An Implementation of the TRON Keyboard

Sadao Tachibana
Physical Design Department, Engineering Division, Data Processing Group
Oki Electric Industry Co., Ltd., 3-1 Futaba-cho, Takasaki, 370 Japan

Ken Sakamura
Department of Information Science, Faculty of Science, University of Tokyo
Hongo,Tokyo,113 Japan

ABSTRACT

Two important objectives of keyboard input method are to gain speed and to lessen the fatigue of operators. The TRON keyboard layout is based on the data of the physical size of hands of Japanese. Firstly, physical placement of keytops which are easy to strike and causes less fatigue was determined using the data. Secondly, character frequencies in real documents was used to decide the final location of each character in the keyboard. In addition, an electronic pen is proposed for figure input.

Oki Electric Industry Co., Ltd. has built a TRON keyboard prototype on the basis of the TRON keyboard specifications. This paper discusses the design of the keyboard that reflects the TRON specifications for its implementation as a product.

Keywords: Input Device, Keyboard, Finger's Reach, Electronic Pen

1. TRON KEYBOARD DESIGN PHILOSOPHY

The paper [1] describes the design philosophy on the TRON keyboard in detail. This chapter describes its fundamental philosophy.

1.1 KEY LAYOUT

The TRON keyboard has a key layout based on measured data of the extent in which typical Japanese people can move their fingers, i.e., the "finger's reach." The data were collected from about 150 Japanese men and women 20 to 60 of age.

Each of the people tested had each of his/her fingers rested in the center of a key on a keyboard in its home position indicated on a jig, with the thumb and wrist fixed. The extent of each finger's reach was traced. Then the trace of the finger was digitized and extents of finger's reach grouped by percentage of the people tested were defined using contour lines. The 64 keys, beside a cursor key, required by the TRON keyboard were laid out to ensure that all of them should be accommodated toward the center of the trace. The key layout thus determined is shown in *Fig. 1*. The traces drawn in contour lines indicate extents of finger's reach by percentage of the samples: from the inner side, 80%, 60%, 40%, and 20%.

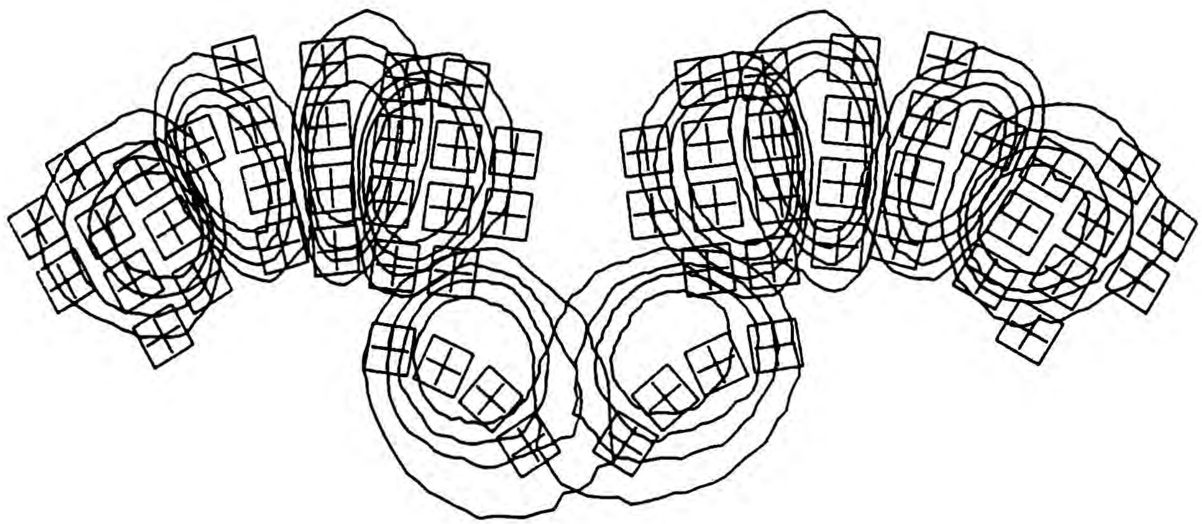

Fig. 1 Layout of TRON Keyboard

Table 1 shows measured data of the distance from the wrist to the tip of the middle finger (hand length). The difference in hand length between maximum and minimum is 51.5 mm; one size alone cannot offer a keyboard which matches all human hands. The TRON keyboard comes in three different sizes, S, M and L, to choose from according to the size of hands.

Table 1 Hand Length Data (in mm)

	Men	Women	Both
Average	194.2	178.9	189.5
Standard deviation	10.6	8.2	12.2
Maximum	218.0	200.0	218.0
Minimum	171.5	166.5	166.5

Consider the spacing between the forefinger and the middle finger in their home position as an example of analyzing the three different sizes. According to the measured data, the

width of the distal knuckles joint (the joint nearest to the fingertip) of the middle finger is 16.3 mm on the average, 1.3 mm in standard deviation, 19 mm maximum and 13 mm minimum. From these results, a value of about 16 mm (calculated value: 16.07 mm) is selected as the home-position spacing between the forefinger and the middle finger on the size-M TRON keyboard. The value 16 mm is increased by 2 for size L (18 mm) and decreased by 2 for size S (14 mm).

1.2 Three-dimensional Keyboard Layout

Again, the TRON keyboard should give the operator as little fatigue as possible, in addition to achieving enhanced input efficiency. In light of this, the aforementioned considerations to the two-dimensional keyboard layout alone were not satisfactory for the TRON keyboard and further analytical efforts were directed to its three-dimensional layout.

The basic concept is that the keyboard design should allow the operator to hit keys in a natural position where his/her muscles are free to develop the highest force. To this end, the keyboard is split into two clusters: the right-handed block and the left-handed block, arranged in a fan-shaped pattern with a certain spacing between them. The keyboard is angled at the front and on both sides. The front is extended to form a wrist support. What angles should be made along the three edges is detailed in the paper [2]. A keyboard layout based on these parameters is shown in *Fig. 2*. Also, the dimensions of the TRON keyboard (size M) defined from *Figs. 1* and *2* are given in *Fig. 3*.

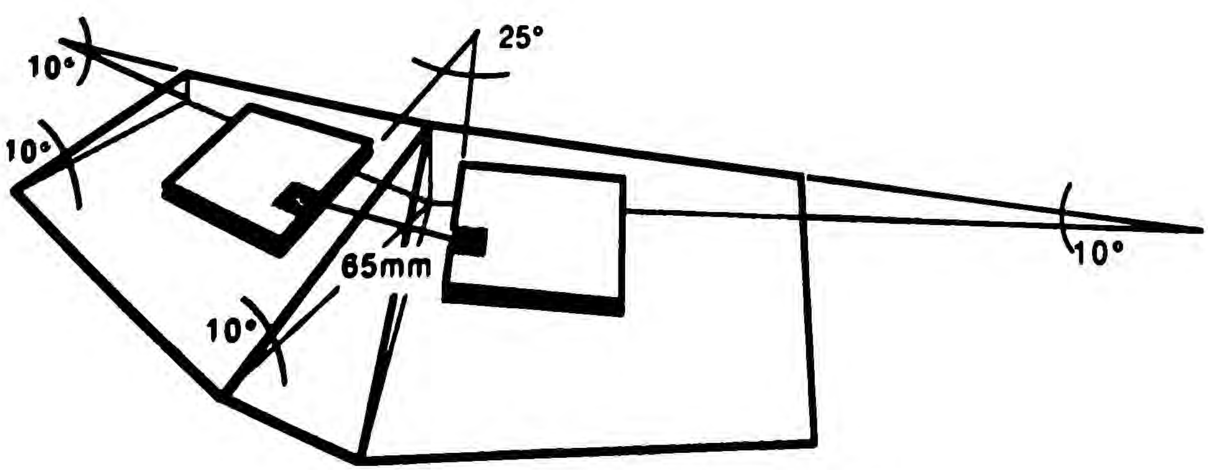

Fig. 2 Three-dimensional Layout of TRON Keyboard Unit

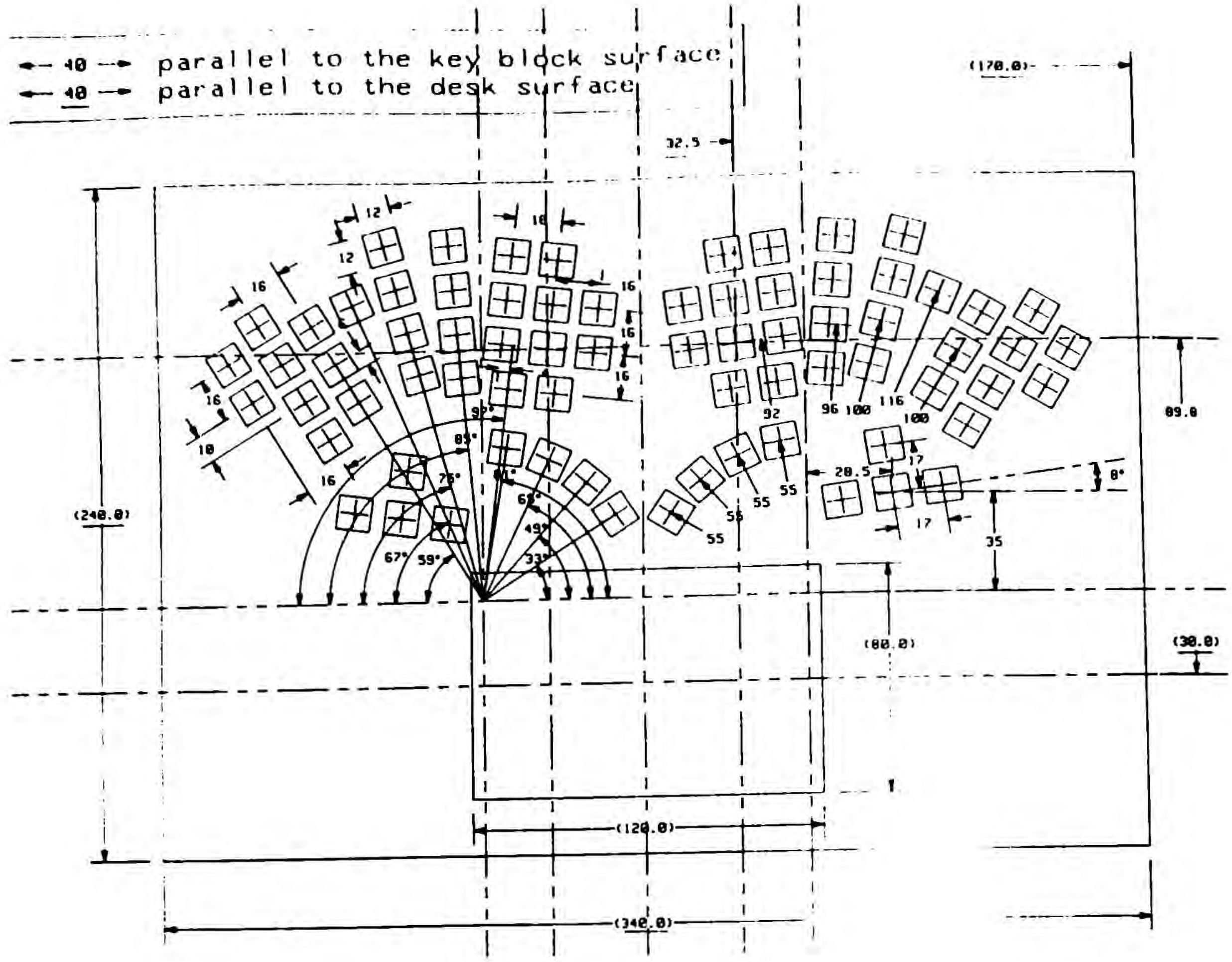

Fig. 3 Dimensions of TRON Keyboard (Size M

1.3 LOGICAL KEYBOARD LAYOUT

The term "logical keyboard layout" means what character should be assigned to what key.

With a view to selecting an optimum logical keyboard layout, a lot of Japanese sentences were analyzed to know the frequency of individual characters being used and that of a combination of two consecutive characters appearing. From the data thus obtained, the following four major design rules were derived for key assignment:

1) The middle row of the keyboard is most frequently used, followed by the upper row and the lower row in that order.

2) Two consecutive characters can be hit alternately from right to left and from left to right.

3) Chances of using the same finger repeatedly are reduced.

4) The frequency of the forefinger and the middle finger is increased, while that of the ring finger and the little finger is decreased.

The alphabetic characters are arranged in accordance with the Dvorak system. *Figs. 4* and *5* show layouts of the Japanese character keys and the alphabetic characters, respectively.

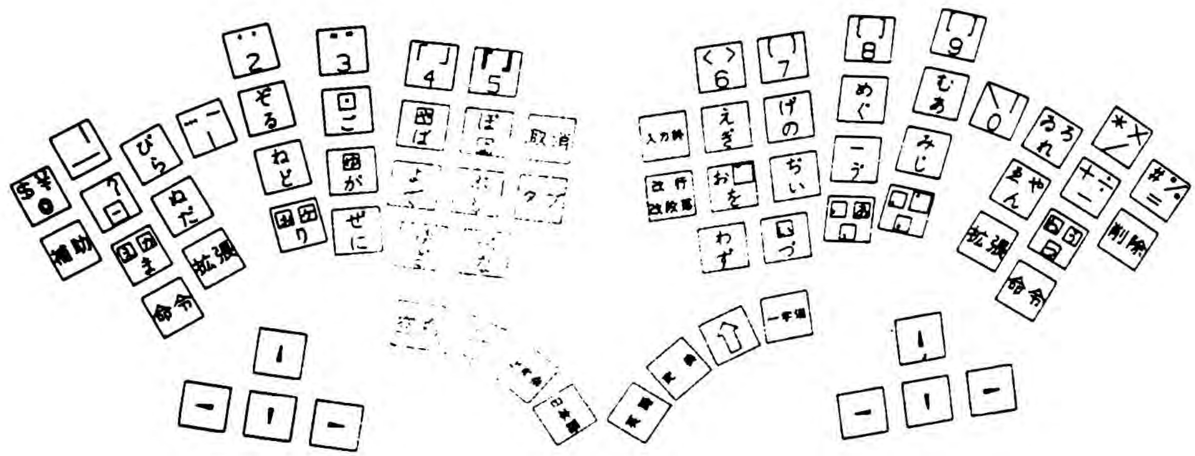

Fig. 4 Logical Layout of TRON Keyboard (in Japanese)

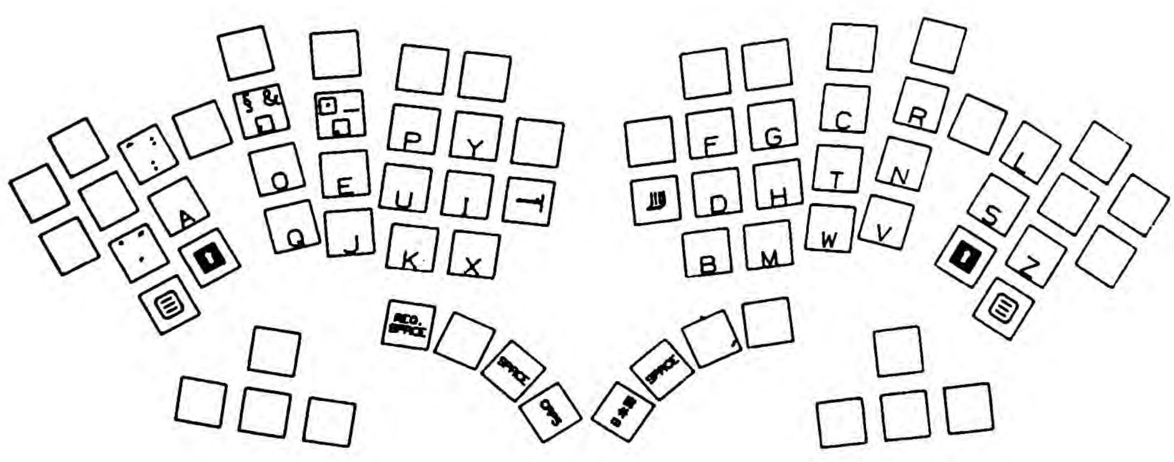

Fig. 5 Logical Layout of TRON Keyboard (in alphabetic)

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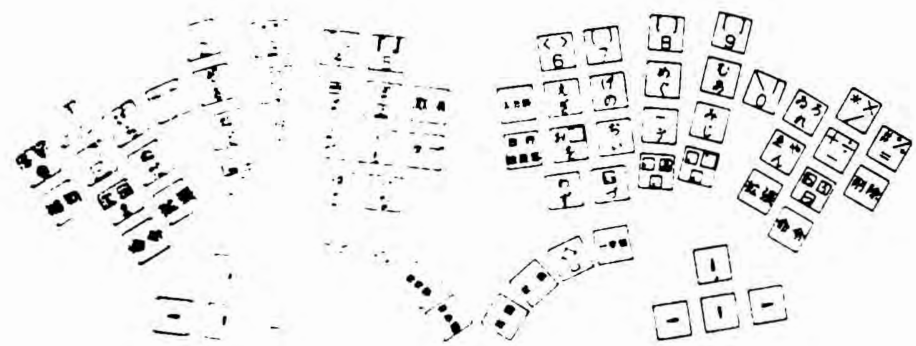

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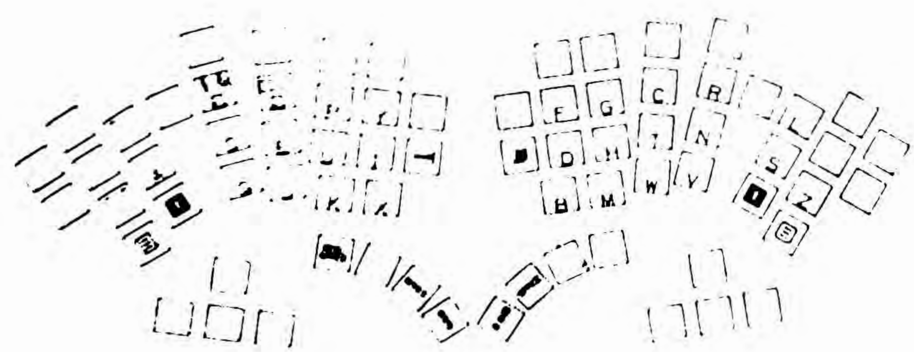

Fig. 5 Logical Layout of TRON Keyboard (in alphabetic)

1.4 TABLET

(a) Pointing Means

The term "pointing means" is defined as a means of pointing to a particular place on the computer CRT screen.

Today, pointing means such as a cursor key, tablet, mouse, track ball, and joystick are individually used according to applications. Of them, the cursor key is not a proper means in the bit map display environment. The mouse requires a certain area of space for its manipulation on the screen. It is difficult especially for a hand-held computer to work with the mouse. As a result of trade-off studies on all of such performance penalties, a small tablet with a pen has been selected as the pointing means of the TRON keyboard.

(b) Input Means for Handwritten Graphics

One may wish to insert figures, pictures and other graphics into a document being edited on the computer CRT screen for use in an office. This cannot be implemented without using a handwritten graphics input means. It may be a tool of the same type as the pointing means. A tablet with a pen has also been chosen with the TRON keyboard as it is considered most suitable for handwriting purposes.

(c) Electronic Pen

For purposes of this paper, the small tablet with a pen used for pointing or entering handwritten graphics is called an electronic pen. The electronic pen has a short-stroke switch at its top so that the operator may use it with the same feeing of manipulation as if it were an ordinary writing means. For the BTRON keyboard, the electronic pen has another switch — a modifier switch — on its body to get th menu frame on the CRT screen.

The tablet should have an appropriate size; if it is too large, it requires a larger space to move in or greater travelling distance of the operator's hand for pointing.

Where should the tablet be located? The TRON keyboard is designed to have its tablet placed in the front center of the board because the front is not considered to provide a useful space for any other purposes. Other important reasons are that, if the tablet is located there, it gives no handicap in the way of manipulation to the operator, right-handed or left-handed and its both sides can support the operator's wrists during keying operation.

2. DESIGN FOR THE TRON KEYBOARD IMPLEMENTATION

The following two basic guidelines underlay the actual designing of a TRON keyboard in accordance with the proposal (see Section 1):

- The dimensions (for size M) given in *Fig. 3* are critical and should not be significantly deviated.
- The resulting product should be compatible with the typical build and sensitivity of Japanese people.

2.1 DESIGN CONCEPT

Most conventional computers and keyboards give an impression of coolness. By contrast, the TRON keyboard should have something warm and a new aspect of value in its interface with human beings. In order to develop a futuristic image, the TRON keyboard basically should be thinner and smaller with curved or angled portions taken in its surface construction from both ergonomic and aesthetic points of view.

2.2 CONSIDERATIONS TO OUTLINE DIMENSIONS

The significant factors governing the final outline dimensions of the TRON keyboard unit are the outline dimensions and thickness of the key switch and tablet.

A key switch 14-16 square-mm, found popularly on most traditional keyboards, is too large for the key switch configuration with the keytop size specified in *Fig. 3*. This is especially true with the two central keys in the lowermost row. Since these two keys are tilted 10 degrees outwards, they come closer to each other as they approach the printed circuit board. Installing the two keys without mutual interference requires a special design strategy. In the present sample of design, the above problem was solved by using two face-to-face key switches each having a deviation of the center to that of the keytop. Further efforts are needed to develop appropriate key switches that can be commonly used with all sizes (S, M, and L) of the TRON keyboard.

The tablet should be designed to have as small outline dimensions as possible with a minimum thickness, while maintaining the effective area shown in *Fig. 3*. The surface of the keyboard cover has such a shape that the two curved areas — tilted 10 degrees to the right and left, and 10 degrees to the front — are partially scraped by the plane of the tablet tilted 10 degrees to the front. The ridge that is formed by the tablet plane should give no feeling of hostility to the operator when resting his/her wrists or hands on that plane during keying or pen-writing. This problem was analyzed by moving the tablet in both longitudinal and vertical directions, thereby determining its optimum position.

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Fig. 6 shows an outside view of the TRON keyboard (size M) developed this time, with its rough dimensions included. It maintains nearly the same dimensions as proposed in *Fig. 3*; only the significant difference is that its depth is about 30 mm greater toward the operator side. This change would not decrease the operability of the TRON keyboard, one of the primary targets in its development. Thus it may safely be concluded that the proposed three-dimensional keyboard configuration has successfully been achieved.

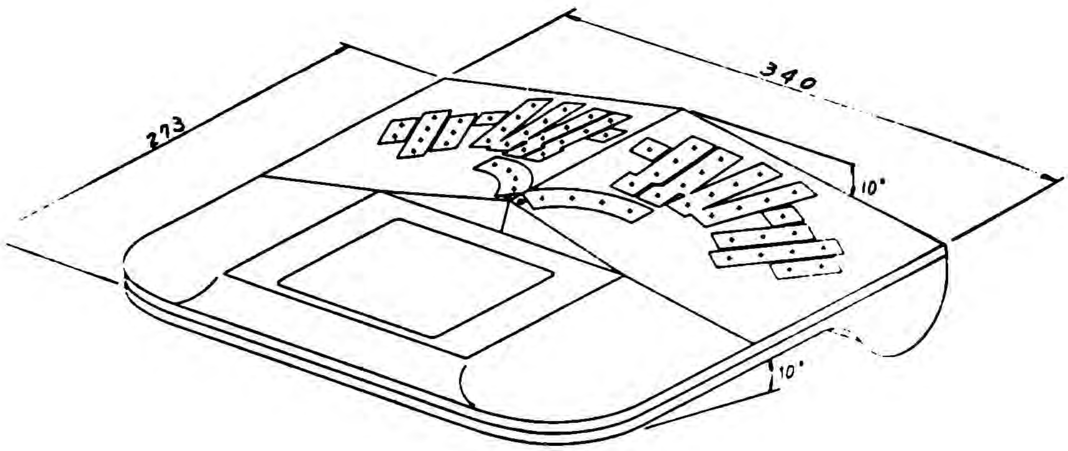


Fig. 6 Outside View of TRON Keyboard (Size M)

2.3 Size and Shape of Keytop

(a) Keytop size

The keys on the TRON keyboard (size M) shown in *Fig. 3* has a basic pitch of 16 mm. However, since the keys are laid out in a fan-shaped pattern in the right-handed and left-handed key blocks, there should be differences from keytop to keytop in the vertical and horizontal lengths that can be implemented depending on the position each key takes. With the character layout taken into account, a keytop size of 15 mm (vertical) by 12.5 mm (horizontal) has been selected, which is the largest possible and which can be installed in any position within the two key blocks.

The keytops in the lowermost row differ in both shape and size from any other key as shown in *Fig. 7*. They are trapezoid as viewed from the top and have a major width of 16.5 mm, about 4 mm greater than other keytops. The reasons for such keytop design are that they substantially are positioned in the lowermost row in the fan-shaped layout pattern and that they are manipulated by the thumb which is the thickest of the five fingers.

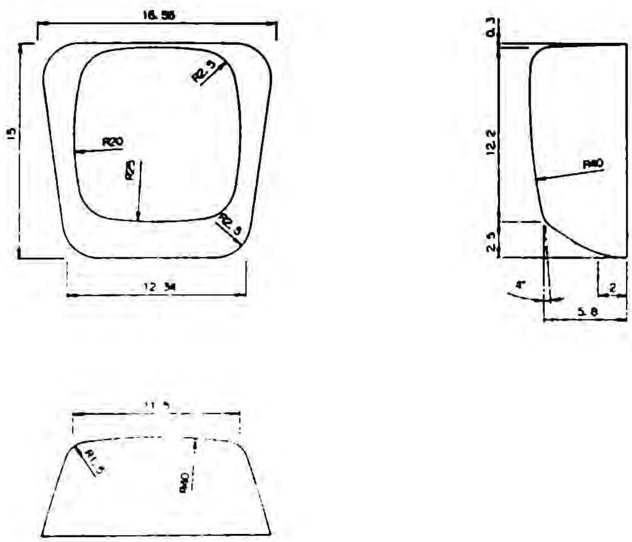


Fig. 7 Shape of Keytop Operated by the Thumb

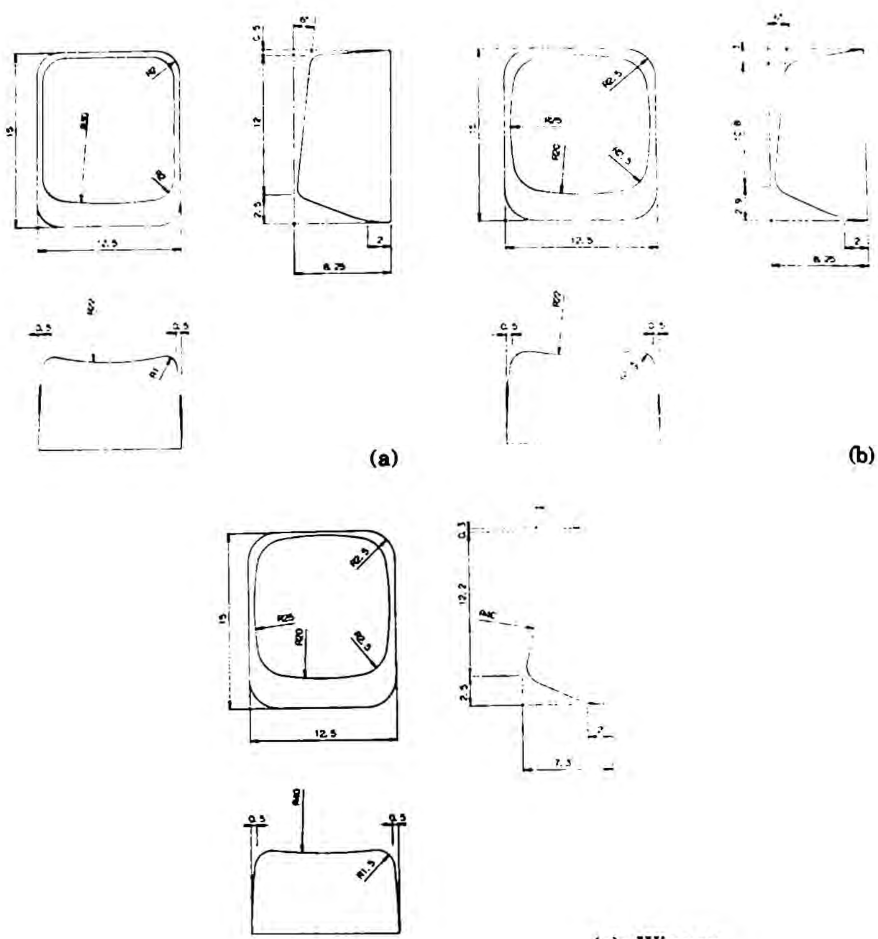
The wide keytop design provides the operator with good reliance when he/she is using the thumb to operate them.

(b) Keytop shape

Three keytop mock-ups were prepared: one cone-cape type and two cylindrical types as shown in *Fig. 8*.

These were analyzed from various points of view. The result has shown that the cone-cape type keytop with a larger radius of curvature (*Fig. 8(c)*) is the best in both affinity for the finger and operability.

The front side of the keytop is designed to have a length enough to accommodate for character printing requirements and to be angled so that the characters printed on it may be reasonably visible by the operator. The top side of the keytop has as large a



(a)

(b)

(c): Winner

Fig. 8 Shape of Keytop

character printed area as possible (23 mm by 11.5 mm) with its surrounding ridges configured with a maximum radius of curvature. This assures the finger of soft touch when it hits the keytop from any direction. With these features, the resulting keytop fully satisfies the two functional requirements — affinity for the finger and character indication — despite its considerably small size compared with conventional keytops.

3. CONCLUSION

We believe that a TRON keyboard (size M) having high operability and breakthrough in keytop shape and dimensions has successfully been developed. The Keyboard virtually follows the dimensions shown in *Figs. 2* and *3* with respect to the mechanical layout of keys and the three- dimensional configuration of the unit. We hope that many people will have chances of using the TRON keyboard and verifying its operability through their experience.

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