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RADIOTRONICS

Volume 18 **July 1953** **Number 7**

By the way —

The front cover this month is taken from the film "Australia makes Radio Valves by the Million" and is reproduced here by courtesy of the Australian Diary Film Unit. It is a study in concentration, showing an operator at work on a miniature bulb tubulating machine.

The second edition of the Radiotron Valve Data Book is having steady sale at a price of twelve shillings and sixpence, post free. This new edition contains revised data sheets on numerous receiving types together with additional sections covering transmitting tubes, phototubes and germanium crystals.

New Zealand subscribers should place their orders with Amalgamated Wireless (Australasia) Ltd., P.O. Box 830, Wellington, or with any branch of National Electrical and Engineering Co. Ltd.

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

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LOUDSPEAKER FREQUENCY RESPONSE CURVES

A. McLean*

That portion of the public that is given to reading literature on electronic equipment has come to look for a set of performance curves as a matter of course. In many cases, these curves are taken from experimental data obtained under conditions so far removed from the practical that any such curves may be said to be meaningless. These remarks apply particularly to speakers, because most of the really important factors that determine the quality of listening cannot be derived from an examination of a response curve.

The frequency response of a speaker is obtained by connecting it, properly matched, to an amplifier which is in turn driven by an oscillator. The speaker is mounted in the desired manner, near a calibrated microphone, and located in a room or in the open. The microphone is used to drive a vacuum-tube voltmeter, the output of which controls the position of a pen or a beam of light, the deflection of which is a measure of the sound pressure in decibels at the frequency to which the oscillator is set.

A loudspeaker comprises essentially a diaphragm which is vibrated so that the air around it is alternately rarefied and compressed. If the frequency of vibration is in the audible range, sound issues from the cone. The cone vibrates because forces are established on a conductor in a magnetic field when current flows in that conductor. The current is provided by the amplifier to which the speaker is connected and the magnetic field, which must be of a steady value, is provided by a permanent magnet or an electromagnet.

The amount of sound coming from a speaker is determined by

(i) The flux density in the air gap.
(ii) The number of turns, or more accurately, the total length of the conductor in the field, and
(iii) The current flowing in the conductor.

The aim is to have as much sound for as little current as possible and therefore the flux density and the length of the conductor must each be a maximum. The flux density will increase as the radial length of air gap in the magnetic structure decreases and the speaker engineer must accordingly keep the air gap down to a minimum. The conductor on which the force is developed is in the form of a cylindrical coil and as a result, the air gap must likewise be in the form of a ring made up of an accurate circular hole in a pole-plate and a cylinder of soft iron ground as nearly circular as possible. In assembly, the core, the inside and outside of the voice coil and the hole in the pole-plate are intended to be closely concentric, but when it is realised that there may only be between 0.020 to 0.030 of an inch of total air gap in modern designs then it can be clearly seen that very minute departures from concentricity can have a marked effect. Thus even if the core is out of centre by 0.001 inch there is a markedly better magnetic path, and therefore more flux density, over the region towards which the core is displaced than that existing diametrically opposite.

Instead of a uniform force being developed over the periphery of the voice-coil, the strengthened and weakened flux densities create a tendency for the coil to move respectively farther in one zone than in the other diametrically opposite. Thus the cone tends to buckle and give rise to sound variations which differ from speaker to speaker while a frequency response curve may give no detectable indication.

In addition to the alignment concentrically, it is important that the axial length of the voice coil should be symmetrically disposed with respect to the thickness of the pole-plate. As an example, suppose that the pole-plate is 0.25 inch thick. A voice coil for such a pole-plate would be about 0.3 inch of axial length and accordingly about 0.025 inch or three turns of wire would, ideally, protrude above and below the pole-plate when the voice coil is stationary.

It is not easy to ensure that this symmetry exists and lack of it results in a drop in efficiency and the generation of distortion. If in the example quoted above, the voice coil is out of symmetry to the extent of having 0.1 inch of the coil protruding above the pole-plate, then the lower end of the coil will be 0.05 inch above its lower edge. When a sine-wave alternating current flows in the voice coil, the cone cannot move as far forward as it can backward, because as the cone is driven forward it draws more turns out of the magnetic field so successively reducing the force acting on it but, for the other alternation, more turns are successively added to be influenced by the field and a greater movement results. This causes the generation of even-harmonic distortion and intermodulation distortion, both of which are readily discernible even in small quantities It is quite possible that the efficiency would fall by two decibels, but that is only within the range of manufacturing tolerances so an inspection of the response curves of several speakers would not necessarily indicate such a fault, while there may

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* **Components Laboratory, A.W.A., Ashfield.**

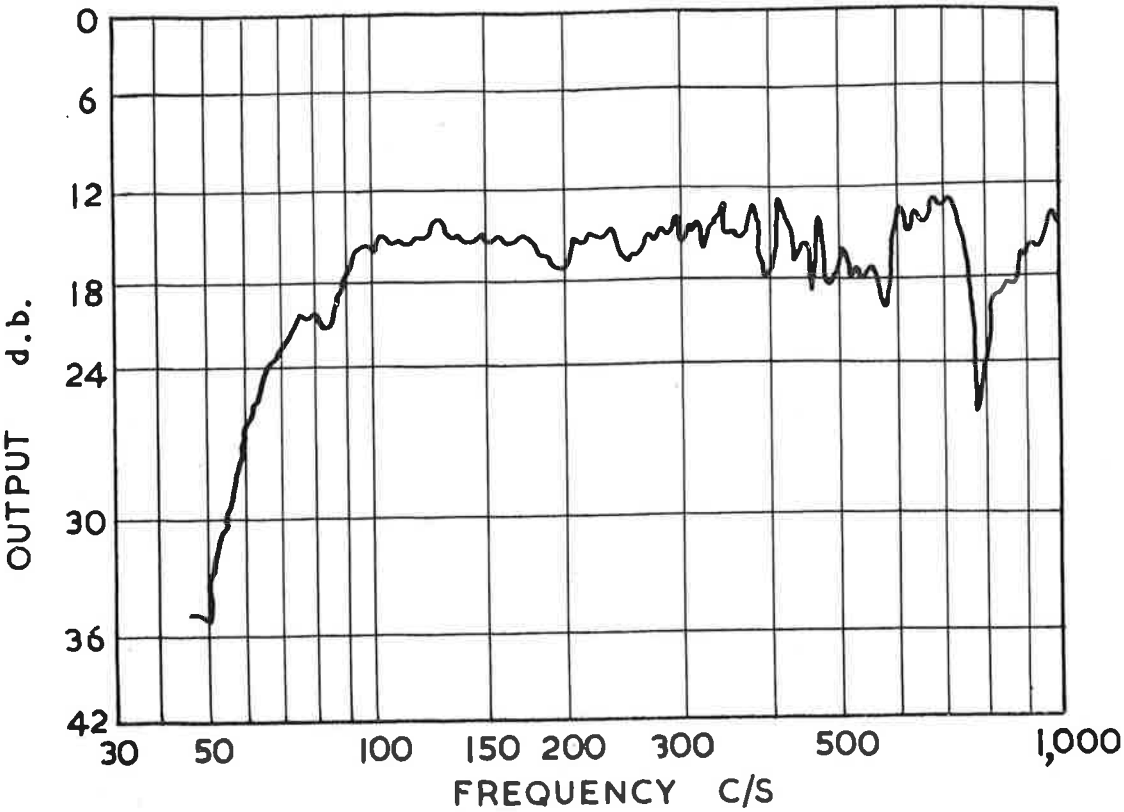


Fig. 1. Microphone one foot from speaker in vented baffle.

be marked differences in listening. Even assuming that the elements of the magnetic circuit and the voice coil are all absolutely in their correct positions, there is still a tendency for the cone to "break up".

The cone does definitely act as a piston up to a certain frequency, generally about 1000 cycles, moving forward and backward as a whole. Under some conditions above that frequency, zones of the cone may vibrate by themselves while others undergo no vibration. Moving a probe microphone over, but not touching the surface of the cone at any frequency, would show a symmetrical pattern of cone areas of high- and low-sound levels. The response curve of such a speaker would comprise a series of dips and peaks. Because of minute variations in the quality or thickness of the cone materials, the frequencies at which these dips and peaks occur change slightly from speaker to speaker. All speakers exhibit this property to some degree and the minute variations, quite undetectable from the frequency response curves, cause sound-quality differences which are very noticeable. The lack of symmetry in the driving force adds considerably to the cone break-up. A most prized possession of a speaker engineer is a pair of speakers which sound the same under identical acoustical conditions.

At the low-frequency end of the spectrum, the bass resonance is expressed as falling anywhere within a range of frequencies covering some twenty per cent. of the mean value. This relatively wide range is not a sop to production engineers but is necessary to cover contingencies in the mounting and application of the speakers. The resonant frequency of any speaker is determined by:—

(i) the stiffness of the various surfaces which allow of the cone movement, viz., the rim or corrugated edge of the cone and the spider or suspension, and

(ii) the mass of every moving element associated with the speaker including the entire cone and its rim, the suspension, the voice coil and its former and the air set in motion by the movement of the cone.

The lastnamed factor is by no means to be neglected. Thus, with increased efficiency in coupling the piston effect to the surrounding air, a greater mass of air is acted upon and the resonant frequency falls below that value obtained when there is no baffling.

Futhermore the value of the resonant frequency of any speaker will differ under given acoustical conditions by the method used to detect resonance, even though a high degree of precision is maintained.

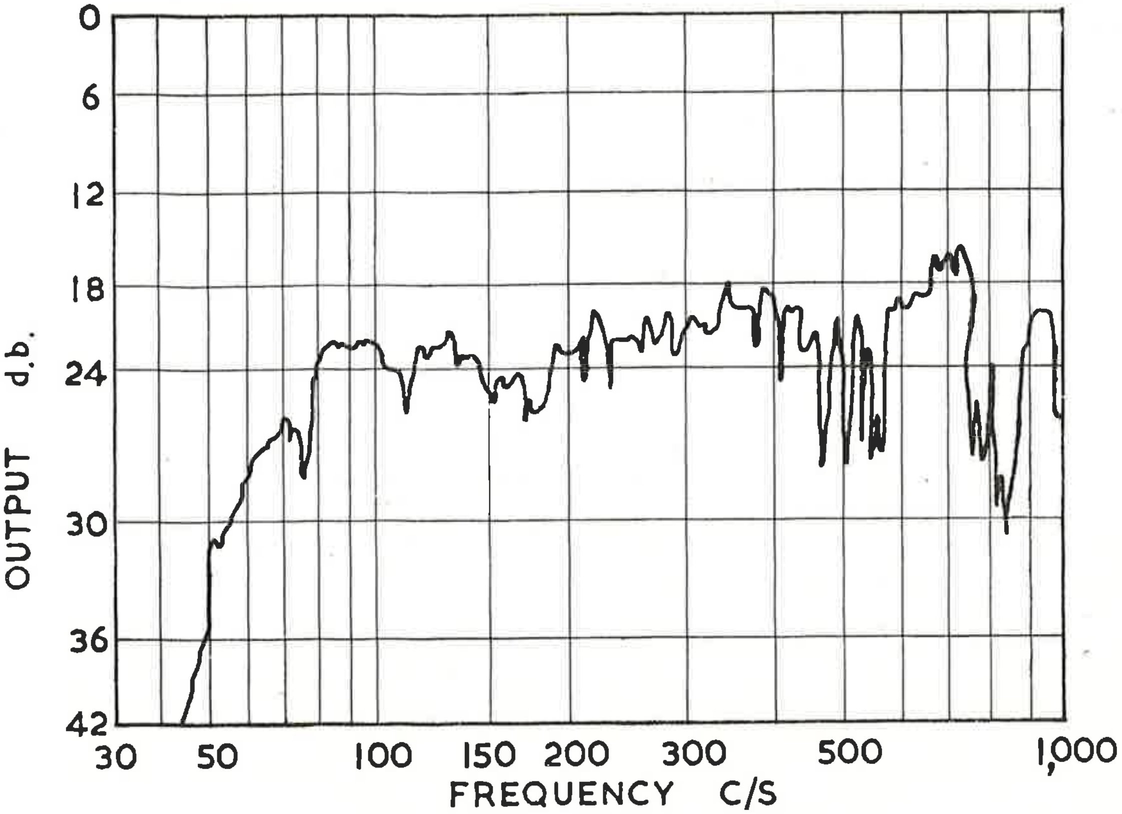
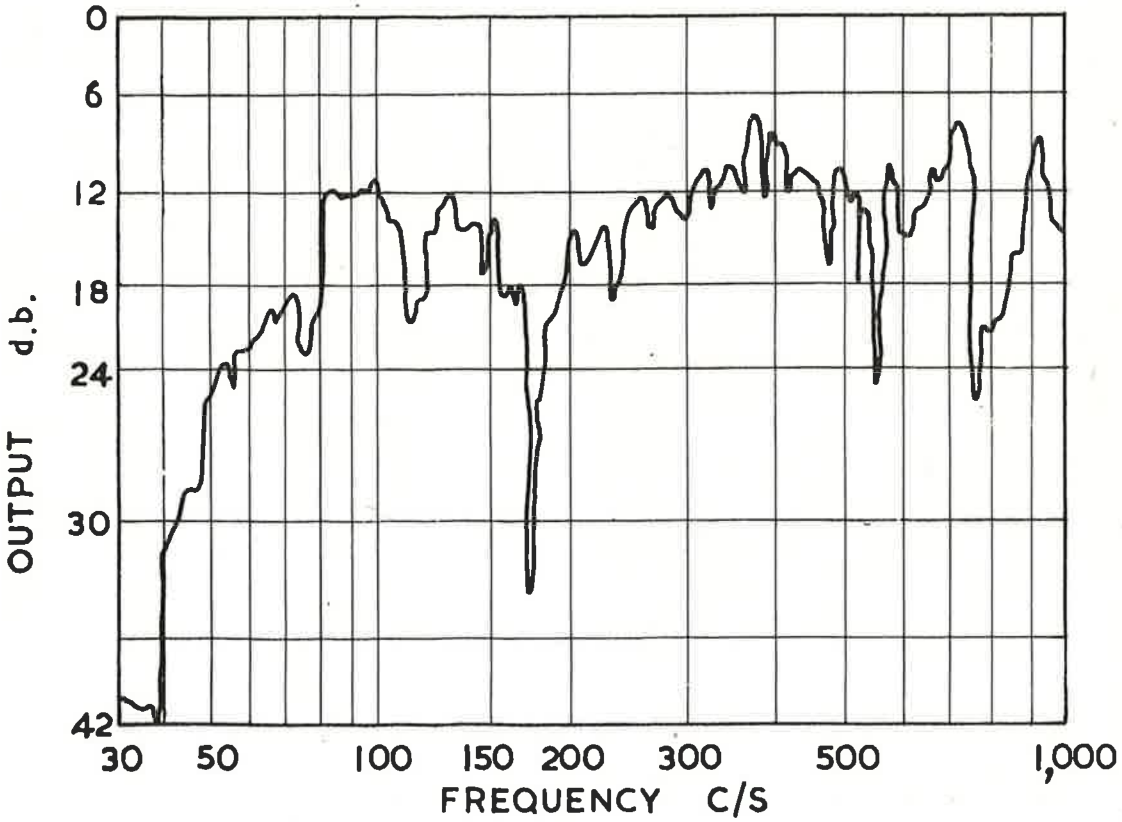


Fig. 2 (above). Microphone distance two feet.

Fig. 3 (below). Microphone distance three feet.



There are available five methods whereby resonance may be indicated, viz.:

- (i) amplitude of cone vibration indicated by a maximum;
- (ii) voltage across the voice coil indicated by a maximum;
- (iii) Current in the voice coil indicated by a minimum;
- (iv) phase relationship between current and voltage in the voice coil indicated by a zero angle;
- (v) maximum sound pressure, but not using the ear as the measuring instrument.

Even these factors are complicated by the fact that the frequency at which resonance occurs is usually different, when the frequency of the oscillator is increasing, from that when it is decreasing. Thus if one starts with the oscillator at zero frequency and increases it to find a resonance at, say, 120 c/s and keeps on increasing it to 200 c/s and then reduces the frequency to pick up resonance again it may this time occur at 110 c/s.

So much in broad outlines for the speaker and its variations, but it is equally important to consider the acoustical conditions of the location at which the response curve is taken relative to those where the speaker may be used. The only set of acoustical conditions conforming somewhat to uniformity is that afforded by an anechoic chamber. Thus a speaker measured for frequency response in one anechoic chamber should give a somewhat similar result in another. Such rooms do, however, differ quite noticeably one from another, particularly at the low-frequency end of the range. Although close to perfection, one would cost at least £50,000, which is rather much to provide idealised acoustical conditions even for a radiogram worth £300. Apart from being a distinctly unsightly structure, impossible to keep clean and unusable for conversation, the unit would need an output four or five times that required in a room with reflecting surfaces, for the same sound level. The anechoic chamber is completely impracticable and with that decision has gone any pretence of defining "room".

It has been determined that up to eighty per cent. of the sound reaching the ear, when the sound originates in a room, is due to reflection from the walls, floor and ceiling. This means that the acoustical conditions of the room take almost complete charge as far as listening judgments are concerned. In any domestic room, standing-wave patterns are established for every frequency and it is a revelation to walk about a room when a constant frequency tone is radiated in it. The variation in sound level from point to point, even at ear level, is very wide and yet these are the conditions under which most speaker response curves are taken and all speakers are used.

As an example, a good quality speaker was located in a corner of a typical living room and the *only* thing changed was the distance of a velocity microphone along the axis of the speaker. The curves in Figs. 1, 2 and 3 show the response with the microphone at 1, 2 and 3 feet respectively away from the speaker.

It is now desirable to determine the significance of the microphone. It may be thought that using a small unit and mounting it right into the space enclosed by the cone would obviate the effect of the room conditions. It certainly would do that but it would likewise take no account of the baffling efficiency. This is because right at the cone itself, there is not the cancellation of the compressed and rarefied air conditions which exists some little distance from the cone, below a critical frequency. It is also a condition that certain microphones, notably the velocity group, only perform in accordance with their calibration curves when they are a great distance from the source of sound and the departure from calibration is particularly noticeable at the low frequencies. At the high frequencies the dimensions of the structure of such microphones must cause disturbances in the sound field. The velocity group does seem to offer a distinct possibility of minimising room influence, but it must be remembered that the ear is really a "pressure" not a "velocity" microphone, and the interpretation of the low-frequency results is very much open to doubt.

Some authorities suggest the use of a pressure microphone on the end of a rotating boom, thereby sampling large volumes of the room almost simultaneously. Others claim the same effect with a varying tone comprising a range of frequencies, the mid value of the range being taken as the nominal frequency. Still others generate a white noise in which all frequencies are present at equal amplitude all the time and then they select a narrow range of frequencies by means of a band-pass filter.

The first method is good, but the second is fraught with difficulties by introducing more errors than it tries to avoid, mainly because spurious tones are generated which are quite large in proportion to the mean or nominal frequency. Over that region where distinct peaks and dips are encountered in the speaker performance, there may be disturbances introduced which would make the response curve completely false. One very grave difficulty is the choice of the frequency sweep, viz., a constant frequency change as against a constant-percentage frequency change. If we are to measure from, say, 50 to 10,000 c/s, then using the former we could not have more than 5 cycles above and below at the 50 cycle point. At frequencies as low as 1000 c/s, this would have no significance in trying to avoid room standing-wave troubles. Taking a constant percentage, then the reverse action applies. The change at the low frequency end would be too small to be significant and, further, if we use some relationship in between or, more desirable still, a gradual change from one method to the other the generation of spurious notes would be very difficult to investigate. The same criticism may be levelled at the use of a band pass filter with white noise, with the further complication that the filter would be very difficult to construct and with its constantly varying function, may perform in a very different manner from that predicted from steady-state assumptions. So we are once again at a high brick wall across a narrow lane.

Most organisations capable of determining frequency response of speakers can boast of elaborate amplifiers with so much feed back that variations in load impedance mean absolutely nothing. The impedance of a speaker is by no means constant with frequency nor does it even approach this relationship approximately. One very good speaker, internationally famous, has an impedance range from eleven to two hundred ohms, approximately. Considerable impedance variations can be introduced by the baffling itself. A response curve, therefore, should express the exact conditions under which the loudspeaker is driven.

In covering these aspects of speaker performance, one may justifiably ask why response curves are bothered with at all. In spite of the difficulties encountered, there is distinct and valuable information to be obtained from them but only within a limited field. Thus a speaker engineer, ever at work to improve his product, compares one speaker to another, by taking response curves of each, and can glean much information from the relative responses but only providing each speaker is presented to the microphone, its driving amplifier and the room in exactly the same way. Then again, once an engineer knows his equipment he can say that there will be severe intermodulation distortion at frequencies which he can specify and he can say that a speaker will sound "edgy" or "boxy" or "thin" or "boomy". It is emphasised that he will be able to interpret these probabilities from his curves only after long experience with his own equipment in unchanging acoustical conditions.

Unfortunately, his conditions are not related to those of his customer or competitor in any predictable manner and what may be interpreted with a fair probability of accuracy in known conditions becomes dangerously misleading when these are unknown. Speaker response curves — they certainly exist, but like a specialist's diagnosis passed on to one's general practitioner, they should be left strictly to those skilled in making appropriate interpretations.

* * *

The author offers sincere thanks to Mr. R. D. Stewart in charge of the Components Laboratory of A.W.A. for many suggestions.

New RCA Releases

RCA's commercial entry into the Transistor field, after years of extensive research and development on semi-conductors, is marked by the introduction of four types of germanium transistors — two point-contact types and two junction types.

RCA 2N32 is a point-contact transistor intended for large-signal applications such as in pulse and switching circuits.

RCA 2N33 is also a point-contact transistor but is intended for oscillator service at frequencies up to 50Mc.

RCA 2N34 is a junction transistor of the P-N-P (Positive-Negative-Positive) type, intended for use in low-power, audio-frequency applications.

RCA 2N35 is also a junction transistor but of the N-P-N (Negative-Positive-Negative) type, and is likewise suitable for use in low-power, audio-frequency applications.

Those interested should note that details of price, Australian availability, and technical data are not yet to hand. A further announcement will be made when this information is available.

SUMMARY OF INFORMATION ON CINTEL GEIGER MULLER COUNTERS

Self-quenched — Gamma Radiation Type

1. Dimensions.

Bulb Size No.	Cathode Length (mms) (approx.)	Overall Length (mms)	Diameter (mms)
1	650	720—740	34—38
2	450	520—540	29—31
4	105	140—150	21—23
5	225	260—280	21—23
6	320	390—410	35—38
7	320	390—410	21—23
8	160	210—230	22—25
9	510	580—600	35—38
10	410	480—500	35—38

2. Cathode material.

A = Copper.
B = Graphite.

3. Fillings.

Figure	Filling	Temperature Range	Filling Efficiency (approx.) γ—Source
1	Ethyl Alcohol/ Argon.	+ 8°C to + 50°C	100%
2	Ethyl Bromide/ Argon.	— 20°C to + 50°C	75%
3	Methylene Bromide/Argon.	— 20°C to + 50°C	10%
4	Ethyl Formate/ Argon.	— 20°C to + 50°C	100%

4. Designation:—

GM—Followed by first figure denoting size—followed by second letter denoting cathode type—followed by third figure denoting filling.

For example:—Size 5 tube with graphite cathode and ethyl alcohol/argon filling is:—

Type: GM5B1.

NEW A.W.V. RELEASE

RADIOTRON

AV33

●

TUNGSTEN FILAMENT CONTROL DIODE

●

Regulated power supplies are finding wider application in the radio-electronic field. In particular this applies to regulators of A.C. mains voltage.

Such regulators include a sensing element which detects unwanted voltage deviation from some fixed reference value, e.g., the required regulated value. The output of the sensing element is, after amplification, applied at some point in the circuit to minimize the initial deviation and so automatically return the voltage to within the required limits about the regulated value.

The most satisfactory sensing elements for such regulators are temperature limited diodes of which the A.W.V. AV33 is a representative type. Sufficient plate voltage is applied to this tube to obtain temperature limited or saturated plate current. This means that the diode plate current does not vary significantly with plate voltage, but does vary rapidly with changing filament voltage.

The advantages of this diode result from the following properties:—

(a) It responds to the effective or R.M.S. value of filament voltage and can be used to regulate D.C., A.C. or R.F.

(b) It is constructed with a pure tungsten filament giving long life, high stability and reliability.

(c) It is a very sensitive detecting or sensing element as the temperature limited plate current increases very steeply with increasing filament voltage.

For its rating and characteristic curves see Figures 2 and 3.

{Corrn. ex P.126}

RADIOTRON TYPE AV33 TUNGSTEN FILAMENT CONTROL DIODE

GENERAL DATA

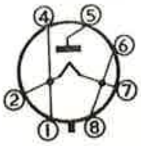
Mechanical:

Mounting Position	Any
Maximum Overall Length	4"
Maximum Seated Height	$3\frac{7}{16}$"
Maximum Diameter	$1\frac{3}{16}$"
Bulb	T-9
Base	Intermediate Octal 7-pin

Base Connections for

Pins 1, 2, 4	Filament
Pin 5	Plate
Pins 6, 7, 8	Filament

BOTTOM VIEW



Electrical:

Ratings —

Filament Voltage (a.c. or d.c.)	~~4.0~~ 4.3	max.	volts
Filament Current	1.0	approx.	amps
D.C. Plate Voltage	250	max.	volts
Plate Current	10	max.	mA

Typical operation:

D.C. Plate Voltage	100		volts
Plate Current, saturated	3		mA
A.C. Filament Voltage	3.7	approx	volts
Filament Current	0.96		amp
Minimum Plate Voltage for approx. 80% sat. plate current	20		volts

APPLICATION DATA

A typical circuit for A.C. voltage regulation is shown in Figure 1. Referring to this circuit, the A.C. input voltage is applied to an autotransformer T_1 in series with the A.C. winding of a saturable reactor L_1. The output voltage is preset by the rheostat R_1 to the desired value.

Any increase in output voltage caused by a rise in input voltage or a decrease in the load current, increases the filament voltage of the diode V_1, and thus reduces its effective plate resistance. The grid of V_2 then becomes more negative decreasing the current through the D.C. winding of L_1. This increases the effective series inductance of the A.C. winding of L_1 and so decreases the voltage across the auto-transformer T_1 to compensate for the initial voltage increase. Similar reasoning shows that regulation is also obtained for an initial decrease in output voltage.

Typical regulators of this type maintain output voltage accurately to 0.5% over a 10 to 1 range in load current, for input voltages varying ± 20% from normal mains voltage. The waveform distortion introduced by these regulators can be made less than 5%.

Possible applications of the type AV33 diode are widespread. The thermal inertia of its filament is low and thus response time is fast. In regulators of the above type the AV33 provides high inherent accuracy and reliability. Furthermore the AV33 is insensitive to changes in frequency which is an advantage in critical applications.

It is mechanically and electrically similar to the services type CV430.

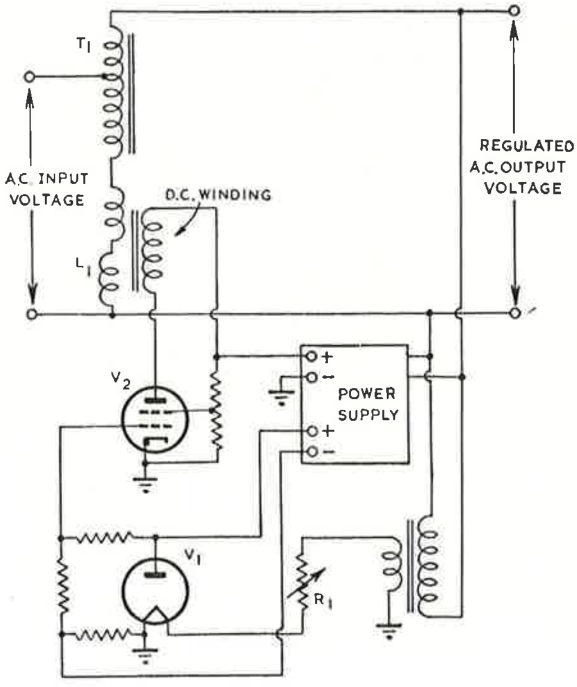


Fig. 1. Typical circuit.

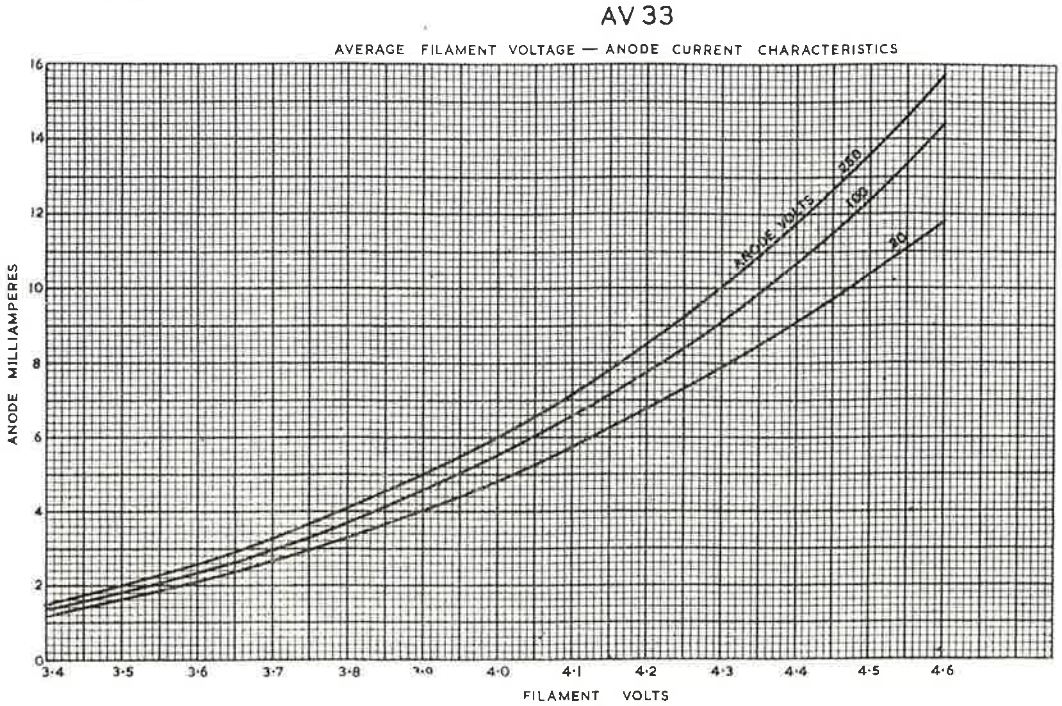
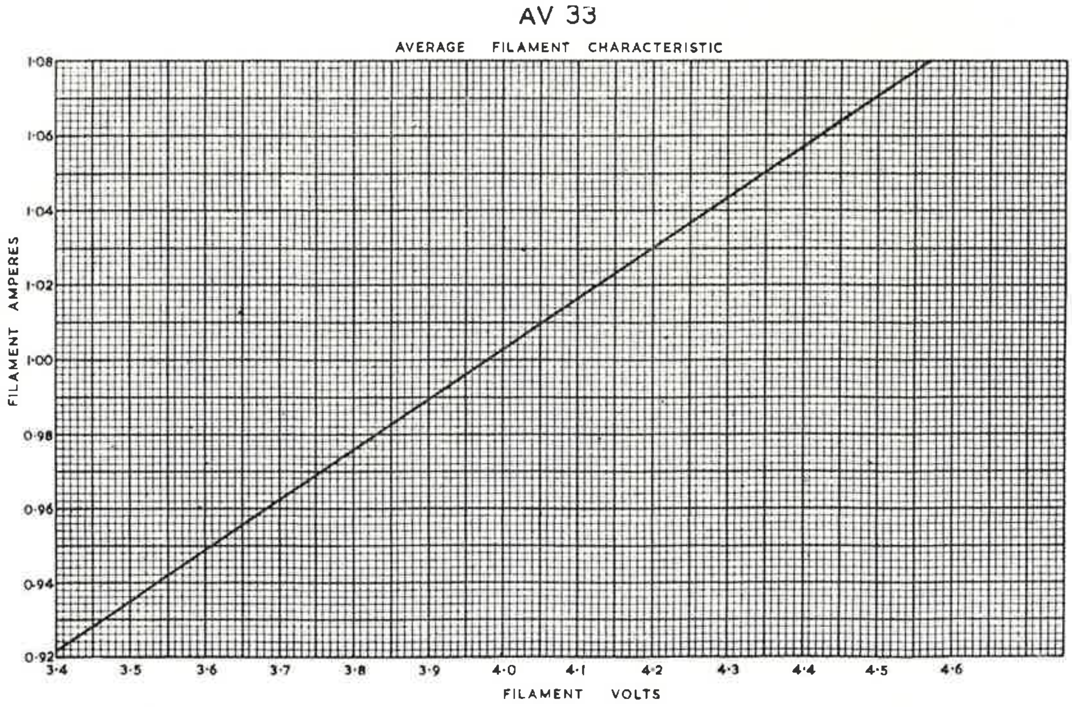


Fig. 2 (above). Filament Voltage — Plate Current Curves.

Fig. 3 (below). Filament Voltage — Filament Current Curve.



Television Principles & Practice **Chapter 9**

By K. Fowler and H. Lippert.

DEFLECTION CIRCUITS

1. Introduction

The deflection circuits in a television receiver perform the operation of supplying a force which acts on the electron beam of the picture tube so as to move the spot in the same manner and in synchronism with the movement of the electron beam in the camera tube.

As pointed out earlier, the force producing the motion of the electron beam is of sawtooth waveshape with a slow linear rise and a rapid fall. Also, that the forces producing the horizontal and vertical deflection be arranged so that they produce beam deflection at right angles to each other so that as the horizontal sweep moves the spot rapidly across the screen, the force due to the vertical sweep will slowly move the spot toward the bottom of the screen and produce a rectangular raster.

The force producing the deflection may be an electrostatic field or an electro-magnetic field. All current television receivers employ electromagnetic deflection. However, several pre-war models made use of electrostatic deflection and since it is somewhat less complicated than electromagnetic deflection, it will be discussed first.

2. Electrostatic deflection

Electrostatic deflection is used in service shop oscilloscopes and is familiar to the majority of radio technicians. With this type of deflection, two pairs of plates are mounted inside the glass envelope of the cathode ray tube somewhat past the end of the electron gun. As mentioned in an earlier chapter, for deflection in the vertical direction, a plate is placed above the beam and one an equal distance below the beam. Likewise, for horizontal deflection a plate is placed on one side of the beam and another plate equally spaced is placed on the opposite side of the beam. If there is no potential difference between the plates, then the electron beam will not be deflected and will follow a straight line between the plates and strike the centre of the screen. However, if a difference of potential is made to appear between the vertical plates, for instance, the electron beam will be deflected up or down toward the plate that is more positive, the amount of deflection being dependent on the difference of potential existing between the two plates.

The electrostatic type of cathode ray tube, its voltage circuits and deflection of the beam by an electrostatic field was discussed in some detail in Chapter 2 and it might be well to review this section before considering actual circuits.

3. The sweep amplifier

When electrostatic deflection is employed, a sawtooth wave of voltage is applied to each pair of deflecting plates.

For proper deflection of the beam the amplitude of this sawtooth voltage applied to the deflecting plates must be considerably greater than that obtained from the output of the sawtooth generators. To accomplish this it is necessary to use an amplifier between the sawtooth generators and the deflecting plates. Two amplifiers are employed, one for the vertical sawtooth voltage wave, the other for the horizontal sawtooth voltage wave, and they are referred to as sweep amplifiers.

In order to maintain the focus of the electron beam as it moves across the screen, the mean potential of the deflecting plates is kept at the same potential as the last or accelerating anode. Since the output of the sweep amplifiers is capacitively coupled to the deflecting plates, the coupling capacitors must be capable of withstanding this high voltage. Push-pull sweep amplifiers are usually employed in order to more accurately maintain focus.

4. Linearity of the sawtooth waveform

In order that the reproduced scene have the proper proportions (good linearity) it is necessary that the deflection forces move the beam at a uniform rate. In other words, for good linearity, the trace portion of the sawtooth voltage wave applied to the deflecting plates should change from minimum to maximum at a uniform rate.

If the trace portion of the sawtooth voltage wave that deflects the beam horizontally, for instance, does not increase at a uniform rate as in A of Fig. 9-1, but changes in the manner shown in B, then the reproduced picture will appear stretched on the left and crowded at the right as shown in C of Fig. 9-1. This is because the electron beam will be deflected at a faster rate during the beginning of the trace (left side of the picture) than during the end of the trace (right side of picture) where the sawtooth voltage wave begins to level off or slow down. The same thing, of course, applies to the sawtooth waveform that deflects the beam vertically, except that in this case the picture would be stretched at the top and crowded at the bottom.

By courtesy of A.G.E., with acknowledgment to International General Electric Co. of U.S.A.

As mentioned earlier, only the linear portion of the charging curve of the charging capacitor is utilized in the sweep generating circuits by the proper choice of charging capacitor, series charging resistor and operating voltage, but in spite of these precautions there is usually a small curvature of the sweep.

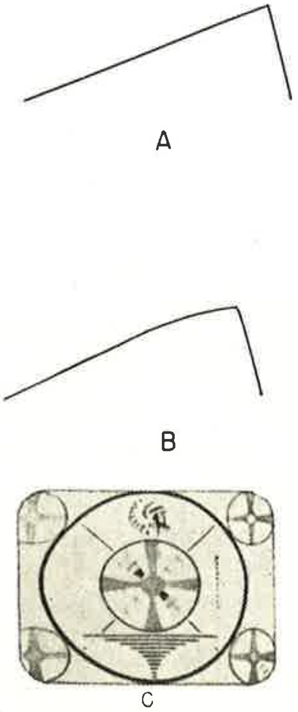


Fig. 9-1. Distortion caused by nonlinear sawtooth waveform.

There are several methods for compensating for any slight curvature of the sawtooth waveform that may exist in the output of the sweep generator and the correction usually takes place in the sweep amplifier circuits. These circuits usually correct for non-linearity either by slightly changing the characteristics of the sweep amplifier tube or by introducing some frequency discrimination.

A simple application of the latter type of circuit is shown in Fig. 9-2 which illustrates the horizontal linearity compensating circuit used in the General Electric Model 185 TV receiver (pre-war). The .001 mf capacitors C_1 and C_2 in combination with resistor R_1 form a frequency discriminating network that is shunted across the input to the sweep amplifier and varies the frequency response of the sweep amplifier sufficiently to correct for any slight non-linearity in the sawtooth output of the sweep generator.

5. Typical electrostatic deflection circuit

The complete circuit for the sweep generators, sweep amplifiers and picture tube for the General Electric model 185 receiver is shown in Fig. 9-3. Starting at the picture tube it will be noted that each deflecting plate is connected to a 5.6 megohm resistor and returned to a point which is at the same potential as the last or accelerating anode for reasons mentioned previously. The 5.6 megohm resistors connected to one vertical plate and one horizontal plate are connected to the arms of R_3 and R_4, the 2 megohm potentiometers, instead of at the junction of R_1 and R_2, as is the case with the 5.6 megohm resistors associated with the other two plates. However, the potential at the centre of the 2 megohm potentiometers will be the same as that at the junction of R_1 and R_2 and, therefore, the mean potential of all four plates will be the same as the last anode potential. The purpose of the two potentiometers is to centre the electron beam on the screen and simply place a small adjustable d-c voltage on each set of plates to compensate for any stray electrostatic or magnetic fields picked up by the plates and for any irregularities in the electron gun structure which might cause the beam to be off-centre. For instance, when the arm of potentiometer R_3 is exactly in the centre of the resistance there will be no d-c potential existing between the two vertical plates. However, under these conditions the spot might be near the bottom of the tube instead of in the centre and to correct for this condition, it is only necessary to make the top vertical plate slightly more positive than the bottom vertical plate which will move the negative electron beam upward.

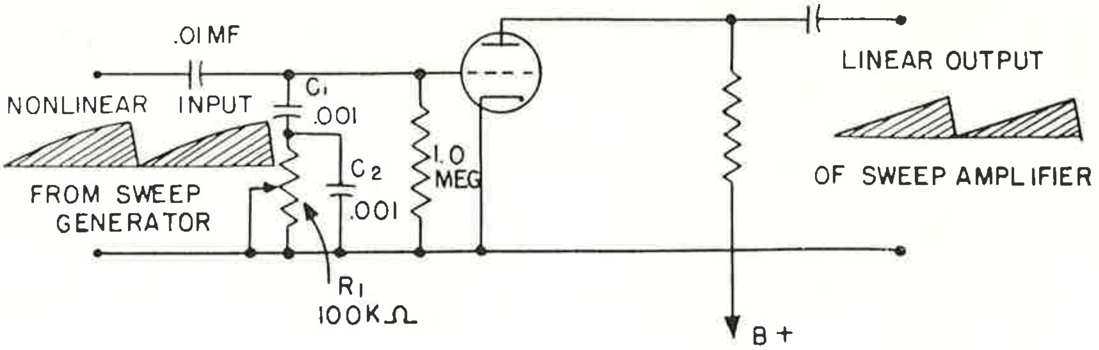


Fig. 9-2. Horizontal linearity compensating circuit.

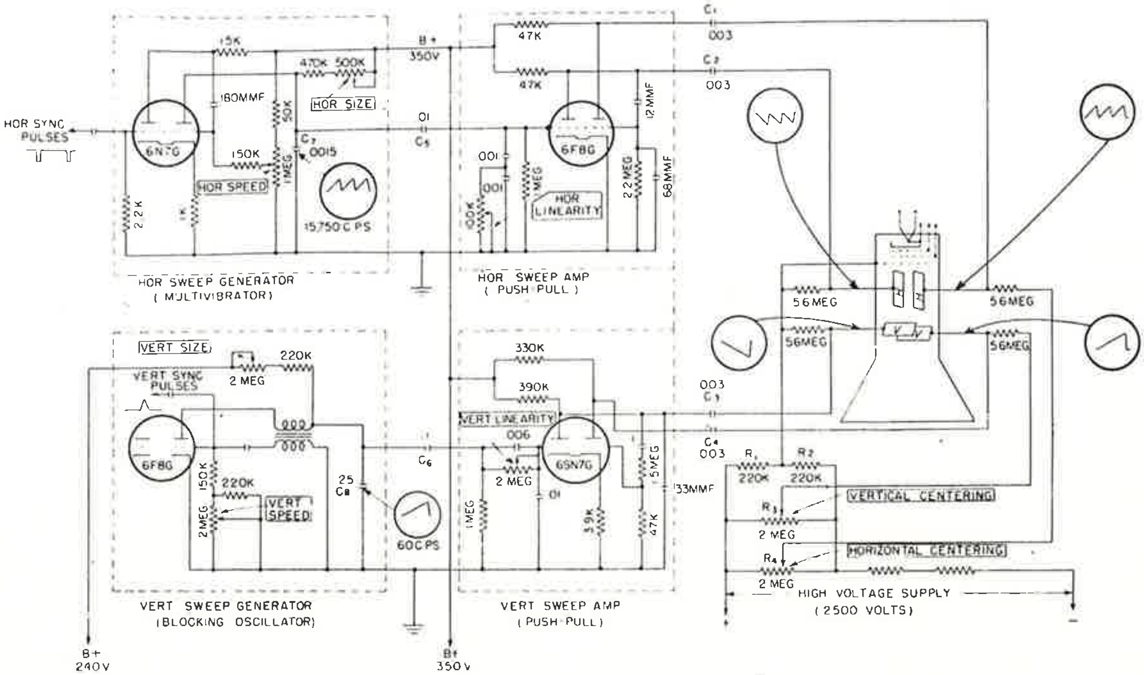


Fig. 9-3. Typical electrostatic deflection circuit.

This is easily done by moving the arm of potentiometer R_3 to the right, which is toward a lower positive potential, as indicated in Fig. 9-3, and since the potential of the top plate remains fixed at the potential existing at the centre of R_1 and R_2, the top plate becomes slightly more positive than the bottom plate which is connected to the arm of R_3. The same thing applies for R_4, which centres the electron beam in the horizontal direction.

The vertical and horizontal deflecting plates are connected to the output of their respective push-pull sweep amplifier by means of the coupling capacitors C_1 and C_2 in the horizontal deflection circuit and C_3 and C_4 in the vertical deflecting circuit. These capacitors must be capable of withstanding the high voltage appearing on the deflecting plates. Although the input to the sweep amplifiers is single-ended, the sawtooth wave of voltage appearing in the output of each triode section is of equal amplitude but 180° out of phase with each other, as indicated by the waveforms appearing on the deflecting plates, thus applying a push-pull voltage to each pair of deflecting plates. This is accomplished by applying the sawtooth voltage from each sweep generator to the grid of its respective sweep amplifier and choosing the value of component parts in the sweep amplifier so that just the right value of voltage from the output of the first triode section is applied to the grid of the second triode section to produce equal but opposite voltages across the plate load resistors of each triode section. Since the plate load of the sweep amplifier is resistive, a linear sawtooth voltage on the grid will produce a linear sawtooth voltage in the output provided the tube is operated class A.

It will be noted that there is a linearity control network in the grid circuit of each sweep amplifier which corrects for any slight non-linearity in the sawtooth output of the sweep generator. The sweep generator circuits are very similar to those already discussed and, as can readily be seen, the vertical sweep generator is of the blocking oscillator type and the horizontal sweep generator is of the multivibrator type.

The sawtooth wave of voltage developed across C_7, the charging capacitor of the horizontal sweep generator is coupled to the grid of the horizontal sweep amplifier through C_5. The horizontal size control determines the amplitude of the sawtooth wave of voltage developed across the charging capacitor C_7, in the manner explained previously, and therefore varies the width of the picture.

Likewise, the sawtooth wave of voltage developed across C_8, the charging capacitor of the vertical sweep generator is coupled to the input of the vertical sweep amplifier by means of capacitor C_6. The amplitude of the sawtooth wave of voltage developed across the charging capacitor C_8 is determined by the vertical size control, thus governing the height of the picture.

Both sweep generators are free-running; that is, they will develop sawtooth waves of voltage with or without the application of a synchronizing pulse. However, as explained earlier, synchronizing pulses are injected in the grid circuit of each sweep generator to lock or synchronize its frequency with that at the transmitter. It should be noted that the horizontal sync pulses are negative going which is the correct polarity for synchronization of the multivibrator while the vertical sync pulses are positive going which is the correct polarity for the blocking oscillator. The speed control in each sweep generator circuit varies the time constant in the grid circuit and thereby adjusts the free-running frequency of the oscillator so that it is slightly below the frequency of the synchronizing pulses, thus permitting the oscillator to lock in at the exact frequency of the synchronizing pulses.

6. Electromagnetic deflection

When electromagnetic deflection is employed, coils are used instead of plates to deflect the beam and they are placed on the outside around the neck of the tube, the details of which were described in Chapter 2.

As brought out earlier, a sawtooth wave of voltage is applied to deflect the beam when electrostatic deflection is used. Contrasted to this, however, a sawtooth wave of current is used to deflect the beam when magnetic deflection is employed. The sawtooth wave of current when passed though the deflection coils causes the magnetic flux to change at a uniform rate. Since the electron beam is deflected in proportion to the flux density of the magnetic field cutting across the tube neck, it will therefore be deflected at a uniform or linear rate.

Two coils are used for each deflection circuit (just as there are two plates for each deflection circuit in the case of electrostatic deflection), making a total of four coils for horizontal and vertical deflection of the beam. The two coils of one set are placed on opposite sides of the picture tube neck so that the resulting flux is at right angles to the neck (cuts across the tube neck). The other pair of deflecting coils is similarly placed on opposite sides of the tube neck but so that their flux is at right angles not only to the neck but also at right angles to the flux of the first set.

It is desirable that the cross-coupling between the horizontal and vertical coils be small to prevent reactions between them. This can be accomplished by inserting an electrostatic shield between the two sets of coils or by making one or both sets of low impedance so that excessively large voltages are not present across the windings. It is customary to use the latter procedure (both sets of coils of low impedance) and utilize step-down transformers between the sweep amplifier tube and the low impedance deflection coils as indicated in Fig. 9-4, which shows one set of deflection coils coupled to a sweep amplifier tube. The sweep output circuit of Fig. 9-4 is basic and may be used for either horizontal or vertical deflection provided that it is modified somewhat in a manner to be discussed in the following paragraph. This is especially true in the case of horizontal deflection.

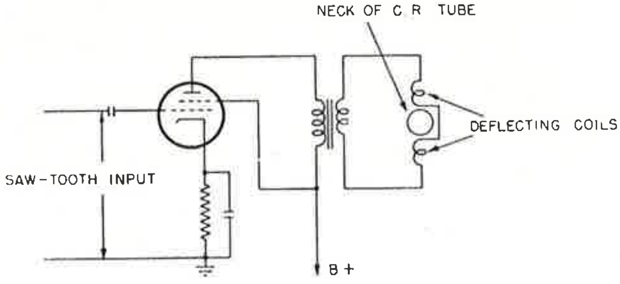


Fig. 9-4. Sweep output circuit.

7. Production of a sawtooth wave of current

It is evident that for good linear deflection the current through the deflection coils must change at a linear rate during the trace portion of the sweep. The difference between minimum and maximum current is a measure of the magnitude of the sweep, which magnitude is determined by the operating characteristics of the cathode ray tube. The higher the second anode voltage of the cathode ray tube, the "stiffer" the beam and correspondingly greater deflection voltage is required. Similarly, the wider the angle through which the beam is to be bent or deflected, the greater the force required to produce full deflection. These considerations are particularly pronounced in projection television receivers where very high anode voltages (for brightness and small spot size) and sharp deflection (wide angle tube for shorter structure) are employed.

The problem of producing a sawtooth sweep in a magnetic deflection circuit is not as simple as it is in the case of receivers employing electrostatic deflection. In the latter, a sawtooth voltage applied to the grid of the sweep output tube produces linear deflection. This is because the plate load is essentially resistive, which causes the plate current wave to have the same shape (sawtooth) as the grid voltage wave. Since the plate current wave is a sawtooth then the amplified voltage wave appearing across the resistive load will also be a sawtooth which is the desired condition for electrostatic deflection.

However, a sawtooth wave of voltage applied to the grid of the sweep output tube when magnetic deflection is used will not ordinarily cause a sawtooth wave of current to flow in the plate circuit. If the waveshape of the current flowing through the plate load (deflection coils) is not a linear sawtooth, then linear deflection of the beam will not be produced. Therefore, the voltage wave applied to the grid of the sweep output tube or the operating characteristics of the output tube must be modified somewhat in order to produce a linear sawtooth wave of current through the deflection coils.

The reason for this may not be readily apparent at first, so in order to illustrate the principles involved in developing a sawtooth wave of current through the deflection coils, several elementary circuits will be considered by which a practical system will be developed. The first circuit is A of Fig. 9-5 upon which the discussion will be based, and is the electrical equivalent of the sweep output tube, output transformer and deflection coils in its simplest form. It will be assumed that the tube is operating over the linear portion of its characteristic. The elements L and R represent the inductive reactance and d-c resistance of the circuit, both of which characteristics appear in an actual sweep output circuit for magnetic deflection. The voltage appearing in the plate circuit, μe_g, is an amplified version of the voltage applied to the grid of the output tube (assuming that the tube is operating over the linear portion of its characteristic). The flow of current will depend upon the internal resistance of the voltage source (Rp of output tube) the resistance R and the inductive reactance L of the deflection coils and transformer.

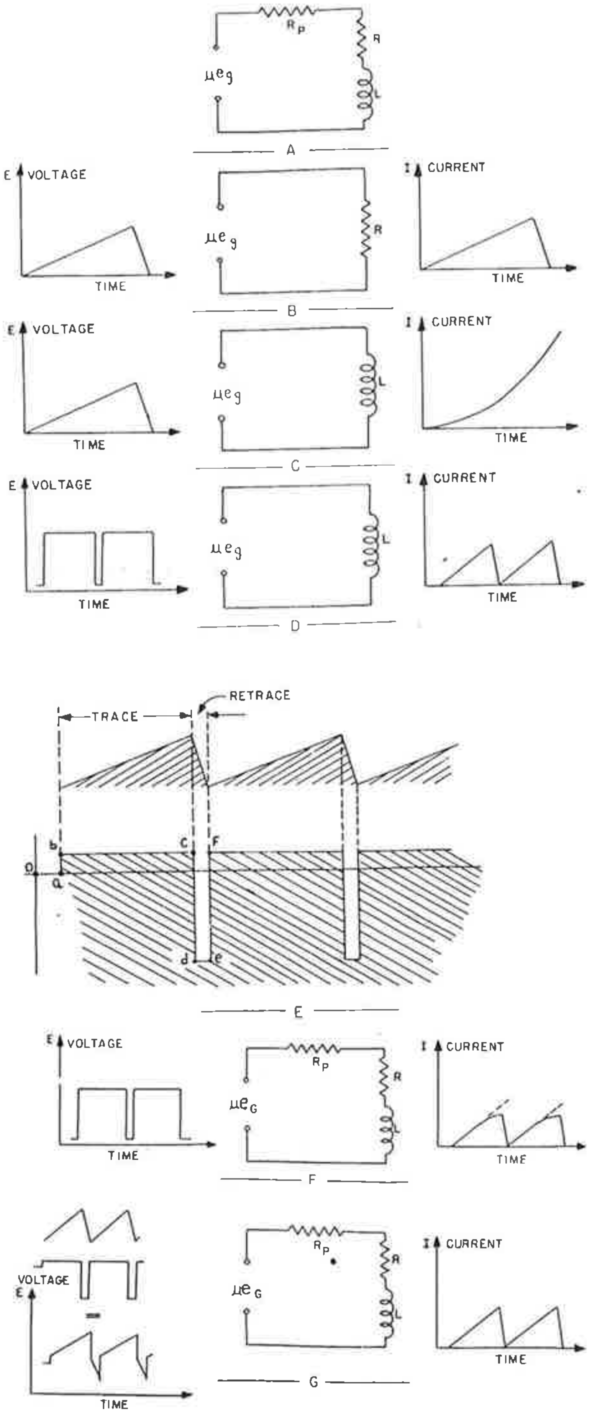


Fig. 9-5. Production of a sawtooth wave current.

The manner in which the resistance of the voltage source and the resistive component of the inductance in the circuit limit the flow of current is readily understood by the application of simple d-c theory. If the circuit were purely resistive, then the required shape of the voltage wave on the grid would be the same (sawtooth) as the desired current wave, and so would be sawtooth, as indicated to the left of B in Fig. 9-5 where the inductance of the circuit is neglected. Since the plate impedance in this case is purely resistive, the plate current wave will have the same waveshape as the corresponding voltage wave applied to the grid, because the plate current (with a resistive load) is at any instant directly proportional to the voltage applied ($I = E/R$) as indicated to the right of B, 9-5.

Now considering the other extreme, if the output circuit were a pure inductance (the plate resistance Rp being neglected in this case) and a sawtooth wave of voltage were applied to the grid of the output tube as in C of Fig. 5, a sawtooth wave of current would not flow through the coils. This is due to the reactance of the coils and the fact that in order to force a current that changes linearly with time through a pure inductance, the voltage across the inductance must rise almost instantaneously to a certain value (depending upon the inductance in the circuit and the rate of current change) and remain at this value during the period that the current is to change at a linear rate. Therefore, since a sawtooth voltage starts at a low value and gradually progresses toward a higher value it will not produce a sawtooth wave of current in a pure inductance. Instead, the waveshape of the voltage must be rectangular rather than sawtooth as indicated by D of Fig. 9-5.

It may not be readily apparent at first that a rectangular voltage wave applied to an inductance will produce a sawtooth wave of current. However, if the basic theory concerning the action of an inductance in a circuit is referred to, it will bring out the fact that whenever a varying or changing current flows through an inductance, a back voltage, the result of the changing flux cutting the turns on the coil, is built up. This bucking voltage, or counter E.M.F. which is built up, is proportional to the rate at which the current is changing in amplitude and the inductance value in the circuit. It is always of such a polarity as to oppose the voltage causing the current change. Since a cycle of sawtooth current has a period in which the current is increasing at a constant rate (trace period) and another period in which the current is decreasing at a constant but much more rapid rate (retrace period) then the voltage across the coils for these two periods will be constant but of a different value for each period. Therefore, since the bucking voltage is constant during each period (trace and retrace) it is only necessary to apply a rectangular voltage wave to the inductance in order to obtain a sawtooth wave of current through the coils. The relationship between the sawtooth current wave and the rectangular voltage wave is shown by E of Fig. 9-5. At the start of the sawtooth current the voltage rises almost instantaneously from a to b and remains at a constant level, b to c, as the current increases at a linear rate to form the trace portion of the current wave. At the completion of the trace portion, the current abruptly changes and decreases from its maximum value to its minimum value to form the retrace portion of the current wave. The voltage across the coil during this period rapidly drops from its level, point c, above the zero axis to point d, which is well below the zero axis and remains at this level, d to e, during the retrace period of the current wave. After retrace is completed the voltage rapidly rises to point f, and remains at this level during the trace portion of the next current wave, and so on. It should be noted that the level of the voltage above the zero axis in the positive direction, a to b, during the trace period, is considerably less than that of the voltage below the zero axis in the negative direction during the retrace period. This is because of the fact that the amplitude of the voltage across the coils is directly proportional to the rate of current change and the inductance value of the coils. Since the current in the coils is changing at a much more rapid rate during the retrace period than during the trace period, the corresponding voltage across the coils during the retrace will be considerably higher as indicated in E of Fig. 9-5 by the high pulse of voltage which occurs during the retrace period.

From the foregoing it is evident that in order to produce a linear sawtooth wave of current through a purely resistive circuit, a sawtooth wave of voltage must be applied. Also, to produce a sawtooth wave of current though a purely inductive circuit a rectangular wave of voltage must be used. In practical circuits, however, both inductance and resistance are present, and neither a sawtooth wave of voltage (except in special cases where the resistance predominates) nor a rectangular wave of voltage by itself will produce a linear sawtooth current. If a rectangular wave of voltage, for instance, is applied across a practical circuit containing resistance and inductance as F of Fig. 9-5, the current will be exponential rather than sawtooth. Therefore, in the actual case where both inductance and resistance are present, it is necessary for the voltage waveform to be a combination of a sawtooth and a rectangular wave in the proper proportions in order to produce a linear sawtooth wave of current.

The arrangement used is shown in G of Fig. 9-5. The input voltage consists of a modified sawtooth waveform, a sawtooth superimposed on a rectangular wave. The rectangular area of the voltage waveform forces a sawtooth current through the inductive part of the circuit while the sawtooth area forces a sawtooth current through the resistive part. If the circuit is predominantly inductive then the major portion of the voltage wave will be rectangular. On the other hand, if the circuit is predominately resistive then the voltage wave will be essentially sawtooth. In fact, when a pentode is used as the vertical sweep output tube, the plate impedance of the tube is so high that the effect of the circuit inductance becomes practically negligible (at 60 cycles) compared to the plate impedance, and the grid voltage is essentially a simple sawtooth.

8. Production of modified sawtooth wave of voltage

The necessary voltage across the deflection coils to produce a linear sawtooth wave of current through them can be obtained in several ways.

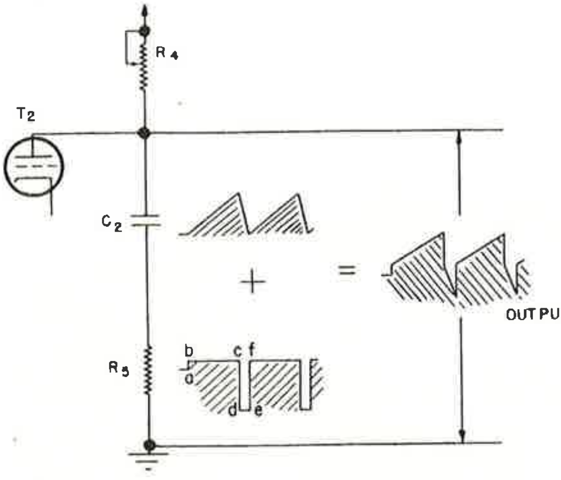


Fig. 9-6. Production of modified sawtooth wave of voltage.

One method that is widely used is to modify the sawtooth output of the sweep generator before applying it to the grid of the sweep output tube. This can be accomplished by placing a resistor in series with the charging capacitor as shown in Fig. 9-6, so that the discharge current of the capacitor, as well as the charging current, flows through it. Instead of the charging capacitor going directly to ground, it returns to ground or B– through this resistor, which is much smaller in value than the series resistor through which the capacitor receives its charge. The voltage developed across the capacitor is sawtooth in nature, while the voltage across the resistor is in the form of a square wave, as indicated in Fig. 9-6. This is due to the fact that during the charging period, when the charge on the capacitor is increasing at a slow but constant rate, the current through the resistor will be small but substantially constant. Since the current through the resistor is constant, the voltage developed across it will be in the form of a square wave, suddenly rising to a value a to b, as determined by the equation V = IR, and remaining there for the period during which the capacitor is gradually being charged. However, when the capacitor is suddenly discharged through the tube there is a sudden rush of current through the resistor in the opposite direction, which causes the voltage across the resistor to go sharply negative, c to d, and remain at this value during the short discharge period. As soon as the discharge period is over and the capacitor starts to charge up again, the voltage across the resistor will suddenly rise from e to f, thus completing the cycle and producing a square wave of voltage across the resistor during the time that the voltage across the capacitor is increasing and decreasing in a sawtooth manner. Therefore, the voltage developed across this series combination of capacitance and resistance will not be purely sawtooth or rectangular but will be the sum of these two voltages and will appear as shown to the right of Fig. 9-6. This is the modified waveform that may be applied to the grid of the sweep output tube in order to produce a sawtooth wave of current through the deflecting coils. When this method is used the sweep amplifier tube is usually operated over the linear portion of its characteristic curve so that the voltage appearing across the deflection coils is an amplified version of the modified voltage in the grid circuit.

Another means of obtaining the correct waveform of voltage across the deflection coils is to apply the sawtooth output of the sweep generator directly to the grid of the sweep amplifier without any modification and bias the tube so that it is operating near cut-off. This causes the sweep output tube to cut-off during the most negative excursions of the sawtooth voltage on its grid and produces the desired modified waveform of voltage in its plate circuit.

9. Transient oscillations and damping circuits

As mentioned previously, the current through the deflection coils changes very rapidly during the retrace period and the voltage across the coils at this time is quite high — much higher than during the trace period when the current through the coils is changing at a more gradual rate. The relationship of the voltage across the coils and the current through the coils was discussed previously, also it was brought out that whenever a varying current flows through an inductance, a counter emf (back voltage), the result of the changing magnetic flux cutting the turns of the coils, is built up. This voltage is proportional to the rate at which the current is changing through the coils and the inductance of the coils. Since the amplitude of this voltage is the product of the rate of current change and the inductance value of the coils, then the voltage corresponding to the retrace period will be considerably greater than that corresponding to the trace period because the current through the coils is changing at a much faster rate during the retrace period.

This high pulse of voltage developed across the coils during the retrace period, when transformed by the output transformer appears as a very high voltage across the sweep output tube as indicated by Fig. 9-7. As will be brought out later, this high pulse of voltage can be utilized to provide high voltage on the second anode of the picture tube. This condition is much more pronounced in the case of the horizontal sweep circuit because of the higher frequency of the horizontal sawtooth waves (15,750 c.p.s.). The current in the horizontal deflection coils changes from maximum to minimum during retrace in approximately 6 microseconds, whereas the current through the vertical deflection coils changes from maximum to minimum during vertical retrace at a much slower rate, requiring approximately 833 microseconds.

Since the sweep output circuit has a certain amount of distributed capacity which acts with the inductance to form a resonant circuit of comparatively high frequency, the sudden shock of this high pulse of voltage developed across the coil inductance during retrace will shock the resonant circuit into oscillation and set up transient oscillations as shown in A of Fig. 9-8. This will affect the sawtooth wave of current as shown in B. The frequency at which these oscillations occur depends upon the natural resonant frequency of the inductance of the output transformer and deflection coils together with the distributed and stray capacity of the circuit. Since these oscillations distort the sawtooth waveform at the beginning of the trace portion of the sweep, they must not be allowed to persist (must be damped out) if proper linearity at the initiation of the sweep is to be had. Proper damping of these oscillations is shown in C, Fig. 9-8, while D shows the effect of too much damping. If the beginning of the trace portion of the wave is not linear as horizontal blanking is removed, the picture will be distorted at the left edge. No damping or insufficient damping shows up as a bright vertical bar on the left edge of the screen.

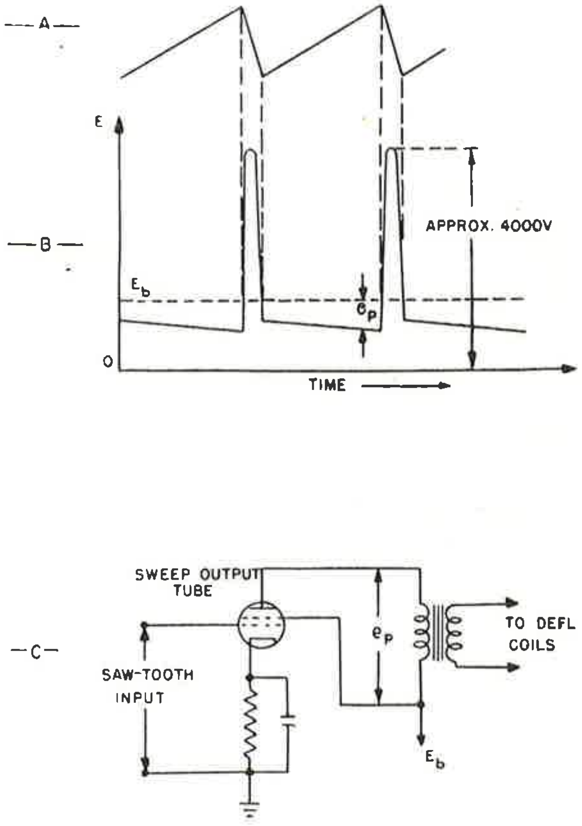


Fig. 9-7. Pulse voltage in sweep output circuit.

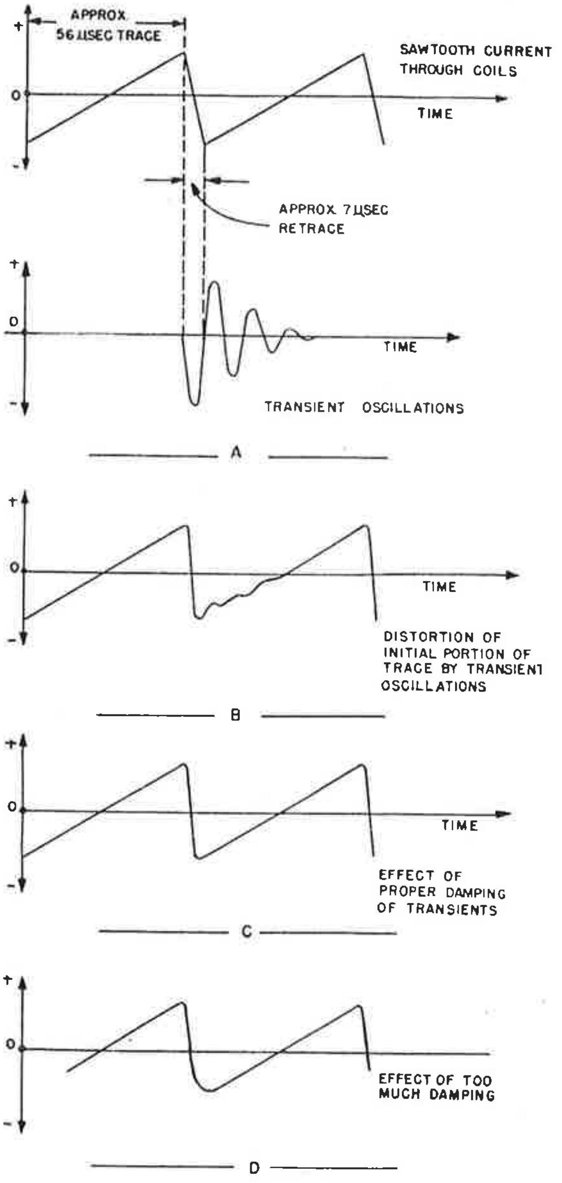


Fig. 9-8. Transient oscillations in sweep circuit.

RC damping circuit

There are several methods of damping these transient oscillations. One of the simplest means of preventing them from continuing is to shunt an RC network across the secondary of the sweep output transformer. This was the method used in the early General Electric model 90 TV receiver and is shown in Fig. 9-9. This shunting network places a load across the inductance and quickly dissipates or damps out the transient oscillations which are set up when the current through the coil suddenly changes during the retrace portion of the sweep, thus preventing these transient oscillations from affecting the linearity of the beginning of the sawtooth of current through the coils. The values of resistance and capacitance are so chosen that this shunting network will load the circuit considerably at the comparatively high frequencies of the transient oscillations and will have no appreciable shunting effect during the trace portion of the sweep. The variable resistor R_2 in Figure 9-9 varies the shunting effect of this network and is used to control the degree of damping.

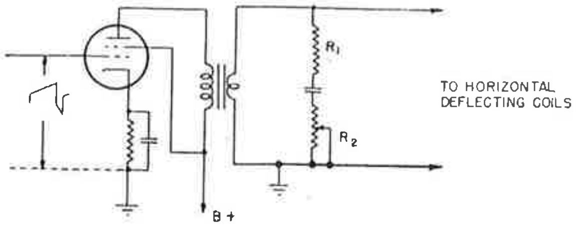


Fig. 9-9. RC damping circuit.

Damping tube circuit

Although the transient oscillations produced during retrace can be satisfactorily damped out by the RC method just described, it is a rather inefficient way of doing it insofar as the horizontal deflection circuits are concerned. Instead of dissipating the energy represented by these transients in a resistance, some of this energy can be reclaimed to increase the efficiency of the deflection system through the proper use of a vacuum tube type of damping circuit.

In addition to damping out the transient oscillation occurring during retrace, the damping tube circuit has several other functions. One of these is to permit the utilization of the magnetic energy stored in the horizontal deflection coils to supply high voltage to the picture tube. The other function is the recovery of some of this magnetic energy to increase the efficiency of the sweep output circuit. By using the stored magnetic energy to provide the above functions, the magnetic energy is rapidly used up and unwanted transients are eliminated.

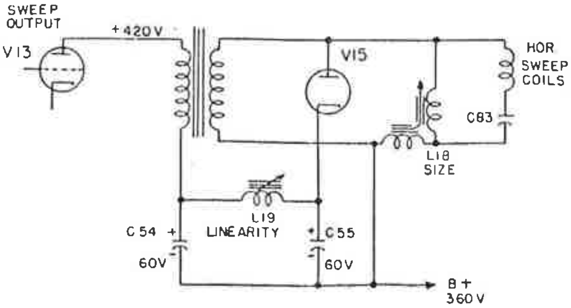


Fig. 9-10. Damping tube circuit.

A typical damping tube circuit is shown in Fig. 9-10 and is the circuit used in a number of General Electric receivers. The action of this circuit is essentially as follows: When the plate current of the sweep output tube V_{13} is suddenly cut off, at the initiation of horizontal retrace, the stored up magnetic field produced by the gradual rise of current through the deflection coils during the trace period begins to collapse. The damping tube V_{15} and sweep output transformer are so connected that as the magnetic field in the deflection coils begin to collapse, the high pulse of voltage developed by this collapsing field is negative on the damping tube plate and the damping tube does not conduct at the instant that the circuit is shocked into oscillation by the collapse of the magnetic field. Since the negative pulse of voltage developed at this time is approximately 1,000 volts, an ordinary small diode cannot be used as the damping tube. It is necessary to use a rectifier type tube having a sufficiently high peak inverse voltage rating. Also a rectifier type tube is required to handle the high peak current when the plate does go positive. The damping tube remains non-conductive for one half cycle of the transient oscillation and does not conduct until the retrace portion of the current through the deflection coils has been completed. This is indicated by Fig. 9-11 which shows the relationship of the current through the deflection coils and the oscillatory voltage on the damping tube plate. It will be noted that the oscillatory voltage on the plate of the damping tube is in the negative direction during the retrace period and does not cross its axis and start in the positive direction until after the current through the coils has reached its maximum negative value as indicated by point A. This first half cycle of free oscillation is necessary in order to permit the proper retrace and also to enable utilization of some of the magnetic energy for the high voltage power supply. (The high voltage supply will be discussed later in this chapter.)

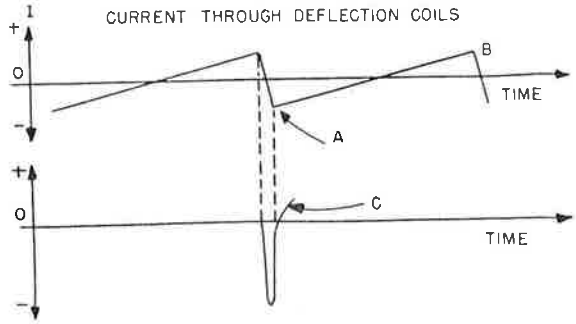


Fig. 9-1 . Transient voltage across deflection coils.

When the current through the deflection coils has reached its maximum negative value, point A, retrace is completed and the current through the coils will reverse its direction and start the trace portion of the sawtooth wave of current, A to B. However, during the retrace period, very little of the stored magnetic energy was dissipated since the damping tube was non-conducting and no load was placed on the oscillatory circuit. Therefore, when the current through the coil reverses itself to start the next trace period, a strong magnetic field still exists in the deflection coil which also reverses itself and causes the oscillatory voltage to go in the positive direction. Now if no damping tube were placed across the deflection coils, the circuit would continue to oscillate at its natural frequency as indicated in Fig. 9-12 until the stored up energy was finally dissipated in the resistance in the circuit. This, of course, is very undesirable since it destroys the linearity of the beginning of the trace as shown by Fig. 9-12.

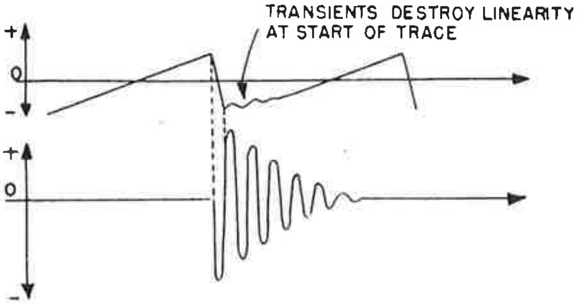


Fig. 9-12. Oscillation in sweep circuit without damping tube.

With the damping tube in the circuit, however, when the oscillatory voltage starts to go positive as at point C of Fig. 9-11, the tube begins to conduct heavily and thus places a load across the deflection coil so that it cannot continue to oscillate. The stored up energy in the magnetic field is dissipated by the load which the damping tube places across the coil at a rate that is suitable for a linear trace.

The sweep output tube is operated so that it cuts off not only during the retrace period but remains cut off during the beginning of the trace portion of the sawtooth wave. It remains cut off for approximately 30% of the initial portion of the trace and during this period the sawtooth current through the deflection coils is due to the stored magnetic energy. This is indicated on the portion of the sawtooth waveform marked A in Fig 9-13.

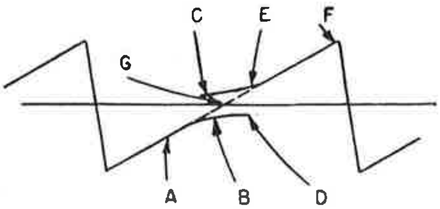


Fig. 9-13. Effect of conduction of damping tube.

As mentioned previously, the stored up energy in the magnetic field is dissipated by the load which the damping tube places across it at a rate that is suitable for a linear trace. As the rate of decay starts to approach a non-linear condition as at point B, Fig. 9-13, the sweep output tube begins to conduct as indicated at point C, and takes over the task of maintaining current through the deflection coil somewhat before the magnetic energy that was stored up in the coil is completely dissipated at point D. The sweep output tube supplies current to the deflection coil of almost constantly increasing amplitude from point E to point F, Fig. 9-13. When point F is reached, the sweep output tube is again cut off, retrace is initiated and the entire cycle repeats itself. The current through the deflection coil due to conduction through the damping tube and that due to the sweep output tube are curved at the cross over point G. However, combined they produced a current through the coil that is linear at this point as indicated by the dashed line of Fig. 9-13.

During the retrace period the damping tube is non-conducting. However, immediately after the retrace period, the diode conducts heavily and the stored up magnetic energy is converted into direct current energy by charging capacitors C_{54} and C_{55}, of Fig. 9-10. The charge built up on these capacitors due to the stored up magnetic energy is on the order of 60 volts and acts as though a battery of 60 volts were connected in series with the regular power supply voltage. The equivalent circuit is illustrated in Fig. 9-14, which shows the charge on the capacitors due to the kickback voltage supplied by the deflection coil in relationship to the regular B+ voltage. It will be noted that the charge on the capacitor is series aiding with the regular B+ supply and raises the effective plate voltage on the 6BG6G sweep output tube by approximately 60 volts. This permits operation of the sweep output tube at approximately 420 volts although the regular B+ supply is only 360 volts, thus increasing the efficiency of the system by reclaiming some of the energy of the magnetic field that would otherwise have been lost and feeding it back into the regular B+ supply for the sweep output tube. The plate current of the sweep output tube does not flow through the damping tube as might at first be supposed after C_{54} and C_{55} become charged (this occurs almost immediately after the receiver is first turned on) but is supplied by the charge placed on C_{54} and C_{55} discharging in series with the regular B+ supply. (Fig. 9-10.)

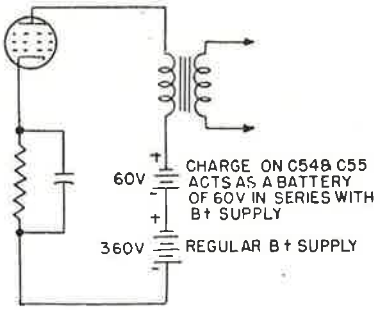


Fig. 9-14. Equivalent voltage distribution in sweep output circuit.

The voltage across capacitor C_{54} and C_{55} due to the coil kickback voltage is pulsating in nature and a low pass filter network consisting of C_{54}, L_{19} and C_{55}, Fig. 9-10, is used to partially smooth out these pulsations. However, there is still some ripple voltage remaining in the output of this filter and by shifting the phase of this ripple with respect to the plate current taken by the sweep output tube it is possible to correct for any slight non-linearity of the sweep. This is accomplished by making the inductive branch L_{19}, of the low pass filter variable as indicated in Fig. 9-10.

The horizontal size is varied by means of a variable inductance, L_{18}, Fig. 9-10, part of which is in series with the horizontal deflection coils and the other part shunted across the deflection coils. An iron core that is common to both sections of the coil is used. When the core is in the section shunted across the coils the picture width will be at its maximum since under this condition the portion of the size control shunted across the coils has its maximum inductance (providing the least shunting effect) while the portion of the size control in series with the coils will have minimum inductance (providing the least impedance in series with the deflection coil current). When the iron core is in the section connected in series with the deflection coil the picture width will be at its minimum since then the size control has the greatest shunting effect (minimum inductance of portion shunting the coils) on the coils and offers the maximum impedance (maximum inductance of series section) in series with the deflection coil. Any variation can of course be obtained by different positions of the iron core. This type of control provides a uniform impedance to the output transformer over a wide range of adjustment. Ordinarily, the size control would be associated with the sweep generator, varying the amplitude of its output which in turn varies the amount of beam deflection. However, when use is made of the inductive kick of voltage developed during the horizontal retrace period for the high voltage supply, it is necessary to keep the amplitude of the signal on the grid of the horizontal sweep amplifier constant, thus necessitating the placement of the horizontal size control in the output of the sweep amplifier.

10. Kick or flyback type of high voltage supply

As mentioned earlier, in addition to utilizing some of the stored magnetic energy to increase the efficiency of the horizontal sweep output stage, some of this energy is also used to develop the necessary high voltage for the second anode of the picture tube.

During the retrace period when the stored magnetic field in the coil begins to collapse, a pulse of voltage of approximately 1000 volts is developed across the deflection coil. This pulse of voltage is negative on the damping tube plate but through transformer action appears as a pulse of much greater amplitude across the primary with the plate side of the primary positive. This inductive kick of voltage appearing across the sweep output primary is on the order of 4000 volts and is further increased by means of an additional winding connected in series with the regular primary winding as indicated in Fig. 9-15. This additional winding, through autotransformer action, provides slightly more than 2:1 step up in voltage and a pulse of approximately 9500 volts appears at the plate of the half wave high voltage rectifier tube V_{14} which is a type 8016 tube, now known as the 1B3-GT.

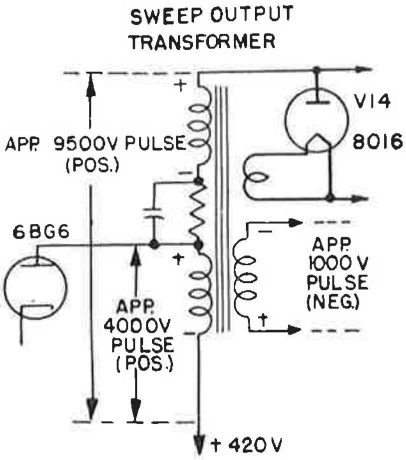


Fig. 9-15. Flyback type of high voltage supply.

The voltage and current relationship is shown in Fig. 9-16, where A represents the sawtooth wave of current and B represents the voltage across the T_{17} primary during the trace and retrace portions of the sawtooth wave. It will be noted that during the trace period, the voltage across the T_{17} primary remains essentially constant at a value somewhat lower than the B+ supply and has a high positive peak of approximately 4000 during the retrace period.

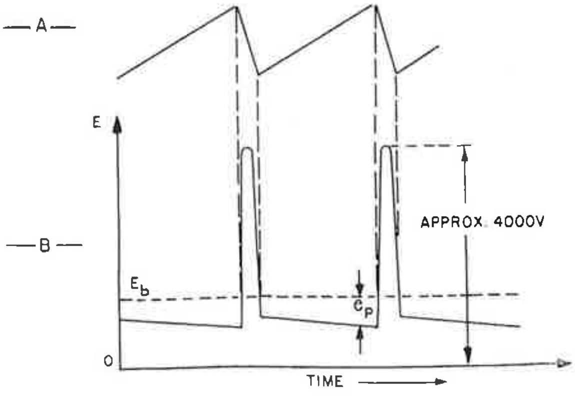


Fig. 9-16. Voltage and current waves in sweep output circuit.

This pulse of voltage is stepped up as mentioned previously and is then applied to the half-wave high voltage rectifier, the rectified output of which is filtered by means of an R-C filter consisting of C_{53} and R_{63} (Fig. 9-20), before being applied to the high voltage anode of the picture tube. Due to the comparatively high frequency of the pulses (15750 cps) very little filtering is required and a 500 mmf capacitor is more than adequate for the purpose. Also, since the filter capacitor is so small, it cannot store a dangerous charge and makes the high voltage supply relatively safe. When the output current from the high voltage rectifier exceeds approximately 200 microamps, the voltage drops very rapidly to a low value due to the poor regulation of the circuit, thus contributing to the safety of the high voltage supply. However, the regulation is more than adequate to supply the needs of the picture tube.

A novel feature of this high voltage supply is the fact that the filament voltage for the 1B3-GT tube is derived from the sweep output transformer by means of a single turn loop around the core of the sweep transformer T_{17}. This eliminates the need for a conventional 60 cycle filament transformer which would have to be insulated for at least 15 kv.

The 470K resistor R_{62} (Fig. 9-20), is placed in series with the two primary windings to prevent excessive current from the B+ supply from flowing through the transformer in case of an accidental short on the high voltage section of the primary winding. C_{92} bypasses the high frequency components of the pulse around R_{62}.

11. Typical electromagnetic deflection circuit. Pre-war vertical and horizontal circuits

The vertical and horizontal sweep generators, along with the associated circuits for magnetic deflection in the G.E. Model 90 television receiver which is typical of pre-war design are shown in Fig. 9-17. The deflecting coils are shown placed around the neck of the cathode ray picture tube, L_1 and L_2 being the vertical set of coils, and L_3 and L_4 being the horizontal set of coils. The output of the 6L6 horizontal sweep amplifier is connected to the horizontal deflecting coils by means of the horizontal output transformer T_2.

The horizontal sweep generator is of the multivibrator type. The modified sawtooth voltage appearing across C_5 and R_{14} is coupled to the grid of the 6L6 horizontal sweep amplifier through C_6. The free-running speed of the horizontal oscillator is controlled by R_8. Negative going synchronizing pulses are coupled to the left-hand section of the multivibrator by means of the capacitor C_c. The amplitude of the horizontal sweep is controlled by the potentiometer R_7, which determines the amount of charge accumulated on C_5 during the trace portion of the cycle. Horizontal linearity is controlled by potentiometer R_6 which varies the bias on the sweep amplifier, changing its characteristics so as to provide a linear sawtooth wave of current through the coils.

Damping in the horizontal sweep output is accomplished by the resistance capacity network of R_1, R_2, C_1, and R_3 which is shunted across the horizontal deflecting coils and is exactly the same circuit of this type that was discussed previously

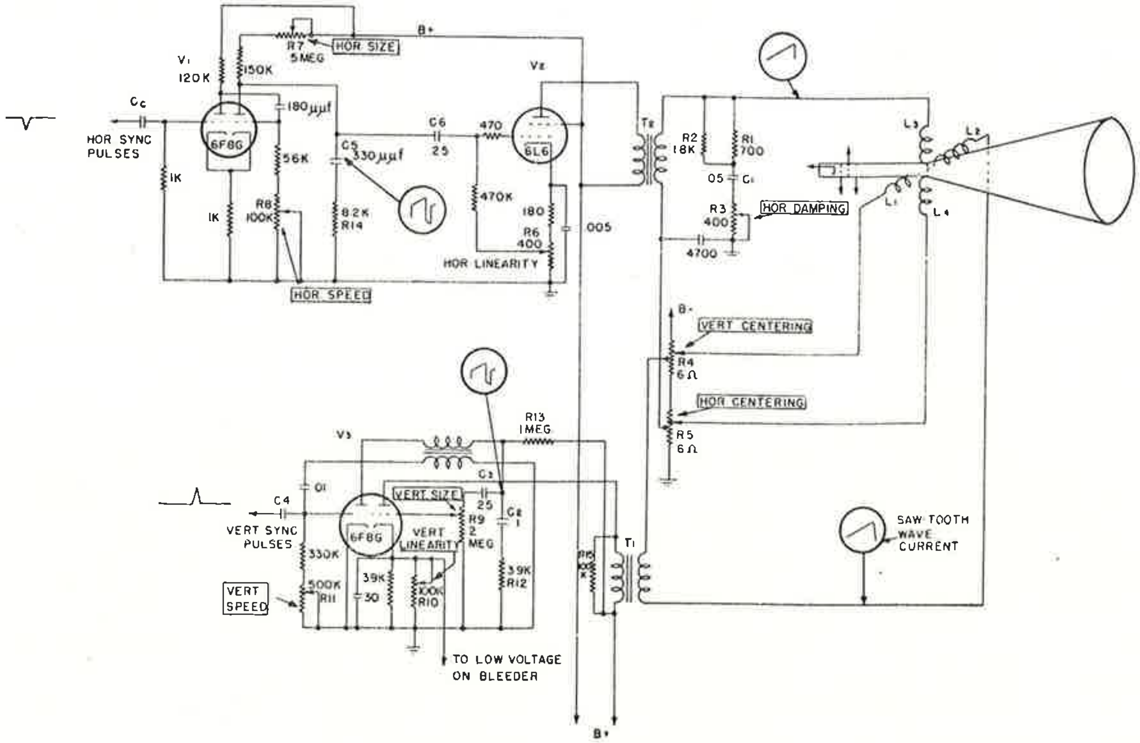


Fig. 9-17. Vertical and horizontal sweep generators.

in connection with the damping of transient oscillations. Since this type of damping circuit does not utilize any of the stored up magnetic energy for other purposes, as in the case of the vacuum tube type of damping circuit, the high voltage for this receiver is obtained from the regular 60 cycle power supply with its obvious disadvantages. Since very little damping is required in the vertical deflection circuit, due to the low frequency employed, it is only necessary to shunt the primary of the vertical sweep output transformer with R_{15} to provide sufficient damping of the circuit.

Centring of the electron beam is accomplished by potentiometers R_4 and R_5, which regulate the amount of direct current flowing through the deflecting coils. The potentiometer R_4 centres the beam vertically, while R_5 centres it horizontally. The controls are so connected that when the arm of the control is at its midpoint no d-c current flows through the coil. Moving the arm of the control on either side of its midpoint causes current to flow through the coil, the direction of current flow depending upon which side of the midpoint that the arm happens to be. This d-c current acts as an axis about which the a-c sawtooth wave of current varies, thus providing a means of moving the entire raster vertically or horizontally.

The right-hand section of V_3 is used as the vertical sweep amplifier and connects to the vertical deflecting coils through the vertical output transformer T_1. The linearity of the vertical sweep is controlled by R_{10}, which varies the bias on the vertical sweep amplifier as in the case of the horizontal sweep amp. The amplitude of the vertical sweep is controlled by R_9, the setting of which determines the amount of the modified sawtooth voltage that is applied to the sweep amplifier. The vertical sweep generator is a blocking oscillator of a type previously discussed and utilizes the left-hand section of V_3. The modified sawtooth wave of voltage is produced across C_2 and R_{12} when C_2 gradually charges up through R_{13} and then rapidly discharges in series with R_{12} and the tube. The voltage is coupled to the grid of the sweep amplifier through C_3, which connects to the high side of the vertical size control. The free-running speed of the blocking oscillator is controlled by the variable resistor R_{11}. Positive going synchronizing pulses are applied to the grid of the blocking oscillator through C_4.

Post-war vertical sweep circuits

A vertical sweep generator and output circuit that is used in a number of post-war models is that illustrated in Fig. 9-18.

As indicated, the vertical deflection coils are coupled to the 6V6 vertical sweep output tube, V_{10}, by means of the vertical sweep output transformer T_{15}. Since the amplitude of the transient oscillations set up during vertical retrace are quite small they are easily damped out by shunting the primary and secondary of the sweep output transformer, with R_{35} and R_{114} and R_{115} respectively.

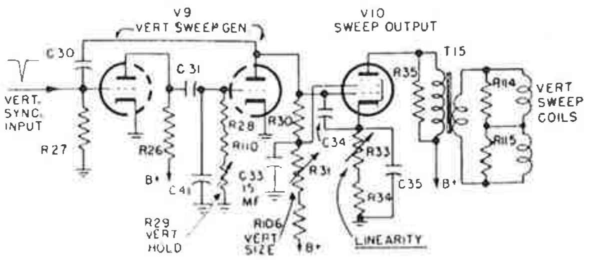


Fig. 9-18. Vertical sweep output circuit.

The sawtooth voltage is generated by a type 6SN7-GT tube, V_9, which is a dual triode connected in a plate coupled multivibrator circuit. The sawtooth voltage developed across the charging capacitor C_{34} is directly coupled to the grid of the vertical sweep output tube V_{10}. Vertical speed is controlled by changing the time constant in the multivibrator grid circuit (as discussed in detail in chapter 8) by a potentiometer, R_{29}. Synchronization is maintained by the injection of negative going sync pulses on the grid of one section of the multivibrator as indicated in Fig. 9-18. The amplitude of the sawtooth voltage developed across C_{34} which determines the vertical size or height of the picture is changed by the potentiometer R_{31} which varies the B+ voltage applied to the charging circuit. The size control, R_{31}, also controls the vertical size or height by simultaneously varying the screen grid voltage on the sweep output tube V_{10}. Thus the size control varies the amplitude of the sawtooth voltage on the grid of V_{10} at the same time that it varies the screen grid voltage of V_{10}. As the amplitude of the sawtooth wave is increased, the screen voltage of V_{10} is also increased and vice versa. The screen of V_{10} is heavily by-passed by C_{33} to prevent it from fluctuating at the sawtooth voltage rate.

It is not necessary to modify the sawtooth output of the sweep generator in the manner discussed earlier, in order to produce a sawtooth wave of current through the coils, since the output circuit is predominately resistive due to the high plate resistance (R_p) of the 6V6 pentode and the low reactance of the vertical deflection coils. However, a linearity control circuit is used to insure that the sawtooth current through the coils is linear.

The linearity is controlled by feeding back a correcting voltage developed in the cathode circuit of the sweep output tube, V_{10}, through the charging capacitor, C_{34}, into the grid circuit of V_{10}. The cathode voltage of V_{10} which is fed back through C_{34} has an opposite curvature corresponding to the non-linear portion of the generated sawtooth output of V_9 so that by combining these voltages in the grid of V_{10} correction for a slight amount of non-linearity may be effected. This is indicated by Fig. 9-19. The amount of this correction voltage is controlled by the vertical linearity potentiometer, R_{33}, in the cathode of V_{10}. It may not at first be apparent that an a-c component of voltage can be developed across the cathode resistor of V_{10} since it is by-passed by a rather large capacitor, C_{35}, but since the vertical sweep frequency is only 60 cycles the reactance of the capacitor is not low enough to by-pass all the a-c component. In fact, the cathode capacitor would have to be many times larger than that shown in order to maintain an absolutely steady voltage across the cathode resistor. The amount of correction voltage fed back to the grid of V_{10} through C_{34} is determined by the variable cathode resistor R_{33}. In addition to the correction voltage fed back, the linearity is also controlled to a certain extent by the change in characteristics of the sweep output tube as its bias is varied by means of the linearity control.

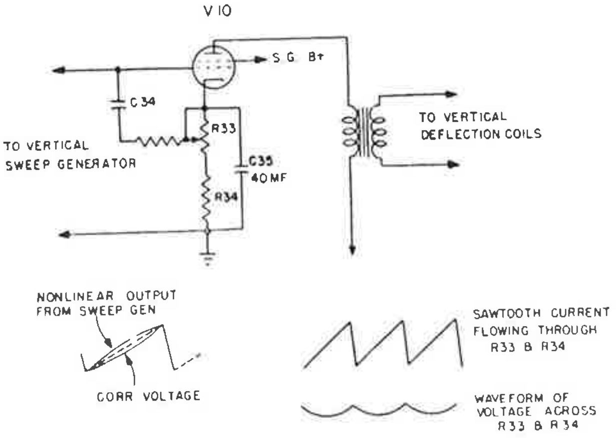


Fig. 9-19. Vertical sweep linearity circuit.

Post-war horizontal sweep circuits

The horizontal sweep output circuits used in current model receivers are considerably more complex than those used for the vertical sweep output, since in addition to supplying sufficient current of the proper waveform to the deflection coils, these circuits also perform the functions of supplying high voltage to the picture tube, the damping of transients which occur during retrace and the recovery of some of the kick-back energy to help increase sweep output voltage, as discussed earlier.

Figure 9-20 illustrates the sweep generator and output circuits typical of those used in many of our post-war models. For simplicity, certain omissions have been made in the horizontal sweep generator circuit since it is controlled by an automatic frequency control circuit which will be discussed in detail in a later chapter. This circuit is practically the same as that discussed earlier in connection with high voltage and damping tube circuits; however, some points may bear repetition. Starting at the horizontal sweep generator, which is a blocking oscillator, the sawtooth voltage developed across the charging capacitor C_{50} is coupled to the grid of the sweep output tube. The output of this tube is coupled to the horizontal deflection coils by means of the impedance matching transformer T_{17}. The capacitor C_{83} allows the a-c sawtooth current to

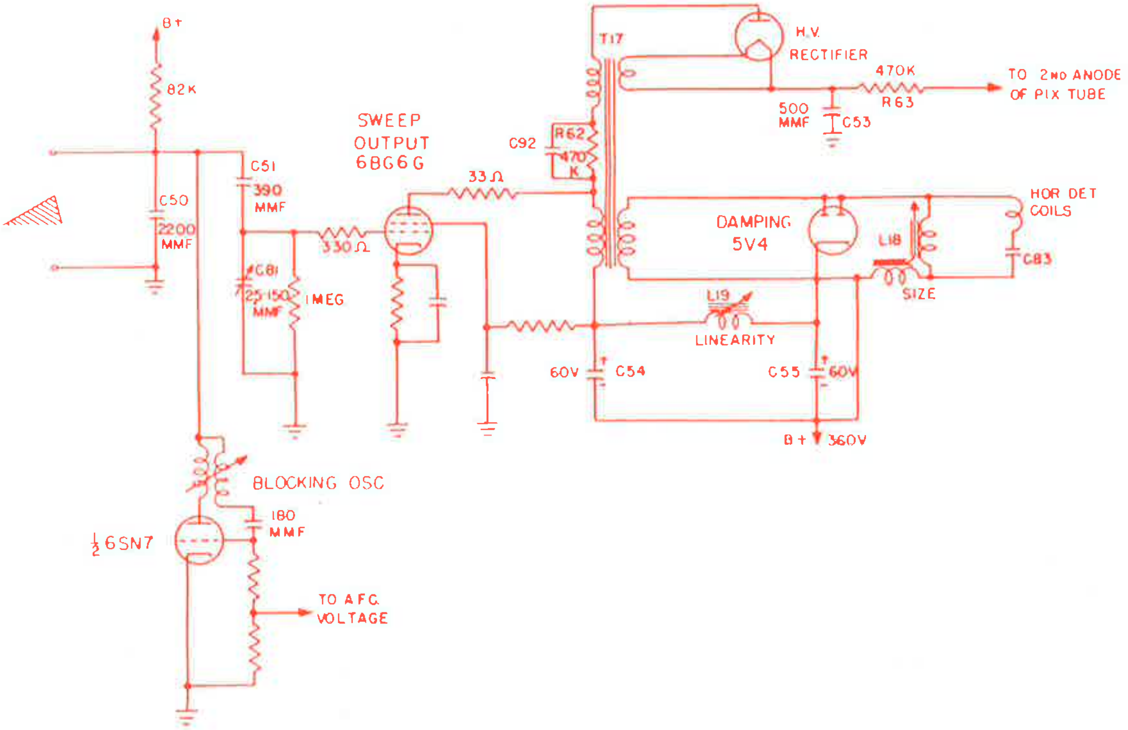


Fig. 9-20. Sweep generator and output circuit.

flow through the deflection coils but prevents the d-c voltage present in the damping tube circuit from appearing across the coils which would affect proper centring of the picture.

The damping tube diode which is a type 5V4-G rectifier tube is used primarily to remove the transient oscillation created by the rapid change of current through the coils during retrace and to retain the positive pulse of voltage in the primary winding for use in the high voltage supply. It is also used to provide a linear trace and to recover some of the energy from the inductive kick-back and use it to help supply the B+ requirements of the output tube. During conduction of the damping tube, capacitors C_{54} and C_{55} are charged up and since this charge is series aiding with the regular B+ supply voltage, it contributes approximately 60 volts to the total voltage on the plate of the 6BG6-G.

The variable inductance, L_{19}, and capacitors C_{54} and C_{55} constitute a phase shift network which changes the phase of the ripple voltage developed across C_{54} and C_{55}. This means of varying the ripple voltage which supplies part of the B+ to the output tube provides a method of controlling linearity. Since the sweep output tube is operated near cut off it is not necessary to modify the sawtooth voltage before applying it to the sweep output tube in order to produce a sawtooth of current through the deflection coils.

A horizontal drive control, C_{81}, in the output of the sweep generator, forms a capacity voltage divider in conjunction with C_{51} so as to control the amount of sawtooth voltage applied to the grid of the sweep output tube. This permits adjustment of the sawtooth driving voltage on the grid to compensate for variations in output tubes. Minimum capacity setting of C_{81} will provide the greatest amount of drive since it will have the least shunting effect on the grid.

The horizontal width control, L_{18}, forms a series-parallel circuit with respect to the output to the yoke. The inductance is varied simultaneously in both coils of this control, the inductance of the series choke is maximum when the parallel choke is minimum and vice-versa. The parallel circuit shunts the current around the deflection coils, depending upon its inductance while the series coil attenuates the current by changing the impedance of the series circuit. This type of control provides a uniform impedance to the output transformer over a wide range of adjustment.

Although there are numerous variations of the deflection circuits discussed in this chapter, the same basic principles are used. The important differences in these circuits between one model and another are covered in the service notes for the particular models.