All the data inputs and outputs are TTL compatible. In addition the data outputs, strobe outputs and parity outputs can be inverted if necessary.

Additional features

The design shown here inherently incorporates the N-key lockout feature. Since the clock is inhibited once the first key is depressed, hitting any number of additional keys will have no effect on the encoder output until the first key is released.

The circuit also has inherent 2-key rollover. In this case, suppose key 1 is depressed, followed by key 2, and then key 1 is released. The circuit will give you the output for key 1, and when key 1 is released it will scan the ROM for key 2 and give you the correct output for it.

This circuit does not have N-key rollover. If more than two keys are depressed sequentially and then released, the chip will not remember the sequence. Adding memory and/or latching circuits will provide this feature if it is required.

The most critical parameters in the choice of MOS encoders are:

- ☐ storage capability
- ☐ the logic levels required
- ☐ maximum power consumption
- ☐ power supply levels
- ☐ lockout capability
- ☐ rollover capability
- ☐ allowable closed contact resistance
- ☐ allowable open contact resistance
- ☐ special logic function, such as parity, etc.

Because the coding for each key is performed by a single mask change during the manufacturing process, any keyboard encoding can easily be accomplished in the ROM. Summing all the advantages points to the MOS ROM as an almost ideal choice for the keyboard encoder function.

Keyboard considerations for design engineers

Don Arnett, DuWayne Pople
Micro Switch, Freeport, Ill.

Rugged, reliable and versatile describes today's data terminal keyboards. They are also colorful, complex and competitive. The designer contemplating the choice of keyboards for mainframe or remote terminal applications finds himself bedeviled by deadlines, bewildered by offerings and just a little bored by outrageous claims, to say the least.

Since the problems of keyboard selection are not simple, our objective is to offer a summary of major design considerations based on experience, application needs, and most frequently encountered trade-offs. (See also the KEYBOARD SELECTION GUIDE in the Sept. 1971 issue of **The Electronic Engineer**) We have kept in mind that many design aspects of any man-machine interface are influenced greatly by *de facto* practices and human emotions. Engineering objectivity has often proven to be secondary.

Many of us take keyboards for granted, in typewriters, adding machines, comptometers, courtroom stenographic devices, and telephones. We are, however, confining our discussion to electronic keyboards. We define an electronic keyboard as a man-machine interface consisting of several finger-operated key stations (usually 10 or more) that convert mechanical energy into coded electrical energy.

History

The history of the office typewriter holds many significant parallels for the data terminal designer. Credit for the first practical office typewriter is generally given to Christopher Sholes, an American, who invented his machine primarily for numbering book pages in 1867. No one is quite sure why Sholes created the QWERTYUIOP keyboard array. In 1873, Sholes sold his device to the Remington Co., which, among other things, produced sewing machines. It is, therefore, not hard to understand why Remington's 1873 office machine looked very much like a hefty Remington sewing machine, complete with flowered sides and a foot treadle for carriage return.

"Touch typing," which uses all 10 fingers, was invented by a man, Frank McGurrin, in the early 1880's. Even then, because so many people were already using the Sholes "standard array," it was easier to memorize the existing key layout than to convert to a more logical format. The same reasoning is applied today with an estimated 60 million Americans. The cost of conversion, in spite of the possible savings, has buried every attempt since Frank McGurrin won his first speed typing contest handily in 1888.

The manufacturers of electric typewriters solved one of the great keyboard problems—errors caused by "burst speed" typing. Burst speeds are easily attained when operators use both hands to type familiar digrams and trigrams such as "or," "the," "and," and the like. The operator can "type" so fast through touch typing procedures that one letter might be depressed before the preceding letter has been released, often producing erroneous output. The mechanical typewriters, reduced errors under these conditions by jamming the input arms. However, this jamming interfered with speed. The electric typewriter manufacturers solved the problem of burst speeds through electro-mechanical linkages and encoding bars with mechanical storage of characters.

The development pace in the electronic keyboard industry was much more rapid than that of the typewriter. In 1964, Micro Switch entered the keyboard industry with a mechanical encoding switch, which generated an 8-bit code by means of eight mechanical switch contacts. Then in 1966, dry reed contacts offered a considerable improvement over the mechanical switches. Encoding for the dry reed contacts was generally accomplished via a diode matrix. Keyboard requirements soon became more sophisticated with the rapid advancement in semiconductor technology and the production of more complex data terminals. Reliability and cost per function became paramount. In 1968, the first practical solid-state keyboard was introduced, employing the long known, but little utilized Hall-effect principle.

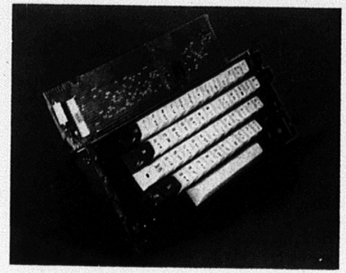
Each key in the Hall-effect keyboard held an integral circuit (IC) chip, which was actuated by passing magnets around it when the key was depressed. With no moving parts, the 1968 solid-state keyboard offered an amazing life span. In 1969, MOS encoding was added to the Hall-effect keyboard. In 1970, "n-key rollover" was accomplished by feeding pulsed input from the Hall-effect IC chip to the MOS encoder memory. It had taken 60 years to go from Sholes to the electric typewriter. Mechanical switch contacts to n-key rollover took six!

Industrial design

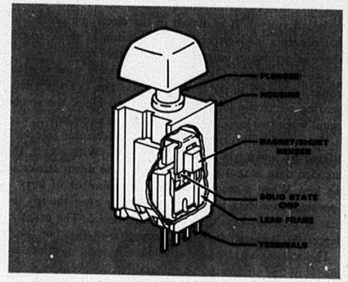
Appearance, one of the major factors in any operator-oriented product, plays an obvious role in keyboards with the design of the key tops—better known as buttons. The variety of shapes, sizes, colors, legends and materials available may be somewhat unbelievable to someone not directly involved with the keyboard industry during the last two years.

The industrial design of the system plays a less obvious but more important role in the mechanical design of the keyboard and vice versa. The considerations here are keyboard structural rigidity, envelope size, weight, modularity and mounting.

Obviously, we are trying to say that keyboard selection should be considered in every design state during the industrial design of the system. Experience has shown that the keyboard, all too often, is not considered until the later stages of system development. The inevitable result is higher cost.



This solid-state keyboard from Micro Switch combines MOS memory with n-key rollover technology. It provides an electronic shift lock, three operating modes, a lighted shift lock key, full 128 character set and ASCII coding.



A cutaway of the Hall-effect, solid-state key switch module shows the IC chip and its actuation by the magnets as the button is depressed.

Operating characteristics

A recent study completed for Micro Switch by Honeywell's Systems and Research Division produced four principal conclusions about displacement and related keyboard operating characteristics of importance to designers:

☐ Efficiency in the use of electric keyboards is greatest if force and displacement are held within the following limits: 0.9 to 5.3 oz and 0.05 to 0.25 in., at the full travel of the keys.

☐ 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.

☐ 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.

An interesting sidelight of numerous studies has been the long-argued value of contacting individual operators for their opinions about keyboards. The universal conclusions are that operators tended to favor their present machines over any changes, but that the adjustment to technological improvements was generally highly satisfactory if approached with proper psychology by managers.

Interlocks

The most expensive part of the data terminal keyboard operation is a input error. The error rate is a direct function of the interlock system built into the individual keyboard. These interlock systems range from a "no-interlock" arrangement through "2 key rollover" to "n-key roll-over."

A no-interlock arrangement would be a "bare bones" keyboard system. It is devoid of the electronic protection that prevents inadvertent 2-key operation at those speeds where an erroneous output would probably result.

Two-key rollover (2KRO) has been widely used in electronic keyboards in the last two years. The 2KRO is a self-clearing electronic interlock designed to block the strobe signal when two keys are depressed at the same time.

The n-key rollover (NKRO) is a new electronic interlock offered by few keyboard manufacturers. With NKRO, the encoded data is sent into memory on the down stroke of the key. When a second, third or any number of keys is operated, new data is sent into memory even though the first or previous keys may still be depressed. The order of depression is the all important item: first-in/first out.

The same study proved that good typists could attain speeds of 250 strokes/s! That speed is equivalent to 4 ms/stroke. The normal "burst speed" range had been assumed to be about 33 strokes/s. This was one reason why 2-key rollover resulted in a number of throughput errors. The operator was actually still holding the first key down when the third key of a trigram was depressed and the result was the skipping of the middle letter.

Switching principles

The single most significant component of an electronic keyboard is the key switch. The key switch is that element that converts mechanical motion into electronic energy. All the more exotic aspects of the keyboard may be perfect, but if the key fails to function or functions improperly, the keyboard is worthless.

Therefore, the designer's first concern is for the reliability of switching, and second, the marriage of the switch to its electrical interface. Picking a switch concept without regard to the associated electronics could result in higher costs and/or a marginal design.

There are two basic switching categories into which all electronic keyboards associated with data fit: mechanical contact switches, such as snap action basics, dry reeds, sliding or budding contacts; and solid-state devices, such as capacitance, inductance or cores, Hall-effect and photo-electric elements. With this variety to choose from, a complete test and evaluation program becomes expensive, if not prohibitive. At this point, a designer would be well advised to learn what potential vendors have to offer in the way of reliability data and field experience. Information obtained at this point could be of great assistance later on while evaluating electrical and environmental requirements and in reviewing quality assurance claims.

Reliability

The quality of a product is as integral to the design as its application. Our experience has demonstrated that the concept sells, but quality resells. Perhaps the best way to assure one's self of a quality product is to evaluate both the vendor and the design. Have you had previous experiences with the vendor? What reputation has the vendor earned in the marketplace? Will the vendor allow you to review quality-control procedures and in-process controls early in the program? Will you be permitted to witness production?

Basic design evaluations to substantiate design objectives and application needs should be performed by the keyboard supplier. These include keyboard performance under the expected environmental conditions of shock, vibration, temperature, humidity, radio frequency interference (rfi), corrosive atmospheres, and so forth. By outlining the above, we do not mean to suggest that the vendor should qualify each and every variation in keyboard array. The keyboard manufacturer's basic design evaluations should be all that is necessary to give a designer the confidence that is necessary.

It has already been observed that input error is the most expensive worry of data terminal keyboards. Input errors are not always generated by the operators. Electronic keyboards could generate a miss, especially if the switching device is a mechanical contact. Our definition of a "miss" is the failure of a switch to close and open once, and only once, for one complete cycle of the actuating member. Mechanical contacts, regardless of the packaging or operating mechanisms, can miss sporadically. No misses have ever been recorded with the Hall-effect switch. Facts are not available to us on the miss characteristics of other solid-state switching concepts.

Of nearly equal importance is the cost of a repair call. The two factors to consider are the actual costs of the service call and the less obvious cost of the system downtime. Service call estimates known to us range from $40 to $100 per visit. The obvious glow of the low initial cost may pale considerably in the glare of this simple arithmetic. Therefore, designers should face the facts that the keyboard should be able to meet the operating and service life of the terminal and, the reliability of all the components used in the keyboard, primarily the key switches, must be sufficient to meet the system requirements for servicing.

Conclusions

In the terminals market of the 70's, electronic keyboards are, and will continue to be, the primary means of data entry, information retrieval and information interchange. The single most important component in a keyboard is the key switch. The switch establishes the operator interface, which is all important for performance and throughput; and the basic reliability of the keyboard.

Electronic keyboards incorporate one of two principal switching methods: mechanical contacts and solid-state techniques. In our best judgment, the trend is toward solid-state applications because of increased reliability and overall lower costs.

Faced by the problems of reliability, interlock arrangements, encoding, quality, switching techniques, repair costs, on-line costs, essential features versus desirable features, it has been difficult to generalize the overall problem since each design problem presents unique requirements.

One can buy a keyboard for a data terminal today for under $100. One may also pay over $500 for a keyboard. Keyboard manufacturers offer general purpose off-the-shelf keyboards as well as many tailored to specific requirements. The purpose of this article has been to suggest a number of trade-offs, which will help the designer in his quest for the most suitable keyboard for his needs. ■

DATA COMMUNICATIONS PRODUCTS

PHOTOELECTRIC KEYBOARDS

The Series PK-200 uses photoelectric techniques to detect keyboard actuation. Operating life of the keys is 10^8 operations, and the lamps have a minimum life of 20,000 hours. Digitronics Corp., Albertson, N.Y. 11507.

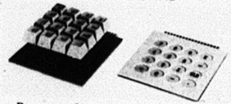
Circle Reader Service #275

TWO SPRING KEYBOARD

This line of keyboards uses the manufacturer's BI-PAC switch modules. These modules are about as simple as you can get; they consist of just two springs. The springs form two sets of parallel contacts, both of which are gold plated. Mechanical life of the contacts is greater than 50 million cycles, and bounce is less than 5 ms. Controls Research Corp., 2100 S. Fairview, Santa Ana, Calif. 92704.

Circle Reader Service #276

DIAPHRAGM KEYBOARD



Because of its unique mechanism, you can get these keyboards in standard configurations or with extremely low profiles. The switch itself uses a gold plated elastic diaphragm to contact a gold plated pad on a printed circuit card. Datanetics Corp., 18065 Euclid St., Fountain Valley, Calif. 92708.

Circle Reader Service #277

LSI/MOS KEYBOARD

Here's a unit that combines reed switch capsules with a MOS/LSI chip. Standard and custom codes are available as are a wide variety of enclosures. Clare Pendar Co., Box 785, Post Falls, Idaho 83854.

Circle Reader Service #278

MERCURY KEYBOARDS

These units have a mercury switching element that eliminates the need to compensate for contact bounce. Signal generation is accomplished by moving mercury in a sealed, flexible tube. Minimum life is spec'd at 25 million actuations. Mechanical Enterprises, Inc., 5249 Duke St., Alexandria, Virginia 22304.

Circle Reader Service #279

MAGNETIC CORE KEYBOARDS

The Series 550 keyboards use a magnetic core switching element to give you a completely electronic keyboard. The switch mechanism has a minimum life of 25 million operations. The keyboard comes with standard or custom coding and either single-, dual- or tri-mode configurations. Licon Division of Illinois Tool Works, 6615 West Irving Park Road, Chicago, Ill. 60634.

Circle Reader Service #280

REED SWITCH KEYBOARD

This series of keyboards uses a reed switch in combination with a "flying magnet" to provide a tactile feel closely resembling that of an electric typewriter. The keyboards are available in a variety of electrical and mechanical configurations to suit a broad range of requirements. Cherry Electrical Products Corp., 3600 Sunset Ave., Waukegan, Ill. 60085.

Circle Reader Service #281