CRT display system for industrial process

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INTRODUCTION

Recently, in such industrial fields as steel mills, power stations, chemical plants, the use of computer control system is promoted more and more for improving productivity. For the efficient use of the computer control system various information generated in the form of characters, graphs, etc., must be accurately communicated with higher response between man and machine.

As for the data input to the computer, punched cards or punched tapes prepared by a puncher are transferred to the memory in the computer through a card reader or tape reader. In this case however, it is usually necessary to verify mispunches by another puncher or to detect rejects, and it is always difficult to change the information on the punched card or tape. Thus, this method expends additional man-hours.

Various output information from the control computer such as process condition and operation program are usually displayed on the panel which incorporates lamps or numeric display tubes. These methods, unfortunately, allow little flexibility for changing the displayed format or contents, and with a scale-up of the system, it proves difficult to display in a limited area.

For these reasons the development of such a new display system has become essential that can simplify input/output information needed for controlling industrial plants. There are already many kinds of CRT (Cathode-Ray Tube) displays developed as peripherals for supporting business computers, that can satisfy such requirements to some extent. These displays, however, are not always suitable to the industrial application with limited ambient temperature or reliability.

In some of these CRT displays a special deflection method or a special CRT are used, but these, consequently, mean the cost-up by the deflection circuits, and complexity of the control circuit, or maintenance. Further, although they might be used in an individual purpose, they are not always suitable when incorporated in various wide computer control application systems.

In consideration of survey results of users' requirement and also the shortcomings of conventional CRT as experienced when employed in actual industrial processes, we have developed a unique industrial process CRT display system by using standard television equipment. This compact display system can be produced at low cost, promising higher flexibility, easy maintainability, and higher reliability.

This device offers an easy man-to-machine communication in computer control systems requiring efficient construction over a wide field of applications. Such applications include the indication of each function of a mill line in steelmaking, the display of the operating state of many tracks in a railway marshalling yard, the display of circuit breaker operation at a power system substation, and so on.

This report concerns itself with the construction, performance, operational principle, special features, test result of the model, etc., relating to this new CRT display system.
CONSTRUCTION AND PERFORMANCE OF THE CRT DISPLAY SYSTEM

A block diagram of the CRT display system is shown in Figure 1. It consists of a common basic unit, and of the optional units that can be selected according to the application.

**Basic unit**

A basic unit consists of a keyboard, basic control circuits, and a viewer using monochrome or color CRT.

The keyboard includes character keys composed of alphanumeric and special letter, cursor keys which control cursor position, special keys used to write simple diagrams by combining a special pattern, color keys used to select a color from among seven, and control keys used to select such modes as "transmit," "receive," "write," or "print." For example, when an operator wishes to display characters on the viewer, he depresses the mode control key to "write" and after setting the cursor on the viewer by the cursor key at the desired initial position from which the display should begin, he selects a desired color by color key, then he may begin depressing the character keys.

The basic control unit consists of a display control circuit, a character control circuit, an interface circuit etc., and it treats several signals for displaying on the viewer as explained later. As the viewer, a commercially produced monochrome or color TV set is employed.

**Optional units**

Several optional units are available for displaying characters other than those on the standard keyboard, patterns or marks, or for displaying the same contents on plural displays and for communicating with the computer or file memories and others.

(a) Optional units for displaying trend graphs or special patterns. The trend graph unit is used to display physical quantity that changes with time, just like a pen recorder.

The special pattern unit is used for the display of histograms, work programs, skeltons of power distribution systems, etc.

(b) Interface units for the viewer.

When the same contents are displayed on several sets of viewers, a multiplexer specified for monochrome or color TV will be used. When the viewer is located remotely, and within the maximum distance of 2 km, a line buffer unit will be used.

(c) Interface units for input/output optional units.

Interface units are used when the previously described basic unit or optional units are connected to other input/output optional parts.

The CPU (central processing unit) interface, used when the display device is connected with a control computer (e.g. the HITAC-7250, HIDIC-500, HIDIC-100 or HIDIC-50, cassette controller), operates as a peripheral device. A cassette tape recorder, disk memory, or core memory is used as a file memory. As shown in Table I, the cassette tape recorder has the maximum value of memory capacity and the core memory has the maximum value of operation speed. An optimum selection among them will be made according to the application fields.

The communication controller is used when the display device is connected with a control computer through a communications network such as a telephone line. As an example of a communications controller, a DC communication system of 2,400 Baud has been

<table>
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<tr>
<th>Devices</th>
<th>Condition</th>
<th>Memory Capacity</th>
<th>Speed</th>
<th>Price Ratio</th>
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<tr>
<td>Cassette Tape</td>
<td>Off line</td>
<td>200 Frame/1 Tape</td>
<td>1-10 min/</td>
<td>1 - 0.1</td>
</tr>
<tr>
<td>Recorder</td>
<td></td>
<td></td>
<td>Frame</td>
<td></td>
</tr>
<tr>
<td>Disk Memory</td>
<td>On line</td>
<td>50 Frame/1 Disc.</td>
<td>50 min/1 Frame</td>
<td>1</td>
</tr>
<tr>
<td>Core Memory</td>
<td>On line</td>
<td>10 Frame/4 k word</td>
<td>1 min/1 Frame</td>
<td>1</td>
</tr>
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</table>
OPERATIONAL PRINCIPLE

Since a commercially produced standard TV receiver is used as the viewer, the operational principle of the display is almost the same as those of USA and Japanese Standard Television systems. Thus, a character is displayed as a set of bright (5 × 7) dots, on a CRT surface by giving a brightness control to the raster scanning electron beam having a horizontal synchronous frequency of 15.75 kHz and a vertical synchronous frequency of 60 Hz.

Display of characters and special patterns

Figure 2 shows a block diagram of the display principle. When the alphanumeric letter A, B and a special pattern I key is pushed down in that order, the keyboard will generate 8-bit code signals (the alphanumeric code is ASCII and the special pattern code is prepared exclusively for this device) which correspond with each character accordingly. Those codes are stored in a memory in the basic controller; therefore memory capacity is made to equal the maximum number of characters displayed on the viewer, and a storing position can be appointed by an underline (a cursor) displayed on the CRT viewer. The change of the cursor position is easy and arbitrary by cursor control keys.

If a character key is pushed, and the character is displayed above the cursor, the cursor moves automatically to the next position simultaneously. The memory has a capacity able to store the corresponding number of codes to that of the displayed characters on a viewer field (e.g., storing capacity of 40 characters × 13 lines = 520 characters).

When the electron beam of the viewer (TV) is scanned by the timing control circuit signal, the refresh memory sends out the stored code corresponding to the character control circuit.

By these transmitted codes and the signals showing the position of the scanning line given from the timing control circuit, the character control circuit generates a brightness control signal necessary for forming the characters or patterns.

As shown in Figure 3(a), the unit size of one character and a special pattern is determined by 8 dots timing in the horizontal direction and 14 scanning lines in the vertical direction. Thus, the unit size of a character is

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displayed in a method whereby brightness is controlled in a fixed position of an 8 × 14-dots matrix. The unit size of a special pattern has a usable limit in all 8 × 14 dots of a matrix, but a character has a usable range of 5 × 7 dots of a matrix. For this reason, when A, B and Γ are displayed, the control signal for each raster becomes as shown in Figure 3(b).

The brightness control signal, and the horizontal and vertical synchronous signals are mixed to form the video signal of a standard TV system at the driving unit, and the viewer’s CRT is driven by this video signal. Figure 4 is an example of such a driving signal.

**Color display**

For displaying colored characters, the specified color code must be stored in the memory. In this case, a color code storage method in which no extension of the memory format is necessary is adopted.

In this storage method, the remaining codes as spared from assigning a character or a special pattern is allocated for each color of, for example, red, green, blue and so on totaling 7 colors, and color identification of character is made from a color code using one character space at the head of the character codes. In this way, the memory stores the color code and the character code in series. This color code storing method offers the special features as shown in Table II.

**Trend graph display**

The deflection method of a CRT electron beam is divided into the two main classes of random positioning and raster scanning. With raster scanning, as a commercial standard TV set can be used, the cost of its CRT control circuit is much cheaper compared with the case of random positioning. But it was very difficult to display a continuous curve, and its programming was very troublesome. However we have succeeded in solving these problems and developed a new graphic display method by raster scanning as described subsequently.

(a) Principle of trend graph display.

The displaying of graphs by raster scanning will be divided into two categories. That is a curve approximation method and a piecewise linear approximation method. In the former, the error of approximation can be made as small as the viewer’s resolution.

However, it is not advantageous from the viewpoint of cost as it needs a large memory capacity with the increase of the number of line elements. Therefore a piecewise linear approximation is selected.

The piecewise linear approximation method is further classified into a dotted pattern or a brightness line method. In the dotted pattern method a curve is displayed by combining several special patterns as shown in Figure 5. The principle of operation of this method is identical to that in the special pattern as explained in the character displaying. Although this method is superior in histogram display etc., it requires, as its drawback, a large number of patterns for displaying a curve.

In the brightness line methods, when displaying a curve designated as (a) in Figure 6 by a broken line...
approximation, either method by analog or digital display can be selected. As shown in Figure 7, an analog displaying method of a trend graph is constructed by utilizing a digital-to-analog converter, multiplier, and voltage comparator.

Its operational principle is that voltage of a saw-toothed wave generator corresponding to a value of \( \Delta q_i/\Delta t_i \) is added to vertical deflection voltage corresponding to \( q_i - 1 \) (for an explanation of the symbols, see Figure 6) by the operational amplifier, and its output and horizontal deflection voltage proportionate to the present position of the electron beam are compared in the voltage comparator, and in coinciding timing, a brightness control signal is given to the CRT. Through these operations, the points marked with block dots on the line (b) in Figure 6 are brightened.

The digital method is practically the same in basic principle as the previously described analog method, except that operations of addition and comparison are effected by the digital value. That is, by adding an analog value corresponding to \( \Delta q_i/p \) to the final value of the last position, the bright spot is moved. By this method, the graph is displayed as shown in Figure 6(c).

(b) Comparison of display methods.

As a criterion of comparison, it is assumed that the memory capacity for the graph display area is as large as that of the character display area (40 characters \( \times 13 \) lines), and the number of patterns is 32. Especially, in the case of the brightness line method, it is assumed that a division unit of time axis has 7 rasters \( (p = 7) \), the resolution of spot position in the horizontal direction is half dot timing \( (n = 640) \) for a character dot, and a maximum value of \( \Delta q_0 \) is 255 dots (8 bits).

A comparison between these graph approximation methods obtained under these assumptions is shown in Table III. As the result, it was found that the digital method was most advantageous for its lower cost, and it was adopted. This method, however, has some limit in displaying the curve (i.e., an origin must be in the upper, left corner; the vertical direction must be selected in time axis and the total number of piecewise lines must be under 26). However, a unit length of each axis can be selected or changed by the software.

Thus far, operational principles of the character displaying, the color displaying and the trend graph displaying were described; however, further descriptions in these regards will be omitted.

OUTLINE OF MODEL SET

The block diagram of a model device is shown in Figure 8. This device is able to display characters, trend graphs, and their scales on the viewer of a monochrome or color TV receiver. In this chapter the control circuit of the trend graph displays will be given further explanation. As illustrated by using Figure 6 in the previous chapter, when a curve is approximated by broken lines, the vertical axis (time axis) is equally divided as a unit of \( p \)-rasters, and unit time \( t_{i+1} - t_i \), or a section is assigned to a piecewise line. In a section, a horizontal component of a piecewise line (for example \( q_0q_i \)) is equally divided by the number of \( p \), so that a line element of constant length of \( (q_i - q_0)/p \) is displayed while each raster is moving along a line (b) in Figure 6 in a former section. In the model device, the number of raster \( p \) is selected as \( p = 7 \) in order to limit the memory capacity. A memory capacity to accommodate the same word number as a divided number of time axis is necessary and in this case the memory capacity is 26 words. The data format of a word is constructed as shown in Figure 9, and the length of the line component

| TABLE III—Comparison of Several Graph Approximation Methods |
|-----------------|----------------|----------------|----------------|----------------|----------------|
| Approximation   | Memory capacity | General algebra | Piecewise       | Brightness     | No. of divisions |
| Method          | (Time axis)     | (Character)    | length          | line method    |                |
| Analog method   | \( \sum q_i \)  | 640 (2 characters) | 640 (640 dots) | 640 (640 dots) |               |
| Linear method   | \( \sum q_i \)  | 640 (2 characters) | 640 (640 dots) | 640 (640 dots) |               |
| Raster method   | \( \sum q_i \)  | 640 (2 characters) | 640 (640 dots) | 640 (640 dots) |               |

Legend: 1. Number of memory/line area frames
2. Number of vertical dots/line area frames
3. Number of raster/raster divisions
4. Piecewise number/total length of a raster
5. Number of bits in a pattern
6. Number of bits in a character
7. Number of bits for brightness control
8. Number of bits determining brightness control increment

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BINC

**INC**: Code indicating the increment

**B**: Display in "1"

Nondisplay in "0"

**S**: Negative slope in "1"

Positive slope in "0"

Figure 9—Data format of graph display

is indicated by the INC part. This memory is termed as "graph memory."

Circuit construction of the trend graph display is shown in Figure 10. As clear from the figure the hardwares consist of several circuits such as (1) a graph memory having a capacity of 26 words whereby the length of divided line elements in every piecewise line is stored; (2) a start and stop register that sets a start and stop point of the brightened line on the raster; (3) an arithmetic gate that calculates traveling distance of the brightened spot for every raster; (4) an increment counter, for coding the position of the brightened spot with digitals; (5) a coinciding circuit that effects coincidence between data of the start and the stop resistor and of the increment counter; (6) a brightness controller that generates the brightness control signal from the coincidence detectors; and (7) a timing controller that generates the timing and control signals.

Nextly, the function of the trend graph display circuit will be explained. In the example of a trend graph display shown in Figure 11, data with a length of line increment \( \Delta q = \Delta q_i, \Delta q' = \Delta q'_i (i = 1, 2, \ldots, 7) \) and so on are fed to the graph memory. By the control of the timing circuit, the contents of the memory is read out, and calculations of \( q_i = q_i - 1 + \Delta q, q_{i+1} = q_i + \Delta q \) and so on are carried out in the arithmetic gate, and their results are stored in the start and the stop register respectively. As soon as a brightened spot of raster \( r_i \) enters the graph display area, the increment counter starts counting, and when the contents of the counter coincides with the start register \( q_i \), the brightness control signal is generated from the brightness controller. This signal output is kept to generate until the contents of the counter coincide with the stop register \( q_i + \Delta q \). Just before the scanning spot moves to the next raster, \( r_{i+1} \), contents of the start register are replaced by \( q_i \), and contents of the stop register are replaced by \( q_i + \Delta q \) by transfer control between both registers (as shown in the upper column of Table IV).

When the slope of broken lines is in the negative sign with the time axis as a base, or in the case of reverse slope as \( \Delta q'_i \) as shown in Figure 11, information will be transferred between the two registers as shown in the lower side in Table IV.

Since the model device uses 6 bits for an appointment of the length of increment lines, the slope of the

![Figure 10—Circuit construction of graph display](image)

| Table IV: Transfer Control Between Registers According to Slope of Increment |
|-----------------------------|-----------------------------|-----------------------------|
| Slope of Increment | Contents of Start Register | Contents of Stop Register |
| +                | (Stop Register)            | (Stop Register) + (Increment) |
| -                | (Start Register) - (Increment) | (Start Register) |
piecewise line can be selected for an angle of 0 or ±63 against the vertical axis.

TESTED RESULTS

Some examples of character display are shown in Figure 12(A), and the trend graph display is shown in Figure 12(B). The test model performed reliably at an ambient temperature from 0 to 50°C with the source voltage of 100V, +10 percent, −15 percent.

SPECIAL FEATURES OF THE DISPLAY DEVICE

The newly developed display system offers the following special features:

(1) Higher reliability and simpler maintenance

Because the composing elements are carefully selected, this device can be used under severe conditions as familiarly encountered in usual electronic devices for industrial use, and this can operate normally even at ambient temperatures from 0 to 50°C and with voltage variance of 100V, +10 percent, −15 percent.

ICs and LSIs are used in the logic elements, in the character generator and in the main memory, and an all-solid-state transistor TV receiver is used as the viewer.

(2) Higher flexibility

The basic units such as keyboard, control unit, display unit, source unit, etc., of the device are designed as blocks and are incorporated into each standard unit of specific performance. These are easily expandable to meet various application requirements such as changes or additions of the characters, colors, trend graph performances, and such as enlargements of the display units and the printer units or such as an installation of long-distance transmission system between the control unit and the viewer unit, and so on.

(3) Lower cost

As the result of the development of a new control method, a commercially produced low-priced TV set can be used for the viewer. The use of IC or LSI has enabled the reduction of the component parts, as well as the easy manufacture and inspection since the control circuits were assembled into each unit of its specific performance. By optimum selection of options from many available here, a display system with a high performance per cost can be achieved.

EXAMPLES OF APPLICATION

As shown in Table V, this display system is enjoying many practical applications, and in the future, we anticipate its use in every industrial field.

CONCLUSION

This report has described a newly developed industrial process display system, and explains the construction
TABLE V—Examples of Industrial Applications

<table>
<thead>
<tr>
<th>Application Field</th>
<th>Objective (and system configuration)</th>
<th>Performance</th>
<th>Optional Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric power system</td>
<td>Synchronous power monitoring of complete system</td>
<td>1. Synchronous monitoring of process control 2. Data setting or adjustment 3. Monitoring of system diagram 4. Menus of switching change</td>
<td>15, 15, 15, 15, 15, 15</td>
</tr>
<tr>
<td>Electric power system</td>
<td>Supervisory control of terminal operation</td>
<td>1. Monitoring of distribution system 2. Display of terminal operation</td>
<td>15, 15, 15, 15, 15, 15</td>
</tr>
<tr>
<td>Chemical process</td>
<td>150 size of by-pass system</td>
<td>1. Data display 2. Display (line, graph, block, diagram, graph, display) 3. Display of system</td>
<td>15, 15, 15, 15, 15, 15</td>
</tr>
<tr>
<td>Management</td>
<td>Management interface of management information system</td>
<td>1. Information retrieval 2. Control of work progress 3. Management of personnel inventory</td>
<td>15, 15, 15, 15, 15, 15</td>
</tr>
</tbody>
</table>

and performance of the system as well as the operational principle and special features of character display, color display, and trend graph display.

From the test results of the prototype model, it has been proved that this device can operate normally as expected and demonstrate its every unique performance.

Presently, this type of display system is produced in quantity and is employed in various industrial fields.

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