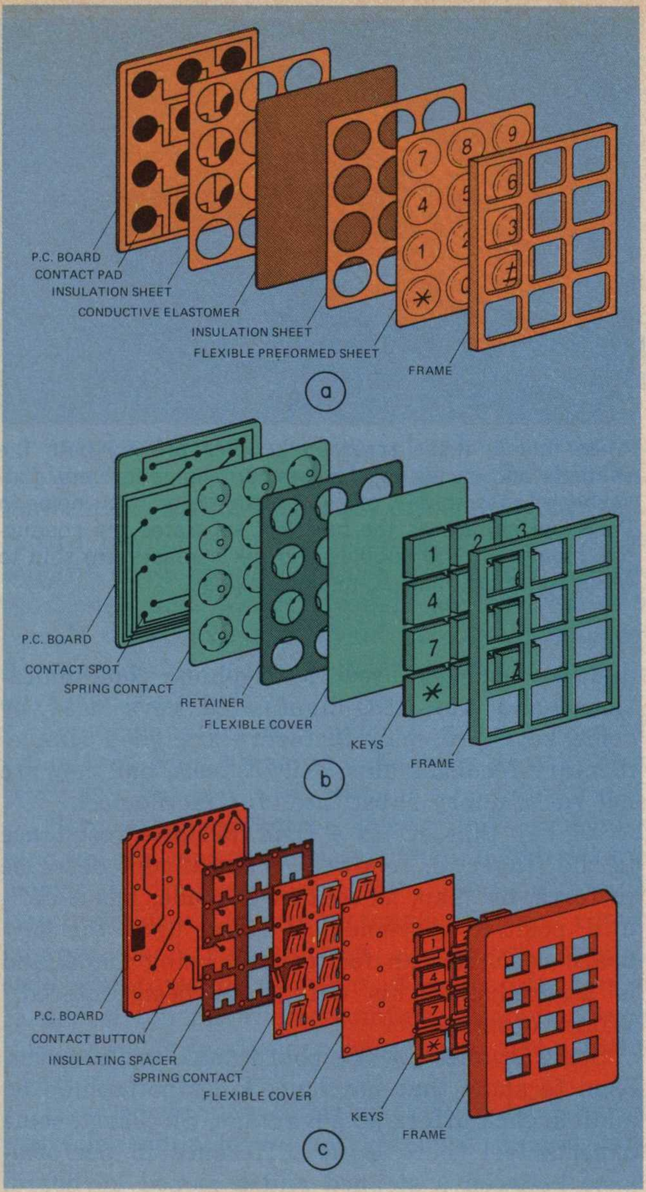
The ASCII and EBCDIC codes both save keyboard space and cost by using each key to represent more than one character or function. This multilevel operation, as in the upper and lowercase modes, needs one or more additional shift keys to change the mode. For the usual dual-mode use, a single shift key with alternate action is often employed. For tri-mode, which allows even greater space saving, both a shift and control key are needed. For this case, a lighted shift key is almost a necessity to identify which shift level the keyboard is locked into.

But, of course, multilevel operation tends to slow data throughput and can cause confusion and errors. In addition, extra control logic is needed. Thus, some designers prefer a monomode operation—a single function for each key.

Keyboard logic shows two-way trend

While some forces want to push electronics off the keyboard, other trends—multilevel operation, lighted keyswitches and readouts—tend to put electronics right back. In some cases, the keyboard even takes on such system functions as serial/parallel and parallel/serial interfacing, handshake-sequencing logic, data storing and parity checking.

A keyboard usually only transmits data. However, sometimes it also receives data, for example, enable/inhibit control signals to modify the key-



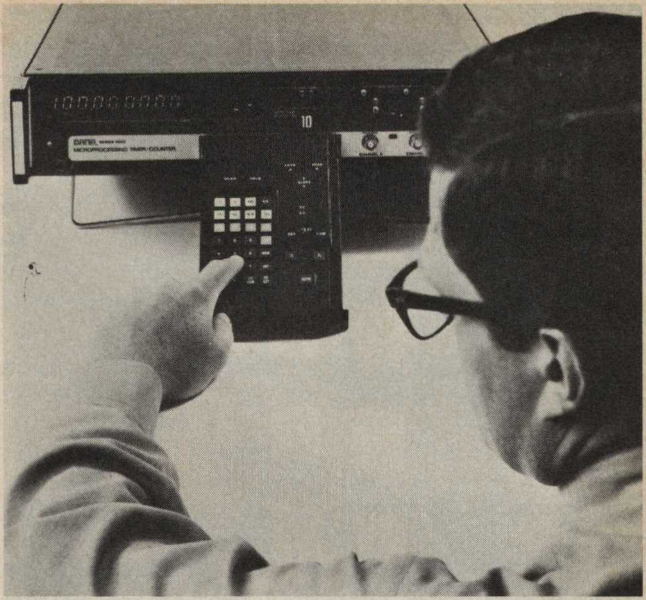
Low-profile, calculator-type keyboards frequently use one of these three methods of switching. Low-cost units, such as those offered by Chomerics and Flex-Key, use a conductive elastomeric sheet as the contacting medium (a). Domed-disc units (b) with an inherent snap-action are offered by Texas Instruments. Digitran prefers the flexible-design capability of its spring-type switch (c) for its keyboard (courtesy of Digitran).

board's performance, or shift signals to automatically change the keyboard from letters to numbers.

Also, interface circuits between keyswitches and data systems, such as three-state open-collector (wired-OR) drivers are often needed.

Other keyboard options also tend to pile electronics onto the keyboard. Thus the trend of electronics on the keyboard will probably go both ways: Electronic circuits will be added to the keyboard as frequently as circuits are removed.

The design engineer, in choosing between electronics on the keyboard and in his system, must base his decision on relative cost and his own special technical problems: There are no general rules or trends to guide him.



Instruments now feature keyboards for function controls rather than traditional knobs, buttons or switches. The only nonkeyboard switch on this Series 9000 microprocessing timer/counter made by Dana Laboratories is the power switch.

One keyboard area—rollover—can require a large amount of on-board electronics.

On the rollover bandwagon?

Not all keyboards need N-key rollover. This option loads electronics onto the keyboard, adds cost and may increase equipment failure rate. Many engineers demand it merely because they've heard the word; they are victims of a name-dropping syndrome, according to some experts.

It's true that because MOS LSI circuits have allowed a substantial cost reduction in such keyboard options, opposition to N-key rollover has diminished.

High throughput applications—for example, typesetting, text editing, data communications and word processing—can very profitably use N-key rollover. The 10-to-15% higher cost over other rollover variations appears to be fully justified. For high-throughput work, studies show that about 30% fewer errors are made with N-key than with two-key rollover.

Two-key rollover is better, however, where one-handed operation is called for, as in high-speed desk calculators.

If you do choose a rollover option, be warned: Not all options work exactly alike, even if called by the same name. There are many versions of each type. Even a single company can offer several choices. Key Tronic offers a choice of three types of two-key and four N-key rollover. Although Key Tronic explains its versions, many companies don't.

For example, in a two-key rollover situation, say key A is pressed first, but key B is released first. Many outputs are possible. Will character A register first and then B, as probably desired? Or will you get B before A? A alone or B alone are also possible.

Some two-key rollover systems even have the deficiency of A coming out twice—or worse—character A coming out as many times as any second key is pressed and released, while A is held down.

Read spec sheets very carefully to determine which version is being offered. Then ask questions.

It's human to disagree

Even more controversial than rollover are the questions of such human factors as tactile feel and audible or visible feedback from the keys. Naturally, the shape, arrangement, color and labeling of keys also are subjects of much discussion.

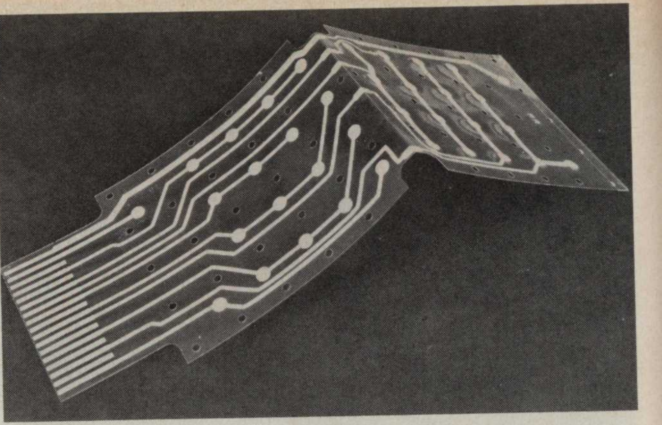
It's very difficult to separate prejudice and opinion from fact when studying the human factors of keyboards. Humans are creatures of habit, and thus tend to prefer what they are familiar with. But they also are adaptable—even though they may grumble a lot while they adapt. Therefore, objective test results of what is best are hard to obtain and even harder to interpret. The mere fact the people are being observed and measured influences the results.

Many electronic-keyboard input devices are operated by experienced typists. One theory holds, therefore, that such keyboards should simulate the feel and configuration of a standard typewriter to take the fullest advantage of the typists' skill. This simulation would also avoid confusing typists when they switch between typewriter and keyboard.

Other experts, however, claim that most typists can bring their throughput to normal standards on almost any electric keyboard in about 10 days, unless the keyboard has some clearly objectionable characteristics.

Bob Wilcox, engineering manager of Digitran, and a strong advocate of kinesthetic feedback, says: "An operator, in putting long lists of figures into a keyboard on a calculator, can work much faster if he can feel a definite movement of the individual keys, indicating that a digit has been entered. Looking back and forth from his list to the keyboard to verify the input by watching for an indicator light, or even watching his own fingers, eats up time and adds to potential inaccuracy. It's an inefficient method of data entry."

Other methods, such as introducing an audible click when a key is depressed—the Touch-Tone



When folded, these screened bubbles provide both the contacts and spring mechanism for Chomeric's new flat-keyboard assembly. A piece of clear Mylar, with holes in the same pattern as the bubbles, separates the conductive members. The bubbles and ink contacts are said to withstand more than 10-million flexings.

audible feedback used in telephone communications—and the LED-illuminated keys used by some keyboard manufacturers are good supplementary feedback aids, Wilcox feels, but they are not satisfactory substitutes for tactile feel.

"A key that offers a firm, definite resistance to the fingertip, followed by an abrupt decrease in force, or snap, as contact is made, has a definite, positive psychological effect upon the keyboard user. He can feel contact being made, and is assured that his data have been entered," Wilcox observes.

Some studies by keyboard makers, however, seem to show that having a kinesthetic snap or audible click offers no advantage. Similarly, some experts feel there is no difference in performance between a stepped and a sloped keyboard. Of course, others disagree.

But everybody agrees that keys should not be so hard to push that the fingers soon tire. Neither should the touch be so light that bumping or vibrating the keyboard can easily actuate a switch.

Studies made by Honeywell show that the force needed to actuate a keyswitch fully should be between 0.9 and 5.3 oz, and full travel should be between 0.05 and 0.25 in. These values still allow a wide range of discretionary choice. Honeywell's recommended travel lengths, interestingly enough, appear to be smaller than those found in most mechanical typewriters and even in many electric typewriters.

Cortron (a division of Illinois Tool Works) says it can duplicate the "feel" of most electric typewriters: "Our tactile feedback switch can easily be tailored to match almost any specified force-displacement curve."

If you do decide to ask for a particular feel and tactile feedback, you will find it difficult to specify. Of course, a displacement-force curve with tolerance limits is most definitive, and some manufacturers can meet such specs. Some can even supply different key groups on a single keyboard each with a different feel.

Stick to standards

Special keycap requirements can add tremendously to cost, according to Meryl Miller, manager of engineering services of Datanetics. New legends requiring special tooling instead of standards and keycaps with mixed colors, odd shapes or sizes can be very expensive.

Keyboard envelope size, structural rigidity, weight and mounting can raise costs when requirements are off-beat. An extremely long keyboard obviously offers more of a challenge to obtain rigid mounting than a "normally" proportioned unit. Miller strongly advises that you should take maximum advantage of your housing to provide any needed support, and avoid expensive configurations.

Some manufacturers offer a wider choice of standards than others, so shopping around may get you what you want without a premium price.

Many standard keytop colors, finishes, shapes and orientations are offered. They include all the colors in the rainbow; gloss, semi-matte and matte finishes; square, rectangle, "L" and round shapes, among many others; and sloped, stepped and sculptured orientations. Keycaps often have a dished top for finger comfort. Deep-dish tops are available to allow an operator to feel a home position without looking.

Key Tronic says it has over 7000 hard-tooled legends available in nearly every human language.

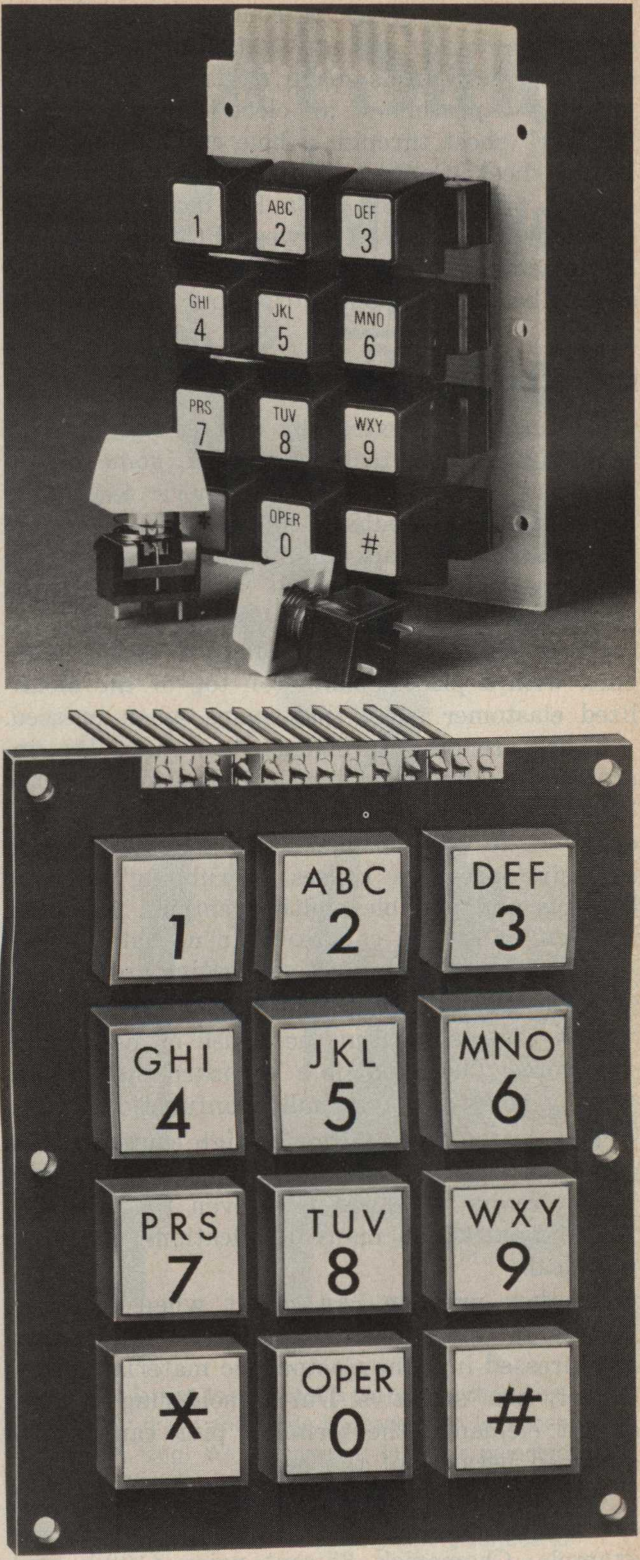
The choices are many. Let good taste and economics decide. Human factor studies seem to provide too many conflicting answers to be helpful guides, so far.

Low-profile keyboards—a high-volume market

The rapid spread of calculators has also expanded interest in low-profile keyboards for use in data-handling, communications equipment, instruments and consumer goods. A number of keyboard devices have appeared for specific use in this OEM market; however, most are designed with low cost rather than high quality in mind. Swift changes in the dynamic calculator market make these keyboards almost throwaway items, because the products are destined to be quickly superseded. Performance often receives only passing consideration.

Keyboards usually used in terminals, desktop calculators and similar equipment permit a long key travel and the incorporation of tactile feel. Low-profile keyboards, however, are denied the advantage of long key travel; limited space considerations restrict vertical key movement. A low-profile key must actuate in an average travel distance of about 0.07 in. This small travel offers a considerable challenge to the manufacturer wishing to provide a good tactile feel.

Currently, low-profile key designs fall into



Telephone or scratchpad-type keyboards for phone or other control use are offered by Stackpole (top) and REFAC (bottom).

three broad categories of contacts: elastomeric, domed-disc and spring contacts. Conductive-elastomer keyboards make electrical contact by pressing a portion of an electrically conductive "rubber" sheet through a hole cut into an insulating sheet. Contact is made with a metallic contact pad mounted on a PC board. The thin insulator spacers used between PC-board contact and elastomer dictate a very-short key travel—usually between 0.005 and 0.010 in.

Introducing feedback raises cost

Because of an extremely soft contact mating with virtually no tactile feedback, some manufacturers (or users) of elastomeric keyboards provide visual feedback, often with a lighted LED. But such back-up indicator systems can add an appreciable cost that tends to nullify the advantages of the low-cost keyboard.

Other manufacturers simulate a tactile feedback with a plastic bubble on top of the metallized elastomer sheet that snaps when pressed.

There are other problems, too. Since the operator has almost no tactile indication that the bottom of the stroke has been reached, the tendency is to push harder than necessary. Such excessive pressure causes "scrubbing" of the contacts and possible multiple entries. Too light a touch, of course, can result in no data entry.

Moreover, the conductive coating, often carbon, on the back of the elastomer breaks down easily, especially from the abuse of heavy contact force. The result is a keyboard that is electrically noisy and eventually nonfunctional.

The elastomeric's normally high contact resistance—20 to 50 Ω—can be a problem, but today's MOS circuits work well with even 100-to-1000-Ω input contacts, so many applications are quite practical.

Another problem can result when interconnecting to the keyboard terminals. Metal terminals pressed into the elastomeric material are extremely heat sensitive. During soldering to other circuit elements, the terminal pins can become detached because of the heat.

Nevertheless, elastomeric boards are cheap and can do a good job when properly applied. For example, Chomeric's 35-cent price (100-k qty) for its new 17-key KCS assembly is hard to beat.

Another popular and inexpensive keyboard—such as the one made by Texas Instruments—uses a domed disc placed directly over a PC-board contact and separated by one or more insulation spacers. Pressing the keytop deflects the top of the disc downward through the spacer to make metal-to-metal contact with the PC-board contact pad. Nominal key travel on TI units is 0.01 in. and the standard actuating force is 6 oz. When deformed, the domed disc makes an inherent clicking sound that serves as an audible feedback.

An overcenter-spring design, such as the one used in Digitran's KL keyboard, can also provide the snap action and nearly tease-proof contact of the domed disc, and perhaps even some greater degree of manufacturing flexibility, as claimed by Digitran. The design permits a sharply defined tactile feel, which can be customized for the user, and an audible secondary feedback, if desired.

Built-in overtravel and a preloaded spring allow electrical contact at about 70% of the full stroke; additional pressure on the keytop has no effect on the contact closure. A key travel longer than that of other low-profile key designs—

Need more information?

The manufacturers of keyboards mentioned in the report are only a small sample of many more available. For further information, readers may wish to consult the manufacturers listed here by circling the appropriate number on the reader service card. More vendors and information may be found in ELECTRONIC DESIGN's GOLD BOOK.

Alco Elec Prods Inc., 1551 Osgood St., North Andover, MA 01845. (617) 685-4371. **Circle No. 451**

AMP Inc., 449 Eisenhower Blvd., Harrisburg, PA 17105. (717) 564-0100. **Circle No. 452**

Ann Arbor Terminals Inc., 6107 Jackson Rd., Ann Arbor, MI 48103. (313) 769-0926. **Circle No. 453**

Artronix Inc., 1314 Hanley Ind Ct., St. Louis, MO 63144. (314) 968-4740. **Circle No. 454**

Astronautics Corp. Amer, 907 S. 1 St., Milwaukee, WI 53204. (414) 671-5500. **Circle No. 455**

Bowmar Instru Corp., 8000 Bluffton Rd., Fort Wayne, IN 46809. (219) 747-3121. **Circle No. 456**

Capitol Machine & Switch Co., 87 Newtown Rd., Danbury, CT 06810. (203) 744-3300. **Circle No. 457**

Centralab Elecs Div., Globe-Union Inc., 5757 N. Green Bay Ave., Milwaukee, WI 53201. (414) 228-1200. **Circle No. 458**

Cherry Electrical Prods Corp., 3600 Sunset, Waukegan, IL 60085. (312) 689-7700. **Circle No. 459**

Chicago Switch Inc., 2039 W. Wabansia Ave., Chicago, IL 60647. (312) 489-5500. **Circle No. 460**

Chomerics Inc., 77 Dragon Ct., Woburn, MA 01801. (617) 935-4850. **Circle No. 461**

Clare-Pendar Co., Box 785, Post Falls, ID 83854. (208) 773-4541. **Circle No. 462**

Collimation Inc., 4206 Commercial Square, Austin, TX 78745. (512) 444-3191. **Circle No. 463**

Computer Machinery Corp., 2500 Walnut Ave., Marina Del Rey, CA 90009. (213) 829-2926. **Circle No. 464**

Controls Research Corp., 2100 S. Fairview St., Santa Ana, CA 92711. (714) 549-2990. **Circle No. 465**

Cortron, Div. of Illinois Tool Works, Inc., 6601 W. Irving Park Rd., Chicago, IL 60634. (312) 282-4040. **Circle No. 466**

Dacog Elecs, 86-046 Grand Ave., Elmhurst, NY 11373. (212) 779-3560. **Circle No. 467**

Dana Laboratories, Inc., 2401 Campus Dr., Irvine, CA 92664. (714) 833-1234. **Circle No. 468**

Datanetics Corp., 18065 Euclid St., Fountain Valley, CA 92708. (714) 549-1191. **Circle No. 469**

Data 100, 6110 Blue Circle Dr., Minnetonka, MN 55343. (612) 941-6500. **Circle No. 470**

Digitran Co., 855 S. Arroyo Pkwy., Pasadena, CA 91105. (213) 449-3110. **Circle No. 471**

Dittmore-Freimuth Corp., 2517 E. Norwich St., Milwaukee, WI 53207. (414) 483-5100. **Circle No. 472**

Elec-Trol Inc., 26477 N. Golden Valley Rd., Saugus, CA 91350. (805) 252-8330. **Circle No. 473**

Electro Mech Components, 1826 N. Floradale, South El Monte, CA 91733. (213) 442-7180. **Circle No. 474**

Flex Key Corp., 18 Sargent St., Gloucester, MA 01930. (617) 281-2040. **Circle No. 475**

Fujitsu Ltd., 2-chome, 6-1, Chiyoda-ku, Tokyo, Japan. (03) 163211. **Circle No. 476** typically from 0.050 to 0.095 in.—allows the tactile feel to correspond more closely in feeling with the long strokes of large desktop keyboards. And, according to Digitran, keying forces can be tailored to the user's needs.

Contact bounce is usually not a problem with elastomers; not so with metal-to-metal contact keyswitches, including the overcenter spring and domed disc. Bounce characteristics, especially after extended use, can become troublesome, as previously mentioned for long-stroke keyswitches. But to a man, metallic-contact keyboard makers say today's antibounce circuits readily eliminate this problem. Nevertheless the problem exists. It will not go away, unless the design engineer does something about it. ■■

Futaba Elec Ind. Ltd., Super Bldg. 1-11-5 Sotokanda, Chiyoda-ku, Tokyo, Japan. (03) 55-5881. **Circle No. 477**

General Control Co., 1200 Soldiers Fld Rd., Boston, MA 02134. (617) 782-7440. **Circle No. 478**

General Electric, Data Com Prods, GE Dr., Waynesboro, VA 22980. (703) 942-8161. **Circle No. 479**

Grayhill Inc., 565 Hillgrove Ave., LaGrange, IL 60525. (312) 354-1040. **Circle No. 480**

GTE Sylvania Automatic Elec, 400 N. Wolf Rd., Northlake, IL 60164. (312) 562-7100. **Circle No. 481**

IEE Inc., 7740 Lemona Ave., Van Nuys, CA 91405. (213) 787-0311. **Circle No. 482**

IEE/Shadow Inc., 8081 Wallace Rd., Eden Prairie, MN 55343. (612) 944-1820. **Circle No. 483**

Info-Lite Corp., 46-10 104 St., Corona, NY 11368. (212) 476-1287. **Circle No. 484**

Jay-El Prods, 1859 W. 169, Gardena, CA 90427. (213) 321-3260. (I. K. Miller) **Circle No. 485**

Key Tronic Corp., Bldg. 14, Spokane Ind Pk., Spokane, WA 99216. (509) 928-8000. **Circle No. 486**

Korry Mfg. Co., 223 8 Ave., North Seattle, WA 98109. (206) 624-4066. **Circle No. 487**

Ledex Inc., 123 Webster St., Dayton, OH 45401. (513) 224-9891. **Circle No. 488**

Maxi-Switch Co., 9697 E. River Rd., Minneapolis, MN 55433. (612) 755-7660. (C. Stout) **Circle No. 489**

Micro Switch, Div Honeywell, 11 W. Spring St., Freeport, IL 61032. (815) 232-1122. (J. S. Secker) **Circle No. 490**

Mohawk Data Sciences, 781 3 Ave., King of Prussia, PA 19406. (215) 337-1910. **Circle No. 491**

D. P. Mossman Inc., Box 265, Brewster, NY 10509. (914) 279-3725. **Circle No. 492**

Oak Inds Inc., Switch Div., Crystal Lake, IL 60014. (815) 459-5000. **Circle No. 493**

Preso-Matic Lock Co. Inc., 3048 Indl 33 St., Fort Pierce, FL 33450. (305) 465-7400. **Circle No. 494**

REFAC Electronics Corp., P. O. Box 809, Winsted, CT 06098. (203) 379-2731. **Circle No. 495**

Richey Elecs Inc., 10871 La Tuna Cyn Rd., Sun Valley, CA 91352. (213) 768-3800. **Circle No. 496**

George Risk Ind. Inc., GRI Plaza, Kimball, NE 69145. (308) 235-4645. **Circle No. 497**

Seacor Inc., 598 Broadway, Norwood, NJ 07648. (201) 768-6070. **Circle No. 498**

Showa Musen Kogyo Co. Ltd., No. 5-5, 6-chome, Togoshi, Shinagawa-Ku, Japan. (037) **Circle No. 499**

Southwest Tech Prods Corp., 219 W. Rhapsody, San Antonio, TX 78216. (512) 344-3140. **Circle No. 500**

Stackpole Components Co., P. O. Box 14466, Raleigh, NC 27610. (919) 828-6201. **Circle No. 501**

Stacoswitch Inc., 1139 Baker St., Costa Mesa, CA 92626. (714) 549-3041. **Circle No. 502**

Sweda Intl, OEM Prods Div., 34 Maple Ave., Pine Brook, NJ 07058. (201) 575-8100. **Circle No. 503**

Symbolic Displays Inc., 1726 McGaw Ave., Irvine, CA 92705. (714) 546-0601. **Circle No. 504**

TEC Inc., Components Div., 9802 N. Oracle Rd., Tucson, AZ 85705. (602) 297-1111. **Circle No. 505**

Telenetics, Inc., 4120 Birch St., Newport Beach, CA 92660. (714) 752-6363. **Circle No. 506**

Telemecanique Inc., 2525 S. Clearbrook Rd., Arlington Heights, IL 60005. (312) 437-1150. **Circle No. 507**

Telesis Lab, 41-1/2 S. Paint St., Chillicothe, OH 45601. (614) 773-1414. **Circle No. 508**

Texas Instruments Inc., 34 Forest St., Attleboro, MA 02703. (617) 222-2800. **Circle No. 509**

Vector General Inc., 21300 Oxnard St., Woodland Hills, CA 91364. (213) 346-3410. **Circle No. 510**