CAPACITANCE KEYBOARDS:

A Look Beyond Microprocessors

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Key Tronic

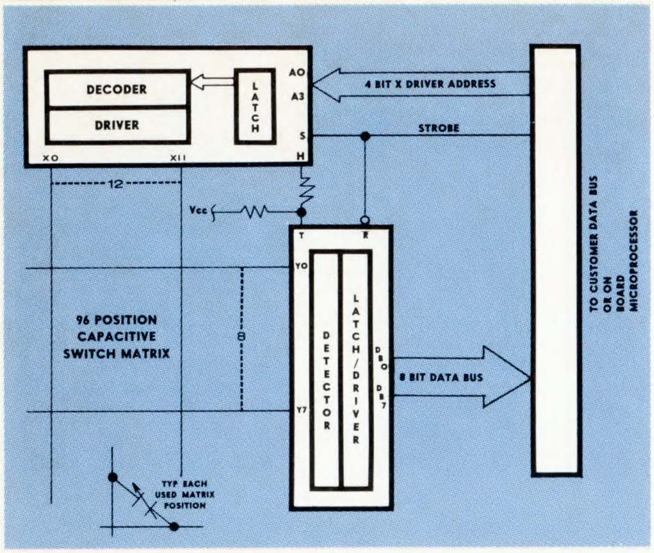
In selecting a keyboard, the first design decision is "which type of switch offers the lowest potential keyboard cost structure?" The choice is purely economic. The consideration is trading a relatively fixed electronic cost against the variable cost of some 70 to 80 switches. The least costly switches are the non-contacting capacitive or core designs, followed by contact types, and finally by active device (i.e., hall effect) types. However, the circuitry surrounding the switch matrix is inversely complex. Contact and active switches use only the simplest decoder/drivers while the non-contact passive switches require rather sophisticated drive/sense designs.

The decision process is straight forward. Pick the least costly switch element (comensarate with reliability requirements) at the expense of sophisticated surrounding circuitry. Material costs are inflationary by nature, while electronic costs are going down more than enough to offset and decrease the cost of surrounding circuitry. With "drive and sense" chip-sets such as the one featured later in this article, indications are that the cost structure of capacitive keyboards (in particular the non-soldered variety) are significantly lower than active device designs and approaching the cost of contact designs. Also, capacitive switch life is equal to the life of any solid-state designs and 5 to 10 times longer than the contact varieties. It's no wonder that capacitive keyboards are becoming dominant in today's terminal designs.

Attempts at making capacitive technology work had been going on for at least a decade when Key Tronic Corporation, in early 1974, married the foam capacitive pad to a current sensing detection scheme. The foam pad cured earlier problems with PCB/switch irregularities, but the real breakthrough came with the development of a detection scheme, insensitive to the stray capacitance characteristic of a dense trace and pad layout.

With grounding traces isolating individual sense lines, shunt capacitance often exceeds switch capacitance. The goal was a detector which caused little or no voltage change on the line being sensed (this, rendering the design insensitive to a "capative-voltage divider"). Of the six vendors currently offering capacitive keyboards, at least half of them possess monolithic detectors.

Once you've come to the conclusion that the non-soldered capacitive switch concept offers the lowest possible keyboard cost structure, the only significant question is: "Does the switch work?". We were always convinced that the switch was potentially as good as our life tests indicated, but the real proof came from the field. Results from over 500,000 keyboards and 5 years, demonstrated the reliability neces-



Key Tronic Corporation's two-chip set capacitive switch interface.

sary to achieve over 40,000 hour MTBFs.

Once past the analog problems of switch detection, validation and encoding are simply digital processes. It became evident to Key Tronic engineers over a year ago, that high volume pricing on the newly emerging single chip processors (8048 families) would fall below that of dedicated keyboard encoder chips in the near future. With this in mind, they set out to design a simple, economic interface between a capacitive-switch matrix and a microprocessor.

The original design (on paper) was a single 40 pin I^2L part. The I^2L technology allowed Key Tronic to mix the analog and digital portions of the design in a single chip. They soon found out that a lot of people were talking about I^2L but not many were willing to quote full custom programs at the time. Those that did were a long way from meeting competitive price and delivery goals.

This led them to the two chip solution. By using two 20-pin parts and a semi-custom design approach they were able to meet price and performance goals and retain in-house control over the design and layout of both parts. For those of you that have been involved in full custom MOS programs you can understand why this approach was a welcome opportunity.

Operation

In order to make efficient use of the microprocessor, it is necessary to be able to interrogate the entire matix very rapidly. This requires simultaneous examination of more than one key — ruling out the old method of decoders and multiplexers using a synchronous one-key-at-a-time interrogation system.

Since they were designing a bus-oriented processor interface chip, it made sense to use an 8 bit system. The final design of the detector chip (**Fig. 1)** allows examination of 8 keys at a time and provides latched data onto the output bus. With one pin dedicated to set the threshold current of the detectors and another for a latch reset/output enable, two for power and 16 for I/O, they were able to use a standard 20-pin package. This allows for easy automatic insertion and is significantly less expensive than 22- or 24-pin packages.

The decoder/drive chip is also packaged as a 20-pin part. With 4 address lines, one strobe, one latched output (for hysteresis control), and 2 for power they were left with 12 pins for matix drivers. This results in a 96 position matrix.

The original design criteria called for an 8 x 14 matrix or up to 112 keys. To make tradeoff decisions regarding 96 vs 112 keys (or 20- vs 22-pin package) they examined the last one hundred custom keyboard designs that they had done and found that only 26% had greater than 96-key positions. About one half of those had over 112 positions and many were large complex control applications that tend to be higher cost, low volume designs.

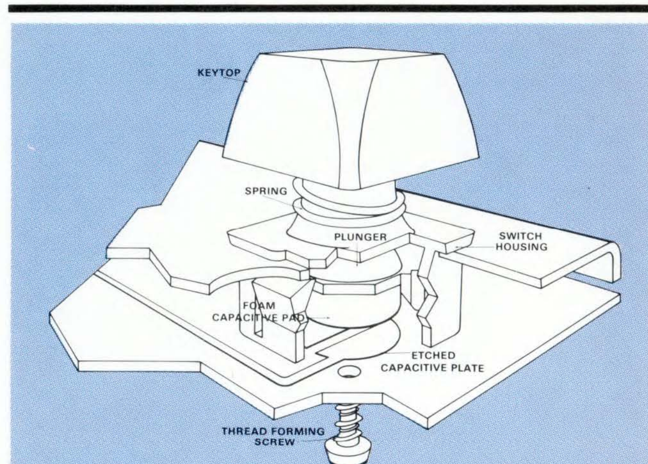
Based on this information and the fact that a second decoder driver chip could easily be added for applications greater than 96 keys they decided that 12 matrix drive lines and a 20-pin package was the best answer.

Since both chips utilize bipolar technologies they inherently offer good resistance to static damage. The matrix drive and sense lines of each device have been designed to exhibit low impedance to the supply in their normal mode of operation. Although ground line isolation is stil required between X and Y lines (to keep the key up capacitance as low as possible) this low impedance concept reduces the amount of grounding required and also provides good immunity to EMI. Care was taken with the design of both arts to eliminate the requirement for external termination or biasing networks on the matrix lines that have become a common part of most capacitive switch designs.

A typical interrogation would begin by bringing the strobe line low. This resets the data latches of the detector chip and places its output in a passively pulled up state. (The address lines can be brought in separately as shown in Figure 1 or can be tied to four of the data lines to provide a true 8 bit bi-directional bus). A four bit address is set up on A0-A3 to select a particular matrix drive line. The strobe line is brought high which latches the address into the decoder driver. The decoder then selects the appropriate line and drives it to a logic 1. After an internally created delay has expired the line driven to logic 0.

This 1 to 0 transition causes a current pulse on each Y sense line that has a key closed in common with the driven X line. The detector senses these current pulses and sets each corresponding latch output to a logic 0. The status of the 8 keys on the interrogated line can now be read from the data bus.

Using an Intel 8048 microprocessor, a complete 96-key interrogation can be accomplished in less than one half millisecond. This is particularly important if you're trying to input or output serial data with routines that cannot be interrupted for periodic matrix interrogation. It is even more important when using slower processors like the 8021.



Simple capacitive switch design.

The photograph shows a custom capacitive keyboard — features include 4 levels of coding, serial output, and LED lighted shift lock key. Seventy-five to eighty percent of the cost of the assembly is custom in nature — printed circuit board, metal plate, keytops, and masked microprocessor. Only the capacitive drive/sense circuitry, switches and some other parts are common to other designs.

Key Tronic has a standard that requires detection and validation of ten millisecond minimum key closures. If one scan requires 0.5 msec, and validation and output of each new key an additional 0.75 msec, the processor could be doing something else for 80% of the time. Thus, the keyboard would be scanned every 8 msec for a minimum of one half and a maximum of 2 msec (assuming only two new keys down per scan).

The customer can take advantage of this periodic interrogation idea by using a minimum interface keyboard and connecting it to the use of the processor in his system that is already handling other duties (the I/O for instance). The point is that it doesn't require a dedicated microprocessor to run the keyboard.

In summary, the most significant aspects of this new chip set are: (1) a comlete analog keyboard interface has been realized using two IC's and only 2 discreet parts (2) a 96 key capacitive switch fully encoded keyboard with auto repeat and serial output can be produced using only three IC's (2) with annual volumes of 25,000 per year, minimum interface capacitive switch keyboard pricing rapidly approaches that of hard contact switch arrays, while offering solid state reliability.

The primary significance of the "two-chip" design is that it allows the terminal designer to decide where the validation and encoding intelligence resides. In the simplest of terminals, a single processor can easily handle the keyboard in addition to its other duties. In multiprocessor designs, the keyboard and other "peripheral" activities may share a second, slower processor. Of course, complicated designs and those featuring detached keyboards, will often specify a single-chip processor residing on the keyboard. The point is that the 2-chip set allows the terminal designer the choice.

With capacitive keyboards as simple as a plate, switches, keytops, two to three chips, and a circuit board, it's not hard to understand why the capacitive keyboard is, by far, the most attractive combination of price and reliability."

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TOO HOT, TOO COLD, JUST RIGHT!

What type of switch offers the best overall keyboard cost structure? Ask the industry.

Capacitive designs offer switch cost structures equal to contact types, but with the reliability of a solid state switch. Furthermore, the economies of a non-soldered design more than offset the cost of simple 2-chip "drive and sense" circuitry.

Key Tronic offers you a 5 year record of reliability. With over 500 different designs and 500,000 keyboards in the field, we have the design expertise and manufacturing controls to make your keyboard selection 'just right'.

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