SIMPLIFIED TELEVISION FOR INDUSTRY

By

R. C. Webb and J. M. Morgan

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RADIO CORPORATION OF AMERICA
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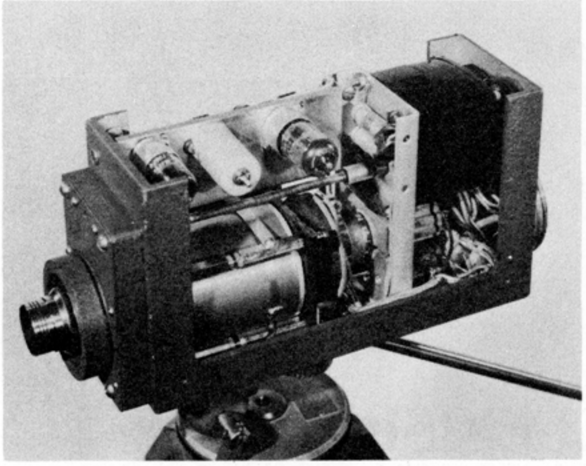
FIG. 1—Vidicon camera unit contains two miniature tubes and the picture tube

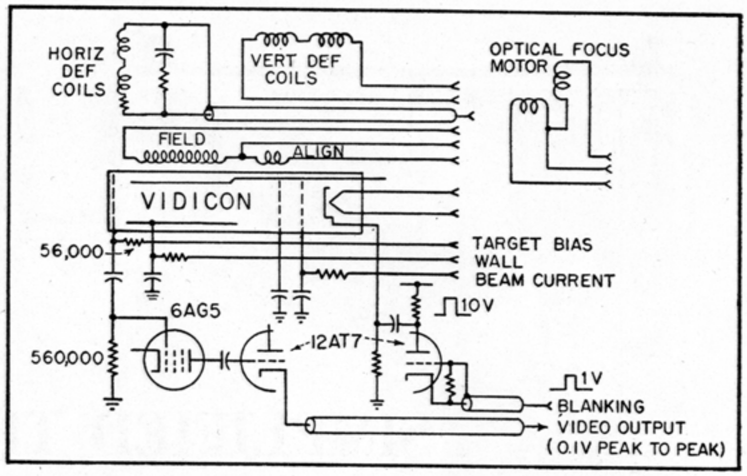

FIG. 2—A standard 24-conductor cable connects the camera and control units

Simplified TELEVISION

System uses recently introduced vidicon camera tube. Synchronizing signals follow RMA standards to allow use of commercial-broadcast tv receivers as monitors. Two units contain total of 48 tubes, including vidicon and monitoring scope

INDUSTRIAL television installations usually employ a multiplicity of camera units and a common centrally-located viewer, in contrast to broadcast television where a handful of cameras is used to serve many thousands of receivers. The most logical approach to cutting the cost of industrial television equipment is to reduce the cost of the camera units and to make them usable with commercial broadcast viewing equipment, which has already undergone substantial price reduction.

There are other basic requirements for industrial television equipment besides low cost. It should be compact and light in weight for portability. It should require a minimum of servicing and be capable of dependable operation over long periods of time.

Such a system is described here. A significant reduction in camera cost has been made possible by the recent introduction of the vidicon tube, which was described in ELECTRONICS last month.[1] The advantages of this photoconductive camera tube include operational simplicity, low cost, good resolution, freedom from spurious signals and high light sensitivity.

Vidicon System

The system consists of a small pickup camera and a master unit. These units are connected by a standard 24-conductor television camera cable, which may be up to 500 feet in length.

The camera shown in Fig. 1 with its cover removed is 10 inches long, 3¼ inches wide, 5 inches high, and weighs approximately 8 pounds. A typical 16-mm lens in a remote focusing mount permits optical focus adjustment by remote control from the front panel of the control unit along with the other camera adjustments.

The vidicon pickup tube can be seen extending inside of the focusing-coil—deflection-yoke assembly and the electron-gun alignment coil. The motor and gear assembly for operation of the remote focusing mechanism is located in the rear of the case and the video amplifier stages extend from the front of the camera toward the rear.

As shown in Fig. 2 the camera has been kept as simple as possible, containing only the pickup tube and those elements intimately connected with it. Scanning currents for both vertical and horizontal deflection coils are sent in over the cable along with the d-c currents for the focusing field and alignment coil as well as the operating potentials for various electrodes in the vidicon. A one-stage video preamplifier followed by a cathode-follower prepare the signals from the target electrode for transmission over the coaxial cable back to the master unit. In order to establish black level it is necessary to blank the target of the vidicon during the scanning return time and this is most conveniently done by applying a positive ten-volt blanking pulse to the cathode. Since a ten-volt pulse on a 52-ohm line represents a very sizeable current it was found more economical to transmit a one volt

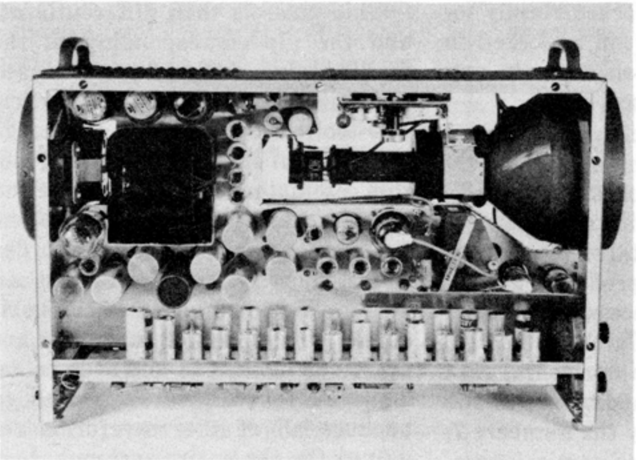

FIG 3—Left-side view of control unit shows video strip and cooling fan

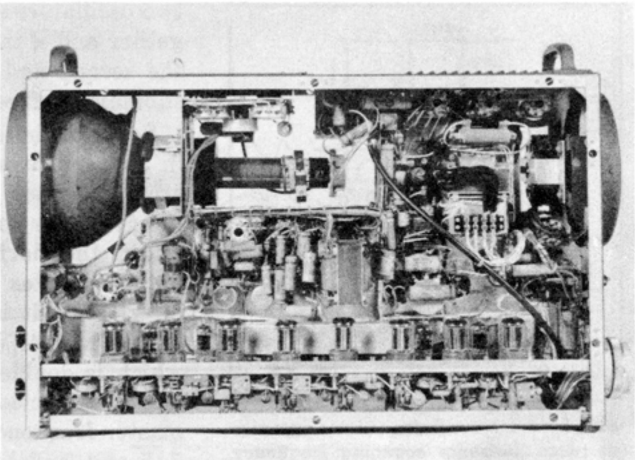

FIG. 4—Right-side view shows frequency-division chain and high-voltage circuits

For INDUSTRY

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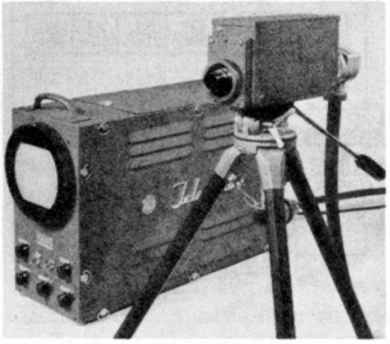

Complete industrial television system draws a total of 350 watts

pulse and amplify it in the camera just before application to the vidicon cathode.

Views of each side of the master control unit are shown in Fig. 3 and 4.

In order to operate standard broadcast television receivers from a system of this kind it is necessary to establish substantially the same scanning rates as those used in commercial broadcasting. Certainly it is necessary to transmit an interlaced signal because otherwise the resolution in the vertical direction will drop to approximately 250 lines. It was therefore decided to establish the same scanning rates for the industrial system as those standardized by the RMA for commercial broadcasting, namely 525 lines, 30 frames interlaced.

Simplified Sync

One of the basic elements of the simplified synchronizing signal generator used in this equipment is an oscillator, which resembles the familiar multivibrator.[2]

This basic oscillator is illustrated in Fig. 5A. Before the plate voltage is applied to the circuit, C is uncharged and the grid of V_2 is at ground potential. As soon as plate voltage is applied, the grid of V_1 is raised to some positive potential determined by the series of resistors. The plate resistor of V_1 is low and consequently a relatively large current can be drawn by that tube down through the common cathode resistance, which raises the cathode of both of the tubes to some positive voltage E_K. With the cathode of V_2 highly positive with respect to its grid, the plate current in that tube is cut off and C is free to charge through R toward B+ according to the logarithmic curve shown in Fig. 5B.

If nothing were to prevent it, C would charge up to a value $(1 - 1/\varepsilon)$ of B+ in RC seconds. However, as the potential on the grid of V_2 increases as C charges, it will reach the shaded region below E_K that represents the negative bias range for which V_2 will be conductive. As soon as V_2 begins to conduct, the plate current flowing through its plate resistor lowers the potential of the grid of V_1 and that tube is quickly biased off. However, since it was largely the heavy current drawn in the left-hand tube that supported the cathode potential at the value E_K, this potential will now drop to a very low value and the grid of V_2 will find itself highly positive with respect to its cathode. Capacitor C then discharges through the diode formed by the grid and cathode of V_2 and the length of time required for the discharge to occur is determined by the value of C and the effective resistance of the diode and the cathode resistor.

Having discharged C to a low value the circuit is ready to restart the cycle. Thus a saw-tooth voltage waveform is available across C and a narrow pulse can be obtained from the plate resistor of V_1. The exact frequency of oscillation of this circuit depends upon several factors including the value of the plate supply voltage, which is carefully regu-

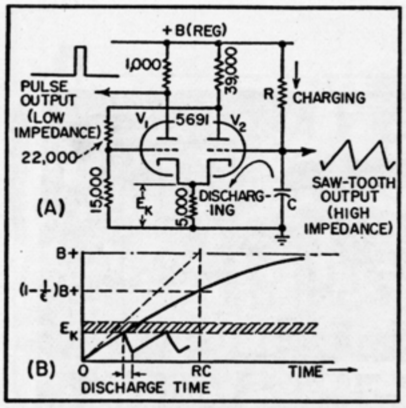

FIG. 5—Basic oscillator-counter operates at twice horizonal scanning frequency

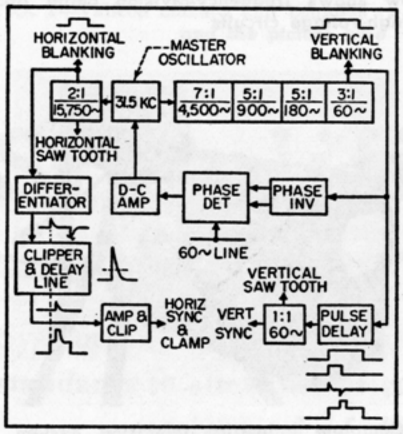

FIG. 6—Vertical and horizontal sync, scanning and blanking voltages are produced by this frequency-division and pulse-shaping network

lated. It depends primarily upon the values of *R* and *C*, and the voltage E_K, and it has been found to be stable enough over long periods of time for this application.

The oscillator is susceptible to being synchronized to external signals. A positive pulse added to the capacitor voltage can precipitate entry into the conduction region periodically, or a negative pulse added to E_K or to the left-hand grid will do as well. A circuit of this kind is especially useful in a television synchronizing generator since use can be made of the square-topped pulse output as well as the nearly ideal saw-tooth wave.

Frequency Division

The positive pulse out of the master oscillator is added to the capacitor voltage of the next stage below, which is an identical oscillator but set to run free at 1/7 or 1/5 the master frequency, as shown in Fig. 6. In this way the two oscillators are locked rigidly together and a third can be locked to the second and so on down to any submultiple frequency.

Seven of these oscillators are used in the synchronizing-signal generator. In order to obtain the half-integral relationship required between the horizontal and vertical scanning rates to produce odd-line interlacing, it is necessary to start with a master oscillator at 31.5 kc, which is double the horizontal rate of 15,750 cycles. Subdivision of the master frequency by the numbers 7, 5, 5 and 3 yields the vertical scanning rate of 60 cycles. The vertical blanking pulse is taken from the 60-cycle oscillator that is made to have a discharge time approximately 5 percent of the vertical period (V) by choice of the time constants governing that oscillator. A sample of the vertical blanking signal is taken through a phase inverter to a phase detector where it is compared to the power-line frequency. The afc signal thus developed is applied to the master oscillator to synchronize it with the power frequency.

The horizontal frequency generator is synchronized at $\frac{1}{2}$ the master frequency and is adjusted to produce a horizontal blanking pulse width that is approximately 15 percent of the horizontal period. The saw-tooth output of this stage is also used as a scanning waveform.

Horizontal sync is made from blanking by differentiating the blanking pulse, clipping the leading pulse and sending it through a delay line to produce a front porch of about 2 percent of the horizontal scanning period H. The pulse is later amplified and clipped to produce a sync pulse with a steep front edge and a duration of approximately 5 percent H. The horizontal sync and blanking pulses are thus similar to the RMA standard waveforms.

The vertical sync pulse, which is quite unorthodox, is produced by allowing the front edge of vertical blanking to key a pulse delay tube into operation. After a time interval, determined by time constants in the delay circuit, the delay tube falls out of its conductive condition having produced a pulse that is a fraction of the length of the vertical blanking period.

This pulse is then differentiated, and the pip corresponding to the trailing edge of the delay pulse used to synchronize a second 60-cycle saw-tooth oscillator. The discharge time or equivalent pulse width from this oscillator is made to be no greater than approximately $\frac{1}{2}$ of the time for one horizontal line in order that a short vertical sync pulse can be slipped in just ahead of one horizontal sync pulse and just after another one in the odd and even fields. Thus 10 tubes have been used to produce all of the waveforms required for the entire system.

The composite waveform is shown in Fig. 7. Although the vertical sync pulse is only about 10 times as long as the horizontal pulse no difficulty has been experienced in tests with commercial receivers in obtaining sufficient vertical sync signal. Furthermore, the signal in an industrial system is always noise free since it will be fed over closed circuits.

The scanning system used is shown in the block diagram of Fig. 8A. A single vertical deflection amplifier is common to both the monitor kinescope and the camera since the power requirements are small and ordinary cable pairs are satisfactory for transmission out to the camera. The horizontal scanning and second anode voltage supply for the monitoring kinescope are combined in one conventional unit of the type normally used in home receivers.

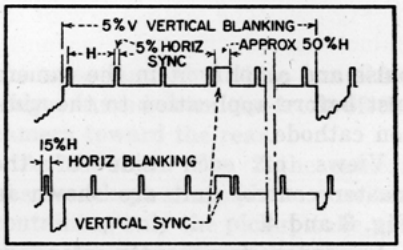

FIG. 7—Composite waveform for the industrial television system

The horizontal scanning for the camera is quite unconventional, however, since it is necesary to send the current to the camera through several hundred feet of 52-ohm coaxial cable. The method of accomplishing this can best be understood from Fig. 8B.

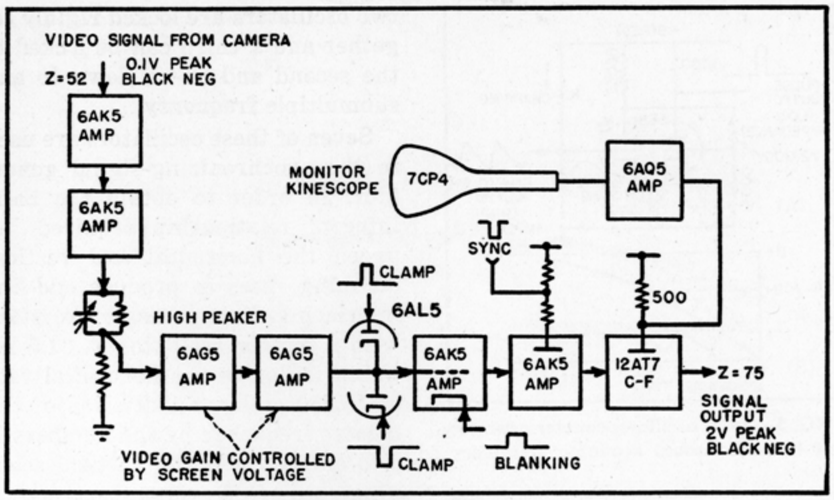

FIG. 9—Video path is similar to that used in broadcast transmitters

The parallel-resonant circuit comprising C and L with R_1 and R_2 connected serially in each arm is known to be antiresonant at all frequencies for the singular condition where $R_1 = R_2 = \sqrt{L/C}$. The terminal impedance Z, looking into the network is a pure resistance equal to $\sqrt{L/C}$ ohms at all frequencies. Such a constant resistance network as this makes an ideal termination for the transmission line and since it includes the horizontal deflection coil as one element it should be possible to produce any desired current waveform in the coil by impressing the proper voltage waveform upon the line. Ringing of the resonant circuit formed by the deflection coil and any capacitance that may be associated with it is very undesirable in the presence of the impulse waveforms used in television scanning. The condition for critical damping of a resonant circuit requires that the total resistance around the series loop must be at least equal to $2\sqrt{L/C}$, a condition that coincides exactly with the foregoing.

Synthesis of the required voltage waveform is accomplished as shown in Fig. 8C. The voltage across the inductance during the scanning period must be $L\, di/dt$ which for a constant rate of change of current is a small constant negative voltage. During retrace time the current change is in the opposite direction and many times faster, hence, the voltage required across the coil is of the form of a positive pulse. The voltage drop iR_2 across R_2 due to the saw-tooth current is of saw-tooth waveform as shown. The sum of these two voltages gives the required waveform that must be impressed upon the line to produce the ideal current saw-tooth in the coil.

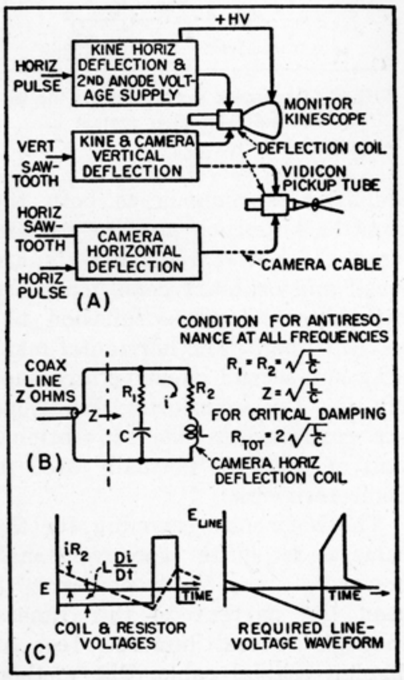

FIG. 8—Block diagram of scanning circuits. (B) and (C) explain operation

Perfection of the scanning linearity depends entirely upon the accuracy with which this complex waveform is produced. It was fortunate that both the saw-tooth waveform and its companion pulse were available from the horizontal frequency stage in the synchronizing-signal generator since it was then only necessary to mix the two waveforms with appropriate amplitude adjustment to obtain the required shape.

Video Amplifier

The video amplifier is almost identical to those used in broadcast equipment. As shown in Fig. 9, the signal goes through two stages of amplification before reaching the conventional high peaker.

Video gain is controlled by varying the screen voltage of the 6AG5's. Black level is established by means of a conventional driven clamp circuit; the clamping pulses are made from horizontal sync. Blanking is inserted in the cathode of the d-c setter and sync signals are mixed with video in the following stage. The composite signal is then sent to the external 75-ohm signal lines by means of a cathode-follower output stage. The output signal is polarized with blacks negative and is 2 volts peak to peak.

Signal for the internal kinescope is taken from a sampling resistor in the output stage and fed through a one-stage amplifier to the kinescope grid.

The gain in the kinescope loop is not adjustable and thus the kinescope serves as a rough monitor of the signal level on the outgoing line in addition to its other uses for black level setting, camera focus and beam adjustments, as well as a check on sync generator operation.

The television instrument described could easily be mass produced and sold within the price range of other business machines of comparable size and complexity. It will produce a sharp, steady picture of useful quality, and the pickup tube is sensitive enough to permit use of the equipment under the illumination levels normally encountered in industrial operations.

The authors are indebted to Dr. V. K. Zworykin of the RCA Laboratories for much helpful encouragement and guidance during the development of this project.

REFERENCES

(1) Paul K. Weimer, Stanley V. Forgue and Robert R. Goodrich, The Vidicon—Photoconductive Camera Tube, ELECTRONICS, p 70, May 1950.

(2) Kurt Schlesinger, Patent No. 2,383,-822 (RCA).