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RADIOTRONICS

Volume 18 February 1953 No. 2

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RADIOTRONICS

Volume 18 **February 1953** **Number 2**

By the way—

The cover illustration this month compares the older Radiotron 833-A, shown on the left, with its modern counterpart, Radiotron 5786, on the right.

This new valve, which costs no more, features a higher plate dissipation than its predecessor and occupies much less space. The maximum operating frequency for full input is 160 Mc/sec for the 5786, compared with 30 Mc/sec for the 833-A.

Complete technical information, together with application data, on the 5786 will be found in Radiotronics 137.

For details of cooling such valves we would refer you to Radiotronics 136.

Both the 5786 and 833-A are in production at the Ashfield Works of Amalgamated Wireless Valve Company Pty. Ltd.

Information published herein concerning new R.C.A. releases is intended for information only, and present or future availability is not implied.

The T.V. course continued in this issue appears through the courtesy of A.G.E. and with acknowledgements to International G.E. of U.S.A.

Back issues of Radiotronics prior to 1953 are no longer available.

We are still receiving inquiries concerning the loose-leaf data book service which was discontinued several years ago. The spiral-bound Radiotron Valve Data Book, which superseded it in 1951, has been revised and supplies are expected from the printer in March. Orders are NOT being received for the book at this stage. Subscribers will be advised in this column when the book becomes available.

With reference to RCA release, type 6198, described in this issue, we would point out that devices and arrangements shown or described may use patents of RCA or others. Information contained therein is furnished without responsibility by RCA for its use and without prejudice to RCA's patent rights.

Editor:
Ian C. Hansen,
Member I.R.E. (U.S.A.).

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THE TELEVISION RECEIVER

GENERAL

1. Comparison with radio receiver.

The preceding chapters have dealt with some general television principles and the make-up of the radiated video signal from the transmitter. Although this was not meant to be a thorough discussion of the subject, it was made sufficiently comprehensive to permit a better understanding of the specific features and requirements of the television receiver as they will be discussed in subsequent chapters.

It might be advisable to first compare the normal radio receiver and television receiver circuits, as shown in block diagram (see Figures 4-1 and 4-2). It will be noted that after the r-f amplifier, converter, and i-f amplifier blocks, very little similarity exists. When these particular blocks are discussed in more detail, it will be seen that they are very much different in design. Thus, it may be better to first indicate the few similarities and then discuss briefly the requisites for each section of the television receivers, to be followed with a more detailed description of the individual circuits in following chapters.

Practically all television receivers are of the superheterodyne type, and, therefore, the output of the r-f amplifier feeds into the 1st detector or mixer (as in the case of the r-f amplifier of the conventional receiver). The 1st detector or mixer stage is similar for both receivers and performs exactly the same functions; i.e., to convert or change the higher r-f frequency to a lower or intermediate frequency and provide some gain. The local oscillator is functionally similar for both receivers; i.e., to supply a heterodyning signal with which to beat against or mix with the r-f signal at the 1st detector or mixer to produce the i-f signal of lower frequency. In the case of the conventional receiver, only one i-f signal is produced, and the i-f signal so produced has a relatively low frequency — usually on the order of 455 kc — and a bandwidth of not more than 10 kc. However, in the case of the television receiver, since the r-f signal for each channel consists of two carriers (video and sound), two i-f signals are produced, one corresponding to the video (or picture carrier with its associated side-bands), and the other corresponding to the sound (or audio carrier). These i-f signals are much higher in frequency than for the conventional receiver (21.8 mc for the i-f corresponding to the sound carrier, and 26.3 mc for the i-f corresponding to the picture carrier). They also have wide-band characteristics, as indicated by the curve representing the signal appearing in the output of the mixer stage, Figure 4-2.

From this point on, very little similarity exists between the two receivers except possibly for the sound channel. Even here, there is considerable difference, since the television sound i-f signal is frequency modulated, as indicated in Figure 4-2.

2. Production of i-f signals.

Although two i-f signals are produced, only one converter and one oscillator is used to simultaneously change the sound carrier and the picture carrier with associated side-bands into corresponding intermediate frequencies which appear in the output of the converter. The local oscillator operates at a frequency that is higher than either of the incoming r-f carriers.

The intermediate frequencies have been increased from the pre-war values in the region of 8 to 13 megacycles to between 21 and 27 megacycles.* Considerable difficulty was experienced with pre-war receivers employing the lower frequencies in the form of poor image rejection and interference from high powered short wave transmitters. Consequently, the RMA has standardized on higher intermediate frequencies, and they recommend that the i-f which

* Most recently to around 45 megacycles.

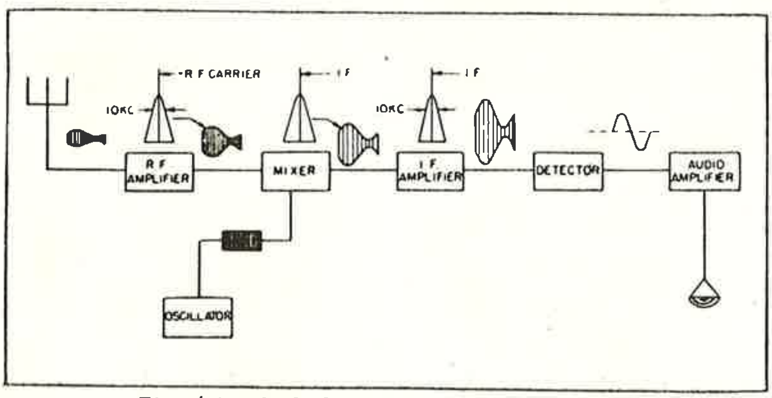


Fig. 4-1. Block diagram of a radio receiver.

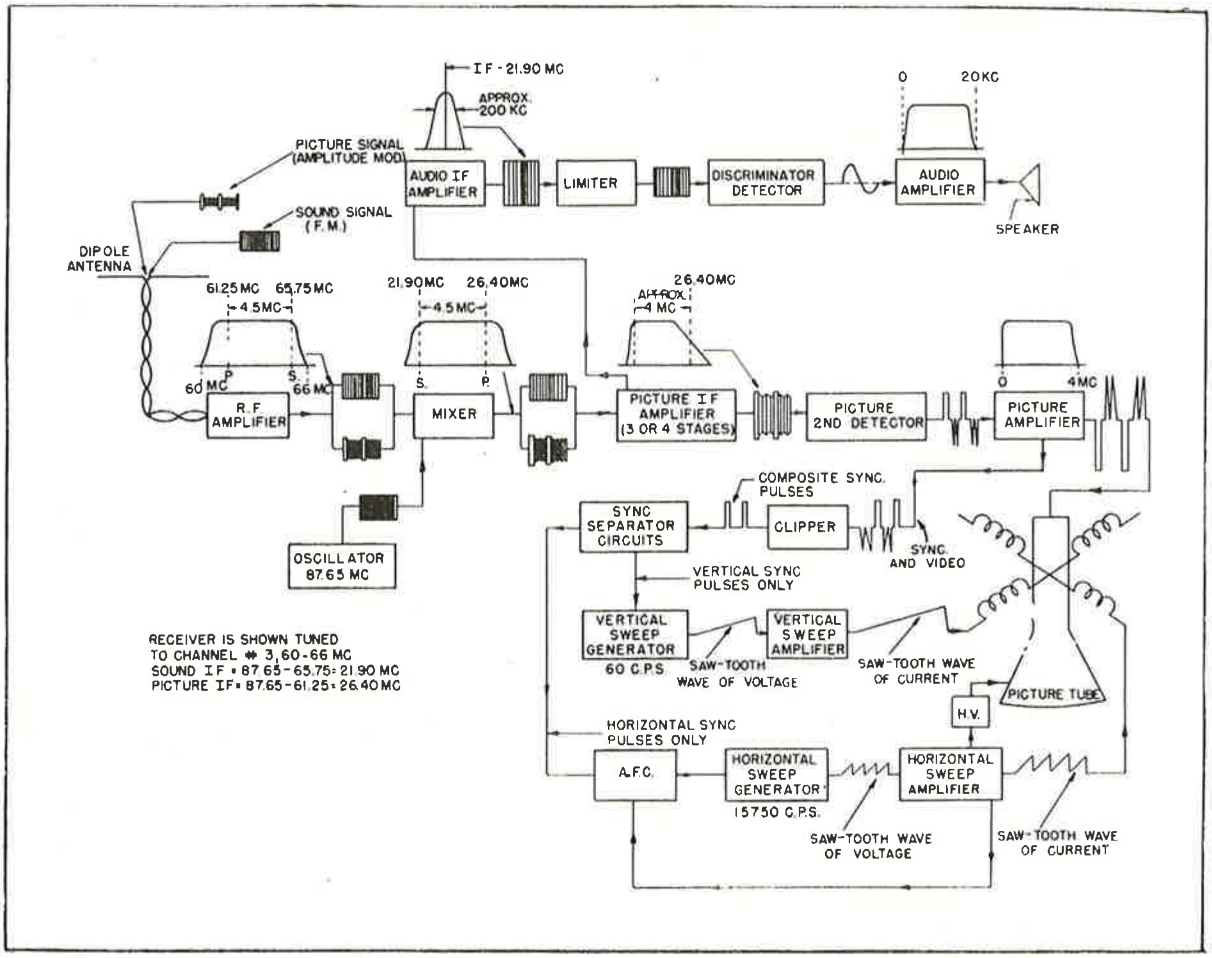


Fig. 4-2. Block diagram of a television receiver.

corresponds to the picture carrier be somewhere between 25.75 and 26.4 megacycles, and that the i-f corresponding to the sound carrier be somewhere between 21.25 and 21.9 megacycles. The i-f frequencies used in many G.E. receivers are 21.8 mc for the sound i-f, and 26.3 mc for the i-f corresponding to the picture carrier. In receivers employing the recently developed intercarrier sound system, which will be discussed in detail in a subsequent chapter, the sound i-f is 4.5 mc.

Since the local oscillator operates on the high side of either r-f carrier, and since the sound carrier as transmitted is higher in frequency than the picture carrier, the frequency of the local oscillator will be higher than the sound carrier by an amount equal to the sound i-f of 21.8 mc.

The relationship between the sound carrier and the picture carrier, with its associated side-bands, and the corresponding i-f signals produced by the heterodyning action of the local oscillator and r-f carriers at the converter, is shown in A and B of Figure 4-3, with A representing the r-f carriers as transmitted, and which appear at the converter grid, and B representing the corresponding i-f signals produced.

For the purpose of illustration, it is assumed that the receiver is tuned to Channel #3 (60-66 mc). The frequency of the picture carrier will be 61.25 mc, while the frequency of the sound carrier will be 4.5 mc higher, or 65.75 mc (as indicated in A of Figure 4-3). The frequency of the local oscillator will be higher than either r-f carrier, and will be 21.8 mc higher than the sound carrier. Therefore, the frequency of the local oscillator when operating on channel #3 will be equal to the sound carrier of 65.75 mc + 21.8 mc or 87.55 mc. The oscillator signal of 87.55 mc will heterodyne with the sound carrier of 65.75 mc at the converter to produce a sound i-f of 21.8 mc, the difference between 87.55 mc and 65.75 mc. This is indicated in B of Figure 4-3. This same oscillator signal of 87.55 mc also simultaneously heterodynes with the picture carrier of 61.25 to produce a corresponding i-f of 26.3 mc, the difference between 87.55 mc and 61.25 mc. Thus, the two i-f signals are simultaneously produced by the superheterodyne method of conversion, using only one oscillator and one converter.

It will be noted that the i-f signals thus produced retain the modulation of the incoming picture and sound carriers, but are decreased in frequency by the action of the converter, with the i-f corresponding to the picture carrier, being higher than the i-f corresponding to the sound carrier. This relationship is illustrated in Figure 4-3.

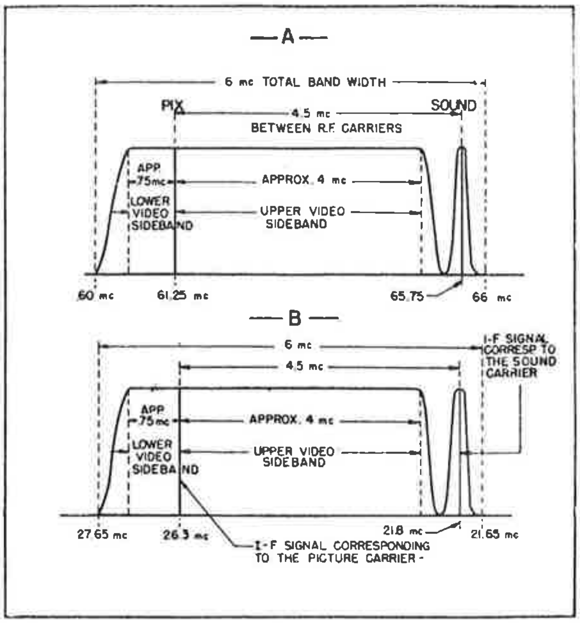


Fig. 4-3. Carriers (before and after mixing).

3. Separation of sound and picture channels.

Since we have these two i-f signals in the output of the mixer stage, it is apparent that if two tuned circuits are used, one resonating to the audio i-f, the other resonating to the video i-f and its associated side-bands, and at the same time each tuned circuit rejects the frequencies to which it is not tuned, then we have a means of separating the picture signal from the sound signal. This is exactly what is done in the television receiver when the conventional i-f amplifier system is used, and the over-all response curves for the picture i-f and sound i-f are shown above their respective stages in Figure 4-2. It should be noted that two separate i-f channels are employed; one for the sound i-f, and the other for the video i-f. Since the sound channel is frequency modulated, the bandwidth of the sound i-f must be at least 50 kc. However, it is usually made approximately 250 kc so as to minimize the effect of any drift in the local oscillator. After suitable amplification in the i-f amplifier stages, the sound signal is usually fed into a limiter stage, the output of which feeds into the FM discriminator stage where the signal is demodulated and, after suitable a-f amplification, is fed into the loudspeaker.

When the recently developed intercarrier sound i-f system is used, no separation of the two i-f frequencies representing the sound and video carriers is made in the video i-f channel, as in the case of the conventional i-f system just described. Instead, the i-f corresponding to the sound carrier is permitted to reach the video detector at a low level and to heterodyne with the video i-f, creating a difference frequency of 4.5 mc. This retains all the characteristics of the original sound i-f corresponding to the audio carrier. The low level 4.5 mc sound i-f is separated from the video signal in the video amplifier, where it is passed into one or two stages of amplification at 4.5 mc before being demodulated.

4. Video (picture) i-f system.

As shown in Figure 4-2, the picture i-f system has a wide, flat band-pass characteristic, and its response at the intermediate frequency corresponding to the picture carrier is 50% down for reasons to be discussed in a later section. The bandwidth of the picture i-f system will vary from 2.5 to 4 mc, depending on the quality of the receiver, with the wider bandwidth allowing for greater detail in the picture. This wide-band characteristic of the picture i-f system is usually obtained through the use of double-tuned, closely-coupled i-f transformers with resistive loading. Tubes having a high mutual conductance with low interelectrode capacitance are used in order to get as much gain as possible with a wide band-pass characteristic. Typical tubes used as wide-band amplifiers in the i-f stages are the Types 6AC7 and the 6AU6 tubes.

Several types of i-f transformers are used. In some receivers they are capacitively tuned with a trimmer or inductively tuned with a iron core. Each type has its particular advantage. The inductively tuned transformers, because of the very low capacity in the tuned circuit, permit greater gain per stage than obtainable with the capacity tuned type. On the other hand, the capacitively tuned transformers provide better circuit stability insofar as tube changes are concerned, since when capacitative tuning is employed, the tube capacity represents but a small portion of the total capacity across the transformer. When inductive tuning is employed, the tube capacity represents a major portion of the total capacity, and any change in it, due to tube replacement, may affect the circuit considerably.

The video i-f transformers usually have trap circuits associated with them to attenuate the audio i-f signal to a point where it does not appear as interference on the picture tube. In some receivers another trap circuit is employed in addition to those just mentioned which attenuate the sound signal of the adjacent channel next lower in frequency. If the sound signal of either the desired channel or adjacent channel should reach the video detector at an appreciable level, it would produce interference on the picture known as sound bars.

Receivers at the present time usually have three or four video i-f stages with an approximate gain of 10 to 12 per stage. The video i-f stages will be discussed in much more detail when the actual circuits are considered in a later section.

5. Video (picture) 2nd detector.

After amplification at the picture i-f, the signal is applied to a diode detector which is conventional except that special precautions are taken to ensure that the full range of picture frequencies will be present in the output of the detector. The video detector removes the i-f carrier, leaving just the picture signal components, together with the synchronizing and blanking signals in its output.

6. Video (picture) amplifier.

The video amplifier may be compared to the audio amplifier in the standard radio receiver. Its function is principally to amplify the small demodulated signal at the detector to a level where it will satisfactorily operate the modulation reproducer. In the case of the television receiver, this happens to be the picture tube. Along with this amplifying function, there are several requisites for satisfactory operation of this amplifier to give a quality picture. They are as follows:—

(1) For good detail and quality in the reproduced picture, it must have good low and high frequency response characteristics, which means that its response must be flat from approximately 20 to 4,000,000 cycles per second.

(2) The voltage gain of the video amplifier must be sufficient to produce enough voltage output at the picture tube to establish the proper contrast of the picture. One or two stages of video amplification can adequately supply this degree of gain with good frequency response.

(3) The polarity of the signal in the output of the video amplifier must be such that when it is applied to the picture tube, the black picture elements from the station will cause the screen to be darkened and the white picture elements will cause the screen to give maximum illumination. Improper polarity will give a negative picture.

(4) The picture signal applied to the picture tube must contain the direct current component of the picture signal which conveys the information as to the average brightness of the picture.

7. Clipper stage.

If applying the picture signal to the control grid of the picture tube were the only problem, the television receiver would be greatly simplified. However, we know that this signal on the picture tube grid will serve no useful purpose unless we can cause the beam of electrons whose intensity is controlled by this signal to sweep back and forth and up and down on the screen of the picture tube in exact synchronism with the beam of electrons on the camera tube at the studio. To accomplish this, we make use of part of the video signal coming from the output of the video amplifier and, as shown in Figure 4-2, it is fed into a clipper stage which separates the sync signals from the composite video wave by some form of a limiting circuit which will pass only the top 25% of the composite picture signal which contains the equalizing pulses and the horizontal and vertical sync pulses. Such circuits will be discussed in a later section.

8. Sync separator.

The output of the clipper stage is then applied to sync separator circuits which separate the horizontal sync pulses from the vertical sync pulses. These circuits will also be discussed in a later section. After the sync pulses have been separated from each other, they are usually amplified, the horizontal synchronizing pulses being applied to the horizontal sawtooth generator to control its frequency, thereby locking it in to the correct frequency of 15,750 cycles per second, while the vertical synchronizing pulses are applied to the vertical sawtooth generator to control its frequency and lock it in at the correct frequency of 60 cycles per second. This synchronizes the horizontal and vertical sweeps of the receiver with those at the transmitter, thus holding the picture stationary on the screen.

9. Sweep generators and amplifiers.

Two sweep generators are employed, one for vertical deflection of the picture tube beam and the other for horizontal deflection of the beam. These are usually in the form of multivibrator or blocking oscillator circuits. Both sweep generators are free-running and do not require any external signal to make them generate a sawtooth waveform. However, external sync signals are required to make them run at the correct frequency. The free-running speed of these sweep generators are adjusted so that their frequency is approximately correct so that when the synchronizing pulses are applied, they will readily lock in at exactly the correct frequency.

The output of each sweep generator is amplified before applying the sawtooth waveform to the deflection coils or deflection plates, as the case may be.

Referring to Figure 4-2, it will be noted that there is a block marked AFC, placed between the horizontal sync amplifier and horizontal sweep generator. This is the automatic frequency control of the horizontal sweep generator. The use of automatic frequency control of the horizontal scanning circuits greatly minimizes the effect of noise and enables the receiver to maintain almost perfect horizontal synchronization under noise conditions that would make it impossible to maintain any semblance of synchronization if direct synchronization were used. Briefly, when AFC synchronization is employed, the horizontal sweep generator is controlled indirectly by the transmitted synchronizing pulses.

10. Power supply.

The power supply is divided into two sections: a low voltage supply which supplies filament and B + power to all tubes, and a separate high voltage supply for the second anode of the picture tube. The low voltage supply is conventional and is not shown in Figure 4-2. The high voltage supply is represented by the block between the picture tube and the horizontal sweep amplifier.

In pre-war receivers, the necessary d-c voltage for the second or high voltage anode of the picture tube was obtained from a 60 cycle power supply which employed a high voltage power transformer, together with one or more tubes in a conventional rectifier circuit. This voltage was usually on the order of 2,000 to 6,000 volts in pre-war receivers. However, in most post-war receivers, this voltage ranges from approximately 8,000 to 12,000 volts on direct view receivers, and as high as 30 kilovolts on receivers of the projection type. Such voltages, if obtained from the conventional 60 cycle power supply, would necessitate the use of large, bulky equipment and, also, be extremely dangerous to service.

In the present television receivers the high voltage is obtained from a kick or flyback type of supply instead of from the conventional 60 cycle type of power supply. This eliminates the undesirable characteristics of the 60 cycle supply — bulkiness and danger of fatal shock.

This type of supply derives its high voltage by making use of the inductive "kick" voltage produced during retrace in the horizontal sweep output transformer, and will be considered in detail in a later section.

11. Picture tube.

The picture tubes used in the post-war television receivers are greatly improved over those used in pre-war receivers, and afford greater detail, brilliance, and contrast.

The face of the tube is essentially flat as compared to the rounded edges of pre-war tubes, resulting in a wider angle of vision.

The glass envelope of the tube is considerably heavier than pre-war, and will not shatter into as many pieces, nor fly as far if accidentally broken. However, it is still dangerous to handle the tube carelessly, and the necessary precautions should be taken.

As discussed in Chapter II, the picture tubes used in all post-war General Electric receivers have provision for preventing the formation of an ion spot.

12. Receiver controls.

The number of controls which can be provided in a television receiver is imposing when it is realized that from the user's standpoint, it is desirable to have as few adjustments as possible. The following is a list of controls which are usually provided:—

General.

(1) On-Off switch.
(2) Station Selector.
(3) Vernier Tuning Control (in oscillator circuit).

Sound Channel.

(4) Volume control.
(5) Tone control.

Picture Channel.

(6) Contrast control.
(7) Brightness control.
(8) Focus control.
(9) Tilt control.

Line Scanning.

(10) Horizontal Hold control.
(11) Horizontal Centering control.
(12) Horizontal Size control.
(13) Horizontal Linearity control.

Field Scanning.

(14) Vertical Hold control.
(15) Vertical Centering control.
(16) Vertical Size control.
(17) Vertical Linearity control.

The controls listed for the scanning system are usually located in some place where they cannot be readily handled by the customer. All the other controls, with the exception of Tilt, are brought out to the front panel. In some receivers, the Vertical and Horizontal Hold controls are also brought out to the front panel. A further explanation of these controls is as follows:—

(1) The Station Selector switch permits the operator to select any one of the 12 television channels by switching in individual coils for each channel, each set of coils being permanently aligned at the factory for optimum performance.

(2) The Television Tuning control enables the operator to adjust for optimum picture detail and satisfactory sound reception. The Television Tuning control provides vernier tuning of the local oscillator so as to produce the correct picture and sound i-f signals. As mentioned previously, the coils for each channel are permanently aligned at the factory; however, fine tuning of the local oscillator is required in order to compensate for any slight shift in frequency. If the oscillator were crystal controlled for each channel, then the Tuning control would not be needed, since the oscillator would be operating at exactly the correct frequency, as the receiver is switched from channel to channel. However, crystal control of the oscillator for each separate channel is not practical.

(3) The Contrast control varies the black and white contrast between the various elements making up the picture. Actually, the Contrast control varies the gain of the video i-f amplifier section of the receiver.

(4) The Brightness control regulates the average brilliance or amount of illumination of the picture tube screen. It varies the bias voltage between cathode and grid of the picture tube.

(5) The Focus control, as the name implies, focuses the image on the picture tube screen. It does this by focusing the electron beam of the tube to the smallest possible size at the point where it strikes the screen.

(6) The Horizontal Linearity control adjusts the symmetry of the picture in the horizontal direction.

(7) The Horizontal Width control, as the name implies, adjusts for the correct size of the picture in a horizontal direction.

(8) The Horizontal Hold control is used to lock the picture in synchronism with the transmitted picture in the horizontal direction.

(9) The Vertical Hold control is used to lock the picture in synchronism in the vertical direction.

(10) The Vertical Height control adjusts the size of the picture in the vertical direction.

(11) The Vertical Linearity control adjusts the symmetry of the picture in the vertical direction.

(12) The Vertical and Horizontal Centering controls are used to centre the beam and correct for variation between tubes. They ordinarily require no adjustment except when a new picture tube is installed.

13. Over-all operation of the receiver.

Without going into too great a detail on any particular section at this time, it might be well to review some of the points discussed in previous paragraphs and follow the signal through the receiver.

The television signal picked up by the antenna contains two r-f carriers — one for the picture and the other for the accompanying sound — together with the necessary modulation components for each carrier. This signal is fed into a broad-band r-f stage which permits the selection of any one of the 12 television channels by means of a rotary type selector switch. This selector switch arrangement changes the r-f tuned circuit to the channel desired and, at the same time, changes the local oscillator frequency to the correct value for that particular channel.

After being amplified in the r-f stage, both carriers are fed into the television converter where they are mixed with a signal from the local oscillator. The local oscillator signal simultaneously heterodynes or beats with each r-f carrier so as to convert or change the higher r-f carriers to lower or intermediate frequencies. This action is the same that takes place in an ordinary broadcast superheterodyne receiver, except that in a television receiver there are two r-f carriers to contend with and, consequently, two different i-f frequencies generated, with an i-f corresponding to the video carrier and the other corresponding to the sound carrier. Also, the frequencies used are much higher than for the conventional receiver and the bandwidth requirements are very much greater.

The output of the converter stage, consisting of two i-f signals which retain all the characteristics of the incoming r-f carriers but decreased in frequency by the converter, is fed into the first video i-f stage.

Three or four stages of video i-f amplification are used as indicated by the block diagram, Figure 4-2. Three stages are most generally used. In the normal two channel i-f amplifier system shown in Figure 4-2, both the video and audio i-f signals are amplified by the first video i-f stage and appear in its output. At this point, however, assuming three video i-f stages, the audio and video are separated by selective tuned circuits (the audio tuned circuit being in the form of a wave trap tuned to the frequency of the audio i-f and coupled to the second video i-f transformer). As mentioned previously, if the intercarrier sound system were incorporated, no separation of the video and audio i-f signal takes place in the video i-f channel.

The audio i-f signal, when it is thus taken off from the output of the first video i-f stage, is fed into the sound i-f stage, as shown in Figure 4-2. This stage amplifies the television sound i-f (which is frequency modulated) and feeds it into the sound FM i-f stage (which acts as a limiter for the FM signal and is conventional, as is, also, the FM discriminator detector which follows the limiter stage). The output of the FM detector is fed into the audio amplifier and loudspeaker.

Returning to the video i-f section, the video i-f signal and associated sidebands appearing in the output of the first video i-f stage are further amplified by the second and third video i-f stages, and is then fed into the video detector. The video i-f circuits have a wide band characteristic, the details of which will be discussed in a later section.

The video detector demodulates the picture i-f signal in much the same manner as in an ordinary receiver, except that special precautions are taken to ensure that the full range of picture frequencies will be present in the output of the detector, which is applied to the picture tube after suitable amplification at video frequencies.

The video amplifier corresponds to the audio amplifier in an ordinary receiver, except that it must handle a much greater range of frequencies — approximately from zero to 4 megacycles. One or two stages of video amplification is used, as indicated in Figure 4-2, the output of which is fed two ways. One channel goes to the picture tube, where the video signal causes the intensity of the electron beam of the cathode ray tube, as it sweeps across the screen, to vary in exact accordance with the video signal of the television camera and, in this way, causes each portion of the picture tube screen to have the proper degree of light and shade to reproduce the original scene.

The other channel going from the video amplifier output feeds into the clipper stage, which, in order to obtain proper synchronization between the transmitted and received signals, separates the synchronizing pulses from the portion of the video signal which contains the actual picture information. The output of the clipper stage is then fed into two channels, as shown in Figure 4-2, one going to the horizontal deflection circuits and the other to the vertical deflection circuits.

The vertical deflection circuits usually consist of a sync amplifier, a sweep generator (which generates a sawtooth waveform), and a sweep amplifier or sweep output stage (which amplifies the output of the sawtooth generator and couples it to the vertical set of deflection coils, which are placed around the neck of the picture tube). The vertical sawtooth generator is free-running; that is, it will generate a sawtooth wave by itself, without the need for any external signal. However, in order to lock it in step or synchronize it with the vertical sweep at the transmitter, it is timed by applying the vertical synchronizing pulses to it after they have been amplified.

The horizontal deflection circuits are somewhat more complex, due to the use of AFC synchronization, and consist of a sync amplifier, the AFC circuits, the horizontal sawtooth generator, and the horizontal sweep amplifier. The horizontal sweep amplifier, or output stage, performs the same general functions as the vertical sweep amplifier — it amplifies the sawtooth wave and couples it to the horizontal set of deflection coils.

The high voltage supply is very closely related to the horizontal sweep output stage, since it is obtained by rectifying the inductive "kick" voltage developed across the primary of the horizontal sweep output transformer during the horizontal retrace period.

The horizontal sweep generator is similar to the vertical sweep generator, except that its frequency is much higher — 15,750 cycles per second as compared to 60 cycles. However, the method by which it is synchronized is altogether different. Instead of using direct synchronization, its frequency is controlled indirectly by feeding a portion of the voltage in the output of the horizontal sweep amplifier back to the AFC circuits, as indicated in Figure 4-2, where a control voltage is developed that automatically corrects for any shift in frequency of the horizontal sweep generator in relation to the transmitted sync signals.

New RCA Release

RADIOTRON 6198

VIDICON

RCA-6198 is a small television camera tube intended primarily for use in industrial applications. Its small size and simplicity facilitate the design of the camera and associated equipment in comparison with that needed for larger types of camera tubes. The resolution capability of the 6198 is about 400 lines.

Utilizing a photoconductive layer as its light-sensitive element, the 6198 has a sensitivity which permits televising scenes with 100 to 200 foot-candles of incident illumination on the scene. The photoconductive layer is characterized by a spectral response approaching that of the eye.

The small size of the 6198 lends itself to use in lightweight, compact television cameras. The size and location of the photoconductive layer permit a wide choice of commercially available lenses.

PRINCIPLES OF OPERATION

The structural arrangement of the 6198, shown in Fig. 1, consists of the signal electrode, a transparent conducting film on the inner surface of the faceplate; a light-sensitive element consisting of a thin layer of photoconductive material deposited on the signal electrode; a fine mesh screen (grid No. 4) located adjacent to the photoconductive layer; a focusing electrode (grid No. 3) connected to grid No. 4; and an electron gun for producing a beam of electrons.

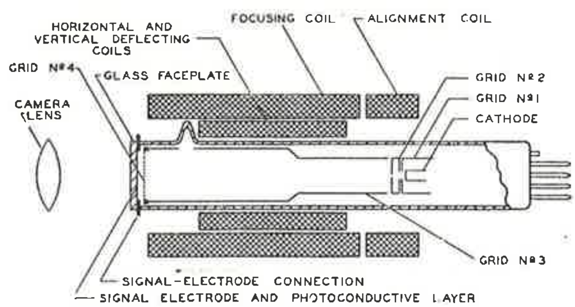


Fig. 1 — Schematic Arrangement of Type 6198.

Each element of the photoconductive layer is an insulator in the dark but becomes slightly conductive when it is illuminated and acts like a leaky capacitor having one plate at the fixed positive potential of the signal electrode and the other floating. When light from the scene being televised is picked up by an optical lens system and focused on the photoconductive-layer surface next to the faceplate, each illuminated layer element conducts slightly depending on the amount of illumination on the element and thus causes the potential of its opposite surface (on the gun side) to rise in less than the time of one frame toward that of the signal-electrode potential. Hence, there appears on the gun side of the entire layer surface a positive potential pattern, composed of the various element potentials, corresponding to the pattern of light from the scene imaged on the opposite surface of the layer.

The gun side of the photoconductive layer is scanned by a low-velocity electron beam produced by the electron gun. This gun contains a thermionic cathode, a control grid (grid No. 1), and an accelerating grid (grid No. 2). The beam is focused at the surface of the photoconductive layer by the combined action of the uniform magnetic field of an external coil or permanent magnet and the electrostatic field of grid No. 3. Grid No. 4 serves to provide a uniform decelerating field between itself and the photoconductive layer so that the electron beam will approach the layer in a direction perpendicular to it — a condition necessary for driving the surface to cathode potential. The beam electrons approach the layer at low velocity because of the low operating potential of the signal electrode.

When the gun side of the photoconductive layer with its positive potential pattern is scanned by the electron beam, electrons are deposited from the beam in sufficient quantities until the surface potential is reduced to that of the cathode, and thereafter are turned back to form a return beam which is not utilized in this tube. Deposition of electrons on the scanned surface of any particular element of the layer causes a change in the difference of potential between the two surfaces of the element. When the two surfaces of the element, which in effect is a charged capacitor, are connected through the external signal-electrode circuit and the scanning beam, a capacitive current is produced and constitutes the video signal. The magnitude of the current is proportional to the surface potential of the element being scanned and to the rate of scan. The video-signal current is then used to develop a signal output voltage across a load resistor. The signal polarity is such that for highlights in the scene the grid of the first video-amplifier tube swings in a negative direction.

Alignment of the beam is accomplished by a tranverse magnetic field produced by external coils located at the base end of the focusing coil.

Deflection of the beam is accomplished by transverse magnetic fields produced by external deflecting coils.

DATA

General:

Heater, for Unipotential Cathode:		
Voltage (AC or DC)	6.3 ± 10%	volts
Current	0.6	ampere
Direct Interelectrode Capacitance:		
Signal Electrode to All Other Electrodes	4.5	μμf
Spectral Response		See Curve
Photoconductive Layer:		
Maximum Useful Diagonal of Rectangular Image (4 x 3 Aspect Ratio)	0.62	inch

Orientation of Quality Rectangle — Proper orientation is obtained when the horizontal scan is essentially parallel to the plane passing through the tube axis and short index pin.

Focusing Method	Magnetic
Deflection Method	Magnetic
Overall Length	6¼" ± ¼"
Greatest Diameter (Excluding Side Tip)	1.125" ± 0.010"
Maximum Radius (Including Side Tip)	0.805"
Bulb	T-8
Base	Small-Button Ditetrar 8-Pin (JETEC No. E8-11)
Operating Position	Any

Maximum ratings, *Absolute Values*:§

SIGNAL-ELECTRODE VOLTAGE	125 max.	volts
GRID-No. 4 & GRID-No. 3 VOLTAGE	350 max.	volts
GRID-No. 2 VOLTAGE	350 max.	volts
GRID-No. 1 VOLTAGE:		
Negative bias value	125 max.	volts
Positive bias value	0 max.	volts
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	125 max.	volts
Heater positive with respect to cathode	10 max.	volts
FACEPLATE TEMPERATURE	60 max.	°C

Typical operation and characteristics:

For scanned area of ½" x ⅜"

Signal-Electrode Voltage for Dark Current of 0.02 μamp	10 to 125	volts
Grid-No. 4 (Decelerator) & Grid-No. 3 (Beam Focus) Voltage	200 to 300	volts
Grid-No. 2 (Accelerator) Voltage	300	volts
Grid-No. 1 Voltage (For Picture cutoff)	−45 to −100	volts
Signal-Output Current*		
Normal Operating Range	0.1 to 0.2	μamp
Minimum, with 0.6 foot-candle of uniform 2870°K tungsten illumination on tube face	0.02	μamp
Uniform 2870°K Tungsten Illumination on Tube Face to Produce Signal-Output Current of 0.1 to 0.2 μamp	3 to 10	ft-c
Ratio (Approx.) of Tube-Face Illumination Required to Produce Signal-Output Current of 0.2 μamp to That Required to Produce 0.02 μamp	30	
Minimum Peak-to-Peak Blanking Voltage:		
When applied to grid No. 1	30	volts
When applied to cathode	10	volts
Field Strength at Centre of Focusing Device	40	gausses
Field Strength of Adjustable Alignment Coil	0 to 4	gausses

* Defined as the component of the signal-electrode current after the dark-current component has been subtracted.

OPERATING CONSIDERATIONS

The *base pins* of the 6198 fit the ditetrar 8-pin connector, such as Cinch No. 54A18088, or equivalent.

The *signal-electrode connection* is made by a suitable spring contact bearing against the edge of the metal flange at the face end of the tube. This spring contact may conveniently be provided as part of the focusing-coil design.

Support for the 6198 is provided by a suitable spring-finger suspension at the face end of the tube and by a clamping mechanism near the base end. Orientation of the 6198 in its support should be such that the horizontal scan is essentially parallel to the plane passing through the tube axis and the short index base pin.

The *lens* used with the 6198 may be chosen from a large variety of commercially available camera lenses. It should be a high-quality type incorporating an iris to control the amount of light passing through it. An f:2 lens of the type used for 16-mm movie cameras is satisfactory for many applications. The lens holder should have all inside surfaces finished in matte black to prevent internal reflections from reaching the photoconductive layer, should provide suitable focusing means. Under almost all conditions, the use of a lens shade is beneficial.

Electrostatic shielding of the signal electrode from external fields is required to prevent interference effects in the picture. Effective shielding is ordinarily provided by grounding a shield on the inside of the faceplate end of the focusing coil; by grounding a shield on the inside of the deflecting yoke; and by grounding the lens mount and its supporting assembly.

The *temperature* of the faceplate should not exceed 60°C (140°F), either during operation or storage of the 6198. Operation with a faceplate temperature in the range from about 25°C to 35°C (77° to 99°F) is recommended. The signal-output current and the dark current both increase with increasing faceplate temperature for a given signal-electrode voltage and illumination. Since the dark current increases the more rapidly of the two, it is necessary to reduce the signal-electrode voltage in an effort to restore the signal output-to-dark current ratio. Operation with the faceplate at 50° to 60°C causes some sacrifice in performance because the sensitivity at a given signal output-to-dark current ratio or the signal output-to-dark current ratio at a given sensitivity is somewhat lower than at lower temperature. Operation at the higher temperature, however, does not adversely affect the performance of the tube when it is subsequently operated at lower temperature.

The *signal-electrode voltage* should be obtained from a dc source which can provide a voltage adjustable over a range of 10 to 125 volts. As the

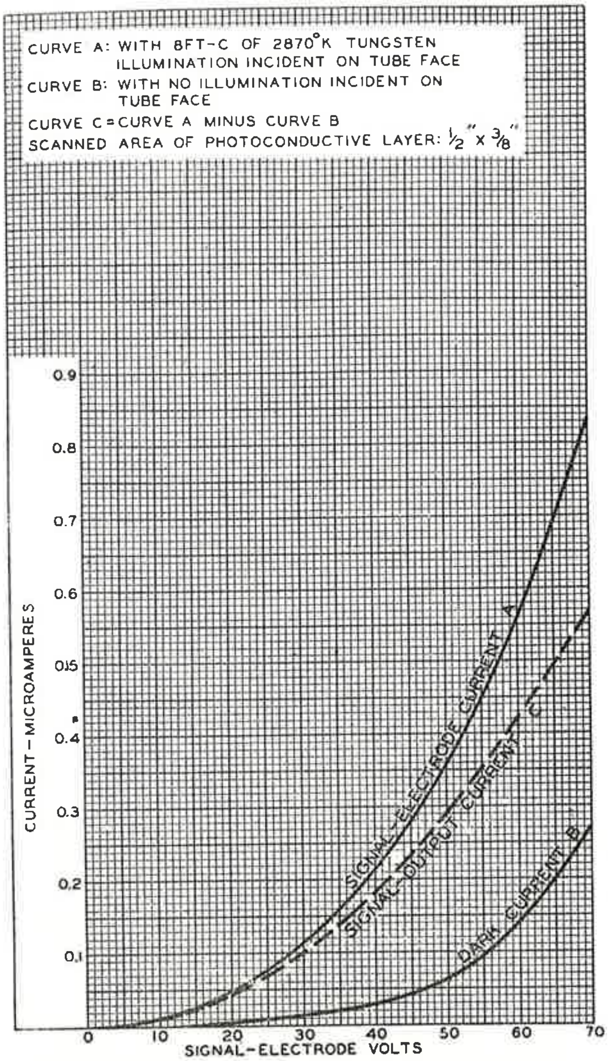


Fig 2.—Typical Characteristics of Type 6198.

signal-electrode voltage is increased, the signal-output current (i.e., the component of the signal-electrode current after the dark-current component has been subtracted) and the dark current both increase, as shown in Fig. 2. However, a limiting value of signal-electrode voltage is reached beyond which the non-uniformity in the dark-current background of the transmitted picture is no longer tolerable.

For a given signal-electrode voltage, the sensitivity and dark current both tend to change gradually during the life of the tube. By making the signal-electrode voltage supply adjustable, the equipment designer can provide means to compensate for these changes.

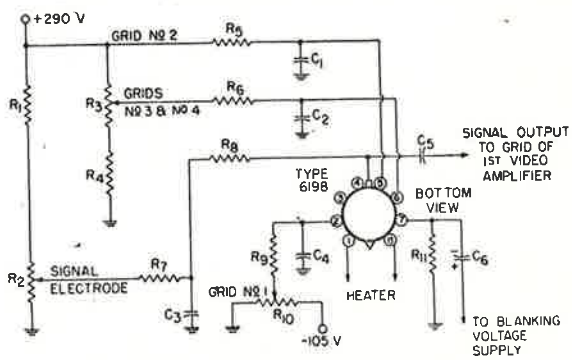
The *focusing-electrode (grid No. 3) voltage* may be fixed at a value of about 250 volts when focusing control is obtained by adjusting the current through the focusing coil. The necessary range of current adjustment will depend on the design of the coil, but should be such as to provide a field-strength range of 36 to 44 gausses. When it is desired to use a fixed value of focusing-coil current, or to use a permanent-magnet type of focusing device, capable of providing a fixed strength of 40 gausses at the centre of the focusing device, the grid-No. 3 voltage should be adjustable over a range from 200 to 300 volts.

The *grid-No. 1 voltage* should be adjustable from 0 to –100 volts.

The *dc voltages* required by the 6198 can be provided by the circuit shown in Fig. 3.

A *blanking signal* should be supplied to grid No. 1 or to the cathode to prevent the electron beam from striking the photoconductive layer during the return portions of the horizontal and vertical deflecting cycles. Unless this is done, the camera-tube return lines will appear in the reproduced picture. The blanking signal is a series of negative voltage pulses when the blanking signal is applied to grid No. 1, or a series of positive voltage pulses when the blanking signal is applied to the cathode.

Beam intensity is controlled by the amount of negative voltage on grid No. 1. The beam must have adequate intensity to drive the highlight elements of the photoconductive-layer surface to cathode potential on each scan. When the beam has an intensity sufficient only to drive the lowlight elements to cathode potential, the highlight elements are not returned to cathode potential. As a result, the picture highlights all have the same brightness



C1, C4: 0.01 μf, 300 volts (working voltage)
C2: 0.1 μf, 300 volts (working voltage)
C3, C5: 0.1 μf, 200 volts (working voltage)
C6: 4 μf, electrolytic, 300 volts (working voltage)
R1: 120,000 ohms, ½ watt
R2: 100,000-ohm potentiometer, 2 watt
R3: 50,000-ohm potentiometer, 2 watt
R4: 70,000 ohms, ½ watt
R5: 5,000 ohms, ½ watt
R6: 10,000 ohms, ½ watt
R7: 200,000 ohms, ½ watt
R8: 50,000 ohms, non-inductive, ½ watt
R9: 100,000 ohms, ½ watt
R10: 500,000-ohm potentiometer, 2 watt
R11: 1,000 ohms, non-inductive, ½ watt

Fig. 3—Typical Voltage Dividers for Supplying DC Electrode Voltages to Type 6198.

and show no detail. It is also to be noted with a beam of insufficient intensity that the photoconductive-layer surface, which normally rises in potential by only a small fraction of the signal-electrode potential during each scan, gradually rises in potential to a value approaching nearly the full signal-electrode potential in the highlights. Under this condition, many scans of a beam with inadequate intensity are required to drive to cathode potential any element which has changed from a highlight to a lowlight because of movement of the subject. As a result, the highlights tend to "stick". The loss of detail in and sticking of the highlights is referred to as "bloom".

On the other hand, a beam with excessively high intensity should not generally be used because the size of the scanning spot increases with resultant decrease in resolution.

When the 6198 is operated under normal conditions with adequate but not excessive beam intensity, it will be noted that any sudden, large excess of illumination on the televised scene will cause bloom in the televised picture.

The *video amplifier* should be designed to cover a range of ac signal voltages corresponding to signal-output current of 0.02 to 0.2 microampere in the load resistor. A low-noise, video amplifier suitable for use with the 6198 is shown in Fig. 4. This amplifier has an 8-Mc bandwidth and incorporates a gain control as well as a frequency- and phase-compensation control.

Resolution of better than 350 lines at the centre of the picture can be produced by the 6198. To utilize the resolution capability of the 6198 in the horizontal direction with the standard scanning rate of 525 lines, it is necessary to use a video amplifier having a bandwidth of at least 6 megacycles per second. The maximum resolution obtainable is limited by the size of the scanning-beam spot.

The *illumination* on the photoconductive layer is related to the scene illumination by the formula

$$1_s = \frac{4f^2\ 1_{pl}\ (m + 1)^2}{TR}$$

where

1_s = scene illumination in foot-candles
f = f-number of lens
1_{pl} = photoconductive - layer illumination in foot-candles
m = linear magnification from scene to photoconductive layer
T = total transmission of lens
R = reflectance of part of scene under consideration.

Except for very close shots, the linear magnification (m) from scene to photoconductance layer may be neglected.

For example, assume that the lens is f:2 having a transmission (T) of 75%, that the photoconductive layer illumination (1_{pl}) is 3 foot-candles, and that the brightest part of the scene under consideration has a reflectance (R) of 50%. Then,

$$1_s = \frac{4 \times 2^2 \times 3}{0.75 \times 0.50} = 128 \text{ foot-candles}$$

It is good practice before attempting to transmit a particular scene to check its incident illumination with an illumination-measuring device, such as an exposure meter.

The *minimum illumination level* which can be used on the photoconductive layer to give a picture depends on a compromise between the ratio of signal-output current to amplifier noise and the ratio of signal-output current to vidicon dark current. Either of these ratios may be a limiting factor depending on the choice of signal-electrode voltage. When the signal-electrode voltage is kept low, the dark current is low. Under this condition, the minimum value of illumination is that which will give a signal-output current larger than the noise of the amplifier. With the usual compensated amplifier, the rms amplifier noise is a fixed amount equivalent to a signal-output current of about 0.002 microampere. The signal-output current can be increased for a given illumination level by raising the signal-electrode voltage as indicated in Fig. 2, but it will be noted that the dark current also increases and at a faster rate than the signal-output current. As the signal-electrode voltage is raised, the dark current reaches a value beyond which the non-uniformity in the dark-current background of the picture becomes intolerable. When this condition occurs, nothing further can be gained by increasing the signal-electrode voltage. It is evident, therefore, that the optimum operating point is a compromise to give the best ratio of signal-output current to both noise and to dark current, and that a useful ratio can be realized only when the level of illumination is adequate to give a value of signal-output current several times larger than either the amplifier noise current or the dark current.

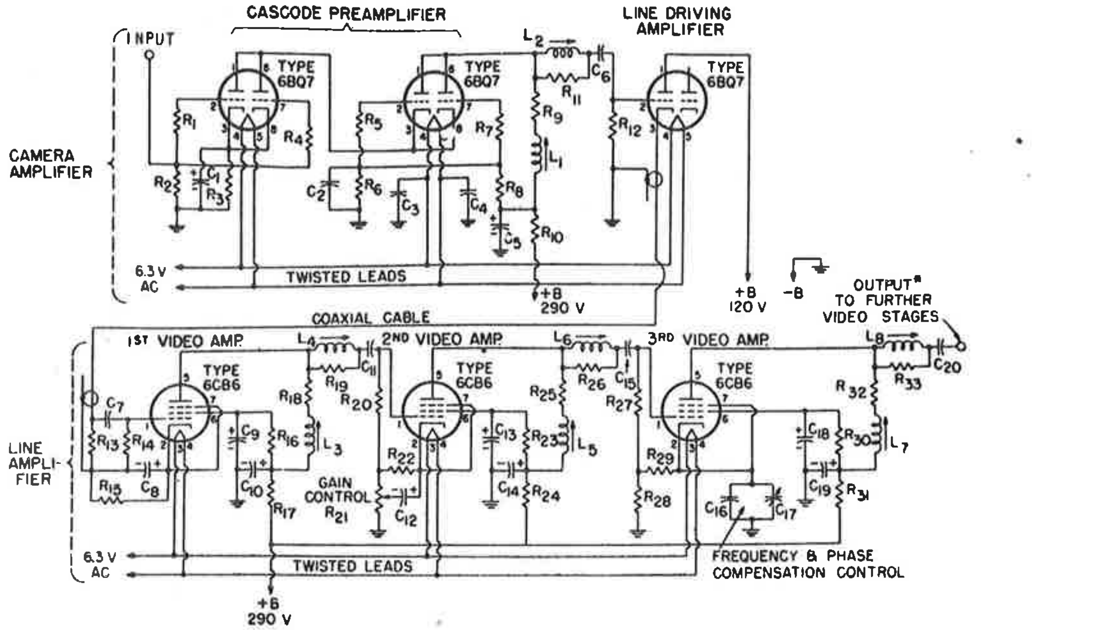
Typical signal output as a function of uniform 2870°K tungsten illumination on the photoconductive layer of the 6198 is shown in Fig. 5. It will be noted that if an increase of 10 times in signal-output current is desired, the illumination must be increased by about 30 times.

Persistence of the photoconductive layer in the 6198 is given by the curve in Fig. 6. This curve shows the decay in signal-output current from an initial value of 0.2 microampere after the illumination is cut off. With adequate illumination on the photoconductive layer, the persistence is sufficiently short to prevent smearing except when the subject moves rapidly across the field of view. With low levels of illumination, the persistence increases somewhat, with the result that there is a greater tendency for moving objects to produce smearing. To minimize smearing, the use of more illumination is recommended.

Signal-output-current buildup when light is applied to the photoconductive layer previously in the dark is as fast as or faster than the rate of decay indicated by the persistence curve in Fig. 6.

The *spectral response* of the 6198 is shown by curves A and C in Fig. 7. Curve A is on the basis of equal values of signal-output current at all wave lengths, whereas curve C is on the basis of equal values of signal-output current with radiant flux from a tungsten source at 2870°K. For comparison purposes, the response of the eye is shown in curve B.

Full-size scanning of the photoconductive layer should always be used. Full-size scanning can be assured by first adjusting the deflection circuits to



Coaxial Cable: Amphenol No. 21-025 (Army-Navy No. RG-59/U), or equivalent.
C1, C8: 50 μf, electrolytic, 3 volts (working voltage)
C2, C11, C15, C20: 0.1 μf, 300 volts (working voltage)
C3, C4, C7: 0.1 μf, 100 volts (working voltage)
C5, C9, C10, C13, C14, C18, C19: 10 μf, electrolytic, 300 volts (working voltage)
C6: 0.05 μf, 300 volts (working voltage)
C12: 100 μf, electrolytic, 50 volts (working voltage)
C16: 120 μμf, ceramic, 150 volts (working voltage)
C17: 50-150 μμf, ceramic, adjustable, 150 volts (working voltage)
L1: 19 μh peaking coil, adjustable core to cover range from 15 to 23 μh
L2, L3, L5, L7: 24 μh peaking coil, adjustable core to cover range from 20 to 30 μh
L4, L6, L8: 5 μh peaking coil, adjustable core to cover range from 4 to 6 μh

All of the following resistors are of the non-inductive type

R1, R4, R5, R7: 100 ohms, ½ watt
R2: 250,000 ohms, ½ watt
R3: 51 ohms, ½ watt
R6: 82,000 ohms, ½ watt
R8: 100,000 ohms, ½ watt
R9: 2,000 ohms, 1 watt
R10: 1,000 ohms, 1 watt
R11: 10,000 ohms, ½ watt
R12, R14, R20, R27: 510,000 ohms, ½ watt
R13: 75 ohms, ½ watt
R15: 120 ohms, ½ watt
R16, R30: 3,000 ohms, ½ watt
R17, R24: 10,000 ohms, 2 watt
R18, R25, R32: 1,500 ohms, ½ watt
R19, R26, R33: 6,800 ohms, ½ watt
R21: 1,000-ohm potentiometer, 2 watt
R22: 200 ohms, ½ watt
R23: 15,000 ohms, ½ watt
R28: 7,500 ohms, 2 watt
R29: 150 ohms, ½ watt
R31: 3,000 ohms, 1 watt

* This output circuit is designed to work into a 6CB6 as video amplifier. With gain control (R21) set at minimum and 0.2 microampere signal-current input to camera amplifier, the output voltage is 0.25 volt peak to peak; with gain control set at maximum and with 0.015 microampere signal-current input, the output voltage is 0.25 volt peak to peak.

Fig. 4 — Low-noise Video Amplifier for use with Type 6198.

overscan the photoconductive layer sufficiently to cause the edges of the sensitive area to be visible in the corners of the picture, and then reducing the scanning until the edges just disappear. In this way, the maximum signal-to-noise ratio and maximum resolution can be obtained. It is to be noted that overscanning the photoconductive layer produces a smaller-than-normal picture on the monitor.

Underscanning the photoconductive layer, i.e., scanning an area of the layer less than the useful quality area, should never be permitted. Underscanning produces a larger-than-normal picture on the monitor. Because the scanned area may exhibit a permanent change in sensitivity and dark current during operation, an underscanned area showing such change will be visible in the picture when full-size scanning is restored.

Failure of scanning, even for a few minutes, may permanently damage the photoconductive layer. The damaged area shows up as a spot or line in the picture during subsequent operation. To avoid damaging the 6198 during scanning failure, it is necessary to prevent the scanning beam from reaching the layer. The scanning beam can conveniently be prevented from reaching the layer by increasing the grid-No. 1 voltage to cutoff.

The *sequence of adjustments* in operating the 6198 is as follows: With the grid-No. 1 voltage control set for maximum bias (beam cutoff), and with the camera lens iris closed, apply voltages to the tube as indicated under Typical Operation. Make certain that the deflection circuits are functioning properly to cause the electron beam to scan the photoconductive layer. Set the signal-electrode voltage at about 25 volts for a first trial. Then open the iris partially and image a scene of adequate

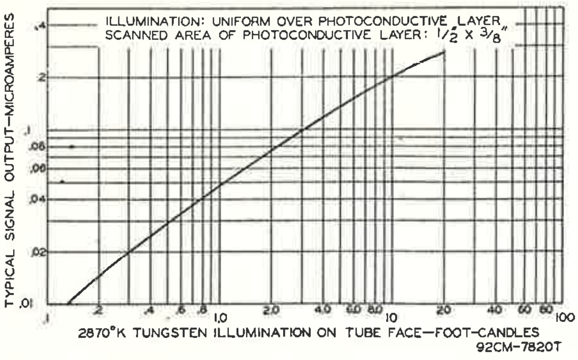


Fig. 5 — Typical Signal Output of Type 6198.

intensity on the photoconductive layer. Next, decrease the grid-No. 1 voltage until a picture appears on the monitor screen. The lowlights will appear first. Adjust grid-No. 1 voltage to bring out a complete picture from the entire scanned area. Then

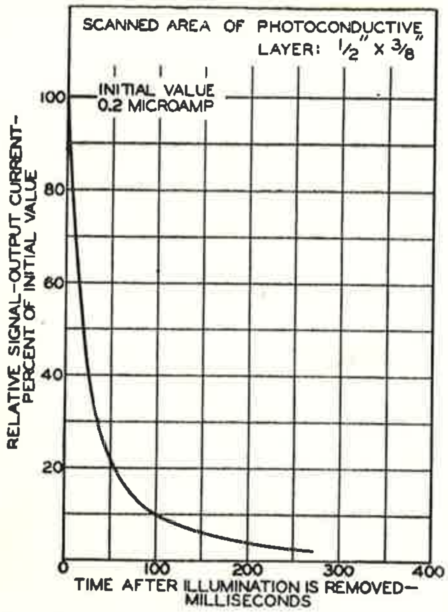


Fig. 6 — Persistence Characteristic of Type 6198.

adjust grid-No. 3 voltage (or the magnetic-field strength of the focusing coil if fixed grid-No. 3 voltage is used) and the optical focus alternately to obtain the best picture. Next, adjust the deflection amplitude and centering to scan the desired area on the photoconductive layer. If the picture is faint (corresponding to an average signal-electrode current of less than 0.05 microampere), even with adequate video amplifier gain, open the lens iris somewhat more and, if necessary, increase the signal-electrode voltage to give a brighter picture. The signal-electrode voltage, however, should not be increased to the extent that it produces an uneven background that is visible on the monitor with the lens capped. Dark current in excess of 0.1 microampere will cause excessive shading. Then, adjust the alignment field so that the centre of the picture does not move as the grid-No. 3 voltage is varied, and so that the picture has the best shading. Finally, readjust the grid-No. 1 voltage for the best resolution in the picture. A signal-electrode current of more than 0.2 microampere is not desirable because resolution is sacrificed.

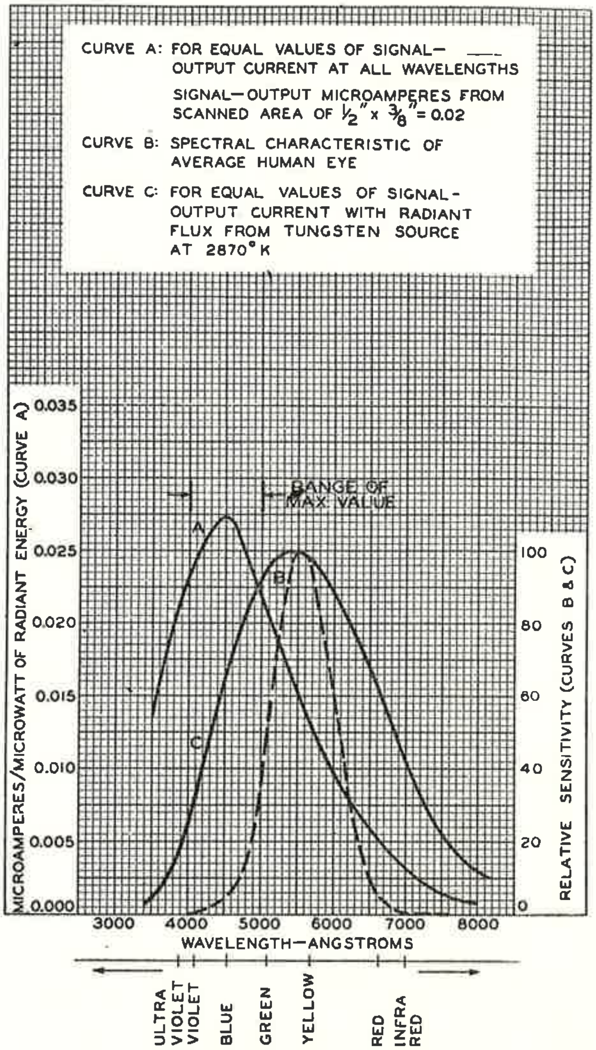


Fig. 7 — Spectral Sensitivity Characteristic of Type 6198.

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RCA Application Note AN-155

RADIOTRON 6CL6 NOVAL POWER PENTODE IN VIDEO OUTPUT STAGES*

This Note discusses the use of power pentode RCA-6CL6 in video output stages. The 6CL6, a nine-pin miniature equivalent of the metal type RCA-6AG7, is intended primarily to drive large kinescopes requiring a peak-to-peak video voltage of approximately 120 volts. This tube offers several advantages over the 6AG7: its miniature construction saves space, its smaller mass reduces microphonic output, and its lower input and output capacitances result in higher gain.

Fig. 1 shows a typical video output stage employing the 6CL6 and designed to have a bandpass of 4.0 megacycles. In this circuit, a peak-to-peak output voltage of approximately 130 volts is obtained with a peak-to-peak driving voltage of approximately 3.0 volts. Because of this high sensitivity, the 6CL6 can be driven to full output directly from the detector stage.

Shielding considerations.

When the 6CL6 is used in a video application, consideration must be given to the "Miller Effect", that is, the effect of the grid-plate capacitance in increasing the effective input capacitance. This effect can be expressed by the formula

$$C_{in} = C_{in}' + (M + 1)\ C_{gp}$$

where C_{in} = effective input capacitance in micromicrofarads,

C_{in}' = "hot" value of input capacitance in micromicrofarads,

M = stage gain (approximately equal to transconductance in mhos times load impedance in ohms),

C_{gp} = grid-plate capacitance in micromicrofarads.

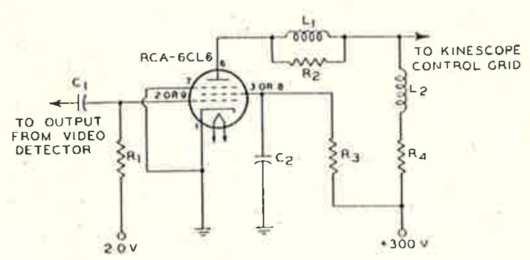
The tube capacitance values, however, are affected by the presence of an external tube shield, as shown in the following tabulation:—

6CL6 CAPACITANCES

	Unshielded	*Shielded*	
C_{in} (cold)	11.0	11.3	μμf
C_{in} (hot)	14.0	14.3	μμf
C_{gp}	0.1	0.06	μμf
C_{out}	5.5	10.5	μμf

In the 4-megacycle amplifier shown in Fig. 1, the stage gain is approximately 43. Thus, the effective input capacitance with the tube unshielded is 18.4 micromicrofarads; of this value, the incremental capacitance due to the "Miller Effect" is 4.4 micromicrofarads, (43 + 1) × 0.1. When the tube is shielded, the effective input capacitance is reduced to 16.9 micromicrofarads. This slight reduction is hardly sufficient to warrant the use of a shield in this circuit solely to reduce the effective input capacitance.

In the case of a narrow-band video amplifier, however, in which the load impedance is approximately 10,000 ohms, the stage gain is approximately 110 and the effective input capacitance with the tube unshielded is 25.0 micromicrofarads. In this case, the incremental capacitance due to the "Miller Effect" is 11.0 micromicrofarads. Shielding the tube reduces the effective input capacitance to 20.9 micromicrofarads. This reduction is of sufficient magnitude to justify the use of an external shield.



C1: 0.1 μf, 400 volts
C2: 4 μf, 400 volts
L1: Peaking Coil, 180 μh
L2: Peaking Coil, 120 μh
R1: 100,000 ohms, 0.5 watt
R2: 47,000 ohms, 0.5 watt
R3: 24,000 ohms, 2 watts
R4: 3,900 ohms, 5 watts non-inductive type

Fig. 1—Typical Video Output Circuit Having Bandwidth of 4 Megacycles.

* Reprinted with acknowledgements to RCA.

The substantial increase in output capacitance due to the use of an external shield may require a reduction in the maximum allowable plate-load impedance for the required bandwidth. Because video-output tubes usually work into loads having high circuit capacitance, produced by long leads from the output stage to the kinescope, the increase of output capacitance due to shielding probably will not materially reduce the performance.

A further consideration is the effect of a shield in increasing envelope temperature. The maximum envelope-temperature rating for the 6CL6 of 200 degrees Centigrade should not be exceeded. In circuit-design work, the envelope temperature may be measured by means of temperature-resistive paint or crayons*. When an external shield is required, the use of a blackened shield is helpful in reducing the envelope temperature.

Tube ratings and characteristics.

When the 6CL6 is substituted directly for the 6AG7, the differences in the ratings of the two tubes must be considered. Due to the smaller envelope of the 6CL6, its plate-dissipation rating is 7.5 watts, as compared to 9.0 watts for the 6AG7. The plate-dissipation rating of 7.5 watts is adequate for most video-amplifier applications because such amplifiers operate with resistive loads and, therefore, with low values of plate voltage. A higher dissipation may be required for some video applications, such as studio "chain" amplifiers or cathode-follower circuits, or for some types of voltage-regulator service. In these applications, the 6AG7 should be used or the equipment design should be modified to permit operation of the 6CL6 within its ratings.

The maximum permissible values of Grid-No. 1-circuit resistance for the 6CL6 are 0.1 megohm for fixed-bias operation and 0.5 megohm for cathode-bias operation, as compared to 0.25 megohm and 1.0 megohm, respectively, for the 6AG7. The lower values of resistance are specified for the 6CL6 to provide added protection against the possibility of grid-emission effects.

When the 6CL6 is used unshielded, its Grid-No. 1-to-plate capacitance is about twice that of the 6AG7; its input and output capacitances, however, are lower than those of the 6AG7. The use of an external shield with the 6CL6 increases its input and output capacitances and decreases its grid-to-plate capacitance to approximately the same values as the 6AG7.

The envelope-temperature rating of the 6CL6 must also be considered, especially in equipment operating at high ambient temperature. Although the 6AG7 has no envelope-temperature rating, it is obvious that it too has a practical limit to its permissible ambient temperature.

It should be noted that the 6CL6 has two base pins connected to grid No. 1 and two to Grid No. 2. In applications in which the tube operates at maximum ratings, or in equipment in which abnormally high temperatures prevail, it is advisable to connect circuit leads to both Grid-No.-1 and both Grid-No.-2 socket terminals.

Because it is desirable to operate the 6CL6 with an unbypassed cathode resistance in some applications, a separate base-pin connection to the suppressor grid is provided to permit this method of operation without feedback problems.

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