The Station

The *Picturephone*® System:

2C Video Telephone Station Set

By W. B. CAGLE, R. R. STOKES, and B. A. WRIGHT

(Manuscript received October 14, 1970)

This article describes the station set designed for use in commercial Picturephone® *service. Coded the 2C Video Telephone Station, it consists of three new pieces of apparatus—the 1A Display Unit, the 1A Service Unit and the 72A Control Unit. We discuss details of the electrical and physical design.*

I. INTRODUCTION AND OBJECTIVES

The station set is that part of the *Picturephone* system with which the customer interacts directly and is the principal basis for his reactions to the service. The set should provide the video camera and display functions, hands-free audio facilities, and the necessary customer controls in an attractive, easy-to-use, and economical form. The fundamental design requirements for the 2C Video Telephone Station, commonly known as the Mod II *Picturephone* Set, evolved from laboratory and field studies as discussed in other papers in this issue.[1,2] From these and other studies, the following general objectives were formulated:

(*i*) The *Picturephone* station equipment should initially be designed for desk-top location and should work in conjunction with any standard 12-button *Touch-Tone*® telephone.

(*ii*) The set should incorporate a built-in speakerphone with ON, OFF, and VOLUME controls.

(*iii*) The camera and display should utilize a 1-MHz video signal containing 251 visible scanning lines in a two-to-one interlaced, 30 frames per second format.

(*iv*) The camera should be physically centered above the display tube which should provide a picture with an 11 by 10 aspect ratio.

(*v*) The user will sit about 0.9 meters in front of the set and should be able to operate the major controls from this position.
(*vi*) There should be controls for changing the display brightness, viewing the outgoing picture and shutting off the camera for video privacy.
(*vii*) The set should contain simple means for customer control of the camera field of view for size, elevation and azimuth.
(*viii*) The camera should automatically compensate for a wide range of ambient illumination covering the levels to be encountered in offices.
(*ix*) The set should utilize local 110 V ac power and telephone service should not be impaired during power failure.
(*x*) A convenient means for transmitting graphical material should be incorporated.

The resulting station equipment designed to meet these objectives consists of a display unit and control unit which, together with a standard *Touch-Tone* telephone, are located on the user's desk. These units interface with the network through a service unit which can be remotely located with a cable run of 26 meters maximum length.

A 55D Control Unit is also required for speakerphone operation. This unit is connected into the *Picturephone* station equipment at the service unit. The 55D Control Unit has more received signal handling capability than the 55B used with the 3A Speakerphone.[3]

The 1A Display Unit (Fig. 1) contains the camera and display tubes and associated transmitter and receiver electronics, the loudspeaker, and the tone sounder for distinctive *Picturephone* call alerting. While designed primarily for face-to-face communication, it includes a built-in capability for showing graphics placed on the desk in front of the set. The display unit design is discussed in detail in Section II of the paper.

The 72A Control Unit (Fig. 2) contains the user controls and the microphone for speakerphone operation. The ON, OFF and VOLUME controls are for hands-free audio operation on telephone and *Picturephone* calls. The microphone can be muted for audio privacy by holding the QUIET button depressed. The VU-SELF and PRIVACY switches provide for checking the transmitted picture and for shutting off the camera for video privacy. A distinctive horizontal bar pattern is transmitted when the PRIVACY switch is operated. The ZOOM and HEIGHT controls allow the user to adjust the size and elevation of his

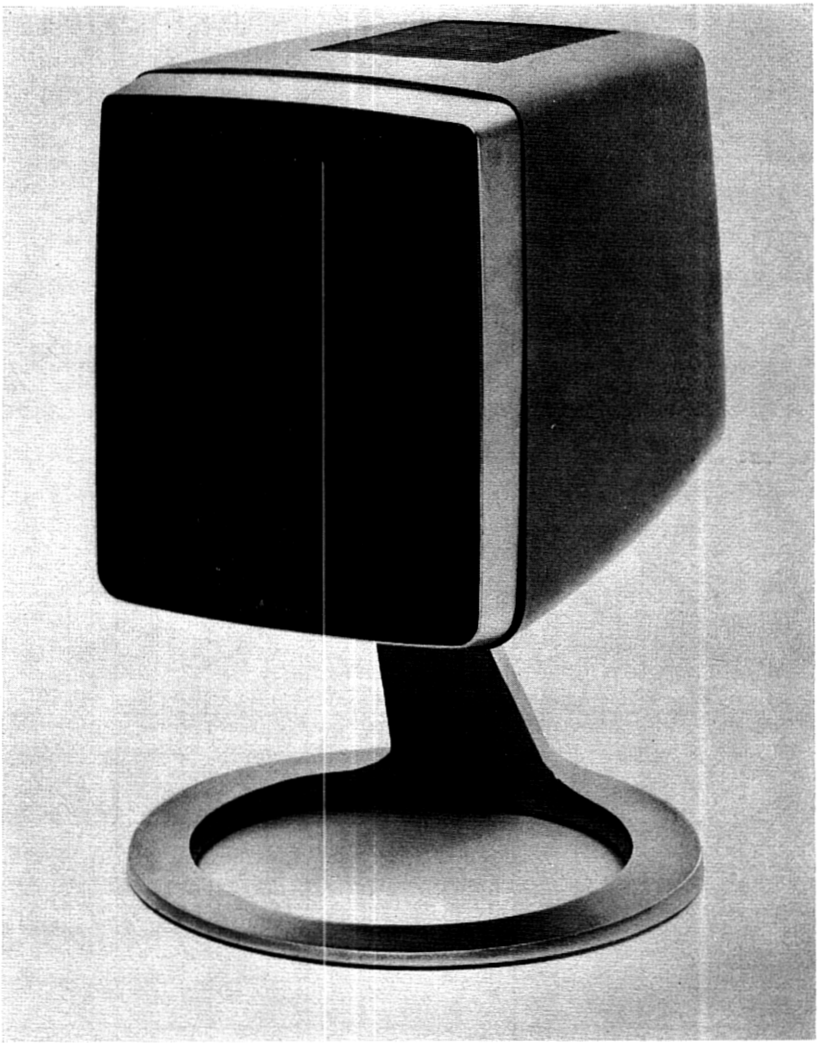


Fig. 1—1A Display Unit.

camera's field of view. The BRIGHT control permits adjustment of the display brightness for best subjective performance. The design of the control unit is described in Section III.

The 1A Service Unit (Fig. 3) contains the station power supply, supervisory and control logic, and the video line/loop termination, protection and maintenance electronics. All installer adjustments and options are located in the service unit to simplify installation and maintenance. The service unit design is described in Section IV.

II. DISPLAY UNIT

2.1 *General Factors*

2.1.1 *Lens Considerations*

The display unit is a desk-top instrument designed to accommodate the heights of 99 percent of the American male and female adult population when seated. For convenience of desk use and other reasons, a 92-cm viewing distance has been established.[2] A survey of subjects using the Mod I *Picturephone* set showed that users seldom remain at a fixed viewing distance, but move from a near position of 50 cm to a distant position of 150 cm, with an average distance of 92 cm. This established an object focal distance of 92 cm for the camera lens and permitted the display unit to be positioned beyond the central working area of a desk.

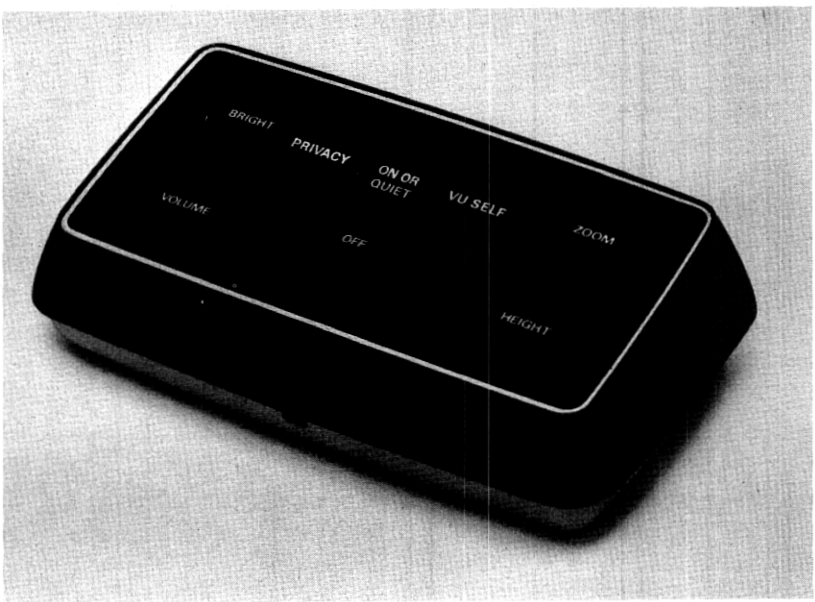


Fig. 2—72A Control Unit.

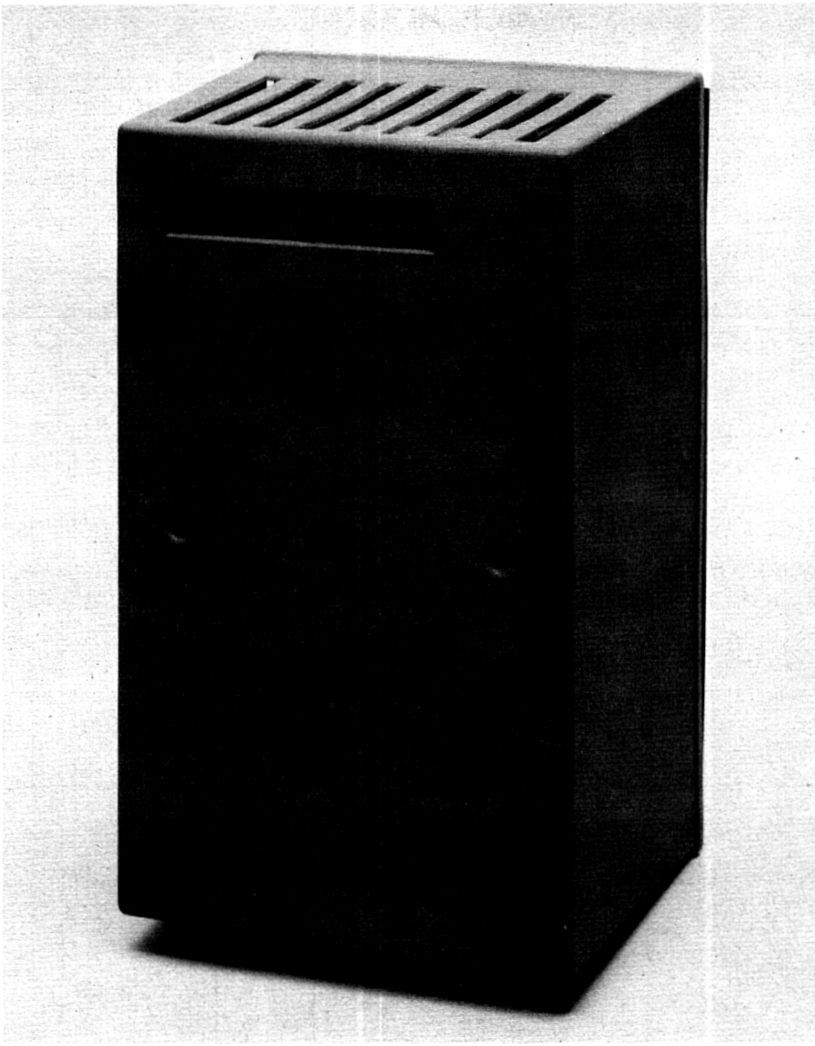


Fig. 3—1A Service Unit (cover on).

An aperture stop of f/2.8 was selected as a compromise between depth of field consideration and the advantages of a small lens. The resulting front glass diameter of 1.65 cm is consistent with styling, graphics, eye contact angle, cost and size objectives. Above an illumination of four foot-lamberts, an automatic iris progressively closes and thereby increases the depth of field until the 50- to 150-cm range of user motion cited above is accommodated with an illumination of 32 foot-lamberts. For higher light levels, the iris continues to stop down until a maximum design illumination of 520 foot-lamberts is reached. The range of illumination over which the set works exceeds the range of light levels recommended by the Illuminating Engineering Society[4] for office applications.

The lens continuously views the maximum object field. Zooming is accomplished electrically by reducing the raster size on the camera target to scan a portion of the wide angle field. Similarly, adjustment of the effective optical axis for users of different heights is obtained without moving the lens by displacing the reduced raster vertically over the full image field height.

Because of the method used for height adjustment, the maximum object field height is determined by the range of customer heights. Referring to Fig. 4, the 99 percentile large man seated upright measures 68.8 cm from the desk to the top of his head, while the 1 percentile small woman seated relaxed measured 20.4 cm from desk to chin.[5] This range of 48.4 cm is supplemented with vertical margins to frame the subjects and allow for variations in desk-to-chair height differences, yielding a desired vertical field height of 60.7 cm. To accommodate this object field height at a 92-cm viewing distance with an 11 to 10 aspect ratio, a wide angle lens was required with a 53° diagonal taking angle (37° vertical taking angle).

An inverted telephoto lens was designed to reduce the radial varia-

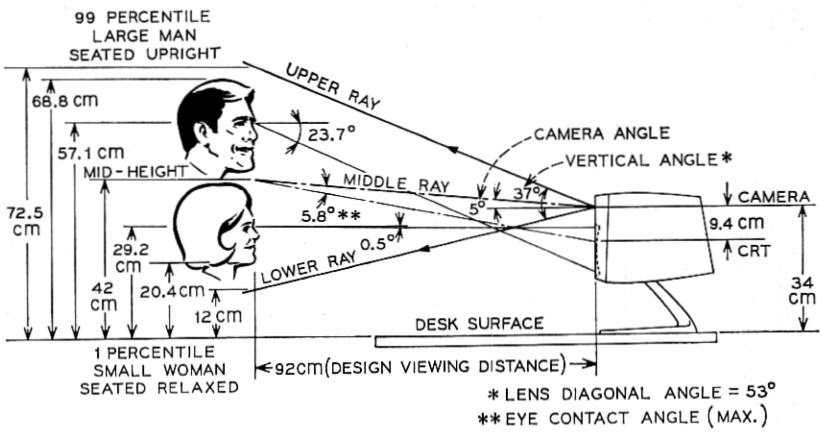


Fig. 4—Human factor considerations for tube placement.

tion in relative illumination typically experienced in a lens due to $\cos^4$ losses.[6] The six-element lens has a paraxial transmission factor of approximately 80 percent with relative illumination at the wide angle radius falling to approximately 52 percent. In addition, the modulation transfer function (MTF) was shaped differently from that of a conventional photographic lens to maximize the signal for frequencies below 1 MHz. At no point does the MTF fall below 78 percent. With a focal length of 16.35 mm and a magnification ratio of 1/57, the lens produces an image of 1.57-cm diameter, which is equal to the diagonal of the 1.16-cm by 1.06-cm image format on the camera target.

2.1.2 *Tube Placement*

The camera is located 33.4 cm above the desk and tilted 5° upwards for the central ray to intercept the center of the desired object field (42 cm above desk height) at the design viewing distance of 92 cm. The placement is a compromise between undue set height and excessive camera tilt which would introduce perspective distortion and the problem of intercepting ceiling lights.

The display tube is placed directly beneath the camera to minimize the eye contact angle. Because the user views the display rather than the camera, the transmitted picture shows the fixation point of the eyes displaced downward. Measurements[7] show that the loss of eye contact is more difficult to perceive on the vertical axis than on the horizontal. The loss of eye contact on the vertical axis is perceptible at about 3° and objectionable at 12°. Fortunately, the center of interest in a display tube—the place where the majority of people prefer to position their eyes in the picture—occurs 10 percent above the tube center. The separation between the camera and the display center of interest is 9.8 cm, as determined by the tube sizes. At a viewing distance of 92 cm, this results in an eye contact angle of 5.8°, which is perceptible but acceptable.

The *Picturephone* screen displays about 250 lines. To obtain satisfactory subjective picture quality at the preferred viewing distance, the display tube height was set at 12.7 cm. The 11 to 10 width-to-height aspect ratio resulted in a 14-cm-wide display. At a viewing distance of 92 cm, the entire display remains within the central 10° arc of best perception[5] (16 cm wide) and permits total viewing without eye motion.

This configuration provides comfortable head inclination for viewing. For a seated person, the typical line of sight is 15° below the horizontal and the comfortable head tilt is $\pm 15°$ about that line.[5] Therefore, the display tube should be placed such that the top edge is below the horizontal eye level for the small woman and the bottom edge is less than 30° below the horizontal for the tall man. Within this 24.9-cm range, the display screen placement resulting from the aforementioned considerations achieved acceptable downward angles of 0.5° for the small woman and 23.7° for the large man.

A simple, visor-mounted mirror on the front of the camera provides a capability for transmitting graphics. When the visor is manually lifted, as shown in Fig. 5, the lens automatically refocuses to the plane

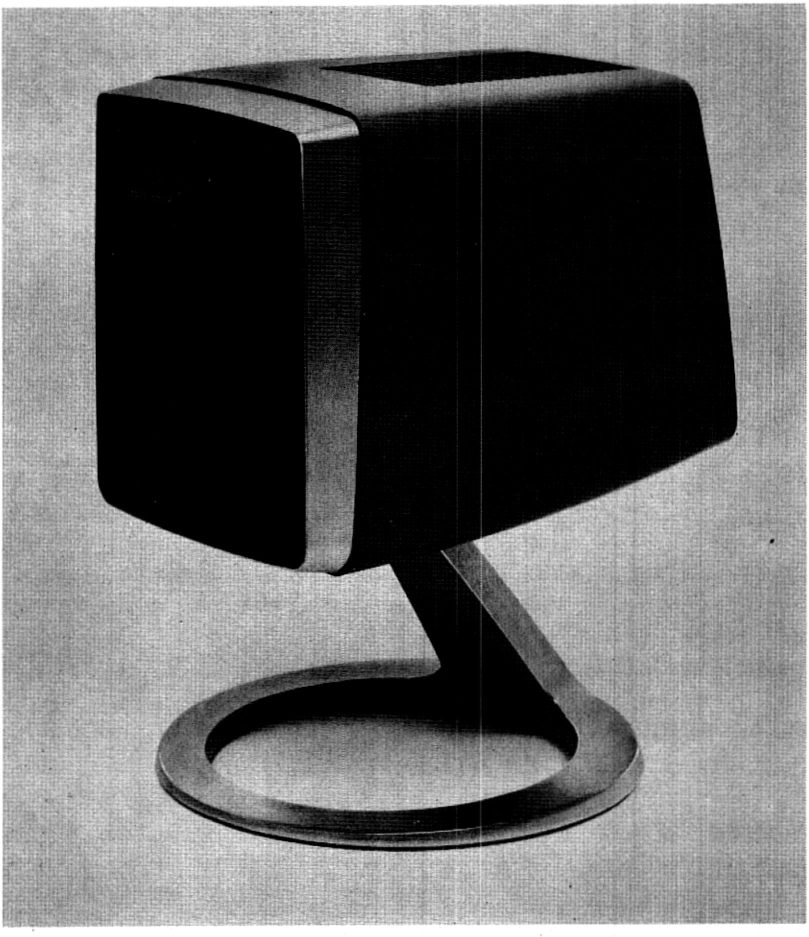


Fig. 5—Graphics visor in open position.

of the desk and a relay reverses the camera horizontal scanning to compensate for the optical inversion caused by the mirror. In addition, the camera raster is automatically centered and changed to the narrow angle mode to increase resolution and hold keystone distortion to 7.5 percent. The graphics object field is slightly trapezoidal due to keystone distortion with a height of 15.5 cm and an average width of 17.3 cm.

2.1.3 *Appearance Design*

The appearance design was done in close collaboration between the industrial design firm of Henry Dreyfuss Associates and Bell Telephone Laboratories. The resulting display unit, shown in Fig. 1, consists of a head assembly measuring approximately 19 cm wide, 25 cm high and 30 cm deep, sitting on the sloping pedestal of a ringstand. The aesthetic objective was to avoid a tall and bulky set, prescribed by the tube locations. This was approached by having the head apparently float on the pedestal and by exposing the desk through the ringstand.

The bezel accommodates the display tube, camera lens, graphics mode visor, and grillwork. A loudspeaker is mounted behind the grill for hands-free speakerphone service. The bezel face is painted with a rubbery black finish which reflects less than 2 percent of the incident light and minimizes undesired glare. The face is framed by an accentuated edge which extends beyond any projecting part of the face. This permits the unit to be stably set on the face for removing the housing. The bezel frame is chrome plated with a satin finish to complement the ringstand and to provide a neutral color isolation band between the black face and the variety of business office colors proposed for the rear housing: gray, white, black, green, beige and ivory. In addition, the frame is contoured to provide visual clues to help the user stay centered on camera.

The cover is a one-piece plastic molding attached to the frame with concealed fasteners. The top and bottom surfaces include grills for vertical air flow for cooling.

The ringstand is a satin finish, chrome plated die casting with a hollow-core, skewed pedestal. The cords enter the base at the desk level so the head can freely pan 330° without cord drag. This arrangement also allows for the base to be oriented to achieve the best drape of the cords over the edge of the desk. The ringstand diameter was set such that the outer edge serves as a document positioning aid for the graphics mode, and the pedestal top was located at the center of the ringstand to maintain this feature in any panning position.

2.2 *Transmitter System*

The video telephone transmitter converts an optical image to a composite video signal for transmission over the *Picturephone* network. The transmitter system must automatically adapt to the wide range of illumination normally encountered in an office or home environment, provide the user with the desired controls over his transmitted picture, and process the signal in a manner that will allow a subjectively pleasing display on a *Picturephone* receiver.

2.2.1 *Camera Tube*

The principal component of the transmitter is an electrostatic-focus, magnetic deflection Silicon Diode Array Camera Tube[8,9] designed specifically for the *Picturephone* application. The photosensitive target in this tube is not damaged by high-intensity light sources, has improved sensitivity over conventional targets, and can be selectively scanned to achieve electronic zooming.

Since the spectral response* of this tube peaks in the 800- to 900-nanometer region, a Schott 2-mm KG3 filter is used to reduce excessive infrared response. With this filter the typical tube sensitivity is approximately 1750 nA per foot-candle in response to tungsten illumination at 2854°K and about 750 nA per foot-candle in response to fluorescent illumination. To compensate for the display tube gamma† of 1.9 and achieve a subjectively pleasing picture, a correction circuit is incorporated in the transmitter video processing circuitry to modify the unity gamma of the camera tube to about 0.7. The combination lens-tube optical sensitivity is about 50 nA per foot-lambert (incandescent) at the maximum lens aperture of f/2.8. With the 200 nA nominal peak-to-peak signal current at which the tube is operated, scenes with highlight luminances from 520 foot-lamberts to 4 foot-lamberts can be accommodated over the f/32 to f/2.8 iris range. Illumination levels down to 2 foot-lamberts are accomodated by adding increased sensitivity in the form of electronic gain at the expense of signal-to-noise ratio (S/N).

The zoom and height adjustment features are obtained by using the deflection circuits to vary the scanned area and position on the camera tube target. In the wide angle mode the transmitted video

---

* Spectral response refers to the output current per unit input light energy as a function of wavelength.

† Gamma as used here is the slope of the transfer function curve relating the logarithmic optical signal and the logarithmic electrical signal (electrical to optical for the display tube and optical to electrical for the camera tube).[10]

signal corresponds to a 1.16-cm by 1.06-cm scanned raster on the tube target. To zoom, the horizontal and vertical deflection currents are simultaneously reduced up to 1/1.6, yielding a raster size of 0.73 cm by 0.66 cm at the narrowest angle and achieving a continuously adjustable zoom over an area ratio of 2.5 to 1. A constant aspect ratio is maintained during zooming by controlling the amplitudes of the horizontal and vertical sawtooth generators in the deflection circuits from a single zoom potentiometer. The height control potentiometer positions the raster vertically between the extremities of the wide angle scan by varying the dc current in the vertical deflection yoke. The user height and zoom potentiometers are coupled to restrict the height adjustment range as a function of zoomed position to remain within the active target area.

The variable scan method of zooming is inexpensive to implement, but system performance is poorer when operating the camera tube in this manner because of sensitivity and resolution considerations. Tube sensitivity, and thus the illumination range which the set can accommodate, is reduced in proportion to the scanned area since less charge per frame is available from the target. The effects of zoom and the spectral content of the illumination upon set sensitivity are summarized in Table I.

Camera tube resolution is limited by the finite size of the scanning beam. This results in an electrical response or modulation transfer function which is near gaussian in shape. When the tube is operated in the wide angle mode, the response to an optical sinusoidal pattern which gives a 1-MHz temporal frequency is between 30 percent and 50 percent (relative to the flat or low-frequency portion of the response curve) with a mean of 38 percent. When the set is used in the narrow angle mode, the optical pattern must be a higher spatial frequency to produce the same temporal frequency. Thus the fixed beam size is larger relative to the pattern it is reading. This produces a temporal MTF shifted in frequency and results in a 1-MHz tube response between 12 percent and 25 percent with a mean of 16 percent. To partially correct for these effects, a linear phase horizontal aperture correction circuit with an 8-dB gain at 1 MHz is incorporated into the camera preamplifier.

The pre-aligned camera tube package is shown in the transmitter block diagram (Fig. 6). The circuits required for tube bias and deflection adjustments have been included in the camera tube package to allow interchanging of tube packages without set alignment. To facilitate this interchangeability, the set provides precision deflection currents to the camera by means of ramp generators and feedback drive circuits which sense the current in the deflection yokes. The currents are set initially to within 0.2 percent and will vary no more than 0.8 percent with temperature and aging. The linearity of the two sweep currents due to initial tolerance, temperature, and aging will be within 0.5 percent displacement error.[11] Adjustments for variations in horizontal and vertical deflection sensitivity in the tube are accomplished by varying the feedback error signal to the deflection circuits. Raster centering adjustments are implemented with a dc voltage control of the deflection circuits. To eliminate a white border around the displayed picture, referred to as "edge effect," and caused by charge migration from the unscanned to scanned portion of the target, about 2.6 percent of the video information on each side and 0.8 percent on the top and bottom of the scanned raster is blanked out of the transmitted signal. To eliminate vertical ringing bars in the video display, caused by horizontal yoke retrace signals coupling into the vertical yoke, the vertical yoke is center tapped and damped with a RC network.

The series connected camera tube and CRT filaments are each operated at 8 V (1 watt) with 2 percent regulation to enhance tube life. When the set is idle, these heaters are each maintained at 0.8 watts to achieve a picture in less than one second.

Although the silicon camera tube has made it possible to provide the user with adequate *Picturephone* performance, temperature and time dependent spatial dark current variations in the electrostatic focus version of the tube limit the set life and require operation in ambients below 30°C.[9] Studies[9,12] indicate that lower operating voltages will increase tube life appreciably and, consequently, a magnetic focus

TABLE I—CAMERA SYSTEM OPTICAL SENSITIVITY

Illumination	Zoom Setting	Operational Range in Terms of Highlight Luminance (foot-lamberts)		
		Minimum	$f/2.8$*	Maximum
Incandescent	Wide Angle	2	4	520
	Narrow Angle	5	10	1300
Fluorescent	Wide Angle	4.7	9.4	1220
	Narrow Angle	11.8	23.5	3050

* Cutover point between AGC and AIC operation.

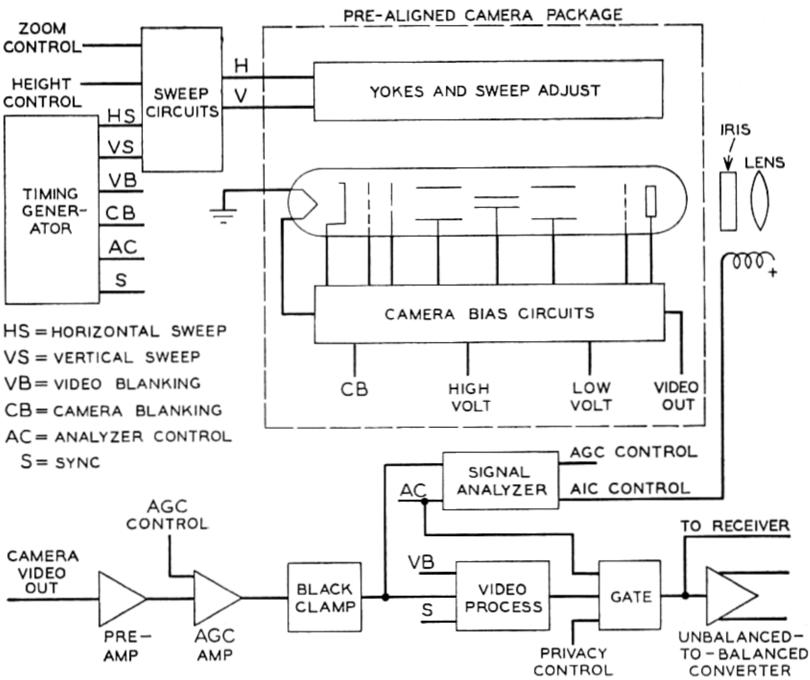


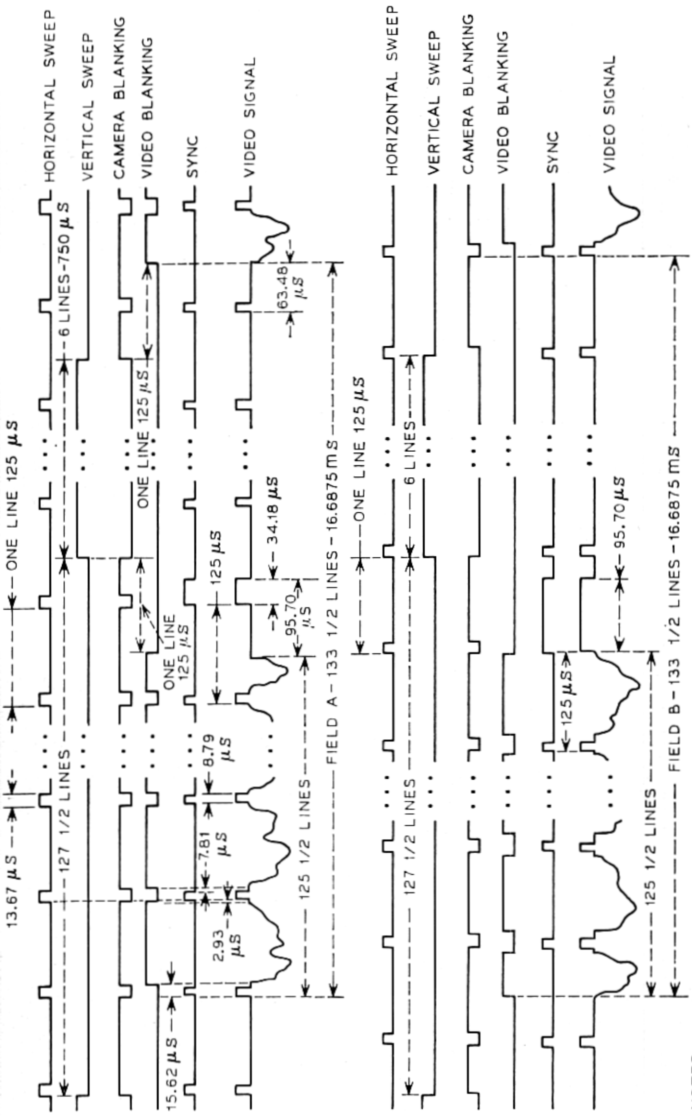
Fig. 6—Transmitter block diagram.

tube with lower operating voltages is being designed and will be used in later sets.

2.2.2 *Video Circuits*

The video circuits in the *Picturephone* transmitter (Fig. 6) amplify, process and control the video signal from the camera tube, add synchronization pulses to form a composite video signal and convert this signal to a balanced format for transmission over the analog loop.

The *Picturephone* timing generator derives the six timing waveforms (Fig. 7) required for transmitter operation by means of a 512 kHz ±100 ppm crystal controlled oscillator and appropriate countdown and logic circuitry.[8] The 13.67-μs horizontal sweep and 750-μs vertical drive waveforms are used to control the respective transmitter deflection circuits. Blanking of the camera tube beam during retrace is provided with the camera blanking signal which is a logical combination of the sweep waveforms. Horizontal timing information at the 8000-Hz ±100 ppm line rate is obtained by combining the 8.79-μs synchronization pulse, 19.5-μs video blanking pulse and the video signal. The



NOTES:

1) THE SIXTH OUTPUT SIGNAL, ANALYZER CONTROL IS "HIGH" DURING APPROXIMATELY THE MIDDLE HALF OF THE ACTIVE SCAN TIME (WHEN VERTICAL SWEEP IS LOW)

2) ONE FRAME: 267 LINES – 33.375 μS 251 LINES OF "PICTURE" INFORMATION TRANSMITTED

3) THE VIDEO SIGNAL IS SHOWN BEFORE PRE-EMPHASIS

Fig. 7—*Picturephone* timing format.

analyzer control (AC) signal (not shown in Fig. 7) is positive during the middle half of each field and is used to generate a distinctive video signal for the privacy mode and to gate the signal analyzer circuit as discussed later.

The camera preamplifier and AGC circuit (Fig. 6) amplify the 200-nA peak-to-peak video signal current (i_{signal}) from the camera tube to a voltage level of approximately 5 V peak-to-peak. At this level it is possible to clamp the video signal with negligible impairment.

A low input impedance, cascode type, preamplifier input stage is employed to negate the effect of stray input capacitance and to achieve a flat 1-MHz frequency response. This amplifier employs overall feedback to achieve a nominal 62-dB peak-to-peak composite video signal to weighted-wideband-rms-noise ratio.* Weighted S/N can be characterized[13] by:

$$S/N|_{\text{weighted}} = 20 \log \frac{1.33\, i_{\text{signal}}}{\left\{\int_0^\infty [(I_{eq})_B + I_{eq}(f)]^2 r^2(f) W^2(f)\, df\right\}^{\frac{1}{2}}} = 62 \text{ dB}$$

where $(I_{eq})_B$ is the shot noise of the camera beam current, $I_{eq}(f)$ is the equivalent preamplifier noise current referred to the amplifier input, $r^2(f)$ is the power transfer function of the station set exclusive of the preamplifier and $W^2(f)$ is a weighting function[2] to account for the subjective effect of the human eye. With a perfect preamplifier, $I_{eq}(f)$ equals zero and the weighted S/N would be limited to about 68 dB by the shot noise of the camera tube beam current. A voltage-controlled, variable-gain AGC amplifier employing a field effect transistor (FET) variolosser adds up to 6-dB additional gain under low illumination conditions at a sacrifice of 6-dB S/N performance.

For proper insertion of the synchronization information and analysis of the video signal for automatic level control, it is necessary to re-establish the dc component of the video signal by clamping. The black clamp circuit is gated to sample the video signal during the 105.5-μs interval shown in Fig. 8 to establish the darkest portion of the scene at a fixed dc reference. This darkest portion of the signal is processed as black in the gamma correction circuitry and is inserted into the composite signal as black, or at the voltage level of the video blanking pulse. By setting the darkest portion of the scene to black

* A 62-dB weighted S/N corresponds to a weighted noise power of −54 dBm at the output of a *Picturephone* transmitter when the transmitter pre-emphasis is removed.

it is possible to obtain a subjectively pleasing display and to utilize the full dynamic range of the transmission system independent of scene content.

After clamping, the video-processing circuit combines the 19.5-μs video blanking pulse and the 8.79-μs synchronization pulse from the timing generator[8] to form the composite video signal shown in Fig. 8. The amplitude of the synchronization pulse relative to porch or pedestal level is used for AGC control in the receiver and is thus maintained at a precise value of 200 $\pm$ 10 mV. In order to reduce the susceptibility of the video signal to radio frequency interference and crosstalk during transmission, the video portion of the composite signal is pre-emphasized by 17 dB at 1 MHz relative to 1 kHz.[14] This amount of high-frequency peaking can cause clipping of large, rapid transitions in the video signal in the analog loop equalizers under allowable positive gain-frequency deviations. The subjective impairment of such clipping is acceptable, but if this same clipping were applied to pre-emphasized synchronization pulses, it would impair the recovery of accurate timing

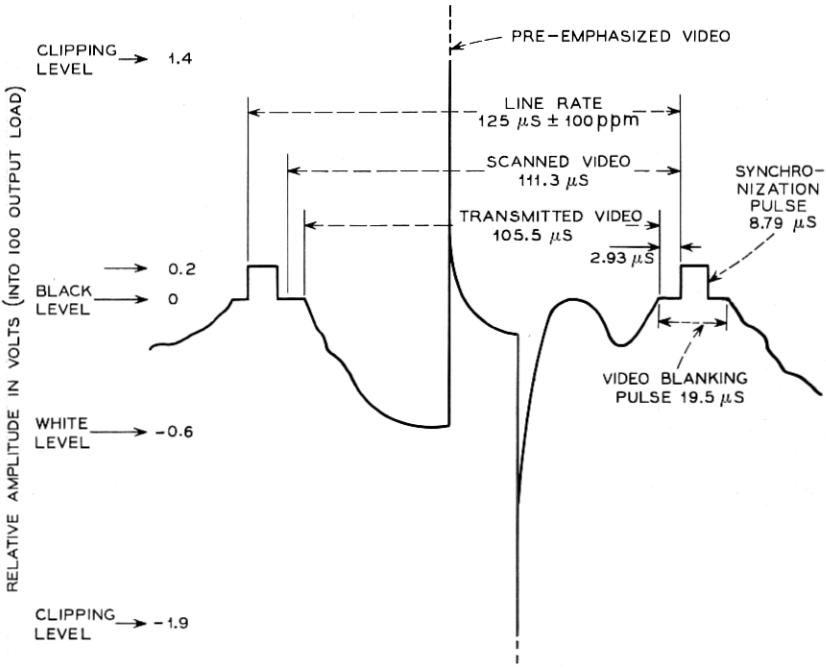


Fig. 8—*Picturephone* line format.

information at the receiver. A rather simple means is utilized to selectively pre-emphasize the video signal and not the sync signal by integrating the pre-emphasis shaping into the sync insertion portion of the circuit. By introducing controlled clipping of the positive and negative signal excursions in the video processing circuit of the set (Fig. 8), the dynamic range requirement of the unbalanced-to-balance (U-B) converter circuit is reduced. The controlled clipping employed is less severe than the clipping that occurs during transmission.

To implement the subscriber's video privacy feature, a gate circuit, under control of the user's PRIVACY switch, selects either the normal video signal or the ac signal for transmission over the video loop and to the receiver for self-viewing.

The unity gain U-B converter circuit converts the unbalanced video signal from the gate circuit to a balanced signal format for transmission over the video pair. This circuit, which is similar to those used in the transmission equalizers,[15] provides a precise termination of the video pair to minimize longitudinal-to-transverse signal conversion. Conventional carbon blocks connected to the balanced pair and voltage limiting diodes in the output circuit of the converter protect this circuit against transient voltage and lightning surges. These loop protection and termination functions are physically located in the service unit while the active circuitry is in the display unit.

The overall optical-input-to-electrical-output sinusoidal frequency response of the transmitter, excluding pre-emphasis, is nominally flat to 1 MHz. Low-frequency response is characterized by less than 0.3 percent tilt in 100 μs to an input step voltage. By carefully controlling capacitor charging in the video amplification circuits during turn-on, a usable video signal is obtained in less than one second while still maintaining excellent low-frequency response.

2.2.3 *Automatic Gain-Iris Control*

In order to achieve a nearly constant video signal level over a 260-to-1 range of illumination, the set utilizes a zero-order, saturating-type, feedback control system. This system employs a combination iris and AGC amplifier (AGIC system) to achieve an advantageous trade off between depth-of-field and signal-to-noise performance. The iris and variable gain amplifier are controlled by analyzing the peak video signal amplitude in the middle 50 percent of the scene and the average amplitude over the full scene.

The basic operation of the AGIC system can be explained with the aid of Fig. 9. At high illumination levels the iris is operated near the upper end of its f/2.8 to f/32 range, and the gain control amplifier is providing a constant gain and S/N. As the light level of the scene decreases, the iris opens to provide more light to the camera to maintain a constant video signal level. The AGC-AIC crossover point occurs at about 4 foot-lamberts scene highlight luminance (for the wide angle case shown here) where the iris reaches its maximum opening of f/2.8. The AGC makes up for further reduction in illumination to 2 foot-lamberts by adding up to 6 dB of video amplification. An important feature of this combination gain-iris mode of operation is the continual improvement of set performance as illumination levels are increased. In the AGC range, increased illumination improves the signal-to-noise performance. At the 4-foot-lambert AGC-AIC crossover point, the desired 62-dB signal-to-noise performance is obtained. Increased illumination decreases the iris opening to achieve increased depth of field rather than excess signal-to-noise performance. The effective depth of field is approximately 50 cm at f/2.8 and increases to about 2.5 m at f/8.

The signal analyzer circuit (Fig. 6) detects the video signal from the black clamp on a combination peak-average basis to obtain an error voltage, compares this error voltage to a precision reference

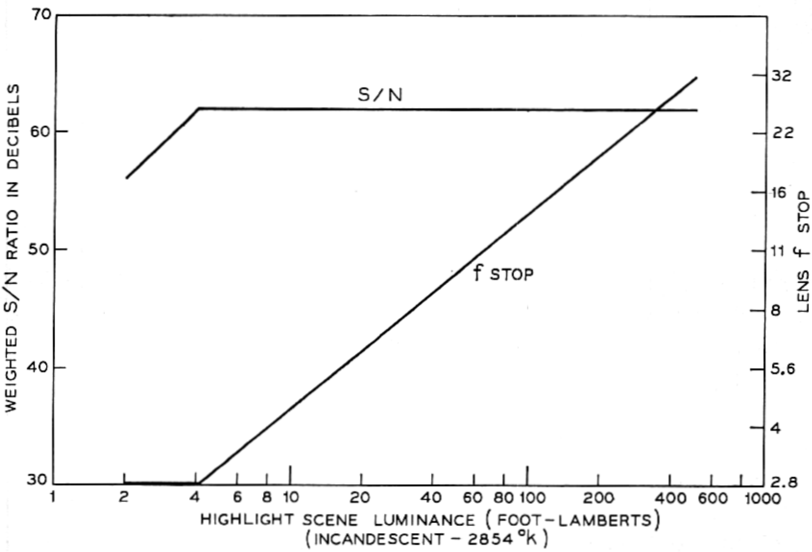


Fig. 9—Transmitter AGIC performance.

voltage and filters the resultant comparator output to derive a dc voltage for control of the iris and AGC amplifier.

The peak-average detector in the signal analyzer is arranged by means of the AC signal to ignore signal peaks in the top and bottom quarters of the scene. This reduces the loss of facial contrast that would occur if the video signal peaks from ceiling lights and white shirts were allowed to set the signal level. With a combination of peak detection over a portion of the scene and average detection over the whole scene the contrast ratio of the transmitted signal will be a function of the scene content. For normal scenes the detector sets the transmitter video output at a nominal 0.6 V peak-to-peak. With black-on-white graphics material, such as a typewritten page, the video output signal is about 0.4 V peak-to-peak. This reduced contrast lowers the display highlight brightness to enhance readability and reduces the impairment caused by transmission clipping of pre-emphasized high-frequency graphics signals.

An RC integrator having a three-second time constant is included at the output of the comparator. This filter inhibits level corrections for short-term scene changes that might occur when a person walks through the camera field of view. Since the iris is included in the AGIC feedback loop, a low friction, nonsticking iris design is essential to guarantee loop stability. With the specially designed *Picturephone* iris, loop stability is dominated by the three-second integrator time constant.

2.3 *Receiver System*

The receiver of the *Picturephone* set processes the incoming composite video signal to produce a high-quality, subjectively pleasing optical display. This processing includes several functions: frequency shaping of the video information to optimize subjective display quality, automatic gain control (AGC) to maintain a display with nearly constant contrast independent of flat gain deviations in transmission, and automatic phase control of the extracted timing information to achieve a stable display. In addition, the receiver system provides the user with the necessary controls over his display and derives the high voltages for camera and display tube operation. A functional block diagram of the *Picturephone* receiver is shown in Fig. 10.

2.3.1 *Video Circuits*

The nominal 0.56 V peak-to-peak composite video signal received from the output of the receiving transmission equalizer [in the service unit or key telephone system (KTS)] is amplified and converted to an

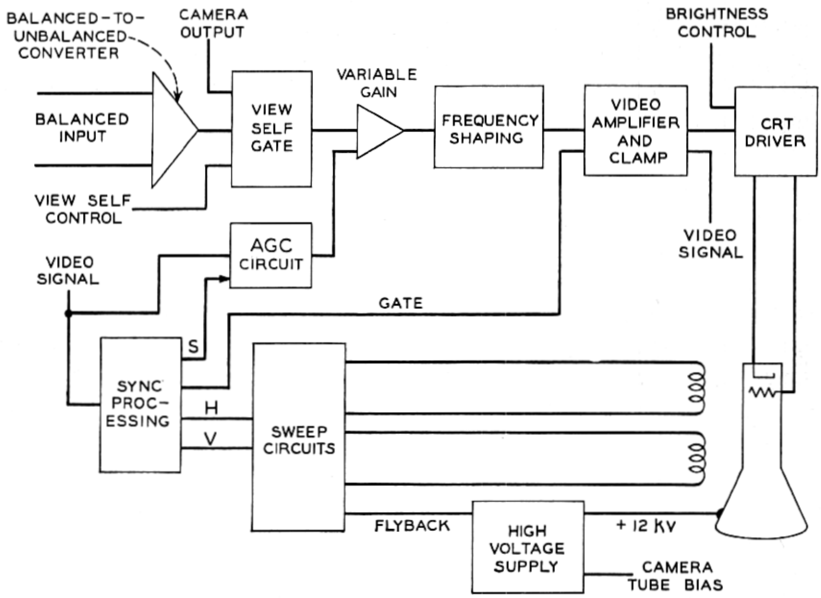


Fig. 10—Receiver block diagram.

unbalanced format by the balanced-to-unbalanced (B-U) converter. This differential amplifier provides a common mode rejection better than 30 dB over the 1-MHz frequency band to minimize the effects of longitudinal or common mode interference signals. The view-self gate circuit selects, under the control of the customer, either the user's camera output signal or his received signal for processing and display. This gate circuit provides a minimum 50 dB of crosstalk rejection over the 1-MHz frequency band which reduces crosstalk below perceptibility.

The receiver employs a sampling type AGC system, comprised of a variable gain amplifier and an AGC circuit, to maintain a constant display over a ±5-dB range of input signal levels which can result from flat gain variations in transmission. This system is arranged to sample the synchronization pulse amplitude, relative to the "porch" level, in order to adjust the gain independent of the video information.

After clamping and de-emphasis of the composite video signal, the AGC circuit samples this signal for 4.7 μs during the "back porch" interval of each horizontal blanking pulse to obtain a measure of the voltage amplitude of the synchronization pulse. This voltage is compared with a precision reference and the resulting comparator output is filtered to derive a dc voltage for control of the variable gain AGC amplifier. An active multiplier type variable attenuator is employed in this amplifier to maintain the output within ± 0.5 dB of the nominal signal over the full range of input signal variations. The AGC system provides the proper gain setting in less than one frame time in response to the full 10-dB input signal change, and can therefore accommodate switched conferencing systems without objectionable picture flashes.

One of the problems that had to be overcome in the design of the AGC is the susceptibility to lockup in an incorrect gain setting when large transient input signal changes occur. For rapid increases in signal, the linear amplifiers saturate while for rapid signal reductions improper separation of the synchronization pulses from the composite signal may occur. Both conditions can produce false timing information and result in improper sampling of the video signal. With certain video signals, the derived sample voltage corrects the gain in the wrong direction and thereby produces lockup. To overcome this lockup condition, a special circuit senses saturation or improper timing and overrides the AGC action to properly correct the gain. The lockup protection circuit also senses the absence of an input signal and is used to control the application of a gray raster to the display tube under this condition.

The frequency shaping network de-emphasizes the composite video signal and returns the pre-emphasized transmitter signal to its nominal spectrum. This reduces the effects of transmission noise and interference. Additional response shaping to a prescribed[2] high-frequency rolloff is employed in the receiver to produce a subjectively pleasing picture and to further mask the effect of impulse noise, radio frequency interference and high frequency equalization deviations accumulated during transmission. This response shaping is added by a crispened rolloff filter (Fig. 11, curve c). When this crispened response is added to the 4-dB equivalent electrical rolloff, due to CRT beam size, the nominal overall optics response of the station set is as shown in curve d of Fig. 11. This overall response shape can be electrically characterized in the time domain. For a step input signal, the output transition is symmetric with a 4 percent single pre-shoot and post-shoot and exhibits a 10 to 90 percent rise time of 0.7 μs. The overshoots emphasize the picture contrast at transitions to "crispen" the picture and produce a more pleasing display.[2] The electrical low-frequency response of the receiver is characterized by less than 0.1 percent tilt in 100 μs in response to a unit step input voltage.

The balanced-to-unbalanced converter, view-self gate, AGC amplifier and frequency shaping network are realized in a single hybrid

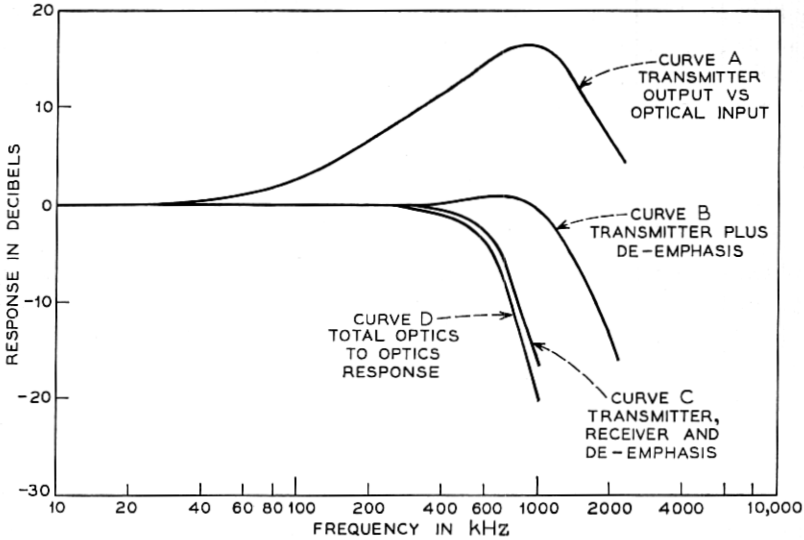


Fig. 11—*Picturephone* video frequency response.

integrated circuit mounted on a ceramic board containing tantalum film capacitors and resistors.[8]

After frequency shaping, the signal undergoes further processing in a feedback type synchronous amplifier clamp. This circuit clamps on the tips of the synchronization pulses to reduce the effects of system low-frequency rolloff and low-frequency crosstalk (power hum at 60 Hz is reduced by 35 dB).

The CRT driver circuit provides the video signal for the CRT grid (G1), brightness control and vertical retrace blanking. The G1 drive circuit has an adjustable gain which is matched in set manufacture to the tube transconductance to reduce contrast variability. User control of the display highlight brightness over a 40- to 110-foot-lambert range is accomplished by varying the tube cathode voltage. In the absence of an input signal the circuitry provides a gray raster display to indicate that the set is operational and to eliminate transient picture flashes during call setup. To protect the CRT from phosphor damage, the circuitry is arranged to rapidly cut off the beam when the set is turned off. In addition, limiting diodes are used to prevent circuit damage from internal tube arcing.

2.3.2 *Synchronization, Sweep and High Voltage Circuits*

The sync processing circuitry removes the timing information from the composite video signal, separates the horizontal and vertical timing and provides stable noise insensitive synchronization pulses to the sweep circuits. These synchronization circuits are designed to provide a stable display without user adjustment over the life and operating extremes of the set.

Sync separation from the video signal is obtained by amplitude discrimination at the midlevel of the synchronization pulses. To improve the stability of timing information, separate sync amplification and clamping of the AGC corrected signal are employed. A Schmitt trigger gating circuit, which requires a 2-μs sync separator output signal to indicate valid horizontal timing, is used to guard against impulse noise. A second Schmitt trigger circuit, which is arranged to require a 25-μs signal, is used to separate the 34.18-μs and 93.70-μs vertical pulses (Fig. 7) from the horizontal pulses. A conventional APC voltage-controlled oscillator is used to lock on the recovered horizontal timing information and reduce timing jitter due to transmission and coding noise. The voltage-controlled oscillator is realized with silicon integrated circuit chips mounted on a tantalum thin film substrate.[8] Both the horizontal and vertical oscillators are arranged to free run to provide raster scanning in the absence of an input signal.

The horizontal and vertical sweep circuits provide corrected deflection currents to the CRT yokes to compensate for the S-distortion[10] which results from the nonspherical face of the CRT. In addition, the five-ampere horizontal current is provided with correction to cancel the distortion caused by ohmic losses in the yoke. Linearity adjustments are not necessary due to the utilization of precision components. Protection of the horizontal sweep transistor, which switches the five-ampere deflection current, is accomplished by arranging this transistor to turn off if there is a loss of timing. The display overscan margin is kept below five percent to increase the information content of the display, particularly for computer-access readouts. Aspect ratio error is held to less than one percent and geometric distortion does not exceed two percent.

A flyback type high-voltage power supply is integrated into the horizontal sweep circuit to provide the required CRT and camera tube bias voltages. This circuit is provided with a safety interlock to disable these voltages when the display unit housing is removed. The 12 kV ultor potential is derived by rectifying the third-harmonic-tuned flyback pulse, at the secondary of the flyback transformer, with a 1X2B vacuum tube diode. To maintain precise raster size and aspect ratio the 12 kV is regulated to within two percent by means of a corona discharge regulator. To reduce shock hazard, a 3 GΩ resistor discharges the 500 pF CRT aquadag capacitance when the set is turned off. Radiation measurements show that the set does not produce any detectable radiation above the natural background (0.02 mR/hr).

The camera tube and CRT bias voltages are obtained by rectification of primary voltages from the flyback transformer. The CRT control grid voltage is adjusted during final set alignment to match the CRT voltage-cutoff characteristic.

Extreme care was taken in the design and mechanical layout of the high-voltage and horizontal-sweep circuits to reduce the coupling of these high energy circuits into the transmitter. Direct electrical and electromagnetic coupling was reduced by providing these circuits with a separate low-voltage regulator, segregating power feeds, eliminating circulating currents and damping flyback pulse ringing.

2.4 *Mechanical Design*

The display unit without its cover is shown in Fig. 12. It is assembled from a number of interchangeable modular subassemblies as shown in Fig. 13 and discussed individually below.

2.4.1 *Structural Framework*

Two aluminum castings of 360 alloy are used as the primary structural members to achieve low cost, uniform assembly and electrical shielding. The front casting accommodates the CRT-yoke assembly and aids in the shielding of the camera from the yoke fields. The rear casting shields the camera from the high energy sweep circuits and high-voltage power supply. A third nonstructural casting is used to encapsulate the flyback transformer. Collectively, the castings provide an 18-dB advantage in electrical isolation over that achieved with a conventional framework. This is important since the camera signal current is unbalanced and approximately 100 dB less than the CRT deflection current and the two tubes are physically adjacent in the display unit.

2.4.2 *High-Voltage Assembly*

The high-voltage assembly consists of the flyback transformer, rectifier tube, ultor voltage regulator and associated circuitry. As mentioned, the transformer uses a separate 360 aluminum alloy casting for ease of potting and curing. For safety, the casting is grounded and the 12-kV anode lead is provided with a back-up screw lock to prevent inadvertent disconnection. Solventless silicone resin is used as the potting material with silicone room temperature vulcanizing

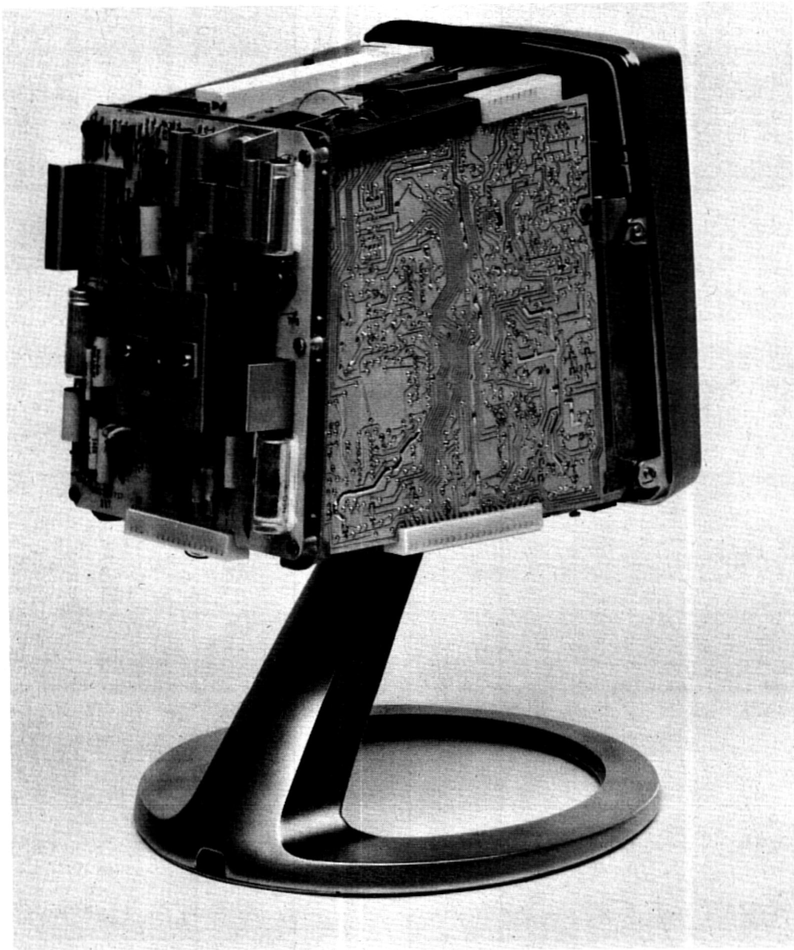


Fig. 12—1A Display Unit (less cover).

(RTV) rubber coatings at the critical interfaces to achieve arc suppression, corona prevention and 8-kHz noise control.

The horizontal sweep rate of 8 kHz is in the audible range and components in the horizontal deflection circuit produce a subjectively objectionable hum. This is true of the flyback transformer and several inductors, which have ferrite cores and expand magnetostrictively at the 8-kHz rate, as well as a laminated core choke and several high-voltage capacitors which vibrate electrostatically. The problem was

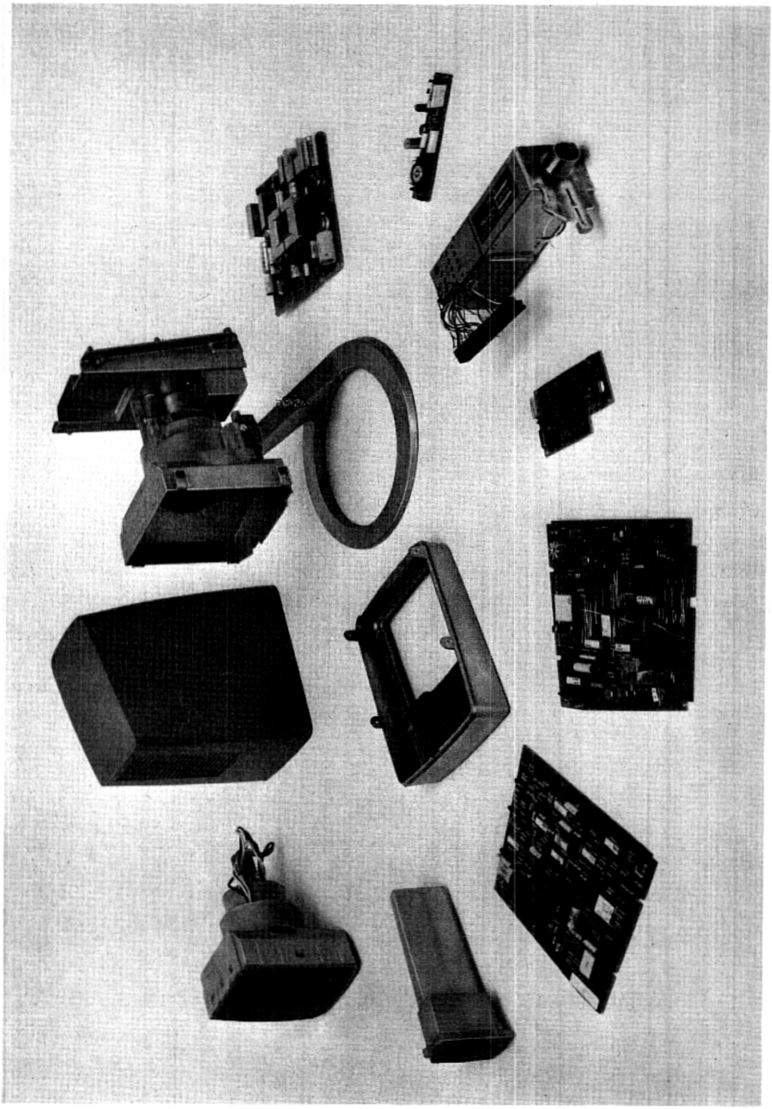


Fig. 13—1A Display Unit (subassemblies).

resolved by enclosing each offending component in an oversized stiff case to achieve an air shunt between the noise source and case.

2.4.3 *465A Display Tube*[8]

The packaged display tube is designed to fit into a CRT casting which has limited rear access to the alignment magnets and anode, yoke and stem leads. The tube funnel region and most of the stem is encapsulated with rigid polyurethane foam. This permits pre-centering of the display tube in the foam, gives better dimensional control than that obtained with the glass tube envelope, allows the use of molded deformation wedges to compensate for tolerance build up when mounting, and holds the prealigned yoke in position to avoid slippage or subsequent misadjustment. The foam also provides two-fold protection: to the user by reducing implosion danger and to the tube itself by reducing handling damage.[16] Customer safety from accidental tube implosion is further improved with a safety panel bonded on the face with clear polyester. The panel has an etched surface to disperse incident light and a transmission factor of 30 percent to improve contrast by having reflected light attenuated twice. The refractive index of the polyester was selected close to that of the glasses used to minimize ghost images at the interfaces. Nonbrowning glass was used for the tube face to resist electron bombardment discoloration. The anode lead is attached to the tube to minimize moisture, dust and safety problems. Likewise, the stem and yoke have flying leads which are stress relieved to minimize lead breakage.

2.4.4 *466A Camera Tube*

The camera tube is packaged in a rectangular mu-metal shield for interference control. An aluminum front plate assembly mounts the lens and iris. Effort was made to keep the camera temperature low since the target dark current doubles for each 9°C rise and thereby reduces the useful dynamic range of the tube. This was partially achieved by connecting the target end of the tube to the cast zinc bezel to take advantage of its high-thermal capacity. The gain of this thermal shunt is degraded by 3°C due to the need for electrical and vibrational isolation between the tube and bezel. The camera temperature rises exponentially during continuous operation, reaching a steady state value of 11°C above ambient after 5 hours.

The camera biasing circuits have been included on two small printed wiring boards in the package.[8] A separate metal shield to accommodate the video preamplifier is attached to the camera package.

2.4.5 *Iris*

The iris, functioning as an element in the video feedback loop, must be stable with time. To accommodate this, an iris having no mechanical friction was designed[17] using the principles described below.

Referring to Fig. 14, two phosphor-bronze cantilever arms, A and B, are mounted to base C and connected by a thin platinum-nickel wire, D. The ends of the cantilever arms form the mating halves of the aperture. By foreshortening the thin wire, the arms are pulled together to open the aperture. This is achieved without mechanical friction by using a taut-band suspended meter movement, E, with a double post actuator, F, attached to it. Since the thin wire is in equilibrium, the tension up and down is equal. As the actuator rotates, the wire progressively wraps around the posts without sliding, foreshortening its length without relative motion, hence without mechanical friction between parts. Worst-case accelerated life testing of 6 units resulted in an average of 7 million operations to failure with a worst-case MTBF of 6000 hours.

The aperture halves are shaped to provide the desired optical-electrical-mechanical transfer function. When off, the iris is closed to its smallest stop, approximately f/32.

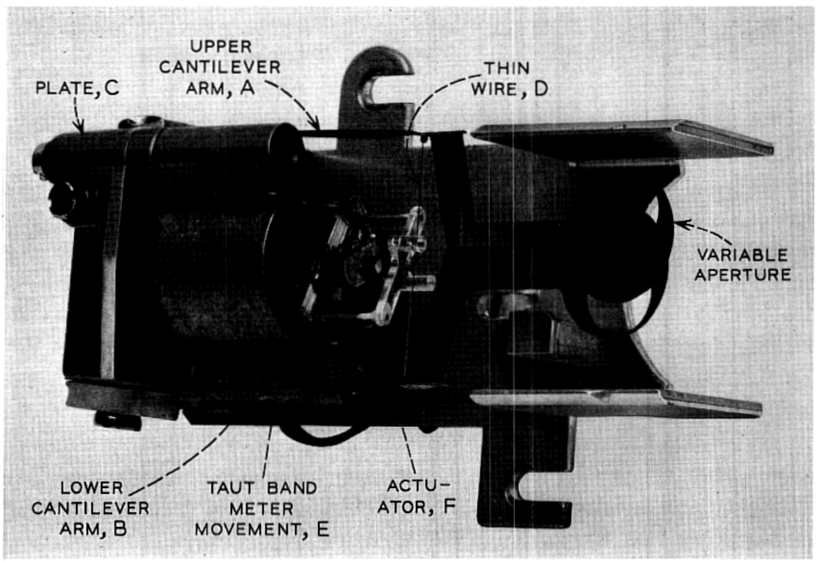


Fig. 14—Iris assembly.

The iris assembly is mounted to the camera plate with the aperture halves entering a cutout in the side of the lens. Thus the lens moves relative to the iris blades and is at the optimum nodal location in only one position. This degradation in iris location was evaluated using a lens design computer program and found to be an acceptable compromise for the advantage of permanently mounting the iris.

2.3.6 *Printed Wiring Boards*

The three major printed wiring boards average 210 square cm each and are made of 0.16-cm-thick G-10 glass epoxy material for strength. The transmitter and receiver boards are retained at four points with the circuit paths facing out to protect against stripping components when the cover is installed.

The printed wiring boards are single sided for reliability and lower cost. Low-resistance straps are used where necessary to avoid double-sided boards with plated-through holes. Wherever possible, components are mounted vertically to achieve improved heat transfer and large components are secured with an RTV adhesive to prevent possible damage during shipment. The wiring side is coated with an acrylic spray finish for moisture and fungus control.

The wiring boards are interconnected by right angle, edge mounted connectors. A common mounting block permits inserting a family of gold-plated, beryllium-copper contact members having different gauge wires.

2.4.7 *Shielding and Grounding*

Considerable attention was given to the mechanical design to reduce electrical interference to an acceptable level. Some of the steps taken to reduce interference have been discussed. In addition, the topographical layout utilized the available space to separate the receiver and transmitter circuits as much as possible. The printed wiring boards were laid out with special attention given to signal level progression, types of adjacent circuitry, parts orientation, low impedance ground paths, and connector land assignments. Equal care was exercised in the harness design to separate and shield wires which were subject to crosstalk.

2.4.8 *Bezel and Graphics*

The bezel is a zinc die casting to permit satin finish, chrome plating of the frame. The front area is painted black for glare control and good contrast. The bezel mounts to the CRT casting, retains the CRT and provides a mounting surface and graphics facility for the camera.

A capability for displaying graphics is obtained by lifting a spring loaded visor. This inserts a mirror in the optical path of the camera and directs the field of view to the desk top. Precise mirror orientation can be made in manufacture with a front adjustment.

The use of a mirror in the graphics mode introduces an optical inversion which is corrected by reversing the horizontal yoke leads. This is initiated by a visor arm actuating a switch. Simultaneously the raster is centered and shifted to the narrow angle. To reduce electrical interference, the switch and lens actuators for refocusing in the graphics mode are insulated from the bezel visor.

2.4.9 *Audio*

A 6.35-cm-diameter speaker is located behind the protective grill on the right-hand side. This relatively small speaker has a 300-cubic-cm back chamber to extend its low-frequency response. It is driven by an auxiliary audio amplifier which adds 6 dB of gain with bass boost frequency shaping.

The output of the speaker introduces considerable radiated and mechanically coupled vibration into the structural framework, requiring isolation of the camera to reduce microphonics below a perceptible level in the video signal.

The tone ringer is mounted on the rear casting and the alerting sound emanates from the vents on the bottom of the housing.

2.4.10 *Panning Mechanism and Manual Tilt*

The structural framework of the display unit attaches to a tilting mechanism for manually adjusting the elevation during initial installation over a 10° vertical range and a panning mechanism for rotating the head through 330°. The thrust bearing design utilizes a differential load near the center of gravity to reduce the torque required to rotate the head. The design accommodates large dimensional variation due to manufacturing tolerance and wear.

2.4.11 *Ringstand*

The ringstand is a satin finished, chrome plated zinc die casting which weighs 2.15 kg and helps lower the center of gravity of the set. To protect against a set being tipped over or pulled off the desk by the cord, the ringstand includes a dual base.[18] The inner surface in contact with the desk is a material with a high coefficient of friction which resists slipping. However, for impacts above the center of gravity, this material holds and becomes an objectionable fulcrum about which the entire set tips. Since desk top slipping is less damaging than tipping, an overhanging edge with a low coefficient of friction is provided. After the set rotates through a small angle after impact, the second surface touches and provides slipping rather than continued tipping.

2.4.12 *Harness and Cord*

The display unit harness passes through the panning mechanism and the hollow core of the ringstand pedestal and terminates in a connector to mate with the cord. The harness can be readily replaced since the end connector can be pulled through the pedestal and panning mechanism. Since the head rotates and the ringstand is stationary, fatigue tests were run on the harness to determine a lacing and mounting arrangement to achieve lead life beyond 100,000 panning operations.

The interconnecting cord is color coordinated to the sets and is of a "V" construction with a 1.2-meter section of 26-lead cordage going to the control unit and a 3-meter section of 50-lead cordage going to the service unit. The 50-lead sections terminate in connectors and permit the use of B25A extension cable. The junction of the "V" construction enters the bottom of the ringstand to connect with the harness. To connect the set, the harness connector is pulled slightly from the base for cord insertion. Thereafter, the mated connector pair is pushed back into the base where it cannot open due to the pedestal width. Subsequently, a cover plate—designed to avoid damage to the desk—is attached to retain the connectors.

2.4.13 *Complete Assembly*

The complete display unit assembly weighs 11 kilograms. In final testing the unit successfully passed a 35 g shock test with six repetitions of a 6.5-millisecond sawtooth pulse in each direction of three mutually perpendicular planes, for a total of 36 drops. Two different tests were used to confirm its vibration endurance. In the first test, the unit was sinusoidally vibrated at 0.05 inches double amplitude from 10 to 31 Hz and at 2.5 g from 31 to 200 Hz at a sweep rate of approximately 4.5 octaves per minute for 60 minutes in each of three mutually perpendicular planes. In the second test, a random input of 0.04 g^2/Hz (equivalent to 2.75 rms g level), clipped at 3σ (8.25 g rms), was applied over a bandwidth of 10 to 200 Hz for 20 minutes in each of three mutually perpendicular planes. Experience gained in actual shipment confirms the validity of these laboratory results. In operation, the unit functions satisfactorily in a relative humidity of 95 percent and reaches an average steady-state temperature of approximately 20°F above ambient.

III. CONTROL UNIT

3.1 *General Factors*

To bring the controls and audio input closer to the customer than the display unit, a separate, small control unit is provided as shown in Fig. 2. This supplements the 12-button *Touch-Tone* telephone set which is necessary for establishing calls for regular telephone service and for privacy when the speakerphone feature is not desired.

The control unit has a family resemblance to the display unit, using a slightly concave black face with an accentuated edge around the perimeter. The molded plastic cover is available in the six matching business office colors. A satin finish aluminum base completes the aesthetic parallel. The composite design achieves a low profile by the use of rocker switches and thumbwheel controls.

3.2 *Audio*

The AF-1 electromagnetic transmitter developed for this application is located behind the small port on the front of the control unit. The microphone measures 2.2 cm in diameter and 0.89 cm in depth. It is suspended in a rubber isolation boot which positively seals the microphone input to the base while providing isolation from microphonic noise above 40 Hz. The housing-to-base gap is sealed on each side of the microphone to avoid deleterious chamber effects.

The microphone is flexibly connected to the audio preamplifier which provides frequency shaping and 75 dB of audio gain. The preamp shares a multipurpose wiring board, shown in Fig. 15, with the video controls and function switches.

3.3 *Mechanical Design*

The rocker type function switches move shorting wipers across commutator lands on the printed wiring board. This eliminates all wires, soldered connections and conventional contact adjustments, resulting in low cost and high reliability. The rocker switches also eliminate the need for lamps since the state of the switch is indicated by its position. The single exception is the ON/OFF switch where compatibility with the 3A Speakerphone[3] circuitry required momentary makes and breaks with the subsequent need for an alerting lamp.

To avoid inadvertently leaving the PRIVACY or VU-SELF switches in the operated position, mechanical linking is provided between the switches such that they are returned to their normal states when the OFF button is actuated.

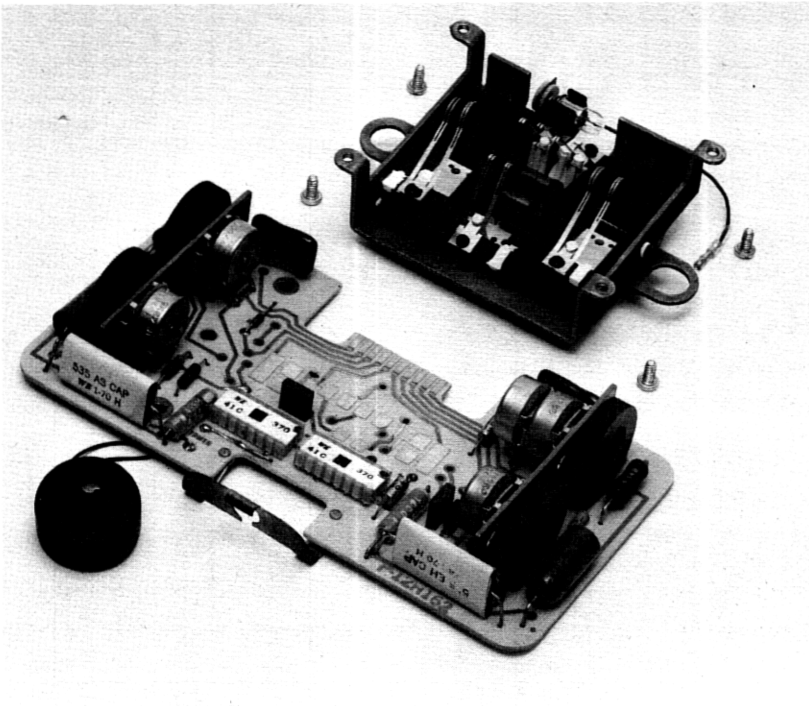


Fig. 15—72A Control Unit (subassemblies).

All of the switches and potentiometers mount directly to the printed wiring board for alignment accuracy and the mounting cord connects directly to gold plated, printed lands. For space reasons, a double-sided, G-10 glass epoxy board was used. The cover and base clamp on opposite sides of the wiring board and the complete assembly is held together with two screws. The complete assembly weighs 142 grams.

IV. SERVICE UNIT

4.1 *General Factors*

The 1A Service Unit shown in Fig. 3 is the third major assembly required for *Picturephone* service. Since the customer does not interact with it directly, it is designed to be mounted remotely with a cable run up to 26 meters from the display unit. It has a stipple finished gray housing measuring 30 cm high, 18.1 cm wide and 15.9 cm deep, and is planned for vertical installation to minimize the projected floor area required. Since this is the only unit connected to a 110 V power source, the 7.7-kg assembly mounts to a metal wall plate and has a fire resistant cover for safety. All adjustments and class of service options are located here to avoid the necessity for opening the display and control units during installation.

4.2 *Circuitry*

4.2.1 *Functional Description*

The service unit contains the power circuits which convert the subscriber's local 110 V to several well regulated dc voltages of lower potential for use in the set; control circuits which detect and process the audio and video supervision signals to control the display unit; and a transmission equalizer[15] which adds frequency shaped gain to correct for the insertion loss of the receiving video pair. A functional block diagram of a service unit as arranged for a non-key telephone installation is shown in Fig. 16.

The basic system plan for station supervision of the video telephone involves the use of normal off-hook and ringing derived from the audio

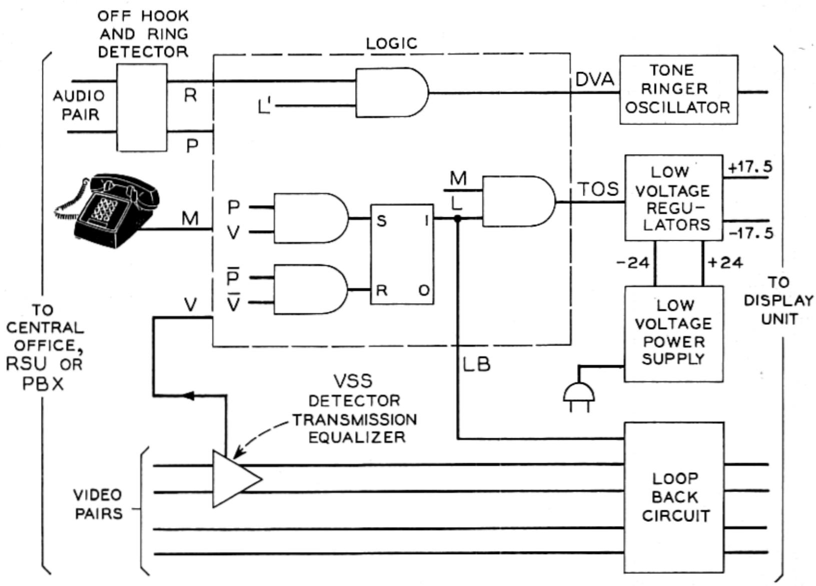


Fig. 16—Service unit block diagram (for single line arrangement).

pair and a video supervision signal (VSS) derived from the receiving video pair. An off-hook and ringing detector and a VSS detector sense the audio and video supervision signals to provide ring, off-hook and video indications to the set logic. The logic circuitry combines these input signals and the main station switchhook indication to derive three control signals required for set operation. The distinctive video alerting signal (DVA) controls a tone ringer oscillator which drives the sounder in the display unit for audible alerting on video calls. A turn-on-set (TOS) signal activates the low-voltage regulators in the service unit which power the circuits in the display and control units. The loop-back (LB) signal controls the maintenance loop-back circuit which provides an equalized loop-back of the video pairs to the central office for maintenance purposes and also connects together the balanced input and output of the display unit when the set is idle.

4.2.2 *Control Circuits*

The circuits required for proper logical control of the display unit are: the off-hook and ringing detector, VSS detector, loop-back circuit and the service unit logic circuitry.

The off-hook and ringing detector[8] consists of a high input impedance differential amplifier which bridges the audio pair and two separate detector circuits. This amplifier responds to voltage changes at its input and provides the detectors with complementary outputs which follow the input voltage changes. The ringing detector reshapes the ringing signal to provide a square wave logic signal (R) that follows the 20-Hz ringing. The off-hook detector is arranged to provide a dc output indication (P) under low voltage input conditions to the amplifier and thus indicates the switchhook status of both the main station and audio extensions. Low pass filtering is used to eliminate response due to the ringing signal. A 60-ms minimum time delay in the off-hook to on-hook indication is included to guard against response to transient excitation of the audio pair.

A VSS detector, which is included as part of the transmission equalizer, samples the VSS or the video signal on the receive pair at an unbalanced equalized point in the equalizer. The 8-kHz content of this signal is filtered and rectified to derive a logic signal (V). The detector has a Q of 40 and a response threshold to a sinusoidal input signal of 10 mV rms. Although this detector will respond to all video signals as well as VSS, the system arrangements never rely on using the video signal in place of VSS for control of the set.

Station logic is summarized in the state diagram (Fig. 17) which

LOGIC INPUTS

V = PRESENCE OF VSS OR VIDEO

R = PRESENCE OF AUDIO RINGING

M = OFF HOOK VIDEO MAIN STATION

P = OFF HOOK ANY STATION

STATION STATES

$\bar{P}$ AND $\bar{V}$ = IDLE

$\bar{L}$ AND R = ALERT

P AND V = LOCKUP (L)

M AND L = ON

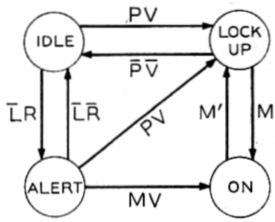


Fig. 17—*Picturephone* logic state diagram.

gives the relationship between the P, M, R, and V logic inputs and the ON, ALERT, LOCKUP, and IDLE station states. The detailed interaction of the station and the switching system during calling procedures is outlined in Ref. 19. Since the VSS signal is never maintained after the called party answers, the set logic must supply memory of a video call. This memory or video lockup state (L) is implemented with a set-reset type flip-flop which is set by the simultaneous occurrence of any audio or video party off-hook (P) and video supervision (V). The station set remains in the lockup state until all audio and video stations on the video line are on-hook ($\bar{P}$) and there is no V indication ($\bar{V}$), at which time the flip-flop is reset and the set is returned to the idle state. At any time during lockup the video circuitry may be turned on when the main video station goes off-hook (M).

During the idle state the tone ringer may be activated with the ringing logic signal (R) which contains the 20-Hz interruption to properly modulate the tone ringer circuits. The 60-ms delay in the off-hook to on-hook transition delays the enabling of the tone ringer upon return to idle ($\bar{L}$). This avoids ring tap which would otherwise occur because of extraneous response of the ringing detector to the on-hook indication. The volume of the tone ringer may be adjusted by the installer to one of three levels to accommodate customer preference and room acoustics.

The maintenance loop-back is on during the idle state and removed during lockup. The loop-back is not replaced prior to entering the idle state because of the possibility of a calling party receiving his own picture through the called party's loop-back. Loop-back is implemented with a relay circuit. The switching systems are arranged to perform a continuity test through the station loop-back prior to setting up a video call. During a local power failure the continuity test will fail because of the unpowered equalizer, and therefore call completion and video charging are inhibited. A *Picturephone* subscriber's normal telephone service is not interrupted by such a power failure although the speakerphone is inoperative.

The service unit circuitry arrangements just described are compatible with single-line video service and will allow the connection of one video unit and the normal complement of audio extensions. Service requirements for multivideo pickup of a single video line and/or multiline access by a single station are accommodated with a video KTS.[20]

In a station set which operates behind a KTS, the service unit is equipped with different plug-in circuit boards to provide a simplified arrangement (Fig. 18). The audio and video supervision detection, logic and loop-back functions are removed from the service unit and the transmission equalizer is replaced by a passive build-out network. Set turn-on is controlled directly from the KTS by the TOS lead which, as before, activates the low voltage regulators. The DVA signal is standard KTS ringing applied to the tone ringer via a balanced ringing pair when distinctive alerting is required. An indication of a loss of station set power is provided to the KTS by means of the PF control lead. In such an event the KTS cancels call completions by arranging for continuity loop-back test failure as was done in the single video-line arrangements. The build-out network is selected at the time of set installation from one of four possible networks so as to achieve a nearly constant electrical transmission loss between the KTS and the station. This loss is pre-equalized in the KTS equalizer.[15]

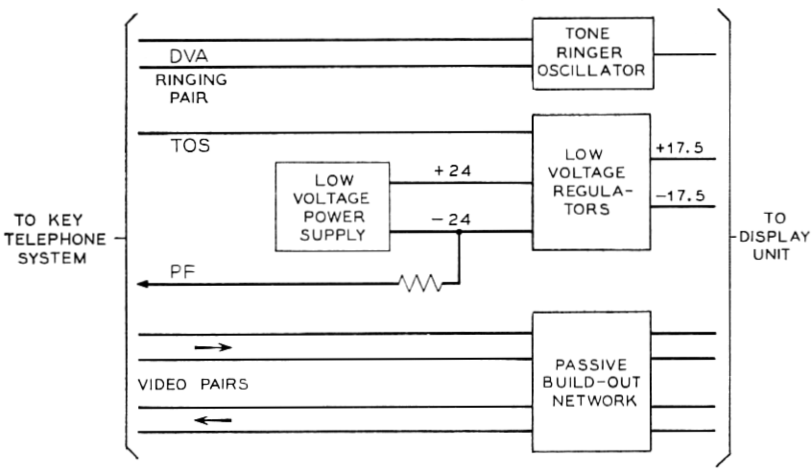


Fig. 18—Service unit block diagram (for key telephone arrangement).

4.2.3 *Power Circuits*

The primary power supplies for the station set are located in the service unit and convert the subscriber's 110 V local ac power to low voltages for display unit operation. This location insures customer safety, since 110 V wiring to the subscriber's display unit is not required, and convenient installation, since it is generally possible to find an existing power outlet within a 26-meter cable run to the display unit. To achieve the well regulated voltages required for the video circuits over the 24 V range of line voltage variations, a ferro-resonant power supply is used. The service unit has been submitted to Underwriters' Laboratories for listing.

A pair of series-type voltage regulators derive the more precise voltages required for video circuit operation from the ± 24 V ferro-resonant power supply. Solid-state low-power on-off switching of the video units by the set logic is accomplished in the regulators by controlling the base current in the series regulating transistors. By performing more precise regulation in the service unit it is possible to reduce overall display unit power dissipation which is 4 watts in standby and 40 watts in service. The service unit dissipates 21 watts in standby and 35 watts in service.

Pair assignment in the 50-pair interconnecting cable between the service unit and display unit was made to reduce transmit-to-receive video crosstalk and audio-to-video crosstalk. This assignment includes separate power feeds and grounds for the receiver and transmitter circuits. Pair quantity in the power feeds is allocated to maintain one-volt regulation at the display unit over all interconnecting cable length variations. Inadvertent disconnection of the interconnecting cable or a loss of either service unit fuse is sensed by a relay circuit in the service unit which automatically switches off all dc power. This inhibits the successful completion of the continuity loop-back test and thereby signals the switching system to cancel the completion of calls under these conditions.

4.3 *Mechanical Design*

The primary framework for the service unit is a one-piece *U*-shaped structural member made of 0.236-cm, cold-rolled steel with a zinc-chromate finish. Mounting tabs, ventilation scoops, stiffening ribs, printed wiring board mounting posts and miscellaneous sub-bracketry are formed from the principal part to provide a simple, low-cost assembly. Structural integrity is maintained by bridging the center with a spacer and the open ends at top and bottom with braces. The 3.6-kg ferro-resonant transformer and other large components of the power supply are mounted on the stiff center section of the U-channel to resist deformation under shock loading. In manufacture, the power supply is wired as shown in Fig. 19 using 300 V test, flame-retardant wire.

The ± 24 V secondary voltages are brought to a central printed wiring board, CP-1, for distribution. CP-1 physically mounts on the open end of the U-channel and interconnects the right, central and left zones. Consequently, all terminations are performed on CP-1 for signal as well as power distribution. The board includes a 50-pin female connector for the display unit cord, a 21 screw connection field to accommodate the loop and speakerphone leads, two fuses, test points and screw lifters. On the left side of CP-1, the gold-plated connector land accommodate either the FW-1 circuit pack for key telephone installations or the FW-2 circuit pack for single-line installations. The right-side lands accommodate the 939-type cable equalizer or appropriate 877-type pad-out networks, depending on the installation. This approach to circuit interconnection utilizes the physical arrangement to lower cost and increase reliability by reducing connectors and harnesses. The assembly without cover is shown in Fig. 20. With any complement of boards, all terminals, fuses, screw lifters, adjustments and test points are available from the front.

The cover is made of 25 percent glass-filled polyester which meets the fire-resistant codes. All labels are molded in. The cover has venting to accommodate the heat dissipating circuitry. Under maximum power dissipation, the temperature rise is 25°C above room ambient.

V. CONCLUSION

The 2C Video Telephone Station is now in production by Western Electric Company and is being used in initial *Picturephone* service. As manufacturing and field experience accumulates, normal engineering improvements will be made to reduce cost and improve reliability. Different versions of station equipment will be required in the future as *Picturephone* service grows, such as designs for residential applications, conference rooms, and public booths. In addition, future designs may incorporate slow-scan techniques for better graphics transmission, and eventually color *Picturephone* sets will become a practical possibility.

VI. ACKNOWLEDGMENTS

The design of the *Picturephone* set has been a collaborative effort of many colleagues whose contributions are gratefully acknowledged.

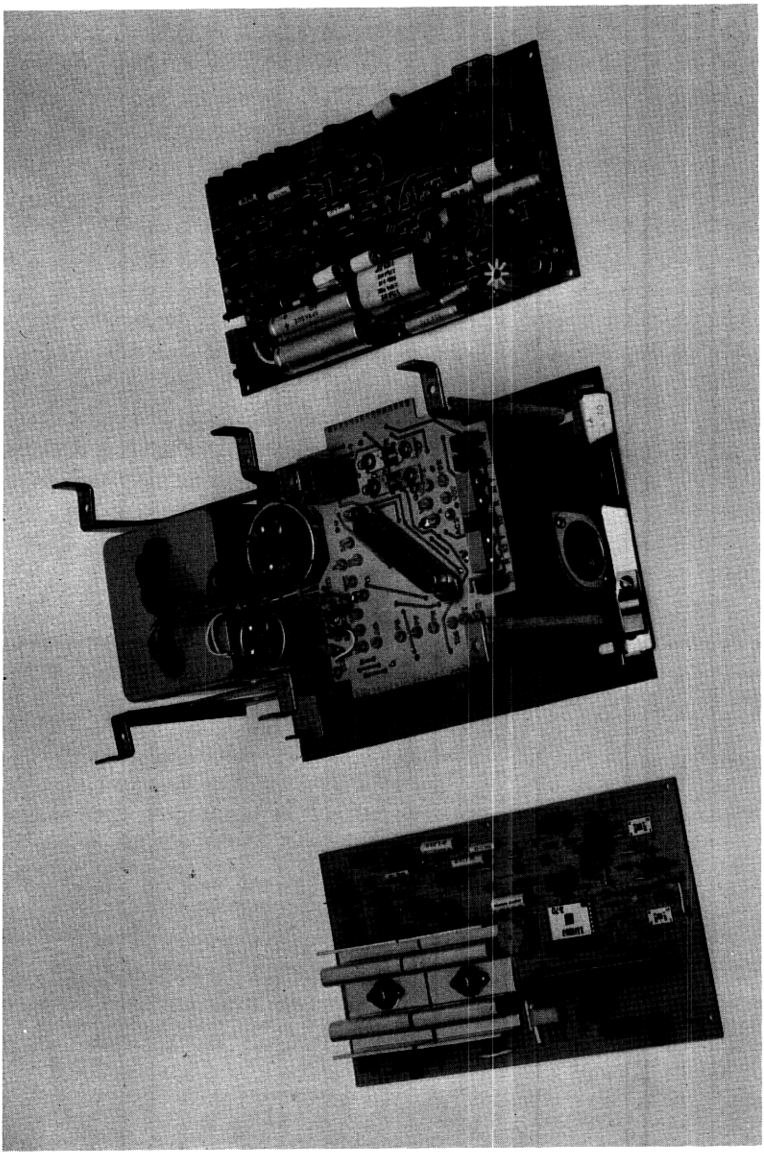


Fig. 19—1A Service Unit (subassemblies).

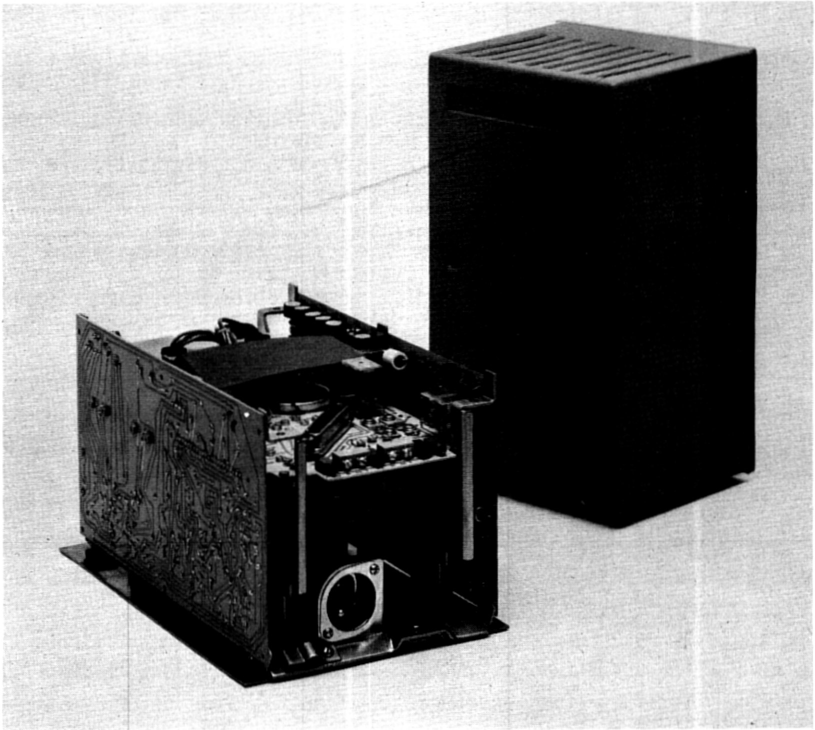


Fig. 20—1A Service Unit (less cover).

The completion of the design on schedule required and received outstanding cooperation from many technical areas and the shops and drafting organizations at Bell Laboratories. The enlightened leadership of C. G. Davis and F. F. Romanow and the technical and supervisory contributions of A. M. Gordon, S. C. Kitsopoulos, V. E. Munson, H. T. Shippen and W. Thommen are especially acknowledged.

REFERENCES

1. Dorros, I., "The *Picturephone*® System: The Network," B.S.T.J., this issue, pp. 221–233.
2. Crater, T. V., "The *Picturephone*® System: Service Standards," B.S.T.J., this issue, pp. 235–269.
3. Clemency, W. F., and Goodale, W. D. Jr., "Functional Design of a Voice-Switched Speakerphone," B.S.T.J., *40,* No. 3 (May 1961), pp. 649–668.
4. Kaufman, J. E. (Ed.), *Illuminating Engineering Society Lighting Handbook,* 4th Edition, New York: Illuminating Engineering Society, 1966, pp. 9–55.
5. Dreyfuss, H., *The Measure of Man: Human Factors in Design,* New York: Whitney Library of Design, 1959, pp. H1–H2.

6. Kingslake, R., *Applied Optics & Optical Engineering, Vol. 2,* New York: Academic Press, 1965, p. 219.
7. Nagata, K., and Miura, A., "A Study of Picture Quality and Video Telephone," 1970 IEEE International Convention Digest, March 1970, pp. 250–251.
8. Gordon, A. M., and Singleton, J. B., "The *Picturephone*® System: Station Set Components," B.S.T.J., this issue, pp. 313–349.
9. *Proceedings of the Camera Tube Symposium,* Bell Telephone Laboratories, Murray Hill, N. J., December 4, 1969.
10. Fink, D. G., *Television Engineering Handbook,* First Edition, New York: McGraw-Hill, 1957, pp. 1–50, pp. 6–58.
11. Millman, J., and Taub, H., *Pulse Digital and Switching Waveforms,* New York: McGraw-Hill, 1965, p. 515.
12. Von Ohlsen, L. H., "Soft X Ray Effects upon Silicon-Diode Arrays Aged in Camera Tubes," IEEE Journal of Solid-State Circuits, Vol. SC-5, No. 5, October 1970, pp. 261–265.
13. Thommen, W., "Noise Characterization of a Television Camera Amplifier," Proceedings of the IEEE, *54,* No. 12 (December 1966), pp. 1953–1954.
14. Brown, H. E., "The *Picturephone*® System: Transmission Plan," B.S.T.J., this issue, pp. 351–394.
15. Brown, J. M., "The *Picturephone*® System: Baseband Video Transmission on Loops and Short-Haul Trunks," B.S.T.J., this issue, pp. 395–425.
16. Hamilton, J. O., and Wachs, M. H., "A Plastic Encapsulation for the *Picturephone* Display Tube," 1969 IEEE International Conference, Electrical Insulation Group (G-32) Special Session, New York, N. Y., March 28, 1969.
17. Kitsopoulos, S. C., Stokes, R. R., and Thommen, W., "An Automatic Electroresponsive Light Regulator Utilizing Taut-Band Meter Movement," U. S. Patent No. 3,561,847, filed June 5, 1968, issued February 9, 1971.
18. Stokes, R. R., "Apparatus Base Configuration for Reduction of Sliding and Tipping," U. S. Patent 3,462,111, filed December 13, 1967, issued August 19, 1969.
19. Urich, J. F., "The *Picturephone*® System: Switching Plan," *B.S.T.J.,* this issue, pp. 521–531.
20. Daskalakis, A., "The *Picturephone*® System: Key Telephone Systems," B.S.T.J., this issue, pp. 567–584.