The *Picturephone*® System:

Computer Access

By P. S. WARWICK and G. W. PHIPPS

(Manuscript received September 17, 1970)

The ability to use a Picturephone® *station set to display computer generated information will be provided as an additional feature of* Picturephone *service. The basic element in providing computer-access service is the display data set, which acts as the interface between the computer and the* Picturephone *station, converting* Touch-Tone® *multifrequency signals from the* Picturephone *station into digital characters for the computer and converting the computer output into a video signal for the station. The operation of the display data set and the influence of the* Picturephone *network characteristics on its design are described in this article.*

I. INTRODUCTION

In addition to face-to-face communication, *Picturephone* stations may be used to access computers. A *Picturephone* user can send information to the computer using his station's *Touch-Tone* dial, and messages from the computer can be displayed on the *Picturephone* screen. Since the computer-access capability is an alternate use of *Picturephone* service, and the objective is that it not interfere with nor increase the cost of face-to-face communication, the additional hardware required has been designed so that no modifications to the station or network are necessary.

II. COMPUTER-ACCESS SYSTEM

2.1 *Description*

The basic element of computer-access service is a display data set, which acts as an interface between the *Picturephone* network and a digital computer-communications system as shown in Fig. 1. To the *Picturephone* network, the display data set appears to be a standard *Picturephone* station. To the computer the display data set presents an interface like those used in standard voiceband data services.

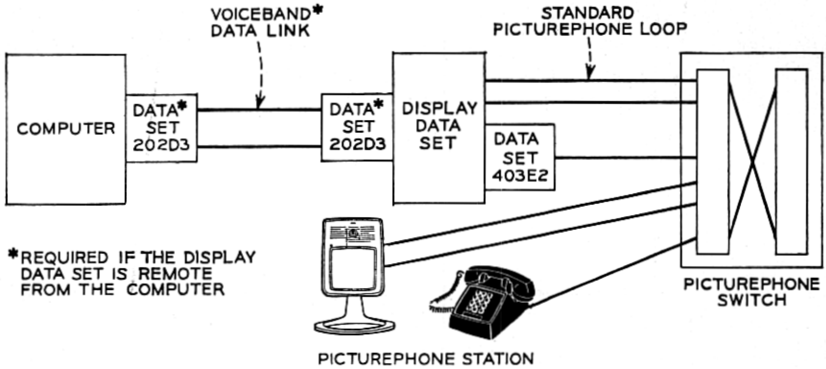

Fig. 1—*Picturephone* computer-access system.

The essential functions of the display data set are to convert *Touch-Tone* signals received from the station to ASCII* characters and transmit them to the computer, to store ASCII characters from the computer, and to convert them to the video signals required to refresh the display at the station.

Since the display data set is connected to the *Picturephone* network like a standard station, it must be located in a *Picturephone* service area. However, there are two alternatives for connecting the display data set to the computer. If the display data set is located at the computer site, a direct cable connection is made to the computer. If the display data set is located remote from the computer, a dedicated four-wire voiceband data link is used to connect the display data set and computer; thus, the computer can be located outside of the *Picturephone* service area. The economic decision affecting display data set location is governed by the cost trade-off between switched video facilities and dedicated voiceband facilities. The computer communicates with a distant display data set in ASCII asynchronously at a 1200-baud rate. If the computer and display data set are directly connected, communication is possible at either 1200 or 2400 bauds.

The display data set is connected over a standard *Picturephone* loop to a central office, private branch exchange, or key telephone system. On switched networks, it can be tested remotely from a test desk in the same manner as a *Picturephone* station.[1] A loopback feature in the display data set allows a test deskman to send *Touch-Tone* signals to the set and see them on the screen of his *Picturephone* set; this

* American National Standard Code for Information Interchange (ANS 3.4-1968).

provides a simple, but thorough, check of the display data set operation. For cases where a voiceband data link is used between the display data set and computer, trouble isolation procedures allow the test deskman to determine whether a trouble is in the *Picturephone* network, the display data set, or in the voiceband data link.

2.2 *Operation*

A user can place a call to the display data set and computer just as he would to another station. Referring to Fig. 2, a call to the computer is answered by the Bell System 403E2 Data Set.[2] The user can then send messages to the computer using his *Touch-Tone* dial. The 403E2 Data Set converts the *Touch-Tone* signals to contact closures, which the display data set converts to serial ASCII and transmits to the computer at 1200 or 2400 bauds.

The computer responds to messages from the user with blocks of up to 440 alphanumeric characters. These blocks are received asynchronously at 1200 or 2400 bauds and stored in a refresher memory. From these blocks, the display data set forms displays of 20 lines of up to 22 characters each. The content of the memory is converted to an interlaced video signal, mixed with synchronizing information, and transmitted to the station as required to refresh the display 30 times per second.

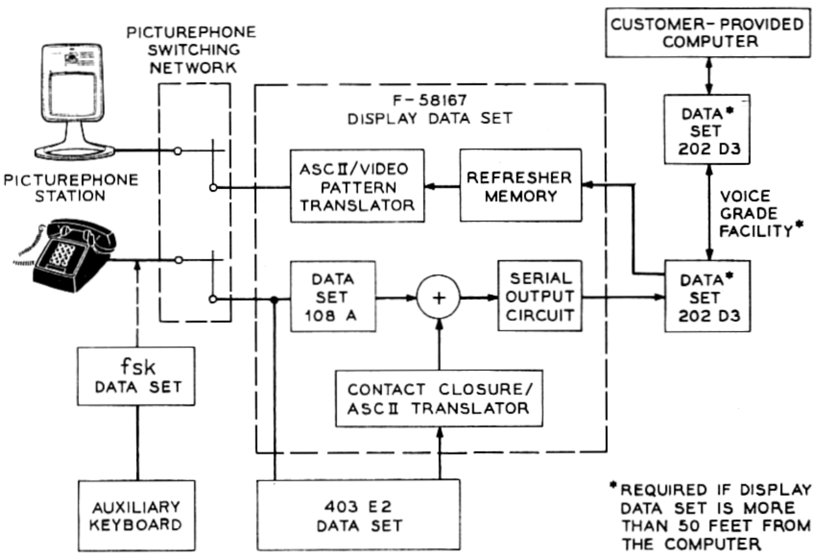

Fig. 2—*Picturephone* computer-access system block diagram.

Figures 3 and 4 show sample displays on a *Picturephone* set. The display data set can generate 60 alphanumeric characters and 16 graph characters; these are shown in Fig. 5. The graticule is displayed whenever any graph characters are shown.

For editing displays, the user has the option of using an alphanumeric keyboard and a frequency shift keying data set (such as the Bell System 113A Data Set) in conjunction with his *Picturephone* station. When this is done, 110-baud serial ASCII signals from the station are received by the Bell System 108A Data Set[3] (See Fig. 2) and speed-converted to 1200 or 2400 bauds before being sent to the computer. With the display data set in the edit mode, an alphanumeric keyboard can be used to modify the contents of the refresher memory. A movable blinking cursor, which marks the location of the next character to be written in the memory, is displayed in the edit mode to aid the user in altering displays. While in the edit mode, characters received from the keyboard are used only to update the display data

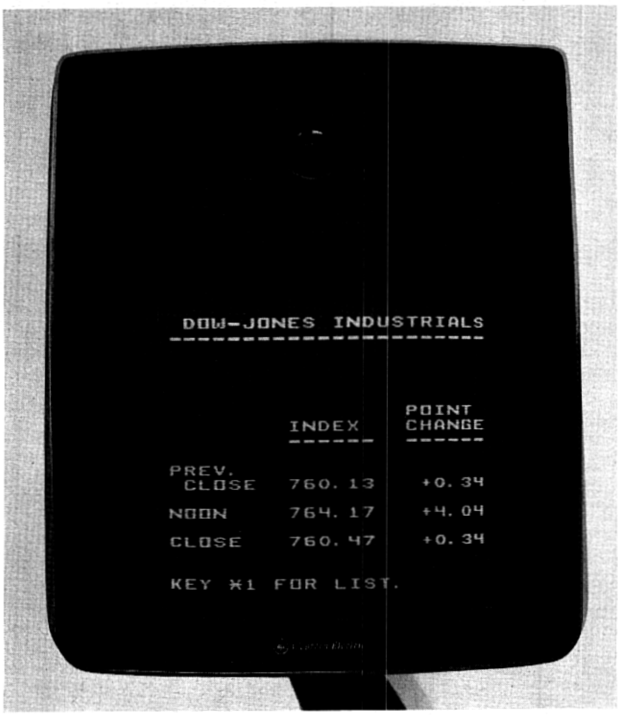

Fig. 3—Typical alphanumeric display.

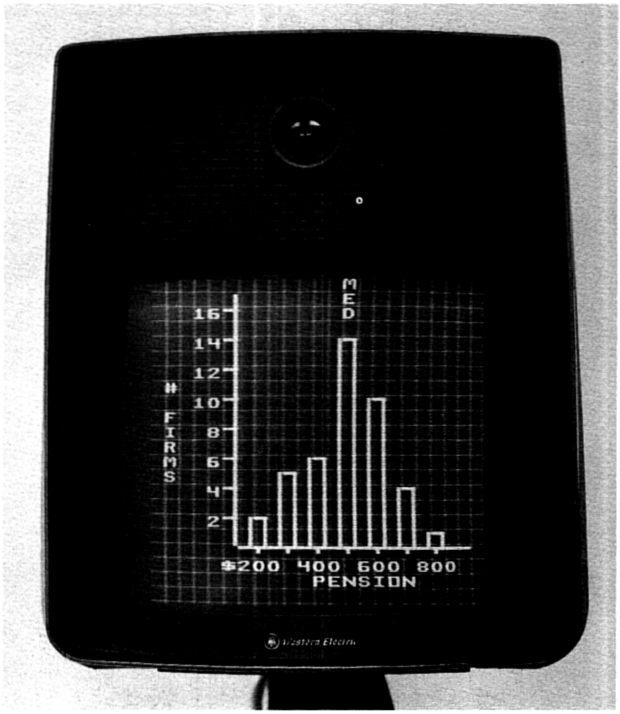

Fig. 4—Typical graphic display.

set memory; they are not sent to the computer. When the user is satisfied with the display, he can request the display data set to transmit the contents of the refresher memory to the computer for storage or processing. This feature allows users to retrieve files from the computer, to modify or update these files, and to send updated files back to the computer.

During the call, the display data set continues to perform its conversion functions, handling inputs and computer responses as required. The information retrieval and input capabilities available to a user of *Picturephone* computer-access service are largely a function of the customer-provided programs. The display data set has been designed not to interfere with or react to most signals sent from the user to the computer, leaving most decisions affecting message formats and interactive procedures to the customer and program designer. Further, the display data set operation is generally under computer control; that is, except when the editing feature is enabled,

Fig. 5—Display data set character symbols.

the user sends a request to the computer, and the computer signals the display data set to respond to the request.

A call is terminated at any time if either the user hangs up or the computer transmits an end-of-call signal.

III. DESIGN CRITERIA

3.1 *Symbol Formation and Screen Capacity*

The maximum number of characters in a single display is determined by considerations of screen size and shape, *Picturephone* raster parameters, bandwidth and nonlinearities of the network and station set, and legibility of the resulting font.[4] The maximum number of characters per line was chosen by an empirical evaluation of several different character shapes and sizes. A judgment was then made that a minimum length white segment should be about 0.5 μs and the minimum black segment about 0.75 μs, making a black-white pair at least 1.25 μs long. By choosing special designs for some characters (see Fig.

5) the maximum number of black-white pairs, including the space between characters, was limited to three per character. Thus, the minimum length of a character space is 3.75 μs. This results in a maximum of 22 characters being displayable, as the visible portion of a horizontal scan line is approximately 85 μs, taking into account worst-case *Picturephone* parameters and allowing space for margins on the sides of the display.

The alphanumeric symbols in the display set are constructed on the basis of 0.25 μs subsegments of a scan line, with each white segment having at least two subsegments and each black segment having at least three subsegments. This allows more flexibility in character design than if a larger subsegment length had been chosen. A character has a 12-subsegment horizontal dimension, and an intercharacter spacing of three subsegments is provided for a total of 15 subsegments in a character space. The resulting character widths are a maximum of 0.165 inches (0.42 cm). Intercharacter spacing is 0.042 inches (0.11 cm) to 0.07 inches (0.17 cm) depending on the particular characters.

The maximum number of lines of characters is determined by the number of scan lines available. Because the *Picturephone* screen is not exactly rectangular, and accounting for worst-case parameters and margins on the top and bottom of the display, only about 207 scan lines will always have the full 85-μs sweep visible. Based on empirical studies, seven scan lines were chosen as the vertical dimension for the character set. Allowing an interline spacing of three scan lines brought the total to ten scan lines per line of characters. Therefore, 20 lines of text can be displayed. Character heights are thus 0.14 inches (0.36 cm) with an interline spacing of 0.06 inches (0.15 cm).

The sixteen graph characters shown in Fig. 5 may be used to display simple curves and bar charts. In order to provide good point spacing for graphs and continuity when creating bar charts, these characters were chosen to be ten scan lines high and 14 subsegments wide on the horizontal dimension. (The graticule occupies the 15th subsegment to provide horizontal continuity.)

As mentioned above, the character shapes shown in Fig. 5 were determined empirically, although some changes have been made in their designs based on experimental use. Subjective experiments are being run to compare the legibility of the present font with alternatives, for example, a font with larger characters and increased interline spacing, but with fewer possible characters per display. The effects of transmission impairments and digital encoding and decoding on the different fonts are also being evaluated.

3.2 *Signal Shaping and Spectrum*

The minimum white scan line segment of 0.5 μs used to form characters has a fundamental component at 1 MHz. This is at the upper end of the *Picturephone* system bandwidth (station-to-station) which is down 20 dB at 1 MHz. The long horizontal parts of letters, such as the top of the letter E, are 2.5 μs in width with a fundamental component at 200 kHz. This results in the horizontal parts of letters being much brighter than the narrow vertical parts and greatly increases the apparent flicker of displays. To make letters evenly bright, the first and last subsegments of a white interval on a scan line are maintained at full amplitude while the middle white subsegments are reduced some 20 percent in amplitude. Figure 6 shows the effect of this shaping on a signal.

The sharp black-to-white and white-to-black transitions inherent in computer-generated displays and the regularity of these transitions due to character spacing can result in an on-line signal with a frequency spectrum quite unlike a typical face-to-face signal. Figure 7a shows the power spectrum for a display of text. (The sentence "Now is the time for all good men to come to the aid of the party" was repeated to fill 20 lines of 22 characters.) The spectrum of a face-to-face signal is shown in Fig. 7b for comparison. As shown, certain harmonics of the horizontal sync rate are emphasized by the synchronous nature of the alphanumeric display. These harmonics are located at 1/3.75 μs, 2/3.75 μs, etc., where 3.75 μs is the horizontal character spacing. The amplitude weighting of the n/3.75 μs spectral lines is different for different displays. For example, if a page full of

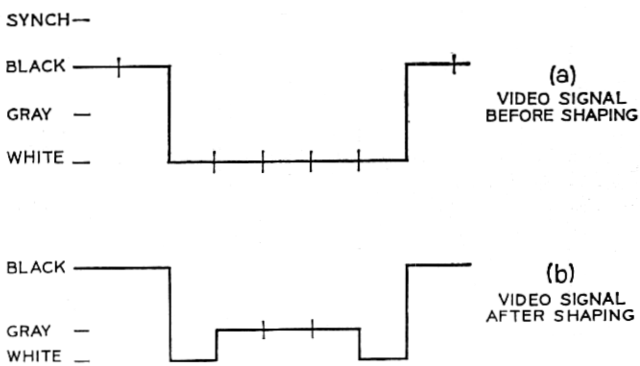

Fig. 6—Video signal before and after shaping.

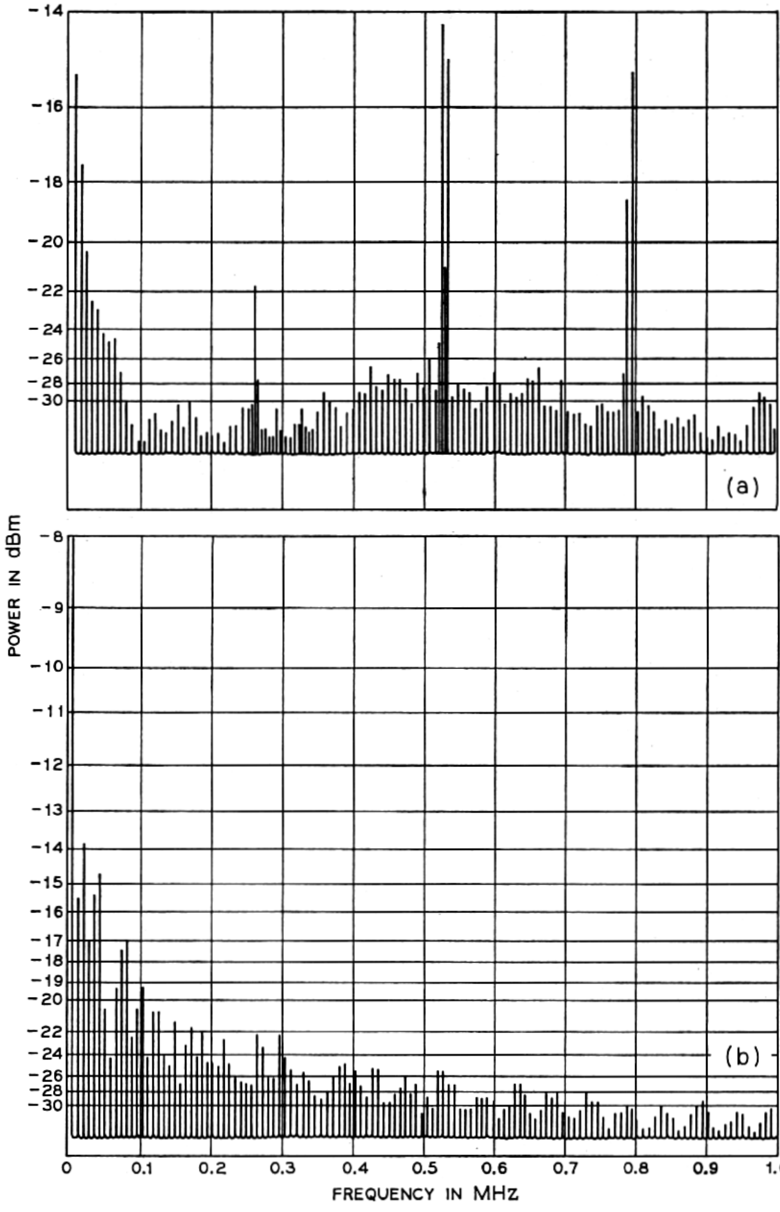

Fig. 7—(a) Example of power spectrum of a display data set signal. (b) Power spectrum of a face-to-face signal.

"I's" were transmitted, the greatest power density would occur at 1/3.75 μs, whereas if a page full of "H's" were transmitted, with two vertical strokes per character, the greatest density would occur at 2/3.75 μs. Similar considerations result in sidebands at multiples of 1625 Hz on these harmonics. The relatively high power density peaks in the display data set signal and possible similar signals generated by *Picturephone* stations in the graphics mode are a factor in the transmission engineering of the network to insure that such signals will not cause excessive interference into other *Picturephone* circuits.[5,6]

IV. DETAILED DISPLAY DATA SET CIRCUIT DESCRIPTION

4.1 *Logic Circuits and Stores*

The bulk of the logic in the display data set is constructed with Western Electric RTL logic chips, coded 1J, 1K and 1L. These are respectively a quad 2-input gate, a dual buffer and a dual type-D flip-flop. The contact closure/ASCII translator and serial output circuit use commercial DTL circuits. The refresher memory is composed of commercial MOS static shift registers. The ASCII/video pattern translator employs a commercial braided transformer read-only memory.

4.2 *General System Organization*

A block diagram of the display data set is shown in Fig. 8. Serial ASCII characters from the computer (or the customer keyboard when in the edit mode) are sampled and converted to parallel information for the refresher memory. Control characters are also detected.

Figure 9 shows part of a typical line of characters as displayed on a *Picturephone* screen. The *Picturephone* station is refreshed with two fixed-interlaced fields, one every 1/60th of a second.[4] Therefore, the odd scan lines in each line of characters on the screen are displayed on one field and the even scan lines on the next field. Because the character plus interline spacing is ten scan lines high with five lines in each field, the ASCII information corresponding to one line of characters on the *Picturephone* screen must be presented for translation to video signals by the ASCII/video pattern translator (Fig. 8) five times before moving on to the next line of characters. As can be seen in Fig. 8, the refresher store is divided into two parts, one consisting of the entire display, called the refresher store, and the other of the line of characters being scanned onto the screen at the moment, called the line store. These two parts of the refresher memory are synchronized and operated in a start-stop mode, so that the required speed

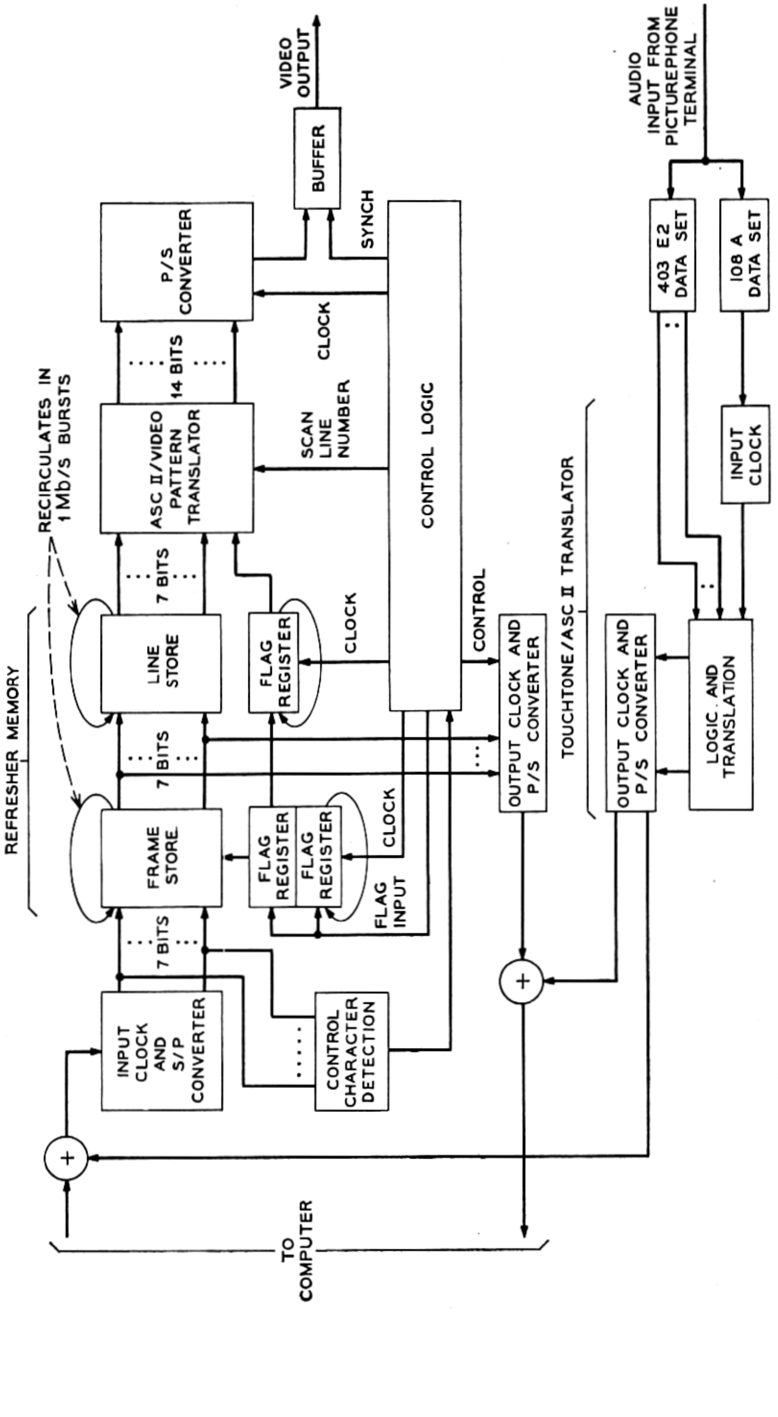

Fig. 8—Display data set block diagram.

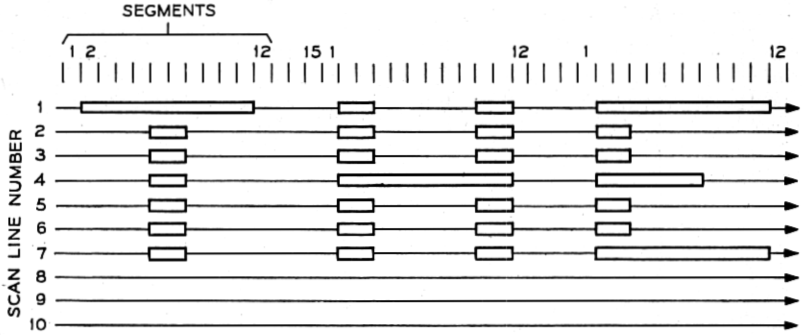

Fig. 9—Part of a typical character line.

of operation is about 1 Mb/s. In addition to lowering the speed requirements on the logic, this allows the use of low cost and compact MOS shift registers for the refresher memory.

The refresher store consists of nine parallel 484-bit shift registers.* Seven of these store in parallel the ASCII characters making up the display. An additional register stores a flag marking the position of the next character to be written on the screen. This flag may be moved about under the command of control characters from the computer or from the keyboard associated with the *Picturephone* station. Another register contains a flag marking the character position in the top left-hand corner of the display and is used when transmitting the contents of the refresher memory to the computer.

The line store consists of eight parallel 22-bit MOS shift registers. Seven of these store in parallel the line of ASCII characters which is presently being scanned onto the screen. The eighth register contains the flag bit marking the next character position to be written on the screen if that position is on the line of characters being scanned at the moment.

The ASCII/video pattern translator accepts from the line store the seven ASCII bits of an alphanumeric symbol being scanned with the additional information of the one-out-of-ten scan line number from the control logic and generates a 14-bit parallel word. This word is the binary pattern corresponding to the appropriate scan line in the symbol. As mentioned earlier, there are 60 alphanumeric symbols in the display data set repertory, and each of these symbols is up to 12

* The design described is capable of generating displays of 484 characters (22 rows of 22 characters) even though only 20 lines of 22 characters are guaranteed to be fully visible.

subsegments wide and seven scan lines high, not counting spacing intervals around each character. The patterns for these 60 symbols are generated by a read-only memory organized into 512 twelve-bit words. A nine-bit address formed from six of the seven ASCII bits of the symbol and three bits corresponding to the scan line number accesses one of the twelve-bit words. The 16 graph symbols are formed with combinational logic whose outputs are OR-ed with the memory output and fed into two alternating-feed shift registers, forming a parallel-to-serial converter.

The control logic shifts the contents of the shift registers into a buffer circuit. Here the signal is shaped as mentioned in Section 3.2 and preemphasized. *Picturephone* synchronizing signals generated by the control logic are then added and the composite video signal is matched to a *Picturephone* line with an unbalanced-to-balanced signal converter.

The control logic provides synchronizing clocking for all these circuits and generates appropriately positioned horizontal and vertical synchronizing signals. The memory may be cleared at any time by a character (ASCII-RS) sent from the computer or station keyboard to the display data set. The control logic then clears the refresher store and positions the writing flag in the top left-hand character position on the screen. All subsequent characters are positioned in sequential order following this character unless flag-moving cursor control characters are received. There are five flag-moving characters: Single step right (ASCII-HT), single step left (ASCII-BS), move vertically up one line (ASCII-VT), move vertically down one line (ASCII-FF), and move to the first character position on the next line down (ASCII-LF). The control logic moves the writing flag in the refresher store when these commands are received.

A transmit command (ASCII-DC2) causes the control logic to place the ASCII character marked by the reading flag in the refresher store into a shift register and output clocking circuit for transmission to the computer. After transmission of the character, the reading flag is stepped to the next character position in the refresher store and the process is repeated until the entire contents of the refresher store have been transmitted to the computer.

The *Touch-Tone* signals from the customer are received by the 403E2 Data Set associated with the display data set and converted into two-out-of-seven contact closures. The 403E2 Data Set also performs line supervision functions associated with the customer's call. The contact closures are translated by the contact closure/ASCII translator logic into 1200- or 2400-baud serial asynchronous ASCII data for the computer. Serial data from an auxiliary alphanumeric keyboard is received via the 108A Data Set and speed-converted before transmission to either the computer or the refresher memory input of the display data set.

4.3 *Control Logic Functions*

A block diagram of the master clocking section of the control logic is shown in Fig. 10. The basic system clock is a 1.0-MHz crystal clock. Each scan line in the *Picturephone* system is 125 μs long. The crystal clock is counted down by a 125-state high-speed counter, which defines each microsecond on a scan line. Counts in this counter define the horizontal synch interval, the start of the visible scan interval, and also drive another 134–135 state high-speed counter, which defines each scan line in the *Picturephone* raster. Counts in this counter define the first and last scan lines on which characters occur and the vertical synch interval in conjunction with counts from the 125-state counter. The precision of a crystal clock and count-down chain is required because each segment in each symbol on the screen must be positioned precisely with respect to the synchronizing pulses and with each other segment in the display to prevent distortion in the shape of characters.

The type of high-speed counters used in the control unit were de-

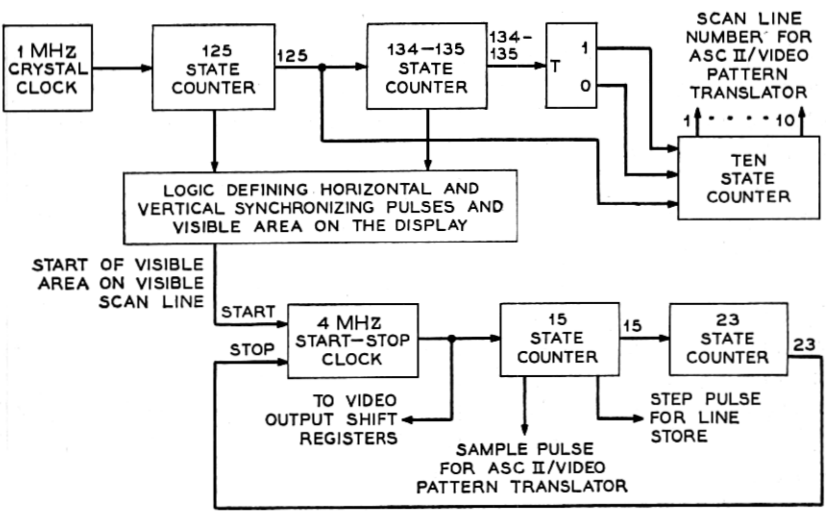

Fig. 10—Master clocking control logic block diagram.

veloped by R. A. Thompson at Bell Laboratories in 1965 and are a form of feedback shift register. The circuit is an n-stage shift register with the conditioning input to the first stage being a one whenever stages n or $(n - 1)$ are one. The counters have a worst-case propagation time of $2t$ where t is the delay of one stage, have $(n - 1)^2 + 1$ states where n is the number of stages, and any state may be detected with no more than a four-input gate plus sampling.

At the start of each visible scan line in the display, a 4-MHz clock is started, which drives a 15-state counter and a 23-state counter in tandem. These counters define each character interval on the visible scan line, and when the 23-state counter reaches state 23, it turns off the 4-MHz clock. During a character interval, the 15-state counter defines a pulse which samples the output of the ASCII/video pattern translator in order to place its 14-bit output into the parallel-to-serial converter. The 4-MHz clock is used to drive the shift registers in the converter, and another state in the 15-state counter is used to step the line stores so as to present a new ASCII character for translation by the ASCII/video pattern translator.

A ten-state counter, driven in tandem from the 125-state scan line counter, defines which scan line out of ten for each line of characters is being scanned at the moment.

The refresher store and line store are kept synchronized to each other and to the display to keep their shift rates down to 1 Mb/s. This can be achieved by having the 22 ASCII characters, composing the next line of characters to be scanned on the screen, at the head of the refresher store when the scanning of the present line of characters is over. Thus it is only necessary to step the refresher store 22 times while reading the new line of characters into the line store. The refresher store then remains idle, with another new line of 22 characters at its head, while the line store circulates the 22 characters it has just received. The line store must step once after each character has been translated in order to present the next character for translation. It circulates its contents five times as the five scan lines composing one field of a line of characters on the screen are generated. During the horizontal blanking interval following the fifth scan line of this group of characters, the line store accepts a new group of 22 characters from the refresher store. By this means it is never necessary to revolve the line or refresher store to look for any appropriate group of characters, since the required characters are always at the head of the store.

The next requirement is to enter characters into the refresher store as they are received from the computer or customer's keyboard. The input clocking circuit notifies the refresher store that a character is ready for entry. The refresher store waits until the first nominally idle interval when the line store is scanning a line of characters for translation. This interval is five scan lines or 625 μs in length. The 484-bit refresher store registers are then stepped 484 times at 1 Mb/s and are thus back in place before the line store is ready to accept a new group of characters from the refresher store. While the refresher store is thus being revolved, the control logic looks for the writing flag marking the character position to be written into. When the character position marked by the flag appears at the head of the refresher store, this position is cleared and the new character is entered as the position shifts into the tail of the refresher store. Thus synchronism between the line and refresher stores is maintained while characters are entered into the refresher store. There are a sufficient number of nominally idle intervals in a field so that characters can be entered at a 2400-baud rate.

The next requirement is to be able to shift the position of the writing flag in the refresher store under command of the computer or customer's keyboard. This is achieved by giving the writing flag and reading flag registers outputs at the 483 and 484 stages and adding an extra 485th stage. The 484th stage output is the one normally used when revolving the store. When a step-left flag moving command is given, the refresher store is revolved once during a normally idle interval, but the 483rd stage output is used for reentry on the writing flag register. This register thus appears one stage shorter than the other refresher store registers and the writing flag moves one character position to the left on the screen. To move the flag one step to the right on the screen and when entering a character into the store, the refresher store is revolved once, using the 485th stage output for reentry, so that the writing flag register appears one stage longer than the other refresher store registers. To move the writing flag vertically upward or downward, the step left or step right processes are repeated 22 times. To move the writing flag to the first position on the next character line downward, the step-right process is performed and a check is made to see if the writing flag is in the first character position on a line. This process is repeated until the flag is in this position. It should be noted that stepping right at the end of a line brings the writing flag to the first position on the next line. The writing flag is also stored as an eighth bit associated with each ASCII character in the line store. During the edit mode the character position marked by the flag is detected by the ASCII/video pattern translator and a blinking underline is displayed on the ninth scan line of the character window in that position.

During all maneuvers of the writing flag and addition of characters to the refresher store, the reading flag in the refresher store remains at the first character position on the screen. When a transmit command is received, the refresher store is revolved once and the ASCII character marked by the reading flag is transferred to an output shift register. During this revolution of the refresher store the 485th stage output on the reading flag register is used so that after the revolution the reading flag has moved one character position to the right on the display. When the ASCII character has been transmitted to the computer, the process is repeated for the next character and this is done 484 times to transmit the entire contents of the refresher store to the computer.

As mentioned earlier, a graticule is displayed on the screen whenever a graph character is present in the display. The graticule is generated by logically OR-ing with an analog weight the ninth scan line in each character position and the first and 15th bit on each scan line in each character position. The analog weights are so chosen that the graticule is equally bright in both horizontal and vertical components and suitably dimmer than the characters making up the graph, so as not be be obtrusive.

V. EPILOGUE

The technical feasibility of computer access from *Picturephone* stations was first tested at Bell Telephone Laboratories in an experimental system. About 40 *Picturephone* users at Murray Hill and Holmdel, New Jersey, and 40 users at American Telephone and Telegraph Company in New York City have been able to call a computer located at Holmdel, to retrieve simple information (such as personnel statistics), to use the computer's calculating ability, and to use an alphanumeric keyboard to modify or update displays.

The computer support for the experimental system was provided by available facilities at Holmdel. An IBM 360/50 computer operating with the System 360/Operating System under a multiprogrammed environment is used in the system. Two display data sets on the experimental *Picturephone* network are connected to the computer via an IBM 2701 Telecommunications Control Unit equipped with IBM Type III Terminal Adapters.

The *Picturephone* software resides in one partition of the 360/50. A small input/output software module, written in Basic Telecommunication Access Method and Basic Assembly Languages, resides in core at all times. The basic element of this module is a new device-dependent program to support the display data set.

A product trial of the display data set in a customer environment was carried out in cooperation with Westinghouse Electric Corporation. Westinghouse provided the computer support for *Picturephone*/computer access using a Univac 494 computer and their own software. It was not necessary to make any hardware modifications. During the trial, over 900 *Picturephone* calls were made to the computer by Westinghouse executives and those testing the system.

Display data sets are now being produced by Western Electric Company and are being used in initial *Picturephone* service. Computer access capability appears to meet the objectives set for it initially. The service will no doubt be extended and improved as *Picturephone* service evolves.

VI. ACKNOWLEDGMENTS

The authors would like to acknowledge the contributions of O. F. Gerkensmeier, M. G. Edelstein and G. E. Larson in the design of the display data set. J. J. Mansell, J. J. Horzepa and R. L. Simms, Jr., were major contributors to the initial systems engineering of the computer access service. E. J. Rodriguez and B. D. Owen have been responsible for the computer support used to demonstrate and test the system.

REFERENCES

1. Dougherty, H. J., Peterson, E. B., and Schachtman, M. G., "The *Picturephone*® System: Maintenance Plan," B.S.T.J., this issue, pp. 621–644.
2. Bell System Data Communications Technical Reference—Data Set 403D 403E, Interface Specification, November, 1967, American Telephone and Telegraph Company.
3. Bell System Data Communications Technical Reference—150 Baud Private Line Channels Interface Specification, February, 1968, American Telephone and Telegraph Company.
4. Cagle, W. B., Stokes, R. R., and Wright, B. A., "The *Picturephone*® System: 2C Video Telephone Station Set," B.S.T.J., this issue, pp. 271–312.
5. Brown, H. E., "The *Picturephone*® System: Transmission Plan," B.S.T.J., this issue, pp. 351–394.
6. Bunin, B. J., Hirsch, R. B., and Olsen, R. E., "The *Picturephone*® System: Crosstalk Considerations in the Transmission of Analog Signals on Paired Cable," B.S.T.J., this issue, pp. 427–457.