FOCUS on Keyboards

Keyboards are everywhere. You'll find them in such diverse products as pocket calculators and computer I/O terminals; telephones and communication terminals; and electronic cash registers and stock-quotation terminals. Their ubiquity almost guarantees that you'll use a keyboard product in the near future. And when you do, our advice is to take a closer look at the keyboard itself—some day you might have to specify one.

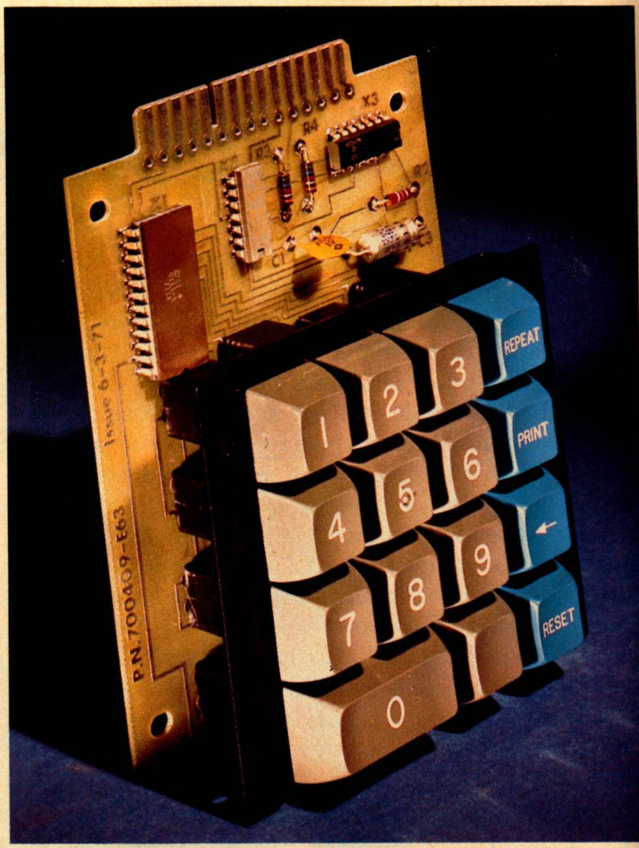
If you do, you're in for a tough time. Each keyboard in the wide range of products with keyboards is unique to its application—in short, customized. Not only must the designer choose from among an overabundance of suppliers—at least 60—but also from among a head-swimming selection of keyswitches, encoders, buttons, frames and options.

Which keyswitch is best?

The keyswitch is the heart of a keyboard, and every major manufacturer seems to feel that his keyswitch must be different from all others. The result: over a dozen different types to choose from. And, naturally, each manufacturer insists that his type is best. The truth is each type has advantages and disadvantages; as with most engineering problems, tradeoffs must be made.

Keyswitches can generally be sorted into two major categories: contacting and noncontacting. The former includes the reed switch, the most popular keyswitch until 1968, and a widely diverse assortment of physical-contact (alternate make and break) switches—such as the crossbar, the elastomeric (elastic diaphragm), the mercury-filled tube, the magnetic-repulsion and the coil-spring crosspoint switch, to name a few.

Stanley Runyon
Associate Editor



Clare-Pendar's 16-station numeric keyboard uses gold crossbar keyswitches and TTL/LSI for ASCII encoding.

The noncontact switch—sometimes mislabeled the solid-state switch—includes the Hall-effect device, the capacitive-coupled switch, the saturating magnetic core and the photoelectric switch. Of these, only the Hall-effect and the photoelectric keyswitch are truly solid state in that they use semiconductor devices to deliver their output signals.

The hard-contact, or mechanical switch, though the oldest of keyboard switches, remains popular

today for one simple reason: It's the least expensive of all the keyswitches. And while it was, for a time, eclipsed by the reed and the noncontact switch, it's making a strong comeback. Many manufacturers are expanding their mechanical switch line—and dropping their prices. Improved manufacturing techniques—plus the use of MOS circuity, which can easily handle high-impedance closures—have led to improved mechanical switches. And they have an added attraction: multiple contacts, which allow easier coding.

The major objections to the mechanical switch have been high contact resistance, contact bounce and relatively short life compared with solid-state switches. They're also difficult, and expensive, to seal (for this reason, most enclosures function as dust covers, not as environmental seals).

However, manufacturers of mechanical switches dismiss the life/reliability and contact-bounce / high-impedance arguments as overemphasized. For example, Clare-Pendar, a manufacturer of cross-bar and reed keyswitches, states: "Since MOS encoders tolerate switch-contact enclosures of up to 200 Ω, the integrity of the contact closure has much less effect on mean cycles before failure than in the old days, when the integrity of the contact had direct impact on keyboard output. With the gold crossbar keyswitch and MOS encoding, keyboard reliability equals that of solid state—at approximately half the cost."

Bounce, it's claimed, can be easily removed with delay or filter circuitry. As for life, most mechanical switches are specified at 10-million operations, a figure that the manufacturers contend is sufficient for most applications.

But some of the newest mechanical switches are promoted as having low bounce and long lifetimes. Stacoswitch, a recent entry in the keyboard industry, says that its keyswitch has contact bounce of less than 100 μs. Maxi-Switch is offering a bifurcated-contact switch with a bounce of less than 500 μs. And Cherry Electrical Products has a new crosspoint switch with reported bounce of less than 300 μs and life of at least 100-million operations. Oak Industries, an old-line manufacturer, also offers a 100-million operation switch, one that Oak claims has never failed in a customer's test program.

Reeds are still popular

Until 1968, when the Micro Switch Div. of Honeywell introduced its Hall-effect keyswitch, the reed switch dominated the keyboard industry. The hermetically-sealed contacts—actuated by a moving permanent magnet—eliminated the corrosion and contamination problems of mechanical contacts.

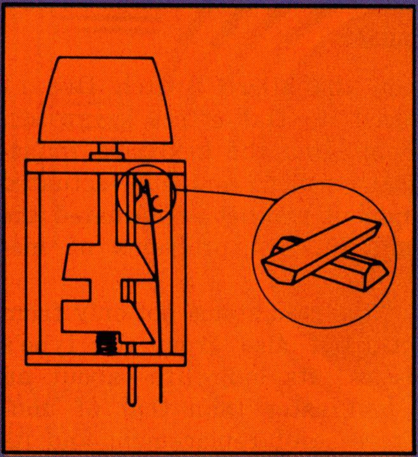
The popularity of the reed stems not only from the sealed contacts, but also from the type's known characteristics: its long life—about an order of magnitude greater than that of nonsealed switches—its ease of replacement and its ability to handle fairly high loads.

Micro Switch's line is represented by these MOS and TTL-encoded data-preparation and communications keyboards. Each uses the Hall-effect keyswitch.

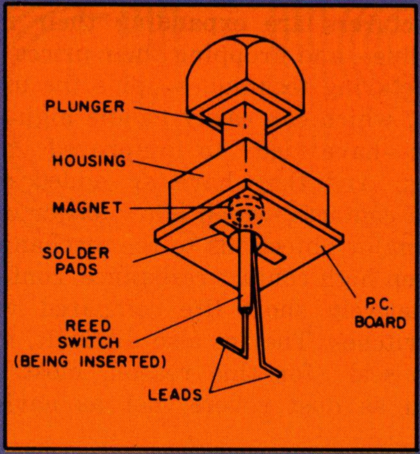
The major disadvantage of reeds is contact bounce. However, mercury-wetted types are available to reduce the bounce and improve dry-load (low voltage, low current) switching. One problem that's rarely mentioned, however, is that reeds can resonate when excited by vibrations of the correct frequency.

While reed switches have a longer life, they cost approximately twice as much as mechanical types, so tradeoffs must be made. Also, reed keyswitches—and reliability—vary considerably from manufacturer to manufacturer, depending on their mechanical design, such as magnet orientation and path of travel. Depending on design, reeds also can have either Form A or Form

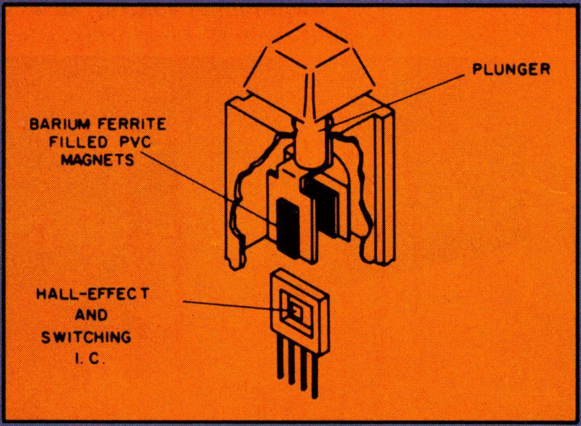
Keyboard switching techniques



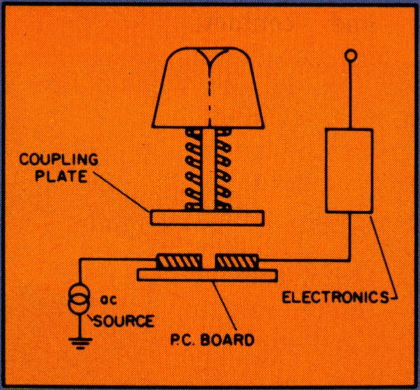
Typical contacting type is this Cherry keyswitch which uses crossed knife-edge contacts made of a gold alloy.



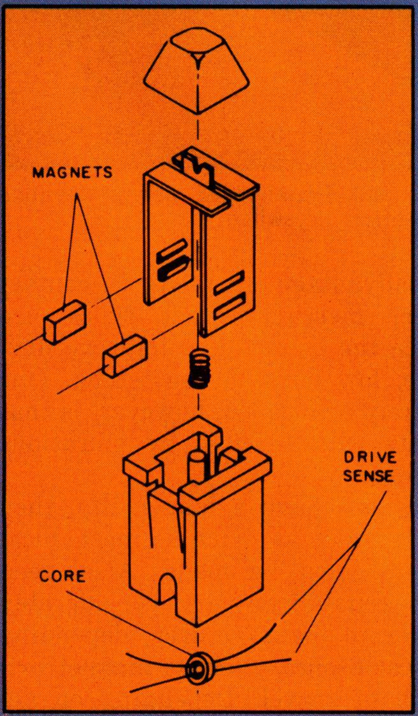
In the popular reed keyswitch, the contacts close when the plunger-attached magnet comes near the reed (Key Tronic).



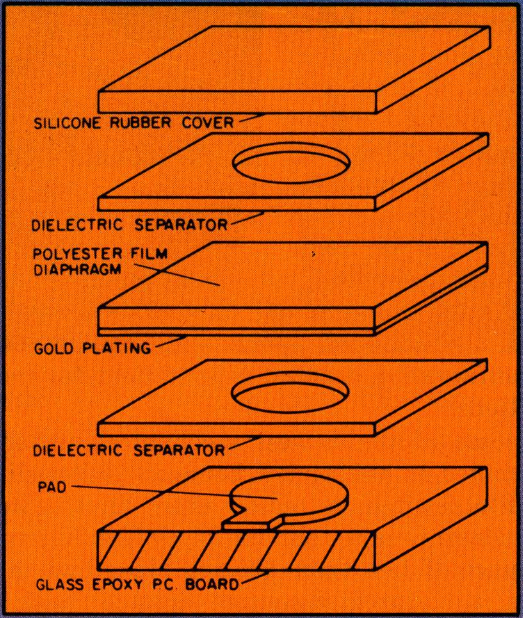
Micro Switch's Hall-effect IC chip gives a pulse output when plunger magnet passes near chip.



Control Devices' keyswitch couples an ac signal to switching circuitry via the coupling plates on the key.



When the keyswitch is operated, the ferrite core unsaturates and transformer-couples the sense and drive wires (Licon).



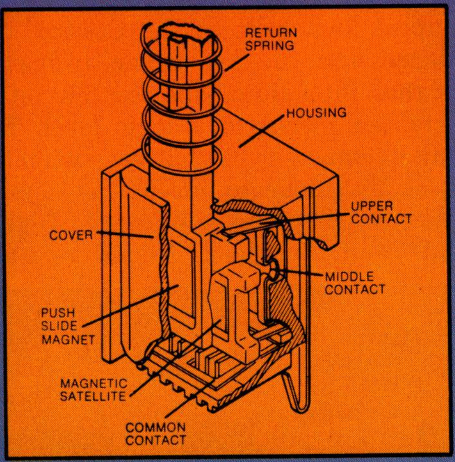
In the Datanetics elastomeric switch, a conductive-film diaphragm contacts pads on a PC board when the switch is depressed.

B contacts and both tactile and audible feedback.

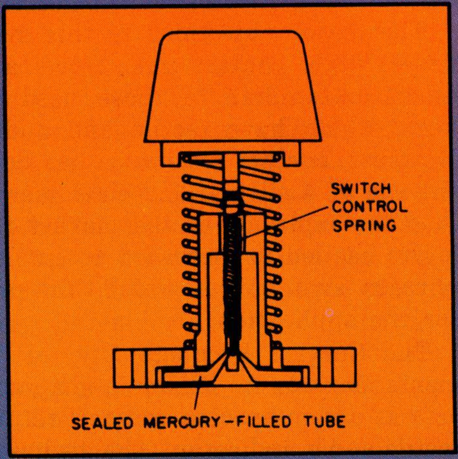
Reed keyswitch vendors include Key Tronic, Cherry, Controls Research, Maxi-Switch, Clare-Pendar, Alco and Dialight.

Unusual designs offered

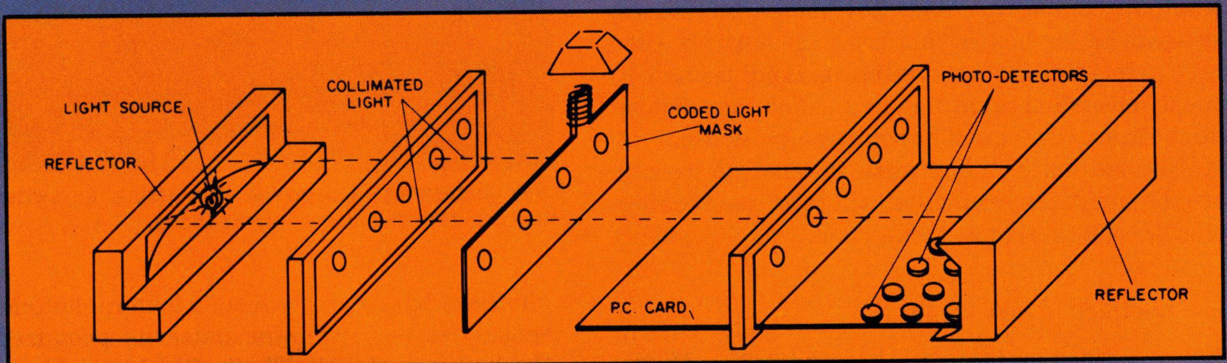
In their quest for originality, keyswitch manufacturers have come up with some unusual designs. Stackpole Magsat, for example, markets a unique magnetic-repulsion keyswitch that provides a 1-ms pulse output and has tactile feedback and an audible click. Controls Research manufactures the BI-PAC, a switch that uses as contacts two coaxial compression springs, which are integral with the pin terminals. And Mechanical Enterprises offers its Mercutronic switch, in which a mercury-filled, flexible tube gives bounceless closures. When the key is in the up position, the tube is pinched, breaking the continuity. Depressing the key releases the tube, allowing the mercury to flow together. The de-



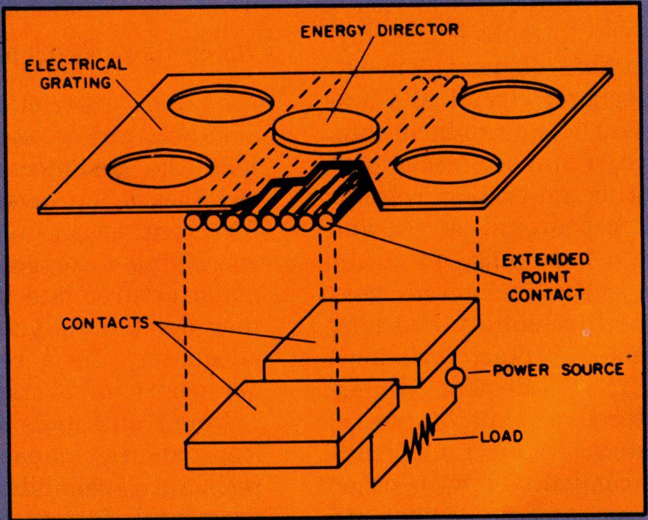
Stackpole/Magsat's flying magnet switch uses magnetic repulsion to create a pulse. The output is independent of user-caused variations in key operation.



Depressing the key joins two pools of mercury in this Mechanical Enterprises' keyswitch. The mercury-filled tube is pinched off when key is released.



Photoelectric keyswitch uses a light source, photocells and coded masks (Western-Digital Systems).



Wild Rover's thin keyboard provides a multiple-contact closure when a flexible grating contacts fixed, bottom lands on a PC board.

vice can operate in any position.

Still another type of contacting keyswitch is the elastomeric, or elastic-diaphragm, switch. Versions are offered by at least four manufacturers—Datanetics, Flex Key, Donnelly Mirrors, and Chomerics—but the basic principle of each is similar. Depressing a key forces a conductive or plated elastomeric membrane against a contact grid or band on a PC board. The advantages claimed include sealed construction, little or no bounce, high reliability and life, and—because of batch fabrication—low price.

The major objections to this switch are relatively high contact resistance and a spongy touch, unfamiliar to those used to typewriter keys, which have tactile and audible feedback. However, contact resistance has been reduced by the use of a silver-filled elastomer (Chomerics). And the explosion of the market for mini-calculators has led to increased acceptance of the diaphragm switch: Its wafer-thin profile is ideal for the application.

The Control Products Div. of Texas Instruments markets its Klixon, a snap-action disc that acts as a combination contact, return spring and tactile-audio indicator. The technique allows TI to make 0.15-inch-thick keyboards.

Another company, Wild Rover, manufactures a low-profile keyboard that uses an entirely different principle. In this switch, a flexible, multi-element electrical grating is pushed against a rigid bottom contact. The multipoint contact is said to distribute the transient energy evenly over the multiple elements, thereby decreasing contact resistance and dissipation.

The Hall-effect: a new trend

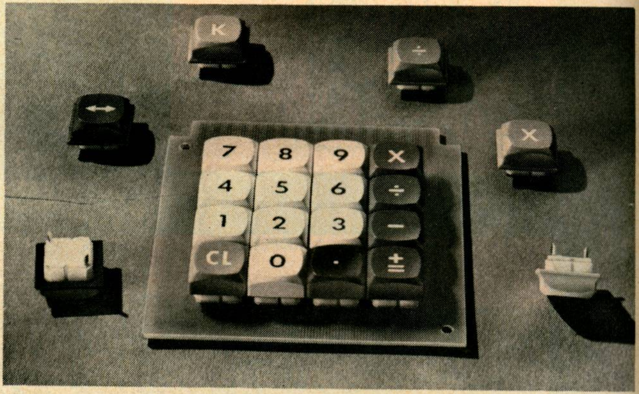
Of the noncontacting keyswitches, Micro Switch's Hall-effect type is by far the most popular. Introduced in 1968, the Hall-effect switch—a true solid-state type—revolutionized the keyboard industry. The switching element, consisting of a Hall generator, trigger circuit and amplifier, is integrated on a 0.04-square-inch chip. When the key is depressed, a magnet moves past the Hall element, generating an analog voltage. The voltage is converted to a digital output and then amplified to produce a 1-ms pulse output.

The advantages of this switch include no moving contacts, no bounce, high reliability and long life, no EMI, no variations in contact resistance and, finally, no misses. The tradeoffs? Higher initial cost and the need for some standby power. However, four price reductions in four years have kept Micro Switch competitive with other manufacturers. And the company states that the quality and reliability of its keyswitch actually reduces costs by eliminating the need for incoming inspection and by reducing service calls.

The magnetic core switch, manufactured by Licon, works by keeping a ferrite core saturated initially with a magnetic field. When the key is depressed, the field is removed and the core unsaturates and transformer-couples an ac signal to the output. The ac voltage is then rectified and used to drive IC logic. The chief advantage is the reliability associated with the ferrite core.

Both Control Devices and Raytheon offer capacitively coupled switches. In the Control Devices unit, depressing the key capacitively-couples an ac signal into signal-shaping circuitry, which converts the signal to a logic level. The Raytheon unit combines capacitive switching with a scanning technique to encode the keys.

At least three companies—Western Digital Systems, TEC and Symbolic Displays—make photoelectric keyswitches in which photodetectors sense the various light patterns produced when the keys are struck. The technique yields a unique code for each key.



Oak Industries' low-profile contacting keyswitch is intended for calculator applications.

Watch those switching specs

System restrictions, such as physical size, available power and coding requirements should help the designer narrow the number of keyswitches to be investigated. According to manufacturers, engineers make two major mistakes in specifying a keyboard: First, they bring in the manufacturer late in the design process; second, they don't familiarize themselves with keyboards adequately. As a result, they tend to either underspecify, or overspecify.

Important specs include force, travel, bounce, load-handling capacity, electrical noise, contact resistance, reliability, human factors and environmental factors—such as operating-temperature range, vibration and humidity. Any of these

Donnelly Mirrors evaluates the lifetimes of its flexible-diaphragm keyswitch on this test rig.

may be important, depending on the application.

For commercial keyboards, force and travel have become standardized at about 3 ounces and 3/16 of an inch, respectively—at least for typewriter and high-speed entry applications. However, for miniature calculators with low-profile keyboards, travel may be negligible.

As for bounce, the makers of contactless switches argue that little or none is desirable for two reasons: First, the keyboard electronics will be considerably simplified; second, if you start out with marginal bounce specs, you may run into reliability trouble later—despite compensating electronics.

Is there a reliable reliability spec?

Life and reliability specs, together with cost, form a major battle line between keyswitch makers—and especially between the makers of contacting and noncontacting switches. Every manufacturer claims long life and high reliability for his product. But for the engineer—who is caught in the middle—there are no standards for failure or for keyswitch life testing. As a result, manufacturers tend to define and test for life in a way that makes their product look good.

Thus an engineer is presented with pages of statistical data that ostensibly demonstrate hundreds of millions—or even billions—of operations, cycles, etc. But these specifications are meaningless unless the manufacturer defines the failure criteria and the actual test conditions—for example, loading, environment, power levels and other factors.

When failure criteria are given, an engineer must still decide on their validity as applied to his own equipment. Thus failure can be defined as either missing or erroneous outputs, as catastrophic failure, as an arbitrary level of contact resistance or contact bounce, or by other factors.

Except for catastrophic failure, none of these constitutes absolute failure; they are relative terms that may be important to a particular application.

Micro Switch, the largest supplier of keyboards, says: "Reliability concerns the 'miss' characteristics of the keyswitch, where a 'miss' is the failure of a switch to open and close once during one complete cycle of the actuator. Mechanical contacts, regardless of the packaging or operating mechanisms, can miss from time to time."

Controls Research, a mechanical-switch maker, counters with this argument: "An occasional intermittent output may be critical in a key-to-storage device, but not to a teletypewriter communications terminal. A keyboard can fail in many ways, and even the best life-test data can't predict when or how it might fail in a customer's situation."

Running around in cycles?

The figure of 10-million operations has been generally used as an acceptable keyswitch lifetime. Of course, as Datanetics points out, it completely ignores the rest of the keyboard, which can involve considerable hardware.

However, increasing competition has led to spiraling claims for keyswitch lifetimes that leave the 10-million figure far behind.

"Many switches," says Clare-Pendar, "are rated at a hundred-million cycles; yet the probability of ever seeing a hundred-million cycles is practically nil. Reliability in meantime-before-failure or mean-cycles-before-failure—at a specified confidence level—is the most meaningful criteria."

Maxi-Switch has published statistical data for

keystroke usage ratios. Using the text of the Gettysburg Address as an example, the data show that the space bar, with 17% of the total strokes, is the key used most often. The space bar, together with the five vowels, make up 49.5% of the total strokes, Maxi-Switch says. Thus if a keyboard were operated continuously at 40 words a minute, 24 hours a day for one year, the space bar would accumulate a total of 17,870,400 operations (based on five-letter words). This, says Maxi-Switch, demonstrates that a keyboard is unlikely to have a requirement for 50-million to 100-million operations.

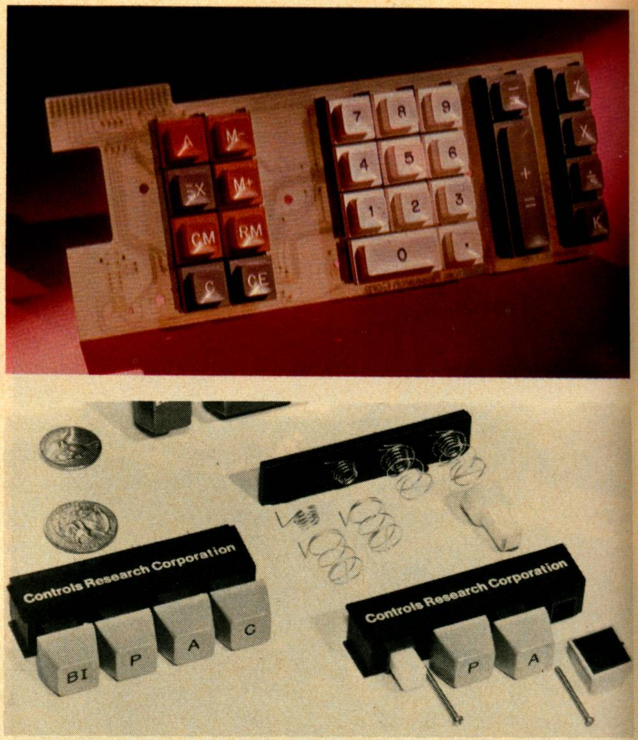
Don't forget the keyboard itself

With mountains of claims and counterclaims of superior switching techniques and reliability to climb over, it's easy to forget the rest of the keyboard. As Micro Switch points out, many systems are completely designed before the keyboard is considered.

Taking that approach will no doubt lead to higher costs, a marginal design, or both. This is because keyboards are not as simple as they appear but require a host of decisions. Questions that should be asked include:

Do I want a direct-wired matrix (array), a self-coded board or a fully-decoded keyboard? What physical size do I need? Does my application call for a thin keyboard or can I use a medium or high profile? Should I specify PC-board or steel-frame construction? Is weight a problem? Does the keyboard environment require oil or splash-proofing? Is mono-mode or multi-mode the way to go? What about buttons: styles, colors, arrangements? What about the human elements? Do I need tactile or audible feedback? Is N-key rollover called for, or can I use two-key rollover? Which special features, if any, are important to my application: Strobe? Data-key idle? Enable input? These, as well as other questions, can't be ignored.

Probably the first decision to be made concerns the keyboard/electronics interface. Three options are generally available: You can buy a collection of uncoded switches and build your own coding electronics; you can buy a collection of self-coded switches—such as the ferrite core, capacitor-coupled and photo-optical types—and build your own interface; or you can opt for a full keyboard system containing the keyswitch array, all coding electronics, plus circuitry for buffering, keyboard modes and other elected features. Which way to go depends on your technical expertise and the economics of building your own keyboard (as a percent of total system cost) versus buying one commercially.



The Bi-Pac, Controls Research's coaxial-spring keyswitch, is used in the company's calculator keyboard.

Actually, most requirements don't allow selection of an off-the-shelf keyboard. Variations in mounting, output codes, key configurations and other factors usually necessitate some customizing. This is why, as Clare-Pendar points out, major keyboard manufacturers have a "boiler-plate" specification, which can be used as a point of departure for a particular application. Specs can be as tight or as loose as a designer wants—but tight specs tend to increase prices.

Which code is best?

A few keyboard types have become fairly standard, at least as far as output codes and character assignments are concerned. These include the so-called data-preparation keyboard, which uses the eight-bit (plus parity) Extended Binary Coded Decimal Interchange Code (EBCDIC), and the so-called communications or data-entry keyboard, which uses the seven-bit (plus parity) American National Standard Code for Information Interchange (known as ANSI, ASCII, or USASCII).

These two types are sometimes confused: The data preparation board is used mostly for key-to-storage (tape, disc, cassette) and other key-punch applications, while the communications keyboard is popular for graphic and computer I/O terminals. As such, the key assignments for the two vary considerably—the basic communications (ANSI) keyboard separates the alpha sec-

tion from the numerals and symbols, while the data-preparation (EBCDIC) keyboard assigns numerals and symbols to the same keys as the alpha characters.

The ANSI code, now a Federal standard, is used in most of the keyboards sold today. This is because the code, when used with proper character-to-key assignments, permits key shifts—lower case to upper case, for example—by inversion of a single bit. Thus this logical-bit-pairing technique saves money, since only a simple inversion is needed to distinguish between shifted and unshifted modes.

The second most popular code, the EBCDIC, was developed to avoid nonlogical bit pairing in keypunch applications, where key assignments differ from those of the ANSI keyboard.

Other available codes include BCD, Baudot, hexadecimal and even custom types. But these are usually more expensive; so stick with the ASCII and EBCDIC, if you can.

Keyboards that assign one code for each key are said to operate in mono-mode. With more than one symbol, the keyboard operates in multimode—with two symbols for each key designated as dual-mode, three symbols as tri-mode and so on. For dual-mode, such as lower-case/upper-case operation, one shift key is required. For tri-mode both a shift and a control key must be operated. The shift key usually has alternate action. It may remain below the level of the unoperated keys to designate shift mode, or it may be lighted to designate a shift. Lighted keys are said to be easier to use since no key-position judgement is required.

The best operating mode (mono, dual, etc.) depends on available keyboard space, the number of characters needed and, as always, on economic considerations. For example, it may be less expensive to use a separate block of numeric keys and to operate in mono-mode than to assign the numerals to other keys and operate in dual-mode. Assigning multifunctions will save panel space, but throughput will be lowered, because an operator must press an additional control key.

As with most other keyboard characteristics, the method of producing the output code—and the output logic level as well—varies from manufacturer to manufacturer. Some manufacturers arrange the switches into an array in which an actuated switch shorts across a row and column. High-speed scanning circuitry then spots the closed switch and delivers a coded output.

Others use interim codes to address bipolar or MOS ROMs. And still other manufacturers use self-coded keys with diode matrices to connect the switches to the various bit lines. Except for logic levels, the results remain theoretically the same for all manufacturers: A unique output code for each keyswitch. But cost tradeoffs can be made.

Clare-Pendar offers this analysis: For three or four-level keyboards, or where non-bit-compatible codes are required, the minimum cost encoder is MOS. For simple mono or dual-mode keyboards with bit-compatible shifts, TTL decoding frequently offers a cost advantage.

N-key rollover—do you really need it?

The use of MOS has thrown new fuel on a long-simmering argument over the need for N-key rollover (NKRO). NKRO, an expression coined by Micro Switch, is a technique to prevent erroneous signal transmission during burst speed typing. When a key is struck, correct information in the proper sequence will be transmitted, even though any number of previously struck keys are still depressed. The technique is an extension of 2-key rollover (2KRO) in which an electronic interlock prevents errors when two keys are simultaneously depressed.

Some manufacturers say that 2KRO is sufficient for all applications. Others contend that the 10-to-15% price differential for NKRO discourages those who want it. And still others claim that their NKRO costs nothing.

Controls Research, for example, states: "Since the cost impact, on large keyboards at least, is really zero with the right encoder chip, NKRO should be specified."

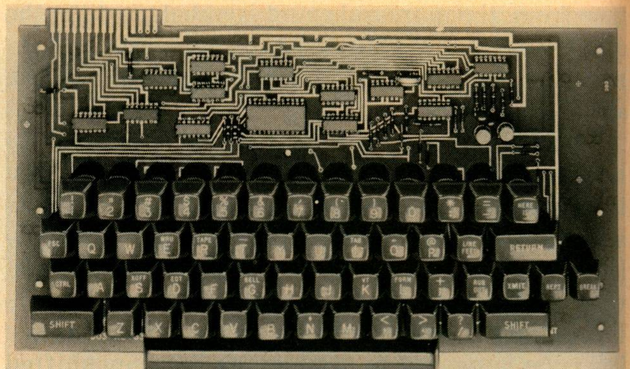
Raytheon says: "NKRO is an excellent feature in high-speed typing applications, since it substantially reduces the number of errors. However, for all other slow-speed and one-finger applications, 2KRO is quite adequate."

Studies by the Honeywell System and Research Div. for Micro Switch seem to substantiate the Raytheon statement. The studies show that about 30% fewer errors were made by high-speed typists with NKRO than with 2KRO.

Key Tronic proposes still another approach—selective N-key rollover, a combination of 2KRO and NKRO. The keyboard becomes locked after a fixed number of keys have been depressed—and they are held depressed. Key Tronic claims that this approach is less expensive than NKRO but just as advantageous.

We're all human

The NKRO debate is usually coupled with another highly controversial area—human factors. Perhaps the least understood of keyboard characteristics, such factors as tactile and audible feedback, switch and button feel and key



MOS-encoded keyboard (above) from Maxi-Switch uses a single DIP to provide any eight-bit code. Contrast this with the company's TTL scan encoded keyboard (above), which uses 14 DIPs to provide codes to 16 bits.

spacing and arrangements are the most hotly debated of all keyboard aspects. Micro Switch says that this aspect of keyboards has been of major concern for a decade.

Perhaps the most controversial parts of the Honeywell studies were these conclusions about displacement and keyboard operating characteristics:

- There is no advantage to having a snap or audible click in the keyboard operation.
- There is no difference in performance between stepped and sloped keyboards.
- Efficiency in the use of electric keyboards is greatest if force and displacement are held within the following limits: 0.9 to 5.3 ounces and 0.05 to 0.25 inches at the full travel of the keys.
- Most typists who are already familiar with electric keyboards should be able to bring their throughput to normal standards on an electronic keyboard within 10 days, usually less. (Throughput is defined as speed minus errors.)

Raytheon agrees: "If, by human factors, you mean keyswitch touch and feel, we think that causes too much concern. People will naturally feel more comfortable with a key feel that they have been accustomed to, but they also adjust rather rapidly to a different key feel, provided it doesn't have clearly objectionable characteristics."

However, Dialight states: "Human factors, next to reliability, are the most important considerations in the efficient, error-free and non-fatiguing operation of the keyboard."

Key Tronic sums up the human factor issues this way: "It seems that different segments of the market want different amounts of noise. Calculators are generally noiseless, whereas alphanumeric keyboards are produced with a small-to-moderate amount of noise. Also, key travel is continually being decreased. A number of years ago a travel of 0.187 inches was more or less an industry standard. As newer switches are being designed, the travel is being shortened. Calculators, for example, have essentially no travel compared to alphanumeric keyboards."

The dispute over the necessity of tactile feedback has resulted in four general schools of thought. The first tries to duplicate the feel of the electric typewriter, in which the key force increases with key displacement until the moment of switch closure. At that point, the force or pressure drops suddenly, accompanied by an audible signal. The second school opts for a constant pressure, usually light for most applications (an exception is keyboards for aircraft, where key pressures are kept relatively high to avoid accidental keying). The third school takes a middle road by increasing the key force with displacement but eliminating the sharp change at closure. The fourth school just ignores the entire situation.

The old problem: Build or buy?

One question that can't be ignored and must be answered right at the beginning of any keyboard specification is: Should I build my own? As might be expected, suppliers are split on this issue. The battle line is drawn, with those who make only keyswitches lined up on one side and those who make complete keyboards on the other. Sitting on the line—with a foot in each camp—are those suppliers who make both keyswitch modules and entire keyboards.

In general, consider building your own keyboard:

- If the quantity justifies the effort economically. Oak, for example, feels that if you need only 500 to 1000 keyboards a year, you can't build your own economically. However, if you're using five to ten thousand a year, you probably can afford to hire the expertise, if you don't already have it. In contrast, Clare-Pendar feels that you should consider building your own if

you need over 50,000 units a year—or less than 100.

- If you've got both the technical people and the facilities. The latter includes PC-board and semiconductor-device fabrication capabilities.
- If "standard" designs don't suit your purpose. For example, you may have an integrated design, with all major components mounted on a single PC board to eliminate interconnect costs. Discrete keyswitches can be mounted to this master board as well, thereby avoiding connectors, mounting hardware, etc.

The don't-build-your-own arguments run this way:

- It will invariably cost more to make your own keyboard than to buy one commercially. This is because designers tend to look at material and labor costs alone and to forget the hidden costs of engineering support, scrap, transportation, tooling and the like. Also forgotten are testing costs, which can be substantial—especially for large numbers of units that require automatic or semi-automatic test equipment.
- For encoded keyboards, a keyboard vendor will negotiate a large-quantity, annual contract with an LSI-chip supplier and pass the savings on to customers who buy modest quantities of keyboards.
- Even if a keyboard requirement is unique, it is still easier and cheaper to modify an existing keyboard. For example, in the case of the integrated design, a keyboard vendor can usually supply a larger PC board, or he can build on a customer-supplied board.

If you decide to buy, then what?

Cost will probably influence your build-or-buy decision more than any other factor. And, if you decide to buy, cost will be a key factor in selection. The plethora of competing suppliers has led to mergers, shakeouts, new products—and tumbling prices. All of which means it's a buyer's market. Let's take a quick look at what's being offered.

Micro Switch, everyone agrees, is the leading supplier of keyboards, with an estimated one-third of the total market. (The No. 2 position is not so well agreed on, being contested by a half dozen or so, of the 60 remaining manufacturers.)

Micro Switch offers its Hall-effect keyboards in practically any desired alphanumeric array and electronic configuration. The choice includes communications, data preparation and numeric keyboards, two-key or N-key rollover, multimode operation and MOS, TTL or DTL encoding.

Latest developments at Micro Switch include an across-the-board price reduction (the fourth in four years) of up to 13%; computerized quality-assurance testing, and both lighted and bi-level switches.

Controls Research offers modules or complete keyboards with either reed switches or its BI-PAC mechanism. Encoding can be either TTL/MSI scanning electronics or MOS with built-in NKRO. The former is used in the company's Model 7100, a 53-position keyboard with ANSI array and four-mode ASCII encoding. The 7100 sells for $49 in quantities of 5000. The latter is offered in a single, 40-pin MOS chip for coding up to 64 keys.

For those who wish to build their own board, Oak offers its 400 series, a gold-alloy crossbar keyswitch that sells for less than 30 cents in large quantities (500,000). Oak will supply any spring pressure or key stem (sloped or stepped) height, as well as a choice of switch configurations: SPST and DPST, N/O or N/C, and alternate-action.

No doubt spurred on by increasing mini-calculator sales, Oak has recently introduced its 415 series, a low-profile keyswitch. The 415 stands 0.415-inches high, including the key cap, and sells for 20 cents each (with key cap and legend) in quantities of one-million.

Cherry manufactures both switch modules and complete keyboards. Both reeds and gold crosspoint switches are offered in a variety of contact forms. The low-profile gold crosspoint, Cherry's latest switch, comes with straight or angled stem, momentary or alternate action, and it's lighted, if desired. The Form A, momentary-contact version sells for 29 cents in quantities of 250,000 and is said to have extremely long life.

Cherry's standard keyboards include 66-key, tri-mode ASCII, 55-key quad-mode ASCII and 12 and 16-key numeric boards. Scanning electronics are used to encode the switches. As with most manufacturers, Cherry offers custom designs and many special features.

Raytheon's line includes plug-in reed modules and its CAPSCAN keyboard (designed to replace the reed line). The CAPSCAN combines capacitive switching with TTL-compatible scanning logic and offers 2KRO or NKRO, splash-proofing, any operating force and, as an option, lighted key caps.

Key Tronic offers a full line of reed keyswitch modules and keyboards, as well as complete customizing service. The latter includes PC-board, injection molding, electronic assembly and tool and die capabilities.

Other features offered by Key Tronic include MOS encoding with selected repeat, stepped or sloped boards by rotating the key caps 180 degrees, selective NKRO, lighted alternate action,

and pROMs to change codes in the field.

Stackpole/Magsat offers a variety of keyswitches and keyboards designed around its digital switch module. The 1-ms pulse output (similar to Micro Switch's) allows Stackpole to use static encoders. Standard features include tactile/audible feedback; NKRO; shift, control and multimode keys; TTL-compatible output and strobe.

The latest Stackpole developments include a mode in which every key can be a repeat key without the need to depress a control key first and the LO-PRO, a new line of low-profile, mechanical keyswitches, designed for calculators and other low-throughput devices.

Clare-Pendar offers reed and gold crossbar keyswitches in various configurations. Individual switches are mounted on steel frames, as opposed to mounting on PC boards, so that the keyboard becomes a rigid structural member (Licon, Oak and others also use this construction). Also offered are alternate action; illuminated keytops; MOS encoders, including NKRO; three-color keytops; one, two or three poles, and IBM-Selectric-shape keytops.

Maxi-Switch has three different switch styles to choose from: the 1800 series keystrip, which uses a series of steel frames and glass reed contacts; the 2700 series individual glass reeds; and the 3100 series, a bifurcated gold-contact mechanical switch that sells for 21 cents in large quantities. The latter is Maxi-Switch's entry in the calculator market. Also offered are TTL or MOS encoders, multimode, two or N-key rollover and delayed strobe.

The increasing demand for low-cost keyboards for desktop and pocket calculators has proved a boon for those manufacturers offering wafer-thin and low-profile keyboards. These include Donnelly Mirrors; Datanetics, with its elastic diaphragm switch; Stacoswitch, with its new IP Series, a modular, mechanical-contact, multistation keyboard; and Wild Rover, with its TC Series of multiple-contact switches and boards. ■■

Need more information?

The companies and products cited in this report have, of necessity, received only cursory coverage. They've been selected for their illustrative, or in some cases, unique qualities. Companies not mentioned may offer similar products. Readers may wish to consult these manufacturers for further details:

Alco Electronic Products, Inc., 1551 Osgood St., N. Andover, Mass. 01845. (617) 685-4371. (John Smerigan, Product Manager) **Circle 400**

Automatic Electric Co., 400 N. Wolf Rd., Northlake, Ill. 60164. (312) 562-7100. **Circle 401**

The Capitol Machine and Switch Co., 87 Newtown Rd., Danbury, Conn. 06810. (203) 744-3300. (Arthur E. Wilson, Sales Manager) **Circle 402**

Cherry Electrical Products Corp., 3600 Sunset Ave., Waukegan, Ill. 60085. (312) 689-7600. (Peter Barthell) **Circle 403**

Chomerics, Inc., 77 Dragon Ct., Woburn, Mass. 01801. (617) 935-4850. (A. Klepper) **Circle 404**

Clare-Pendar Co., P.O. Box 785, Post Falls, Idaho 83854. (208) 773-4541. (Stephen F. Meyer, Marketing Manager) **Circle 405**

Colorado Instruments, 1 Park St., Broomfield, Colo. 80020. (303) 466-1881. (Walter Pounds, Keyboard Marketing Manager) **Circle 406**

Control Devices, Inc., 204 New Boston St., Woburn, Mass. 01801. (617) 935-1105. (Leo Gilson, Sales Manager) **Circle 407**

Controls Research Corp., 2100 S. Fairview, Santa Ana, Calif. 92704. (714) 557-7161. (Don Schulze, Product Sales Manager) **Circle 408**

Datanetics Corp., 18065 Euclid St., Fountain Valley, Calif. 92708. (714) 549-1191. (Joseph DeClue, Engineering Vice President) **Circle 409**

Dialight Corp., 60 Stewart Ave., Brooklyn, N.Y. 11237. (212) 497-7600. **Circle 410**

Donnelly Mirrors, Inc., 49 W. Third St., Holland, Mich. 49423. (616) 396-1441. (Dick Tierney, Marketing Manager) **Circle 411**

Elec-trol, Inc., 26477 N. Golden Valley Rd., Saugus, Calif. 91350. (805) 252-8330. (Ray Freed) **Circle 412**

Hathaway Instruments, Inc., 5250 E. Evans, Denver, Colo. 80201. (303) 756-8301. **Circle 413**

Hi-Tek Corp., 2220 S. Anne St., Santa Ana, Calif. 92704. (714) 540-3520. (Russ Williams, Marketing Manager) **Circle 414**

IDM Corp., P.O. Box 954, Hanover, N.H. 03755. (603) 643-2840. (Warren Loomis) **Circle 415**

ITT Telecommunications, P.O. Box 831, Corinth, Miss. 38834. (601) 286-6921. (John Jakubik, OEM Administrator) **Circle 416**

Ikor, Inc., Second Ave., N.W. Industrial Park, Burlington, Mass. 01803. (617) 272-4400. (Tom Wilbur) **Circle 417**

Industrial Electronics Engineers, Inc., 7740 Lemona Ave., Van Nuys, Calif. 91405. (213) 787-0311. **Circle 418**

Key Tronic Corp., Bldg. 14, Spokane Industrial Park, Spokane, Wash. 99216. (509) 924-9151. (John Deichman, Vice President—Technical) **Circle 419**

Lear Siegler, Inc., 3171 S. Bundy Dr., Santa Monica, Calif. 90406. (213) 391-7211. **Circle 420**

Licon Div., Illinois Tool Works Inc., 6615 Irving Park Rd., Chicago, Ill. 60634. (312) 282-4040. **Circle 421**

Litton ABS, OEM Products Div., 600 Washington Ave., Carlstadt, N.J. 07072. (201) 935-2200. (Frank Misiewicz) **Circle 422**

The Maxi-Switch Co., P.O. Box 4404, Minneapolis, Minn. 55421. (612) 529-7601. (Craig G. Stout, Sales Manager) **Circle 423**

Mechanical Enterprises, 5249 Duke St., Alexandria, Va. 22304. (703) 751-3030. **Circle 424**

Micro Switch, Div. of Honeywell, 11 W. Spring St., Freeport, Ill. 61032. (815) 232-1122. (Edward C. Leibig, Keyboard Marketing Manager) **Circle 425**

Milli-Switch Corp., 1400 Mill Creek, Gladwyne, Pa. 19035. (215) 642-9222. **Circle 426**

National Cash Register Co., Main and K Sts., Dayton, Ohio 45401. (513) 449-2000. **Circle 427**

Oak Industries Inc., Crystal Lake, Ill. 60014. (815) 459-5000. (P. M. Hassett, Vice President, Marketing) **Circle 428**

Raven Electronics Corp., Freeport Blvd., Reno, Nev. 89501. (702) 359-3700. **Circle 429**

Raytheon Co., Industrial Components Operation, 465 Centre St., Quincy, Mass. 02169. (617) 479-5300. (Frank D. Kennedy, Manager, Keyboards and Keyswitches) **Circle 430**

George Risk Industries, Inc., 802 S. Elm, Kimball, Neb. 69145. (308) 235-4645. (Tom Kelsey, Sales Manager) **Circle 431**

Stackpole Components Co., P.O. Box 14466, Raleigh, N.C. 27610. (919) 828-6201. (Robert H. Tillack, Product Manager, Keyboards and Keyswitches) **Circle 432**

Stacoswitch, Inc., 1139 Baker St., Costa Mesa, Calif. 92626. (714) 549-3041. (John Wardlaw, Marketing Services Manager) **Circle 433**

Symbolic Displays Inc., P.O. Box 4322, Irvine, Calif. 92664. (714) 546-0601. (William J. Lang, President) **Circle 434**

TEC, Inc., 9800 N. Oracle Rd., Tucson, Ariz. 85704. (602) 297-1111. **Circle 435**

Texas Instruments Inc., Control Products Div., 34 Forest St., Attleboro, Mass. 02703. (617) 222-2800. **Circle 436**

Transducer Systems, Inc., Eastern & Wyandott Rd., Willow Grove, Pa. 19090. (215) 657-0800.

Unimax, Ives Rd., Wallingford., Conn. 06492. (203) 269-8701. **Circle 437**

Western Digital Systems, 7100 Mesa Dr., Austin, Tex. 78731. (512) 453-8433. **Circle 438**

Wild Rover Corp., 97 Oak St., Norwood, N.J. 07648. (201) 768-8393. (Mike Gordon, Sales Manager) **Circle 439**