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**SOLID STATE CONTROLS FOR THE
HARSH ENVIRONMENT — A
TECHNOLOGICAL BREAKTHROUGH**

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SOLID STATE CONTROLS FOR THE HARSH ENVIRONMENT

A Technological Breakthrough

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The design of products that must resist hostile environments can be divided into two general areas of concern; basic instrumentation and control interface. The paper describes a new solid state technology that virtually eliminates the major concerns of hostile environment or user abuse in control interface design. The discussion includes original design objectives and the market needs which are satisfied, a description of the technology and its application in control systems, as well as the environmental resistance features of systems using the technology.

PROBLEMS WITH EXISTING CONTROLS

Electromechanical controls cannot withstand harsh, hostile or unfriendly environments without special design consideration. Moving parts, contacts, connections, mountings and fragile elements cause premature malfunction and permanent failure if not protected from harsh environments, external disturbances and user abuse. In addition, it is always expensive -- and sometimes impossible or impractical -- to protect control devices. In fact, protection schemes usually impede proper control operation. Further, the action of most electromechanical controls, and the basic designs of others, introduce undesirable effects such as bounce, EMI, RFI and time delay into control systems. The need to suppress or eliminate these effects creates additional design and product expense.

Second, different types of electromechanical control components are usually designed by different manufacturers. As a result, there is little compatibility or operating similarity between them. The devices are designed to serve the use... not the user. Because of this, most control system designs serve the machine and few serve the operator to the extent that they should. And, as instrument and equipment designs go totally digital, it becomes increasingly difficult to design digital control systems that accommodate normal analog control motions of the human operator.

Third, present-day electromechanical devices cannot access the total capabilities of today's sophisticated electronic system. This is because the basic technologies in electromechanical control devices are fifty to one-hundred years old. They have not kept pace with the semiconductor technology in microprocessors, IC's, LSI's and so forth.

The result is that there have been few, if any, alternatives available to instrument or equipment designers. They have been forced to select slightly different sets of do-it-yourself control components and have built their own custom control systems, differentiating them as best they could with colors, sizes, or shapes.

Response to the problems of the harsh environment has been through the use of protective coverings, elaborate gasketing and the reduction of control elements. All of these "solutions" increase operator inconvenience and/or reduce the ability of the operator to access all the capabilities of the instrument or equipment being controlled.

SOLID STATE TOUCH CONTROLS

In response to this need, a new solid state control technology has been invented and commercially introduced. The proprietary technology is called Micro Proximity Sensing, and it can be applied to every manner of human control action except the voice. Therefore, it is now possible to replace every type of control device with a solid state equivalent, operated by the touch and motion of a finger. This totally electronic approach not only eliminates all mechanical motion and its accompanying problems, but also provides a new, integrated control system capability which will have a far-reaching impact on the design of most future electronic instrumentation.

The design objectives set by the developers of the Micro Proximity Sensing technology were straight-forward but extremely challenging. They were:

- Develop a solid state control technology which is on a technological level equivalent with the electronic systems it will control.
- Eliminate all mechanical motion and its attendant problems.
- Develop, simultaneously, a micro packaging technology to ensure a high-volume manufacturing cost structure comparable to the microprocessor.
- Develop an operator interfacing capability to support a system approach to the man/machine control interface market.

"SWITCH" CONTROLS

The TASA Micro Proximity Sensing technology is a method of control which combines the analog world of the human body with the digital world of solid state electronic design without the need for mechanical intervention. Though highly sophisticated, the technology is deceptively simple in its mechanical design. The touch pads are located on a substrate such as a p.c. board. (Figure 1)

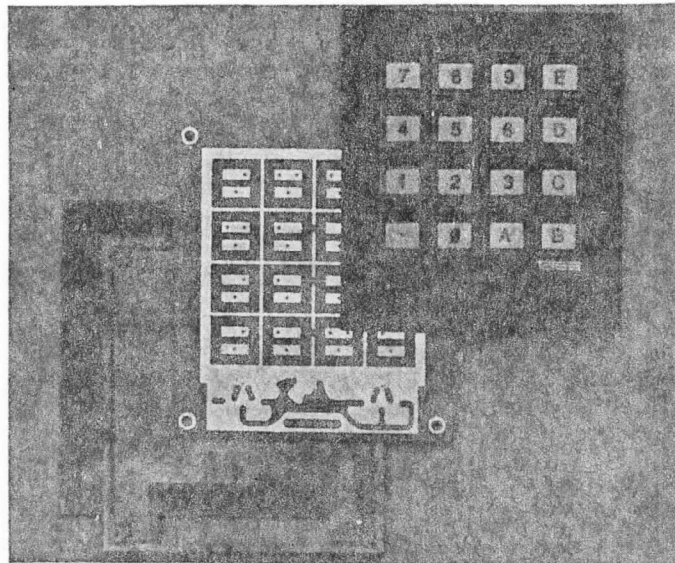


Figure 1

In the case of coded output panels, the sensors are placed in the desired locations, where switches would have been placed. The sensing electronics, a large scale hybrid, also occupies space on the p.c. board. The remainder of the laminated assembly consists of a shield which doubles as a mechanical stiffener, a plastic back cover, front graphics overlay, I/O pin connectors, and laminating adhesive. The overlay also acts as an excellent insulator between the operator's finger and the touch pad. In this way, the body is never in ohmic contact with the sensor, yet the sensor can detect the capacitive presence of the finger.

Binary Code Sensor Timing Diagram

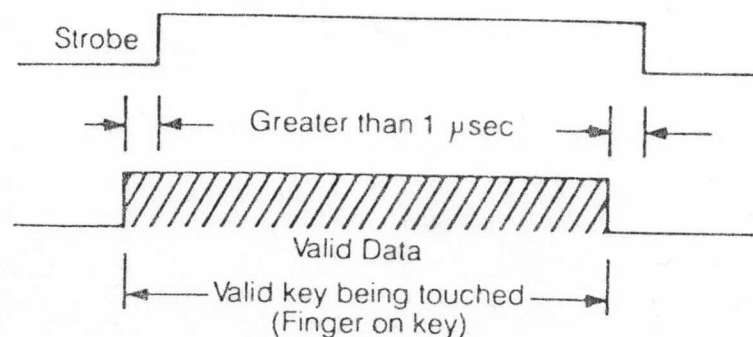


Figure 2

When a touch pad is activated, a distinctive change of electrical voltage levels occurs. (Figure 2) This is immediately reflected in a parallel coded output on the output lines. Approximately 1 microsecond after the data signal is valid and latched, a continuous, latched strobe appears on the remaining output line. All signals are TTL outputs, open collector, single load.

It is inherent in the operating principle of the TASA panels that the operator becomes an active component in the system. The electronic sensors will recognize the bare finger placed on the touch pad as valid entry instruction if the finger flattens to cover an area of approximately 3/16 of an inch (5mm) in diameter. When this occurs, the electrical operating state of the selected sensor changes from low (logic 0) to high (logic 1), passing through the preset threshold.

The sensing is accomplished in the LSI circuit, which also performs the encoding function. It provides a fully coded, bounce-free, parallel output and strobe for each activation. All control panels have two-key lockout capability for all binary encoded sensors. However, internal function can provide simultaneous two-key operations if required.

CONTINUOUS CONTROLS

To further implement its plan to develop solid state replacements for all mechanical controls, TASA introduced the Ferenstat™ controller. Essentially a solid state potentiometer, the Ferenstat sensors respond not only to the presence of the finger but also to its motion and direction. In addition to eliminating an analog-to-digital converter in many control applications, the Ferenstat eliminates mechanical wear caused by moving parts. Its sealed construction also makes it highly resistant to harsh environment and operator-inflicted damage.

The construction of the Ferenstat and its two-dimensional counterpart, the Touch-Graphic™ X-Y positioner are somewhat different from that of the "switch" panel. However, they are technologically the same and can be integrated into a single control system. The development of the Ferenstat involved a high degree of "human engineering". The heart of the design lies in a proprietary array of high-speed capacitive sensors, arranged in clusters. (Figure 3)

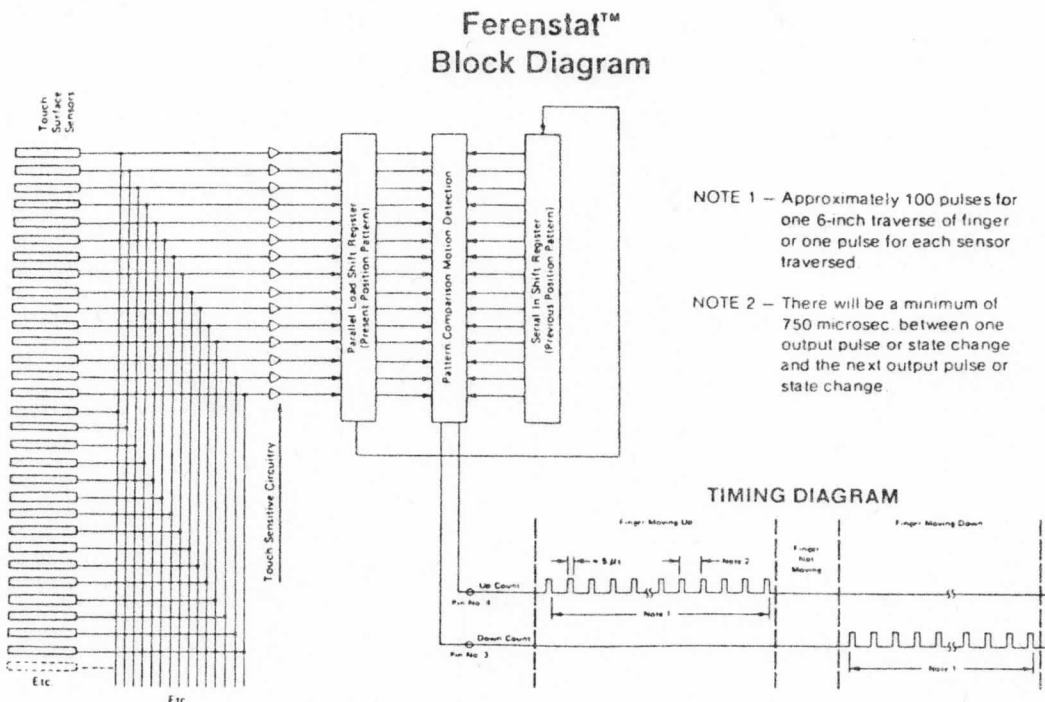


Figure 3

The detectors are able to function in close proximity to one another without interference and register the presence of a finger on the sealed, insulated surface. The total group of sensors are parallel-sampled at a rate which is fast enough to detect the fastest possible finger motion. Each sample clock loads the output of all sensors into a parallel load register. This so-called present register is then compared with the previous sensor sample to detect the direction and extent of motion.

The logic which accomplishes this compares the contents of each bit in the present register to adjacent bit positions of the previous sample. In so doing it is possible to detect that new sensors are activated indicating that motion occurred and the direction of that motion. The results of this count are then applied simultaneously on the digital output terminals which can drive and interface directly with the equipment being controlled.

The Ferenstat generates positive up/down pulses without regard to where the operator places his finger on the surface since the output is relative, not absolute position-oriented. Because of this, the device is not limited in resolution by its length, but only by the manner in which the design engineer chooses to use the pulse train. Further, with a simple software algorithm, the Ferenstat can be given a finger-velocity sensing capability so that its resolution becomes completely controllable by the operator, in real-time, by controlling finger speed. All features and descriptions of the Ferenstat apply also to the two-dimensional controller, Model 3600 Touch-Graphic, which provides both X and Y motion response. (Figure 4)

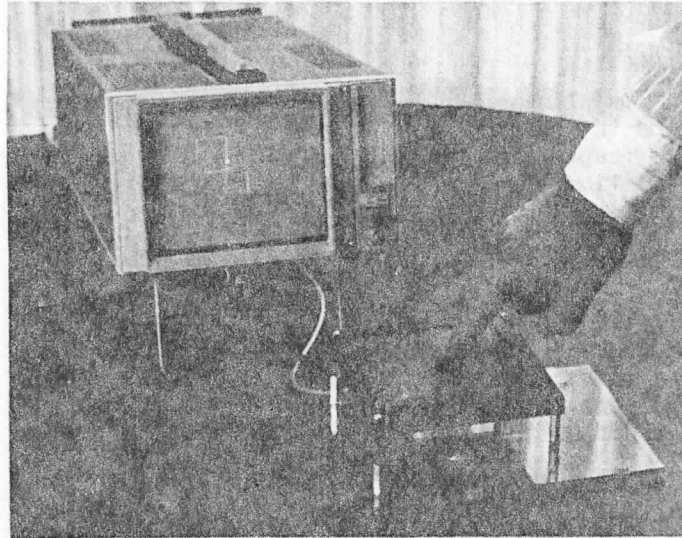


Figure 4

MULTI-FUNCTION, INTEGRATED KEYBOARDS AND CONTROLLERS

With both switch-type and continuous control functions now replaceable with solid state, touch technology, the logical next step was the integration of both into custom turnkey controllers and keyboards. Such integration is possible in vertical and horizontal directions. Vertical integration is the inclusion of additional control panel support requirements, such as indicator or backlighting, audible feedback, displays and drivers, etc., without changing the functional control capability. This is not only possible, but practical, particularly on high-volume products such as consumer products, by designing in these support requirements at the chip level, totally compatible with the chip-based sensing technology.

Horizontal integration is the addition or expansion of control functions and capability, such as combining a solid state ASCII keyboard with an X-Y Touch-Graphic controller in the same sealed keyboard. This type of horizontal integration or expansion is accomplished through the incorporation of additional custom or semi-custom chips, and even a full microprocessor. Under these conditions it is possible to offer plug-compatible computer data entry device replacement for most major electromechanical keyboards, plus adding the full graphics I/O capability, and all in a sealed, solid state panel approximately one-half inch thick. Additional optional or selectable features such as serial or parallel outputs, multi-character buffer, master/slave operation, etc. are also possible with this integrated approach.

DIRECT/TANGIBLE BENEFITS

- Operator control is strictly on a real-time basis; no mechanical intervention or delay.
- Greatly improved reliability and order of magnitude reduction of components. (Figure 5) Average control panel service life is at least 10 years or 50,000 power-on hours.
- Order of magnitude space and power reduction through proprietary micro packaging technology.

- Ruggedness of a sealed plastic "brick" (even the graphics is sealed). Highly resistant to acids, chemical, abrasions, etc.
- Compatible with all control panel technologies such as displays, audible and visual feedback, lenses, deadfronts, and backlighting.
- Immune to high levels of RFI, EMI, and electrostatic charge.
- Simple plug-in interface and simplified mounting arrangements.
- Extreme flexibility for future expansion and product family designs through "hidden" controls, inexpensive graphics and add-on overlays.

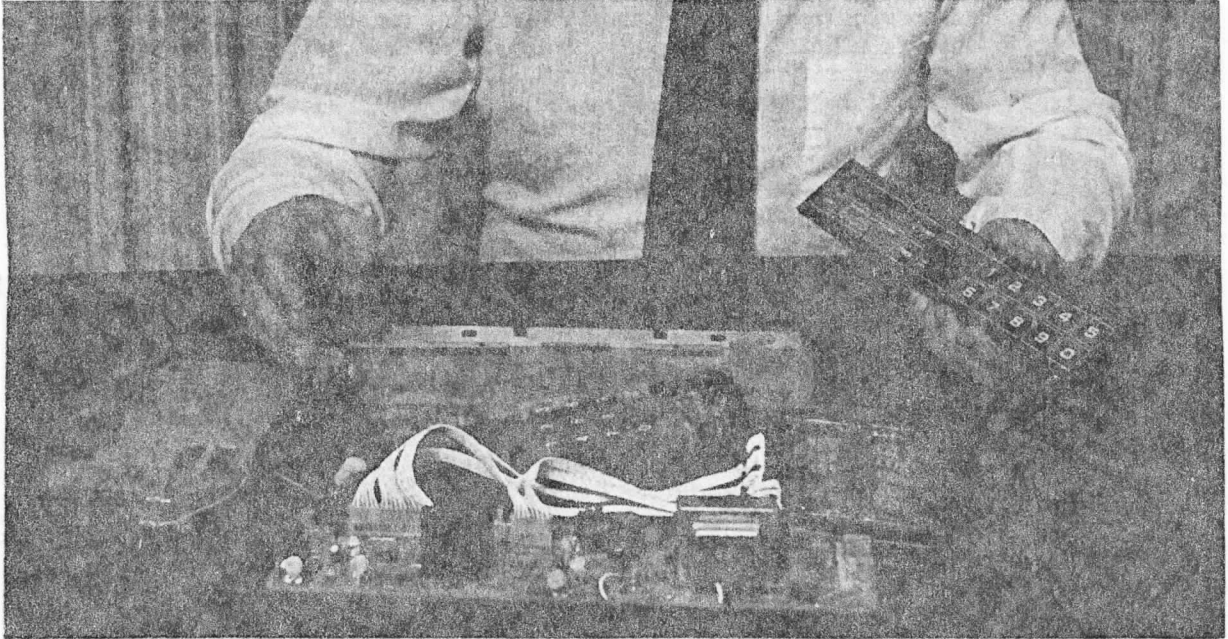


Figure 5

Figure 5 shows a solid state oven control panel (right), and on the left the membrane switch panel and over 230 support parts from a typical electromechanical oven controller.

INDIRECT/INTANGIBLE BENEFITS

- Future cost curve will parallel that of integrated circuits and will continue to decrease with increasing volume.
- Enhances product reliability image. Modular construction facilitates trouble-shooting. Panels may be factory repaired.
- Full graphics freedom ensures dynamic product image and increases its marketability.
- Fast turnaround to prototypes; relieves significant design engineering, product development time and dollars.
- Minimize inventory --- sub-systems can be issued to the production floor directly upon receipt -- no intervening assembly time.

LIMITATIONS/DISADVANTAGES

The few limitations or disadvantages to this new Micro Proximity Sensing technology are in highly specialized and limited applications.

The very thought of "change" and its impact on potential operators of equipment they design, can be viewed as a disadvantage by the less innovative engineer. However, activation of TASA's new technology is easily accomplished by any operator, no matter how unskilled. A simple touch or movement of the finger on the control device's surface is all that is required. To prevent erroneous output from accidental or improper activation, considerable human factors engineering has been designed into the final product. The result has been the creation of a new operator feeling about TASA's micro proximity controls, i.e., they are "friendly" and allow the first-time operator to "fail gracefully" while learning the optimum operating technique.

The absence of "tactile feel" has been mentioned as a disadvantage by some engineers. Except for a few very specific applications where other forms of operator feedback are not available, tactile motion is not an operator-specified requirement. Human factors studies, such as the one conducted for the U.S. Postal Service by the Microswitch Division of Honeywell (EDN Jan., 1970), long ago dissipated the myth that switch motion was mandatory. The simple truth is that the design engineer or product marketing manager has conveniently used the myth as a "market requirement" in order to maintain the status quo, and have not, until recently, offered their customers an alternative. In fact, one only has to look at the broadest operator spectrum of all, the consumer products market, to see the rapid acceptance of, (and strong preference for), "flat panel" interfaces. In the booming microwave oven market, for example, flat panel models totally dominate sales.

A few special application requirements may make it difficult or even impossible to achieve satisfactory performance from TASA's control technology; for example, underwater operation, metal bezels covering the majority of the control panel face, or operation through heavy gloves or mittens. Successful operation through medium and light gloves has been achieved.

APPLICATION

Application of the TASA Micro Proximity Sensing technology are virtually unlimited. Anywhere that human interface controls are required, the new solid state control technology can be applied -- more reliably, in a shorter time and usually far more economically.

Some of the major application areas are:

- Major appliances, home entertainment equipment, teletext/viewdata home information centers and other consumer equipment where the opportunity to add features and performance faster than cost can dramatically increase customer acceptance and market share.
- Controls for outdoor equipment subject to harsh environments such as public use equipment, vending machines, security systems and field equipment. Not only are solid state controls ideal for the harsh environment, but they are far more reliable from the point of view of continuous use since they have no moving parts to be damaged by over-zealous users or the environment.
- Multiple instrument designs in product line families. It's an easy matter to create new models with this technology by providing "hidden" controls and features which can be exposed for a new product model with a simple overlay graphics design change in 3-4 weeks turnaround time.
- High volume products, such as small appliances, electronic games, automobile controls, etc., where the controls are relatively simple and mass production can quickly drive the panel costs to very low levels. It becomes a throw-away piece when defective.
- Medical instruments. The fail-safe nature of chip-based electronics, the frequent necessity for real-time control, the inherent reliability, and the ability to withstand frequent sanitization procedures make the flat-surfaced, sealed control system ideal for this important area.
- Educational system, machine tool and process control equipment. (Figure 6) The "harsh environment" includes the occasional hostile action of the unskilled or uneducated operator, as well as the "electronically hostile" interferences such as EMI, RFI and electrostatic charge. The shielded, plastic-brick construction of TASA solid state panels makes them quite immune to these causes of malfunction.
- Graphics and computer-aided design systems, audio-visual and music control consoles, and high-resolution positioning equipment. These applications have one important operational characteristic in common, i.e., the need for real-time continuous control action where the close coupling of human judgement and control positioning or value-setting is a requirement.

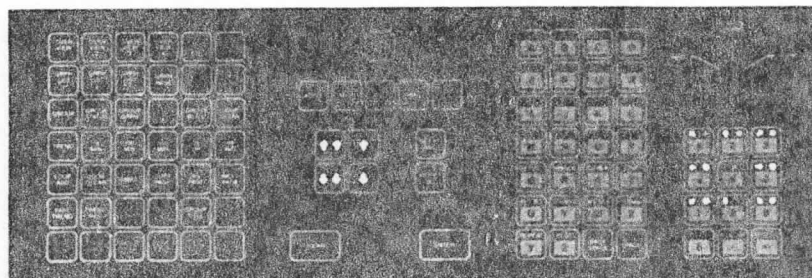


Figure 6

FUTURE RAMIFICATIONS

The application of Micro Proximity Sensing Technology is still in a stage of rapid evolution. As the leaders in the various markets become familiar with its full potential, some dramatic changes in human interfacing to machines and instruments are inevitable. One possible candidate for change -- a human interface with which we are all familiar and which, like most mechanical control interfaces, was designed to serve the machine and not the operator. In fact, it was designed to impede and confuse the operator, to salvage a machine design. As you've probably guessed, it's the QWERTY keyboard. Perhaps you've read the history of its origin.

To summarize the origin -- an inventor named Sholes developed a printing machine in the 1860's which he called the typewriter. After a few months' practice, his speed increased to the level that the type hammers began to jam, so he had a colleague's son-in-law, a school superintendant in Pennsylvania, figure out a format that would be so difficult it would not allow an experienced operator to exceed the speed limits of the machine. By widely separating those letters which most commonly follow each other in English words, staggering the key rows, as well as increasing key stroke movement and finger pressure requirements, he achieved a nearly perfect frustration of natural human learning skills. The coup de grace was to put the most-used letters under the weakest fingers and 65% of the activity on the left side of the keyboard. The result is that this wonderful communication machine can now be operated by only 3% of the U.S. population at a rate in excess of 60 words per minute and by less than 1/2% at the "high" rate of 120 words per minute.

With the advent of the electric typewriter, the QWERTY format became an even greater tragedy. The computer/microprocessor era makes it totally absurd. The memory and training required by the QWERTY design may be the largest single impediment to the rapid acceptance of the computer terminal by the non-typing executive and manager.

The solution to this problem may be found in some very clever work done by Professor Edward B. Montgomery of Dallas, Texas who has developed a format which reverses the difficulties of Sholes' layout. Montgomery's design anticipates the day when most children will learn how to spell and write only shortly before they are put in front of a computer.

Interaction with the Montgomery keyboard (Figure 7) requires only touching and stroking motions.

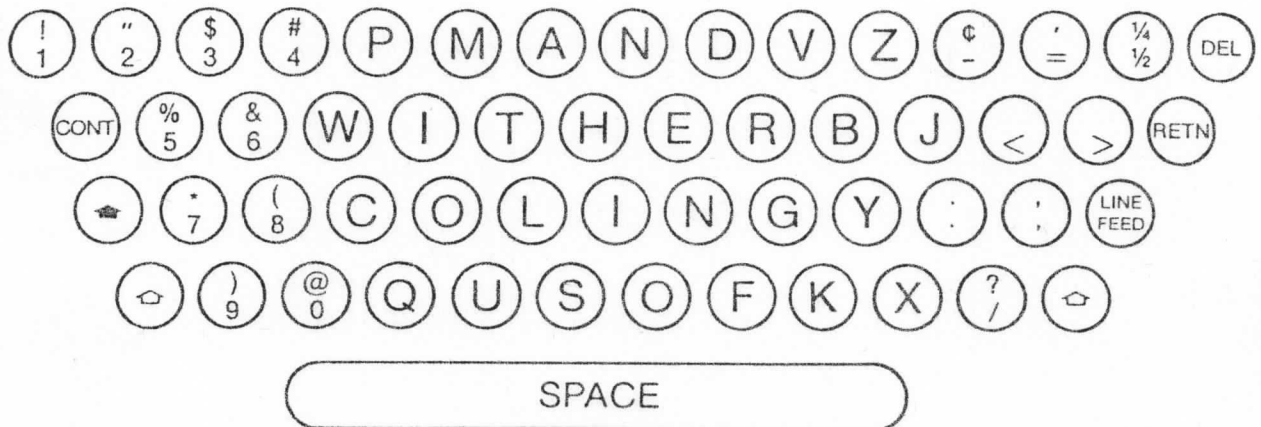


Figure 7

Montgomery's design is based on two related factors. Letters which appear in the most frequent sequences in English are adjacent to each other. Then, by using a keyboard which can be actuated by sliding across the key-points, 2, 3 or more letters may be entered with a single sweeping motion. The operator basically "writes" words as he draws a finger over the proper letters. Built on the inherent knowledge of spelling and writing, persons with no prior training should reach practical speeds in a few weeks and with fewer errors.

What is perhaps more exciting is that the keyboard is interesting, fun, and is far less fatiguing to use. It would also simultaneously teach the young user good spelling habits.

The solid state technology makes the Montgomery approach possible and, by incorporating audio feedback, successfully buries the age-old "sacred cow" of the control designers' world -- "tactile feel".

Other future developments and benefits which will evolve from solid state control technology include:

- Control system price/volume curves which will parallel those of similar technologies such as the microprocessor, digital watches and calculators.
- Economic feasibility for full-scale integration of control elements, displays and feedback devices at the chip level, even at moderately low volume.
- New, dynamic innovations in visual feedback and illumination, particularly in the area of thin-film technology.
- Wireless, remote control systems with very low power requirements.

CONCLUSION

Design engineers now have a solution to the problem of designing control systems to resist the hostile environment. It's a new solid state control technology that can cost-effectively replace any assembly of electromechanical control components. Further, the micro packaging technique employed in these systems can also be applied to integrate displays and visual indicators in sealed control panels. The Micro Proximity Sensing systems provide:

- High reliability
- Real-time control
- High immunity to external interferences, harsh environments and abusive use
- Weight, power and space savings
- More features and extensive design freedom
- Cost-effectiveness through significant savings in
 - unit cost
 - engineering time and dollars
 - service and repairability
 - reduction of purchasing, receiving, inventory and overhead costs

The technology has tremendous future potential in terms of existing applications, new developments and lower costs.

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