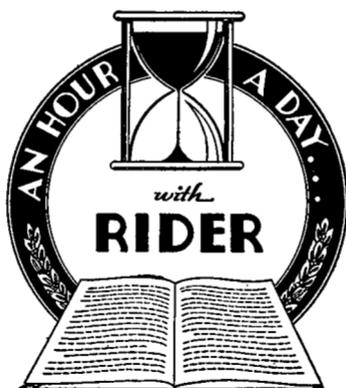


on

**AUTOMATIC
VOLUME CONTROL**



ON

Automatic Volume Control
in Radio Receivers

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Chapter I

GENERAL REVIEW

AUTOMATIC volume control, normally identified as "a.v.c.," has become an integral part of practically all commercial radio receivers. It is true that a few t.r.f. receivers, employing possibly three or four tubes in all, do not incorporate such control systems, but on the whole it is safe to say that every commercial super-heterodyne is equipped with automatic volume control.

When we stop to consider the conditions of signal input which are encountered in practice, and the consequent effects—it is not difficult to see why automatic volume control is essential. There are a number of factors which contribute to the presence of an extremely wide range of signal intensities at the antenna system of any one radio receiving installation; this range may be as great as a million to one. As to the reasons for this wide range—we find first the fact that the power rating of different transmitting stations varies widely. Some stations may employ a power output as low as 100 watts, whereas others may be 5000 watts, 50 kilowatts and even 500 kilowatts. Then again the variation in the distance between any one receiver and the various transmitting stations which are within its range, cannot help but result in reception of signals which may be as weak as 2 or 3 microvolts or as strong as a volt—such as exists across an antenna system located in close proximity to a very powerful broadcast station. The phenomenon of fading due to a change in the transmitting medium located between the transmitter and the receiver, contributes a received signal of fluctuating strength. All in all, these various influences are very undesirable and up to the time when automatic control systems were introduced, represented some of the objectionable characteristics of everyday radio reception.

A.V.C. as Automatic Control of Sensitivity

The desirability of some automatic control system which would eliminate or minimize these difficulties and which would keep the output of the receiver constant in spite of this tremendous variation of signal strength was extremely obvious. The result was the development of automatic volume control.

However strange as it may seem, what is identified as being automatic volume control is not really the control of volume. Instead it is the control of receiver sensitivity. Just why such control of sensitivity is identified as control of volume is hard to say, but we venture the statement that the reason for the use of the word "volume" rather than the word "sensitivity" is the fact that it is more easily comprehended by the lay public, and the word "volume" is more truly representative of the final effect as noted by the person listening to the receiver. . . . *From the technical angle, however, we repeat that a.v.c. is a control of sensitivity rather than of volume.*

When automatic volume control was first introduced, there were many who believed that automatic volume control eliminated fading. Such is not the case. . . . What really takes place is that the sensitivity of the receiver is caused to vary in an inverse manner with the intensity of the received signal. As the received *signal intensity decreases* as the consequence of fading, the *sensitivity of the receiver automatically increases*. In turn, as the *received signal intensity increases*, the *receiver sensitivity automatically decreases*. In this way a state of balance between received signal strength and receiver sensitivity is maintained and the final result is a fairly uniform output from the receiver, despite the fact that the input to the receiver varies very widely. . . . The action of the automatic volume control does not influence the received signal, but it does influence the intensity of the *signal passing through the receiver*.

As to sensitivity, each and every receiver is very definitely limited, which means that while automatic volume control may be a part of the receiver system, it does not increase the sensitivity of the receiver over and above that which would exist if the receiver were not equipped with automatic volume control. It is a well-known fact that a certain minimum, prescribed input signal is required in order that a certain output signal be avail-

able from the receiver. This condition holds true with or without automatic volume control. If, during a fade, the received signal falls below the required minimum, no output signal will be heard. This is quite natural, because the maximum sensitivity which can be built up in a receiver is definitely limited and if the signal input falls below the required minimum, as established by the maximum sensitivity of the receiver, then there is not sufficient signal strength to actuate the various tubes.

The action of automatic volume control eliminates what has been often identified as *blasting when tuning*, which means that it is possible to tune a receiver equipped with automatic volume control over a prescribed tuning band and to shift from a weak to a strong station without being annoyed with a sudden blast of sound when passing over the strong stations. While it is true that the manual audio volume control can be used to minimize such blasting in a radio receiver, it is a customary thing to maintain this control at a reasonably high level setting in order to be able to tune in a weak station properly, or at least to recognize the presence of a weak station. If the manual audio volume control is maintained at a low level setting in order to prevent the excessively loud bursts of sound when passing over strong stations, then it is possible to pass right over or miss the desired weak station.

Another excellent and beneficial effect of automatic volume control is the *reduction of distortion*. In days gone by some receivers not equipped with automatic volume control and which employed a sensitivity control located in the r-f. portion of the receiver, distorted signals badly as the result of overloading and as the consequence of the effect produced when the sensitivity control was so adjusted to reduce a strong input signal to a suitable level as it passed through the receiver. While it is true that this was not really the fault of the sensitivity control, but rather a limitation imposed by the design of the tubes then in use, the disadvantage of a variable control which required continual manipulation when tuning, still existed.

In order to comprehend the function of automatic volume control properly it is necessary to divorce the a.v.c. system from the manual audio volume control located in the audio system. *In other words, it is imperative to understand that in all circuits designated as automatic volume control circuits or as a.v.c. cir-*

cuts, it is the sensitivity or gain of the r-f. and i-f. amplifiers which is controlled and not the audio system. Of course, the volume level of the receiver output is indirectly controlled, but this is not the essential point. The important thing to recognize is that the sensitivity of the receiver up to the second detector in a superheterodyne receiver, is automatically varied so as to insure constant output from the second detector. Expressed in another manner, we can say that the function of automatic volume control is to insure constant input to the audio-frequency amplifier, irrespective of the variation in intensity of the received signal across the antenna system of the receiver. The last named condition should be understood as to be within reasonable limits, as previously stated in connection with fading.

The action of the a.v.c. mechanism in providing constant input to the audio-frequency amplifier implies, as we have previously stated, that the overall output of the receiver will remain constant regardless of the strength of the received carrier signal input. In this sense the designation "automatic volume control" is appropriate, although we do know that absolutely perfect control is not an actuality. In truth, the variation of receiver sensitivity, as the result of the operation of the a.v.c. mechanism, is not always sufficient to produce absolutely uniform receiver output, irrespective of the low level of the signal input. A very weak input signal will not develop as strong an output as a strong signal,—but sufficient uniformity of output is available to justify the statement that as a result of the operation of the a.v.c. system, the output is maintained uniform over a very great range of input signal intensities.

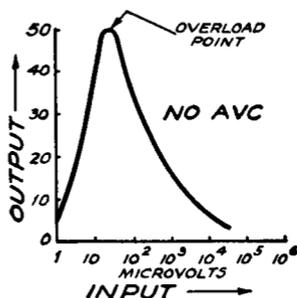
The development of automatic volume control systems has progressed over a period of time and, as a result, a number of different types of systems are in use. It is true that all of these systems are basically alike—but from the practical angle, some systems are simple,—some more complex, and still others very elaborately interlocked with the different parts of a radio receiving system. In this general review we are going to refer briefly to the various general types of a.v.c. circuit arrangements and show how they influence the variation of the second detector tube output with respect to the intensity of the received signal. . . . A discussion of the actual circuit arrangements will follow

later on in this text—after you have absorbed some of the preliminary material.

Various Types of A.V.C. Systems

To what extent do the various types of a.v.c. systems now in use provide a constant output signal from the second detector tube—an output signal which is independent of the strength, intensity or level of the received signal? . . . In order that we have a basis of comparison, it might be well to show the relation between the input signal level and the output of the second detector tube in a superheterodyne receiver not equipped with any form of automatic volume control. Such a relation is illustrated in Fig. 1. If you examine this curve closely, you will note

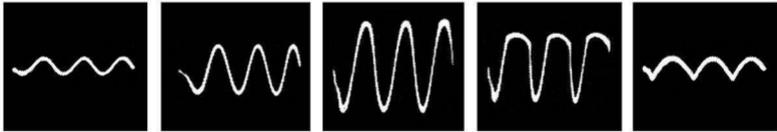
Fig. 1. This curve shows the variation in the output of a receiver, having no a.v.c., with different values of input signal. The point to note is that overloading takes place at a comparatively low value of input signal.



certain very significant details. First is the fact that a continual increase in input does not necessarily result in a continual increase in output. This is indicated by the fact that the curve representing output does not continue rising. Instead it reaches a certain maximum and then starts to decrease. This means that every receiver not equipped with automatic volume control, is very definitely limited in the output which it can supply (for a given setting of the manual gain control). Input signals greater than that required to produce this maximum do not result in greater output. . . . As a matter of fact, as is evident in Fig. 1, they result in weaker output and, in addition, produce distortion. . . . This is the second important detail. The reason why such receivers cannot be operated with input signals greater than a certain level is that if the input signal is greater than the value permitted by design—the tubes in the r-f. and i-f. amplifiers

begin to draw grid current and load or damp the tuned circuits. This has the twofold effect of reducing the amplification and introducing distortion.

A pictorial representation of what is shown in Fig. 1 is given in Figs. 2, 3, 4, 5, and 6. These oscillograms indicate the audio output from the second detector for various values of input signal into the receiver. The input to the receiver is in the form of a modulated carrier which is demodulated in the second detector



Figs. 2, 3, 4, 5, and 6, left to right. These oscillograms show how the character of the output of a set without a.v.c., varies with input signal. See accompanying text for a complete explanation of each oscillogram.

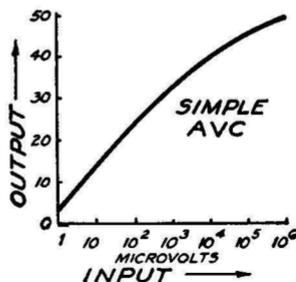
tube. Fig. 2 indicates the condition which is equivalent to an input signal of 3 microvolts. Fig. 3 is the equivalent of an input signal of 6 microvolts, and Fig. 4 is the equivalent of an input signal of about 25 microvolts, which represents the peak output. Fig. 5 is the equivalent of an input signal of 200 microvolts and, as is evident, the output is already distorted, because this much input signal overloads the system. It is also evident that the output from the second detector has fallen off below that of the peak value shown in Fig. 4. Fig. 6 indicates the output when the input signal is 20 millivolts or 20,000 microvolts. These figures do not illustrate the performance of any one specific commercial receiver, but rather are given as simple illustrations of the action of a receiver without a.v.c.

Simple A.V.C.

How is this output-input characteristic modified in the case of a receiver which incorporates a simple a.v.c. system? At the present time it is not necessary to describe this system. Let it suffice if we say that the simplest possible a.v.c. system is employed. The output signal for various values of input for such a receiver is illustrated in Fig. 7. Certain significant details are evident in this illustration, which you should compare with Fig.

1. Note that in Fig. 7 the output for small values of input signal is substantially less than in the case of the receiver without any a.v.c. As the input signal is increased, there is a further marked difference in the output characteristic. Instead

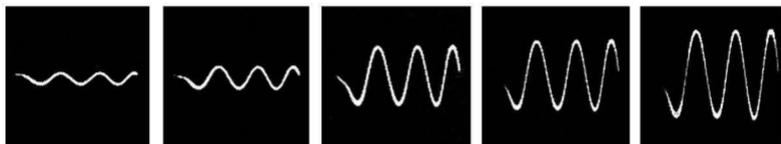
Fig. 7. When the input signal to a receiver equipped with a simple type of a.v.c. is varied, the output varies as is indicated by the curve. If you will compare this curve with that of Fig. 1, you will find that in Fig. 7, there is no sign of overloading.



of increasing at a uniform rate until the overload point is reached, the output climbs slowly and then gradually tapers off.

Figs. 1 and 7 should not be construed as definitely signifying that all receivers which are equipped with a.v.c. possess less sensitivity than receivers which do not employ a.v.c. This is a matter of design. As a matter of fact, the modern receivers equipped with a.v.c. are more sensitive than the older receivers which were not so equipped.

Referring again to Figs. 1 and 7, it is significant to note that in Fig. 7 there is an absence of an overload point. Whereas the receiver without a.v.c., shown in Fig. 1, overloads considerably



Figs. 8, 9, 10, 11, and 12, left to right. The accompanying text will explain these oscillograms that show the waveforms of the output for a receiver equipped with simple a.v.c.

with an input signal of 100 microvolts, the receiver equipped with simple a.v.c. does not overload when the input signal is as much as 1 volt. An idea of the uniformity of output, which can be obtained with a simple type of a.v.c., can be seen from the fact that a change in input signal from 10 microvolts to 1 volt

changes the output of a receiver from 10 units to 50 units. In other words, a change of 100,000 to 1 in the input signal voltage is effective in changing the output of the receiver in the ratio of only 5 to 1. Freedom from distortion over this wide range of signals is shown in Figs. 8-12 inclusive.

Delayed A.V.C.

A close examination of Figs. 1 and 7 shows that a receiver which is equipped with simple a.v.c., has a lower sensitivity for very small input signals than one which does not have a.v.c. The reason for this condition is that the a.v.c. acts to cut down the sensitivity of the receiver as soon as a signal is received, and this happens no matter how weak the incoming signal may be. This is a great disadvantage, because it is with weak signals that the maximum sensitivity of the set is desired. From a practical viewpoint, this would mean that weak signals would be difficult to receive or, at least, hear, because during the time when maximum sensitivity is needed, the presence of the a.v.c. lowers the sensitivity.

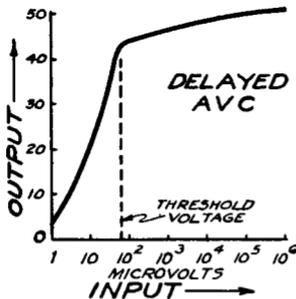


Fig. 13. This curve shows the performance of a receiver that is equipped with "delayed a.v.c." Note the threshold voltage and how the a.v.c. action is delayed until this point of the curve is reached. Beyond this threshold voltage, the output of the set stays practically constant.

To overcome this sacrifice of maximum sensitivity and to enable reception of weak signals—the type of circuit known as *delayed a.v.c.* was introduced. The improved performance of this circuit depends upon the fact that the application of the automatic control voltage, which cuts down the sensitivity of the receiver in the simple type of a.v.c.—is delayed until the signal strength reaches a certain predetermined value. This is the equivalent of saying that for very small values of signal

strength, or for very weak signals, there is no a.v.c. action. Expressed in another manner, this means that the maximum sensitivity of the receiver is made available when tuning to weak signals or when the input signal is very low. The curve shown in Fig. 13 indicates the performance of a typical delayed a.v.c. system. You will note that for small values of input signal, which we arbitrarily set as being up to 60 microvolts, the operation of the receiver is the same as if there were no a.v.c. as, for example, in Fig. 1, wherein the output is proportional to the input. However, for larger values of signal strength, the control voltage begins to function and the resultant action is comparable to that which is obtained with the simple a.v.c. system, as shown in Fig. 7.

Quiet A.V.C.

Noise in a radio receiver always is a problem and a major item is noise which is picked up as a signal or in conjunction with the signal. If the ratio between the noise and the signal is too great, then it is just as well if the signal is not heard at all. . . .

In accordance with what has been said about weak input signals to receivers equipped with a.v.c., the receiver is in its most sensitive state when no signal is being received, because during this time the a.v.c. circuit is not functioning. . . . As such, it is apt to be most responsive to noise and such actually is the case with simple as well as delayed a.v.c. systems. . . . Such noise is usually encountered during the time when tuning from station to station—which means that operation between stations is noisy and very annoying. . . . Often, receivers equipped with delayed a.v.c. of the simple variety are productive of similar conditions, because the high sensitivity is maintained for low input signals, and during this time the ratio between noise and signal may be high and the receiver classified as being noisy.

To overcome this objectionable characteristic of receivers equipped with simple a.v.c. systems, a third type of control circuit was developed. *This type prevents the passage of signals through the receiver if the received signal strength drops below a certain value.* Just what this value is, depends upon the design of the receiver and provision usually is made to vary the level at

which the system becomes operative. . . . In other words, a control is available so that the receiver can be adjusted to pass very weak signals and the accompanying noise or to cut out the very weak signals as well as the noise. . . . Once again this statement should not be construed as meaning that receivers equipped with q.a.v.c. are not as sensitive as those not so equipped. . . . This depends upon the design of the receiver and the q.a.v.c. system is primarily intended to eliminate the noise which would otherwise pass through the receiver when tuning between stations.

The relation between the output signal and the received signal with q.a.v.c. is shown in Fig. 14. In contrast to the information

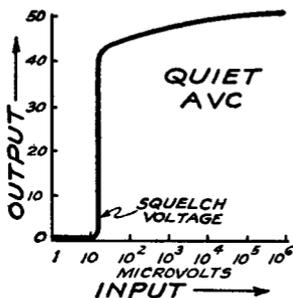


Fig. 14. Here is shown a curve that indicates the action of a receiver that has incorporated in it "quiet a.v.c." or "noise suppression." The output is zero, until the "squelch voltage" point is reached, and then the output jumps to a value that remains essentially constant.

shown in Figs. 1 and 7, Fig. 14 indicates the relation between the receiver output signal and the received signal, rather than the second detector output and the received signal, as in Figs. 1 and 7. The reason for this is that in q.a.v.c. systems, which may also be identified by a number of different names among which are noise suppression, squelch circuits, etc., the action of the a.v.c. system is to block one of the audio tubes during the time that the received signal is below a predetermined level and to open the audio system when the received signal is of sufficient intensity (there are other methods which will be discussed in a later chapter).

If you will examine Fig. 14, you will note that there is no output from the receiver over a certain range of input signal levels—from zero input up to a certain predetermined intensity. . . . It is during this time that the audio system is blocked by the control circuit. . . . Then when the received signal rises to a critical value, generally known as the *squelch voltage*, or if the

receiver is tuned to some station which is received with an intensity equal to or greater than this critical value, then the audio system is unlocked and normal a.v.c. operation is restored. It is because of this steep rise in the output that receivers equipped with q.a.v.c. are silent during the tuning and then when the proper signal is tuned in, the output signal suddenly appears.

Having read these lines you will appreciate that we have made no attempt towards completeness of detail in outlining the properties of the three principle types of a.v.c. systems. . . . What we have tried to do is to develop a general acquaintance with the main features of these systems and to show how each works towards the ultimate goal of a.v.c. . . . The various circuits utilized to develop the properties described are basically the same but contain extensive modifications and we are certain that you will find them of interest as you progress through this book. . . . In the later pages of this book we are going to show how these various functions are accomplished and the manner in which the different parts of the receiver are interlocked to produce the ultimate result.

Chapter II

CONTROL FACTORS

WE STATED that automatic volume control, as we understand the term, is really the control of the sensitivity of the receiver ahead of the second detector tube—and that this control of sensitivity is in accordance with the intensity of the received signal. . . . Now, in order to control the sensitivity of the receiver automatically, it is necessary to control the amount of gain or amplification available in the r-f. or i-f. amplifiers, but—in order to understand how such automatic control of amplification is accomplished, it is essential to comprehend the manner in which the amplifying properties of vacuum tubes can be varied. . . .

Let us examine briefly the operation of a vacuum tube as an amplifier. . . . As you no doubt know, the subject is quite lengthy—as a matter of fact, entirely too long for this book and, consequently, is the text for another of this “An Hour A Day With Rider” series. . . . In the present volume on a.v.c. we will cover the basic facts needed to comprehend automatic control of the amplifying properties of the normal vacuum tube.

Gain or Amplification

When a certain tube is used with a certain transformer as the plate load or with a resistor or choke as the device in the plate circuit, the higher the mutual conductance of that tube, the greater is the gain available with the combination. If another tube suitable for use in the system, but possessed of a lower value of mutual conductance, is used in that system, the overall amplification or gain of the stage will be less. *Variation of the mutual conductance of the tube is used as the means of controlling the gain or amplification in a.v.c. systems.* . . . Let us now see how this is done.

There are a number of ways of varying the mutual conductance of a tube between its zero and maximum limits. . . . Variation of any of the operating potentials will accomplish this end. In other words, variation of the filament or heater voltage, control grid bias voltage, screen grid voltage, suppressor voltage and plate voltage—all will vary the amount that the amplification will change for a specific change in grid voltage. . . . However, all of these methods are not equally suitable for our purpose. . . . Let it suffice to say that of these five possible methods, two of them have found practical application, namely, the control grid bias method and the screen grid voltage method—and that of these two, the control grid bias system has been found to be most satisfactory generally and is used in practically all cases. . . . The primary reason for its use is that the control grid circuit is free of current—whereas all of the other possible methods involve circuits which carry direct current. . . . Under the circumstances, we can analyze the subject of gain or amplification control by examining the relation between the control grid bias and the mutual conductance characteristic. . . . Furthermore, since the mutual conductance characteristic is related to both the plate current and the control grid voltage variations, it is possible to analyze mutual conductance variations by examining the relation between the control grid voltage and the plate current.

The Effect of Grid Voltage on Plate Current and Mutual Conductance

When the cathode, screen, suppressor and plate voltages are held constant, variation of the control grid bias voltage will cause a change in the plate current. Likewise, it will cause a change in the amount of gain available with the stage of amplification. The manner in which the control grid bias variation changes the plate current and the gain available with the tube depends upon a number of different factors—primarily the design of the tube. . . . However, irrespective of the design, one condition exists in general—*an increase of negative bias applied to the control grid reduces the plate current and likewise reduces the gain or amplification available with the stage.* . . . If we express this condition in relation to sensitivity of the receiver rather than

gain or amplification—it means that an increase in negative control grid bias applied to the r-f. and i-f. tubes of the receiver reduces the sensitivity of the complete system. . . . No doubt you recall that in very many of the old t.r.f. receivers control of sensitivity was usually accomplished by means of a variable resistor located in the r-f. tube cathode circuit. . . . This control increased the negative control grid bias, when reduced sensitivity and, consequently, reduced volume was desired.

However, we cannot rest with the mere statement that sensitivity can be controlled by varying the control grid bias. . . . While this represents the most significant detail as far as sensitivity or volume control is concerned, it is still imperative to understand that certain definite requirements must be fulfilled for the use of control grid voltage variation in automatic volume control circuits. . . . The major of these requirements is that *reduction in sensitivity—which means an increase in control grid bias voltage, must be accomplished without changing the operation of the controlled tubes from amplifiers to rectifiers.* . . . Increasing the control grid bias should decrease the gain or amplification, but the tubes so controlled should still function as amplifiers. . . . This means that only certain types of tubes may be used in a.v.c. circuits because of the need for a certain specified plate current variation with change in control grid voltage. This entails a predetermined mutual conductance variation with change in control grid voltage. . . . Figs. 15 and 16 illustrate this point.

Consider Fig. 15 first. In this graph is shown the variation in plate current for two types of tubes. Curve A is that of the average screen grid tube, such as the type 24, the 57, the 6C6, etc. The values of plate current and grid voltage are not necessarily absolutely accurate for these types of tubes, but will serve for the purpose of explanation. Curve B, on the other hand, is for the variable-mu type of tube, such as the 58, the 6D6, etc. Certain significant details justify comment. You will note that curve A is very steep and that the plate current falls from maximum to zero over a control voltage range of about 7 volts, i.e., over a variation of from 0 bias to 7 volts negative. This type of tube is what is known as a “sharp cut-off” type and its operation is typical of those tubes which were used in the r-f. amplifiers of years ago with variable control grid bias type of volume

or sensitivity control. The reason for the troubles experienced with such tubes, when variable control grid bias type of volume control is used, is very evident.

In the first place, the amount of signal voltage permissible in these tubes is definitely limited by the very low bias voltage. . . . Consequently, strong signals overload the tube. . . . Then when the bias voltage is applied as a control voltage, it is very critical and the range of operation is extremely limited. . . . To reduce the intensity of a very strong signal to the required level requires

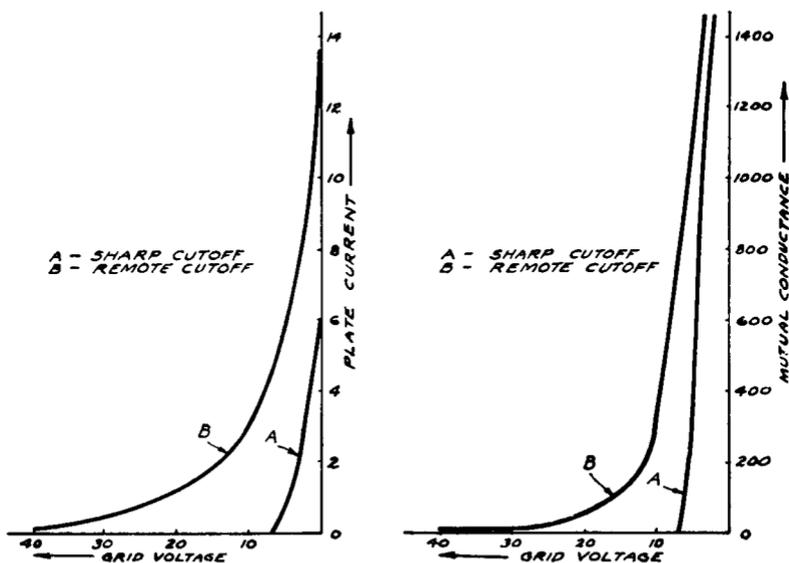


Fig. 15, left, Fig. 16. The curves on the left show a comparison of the effect of grid voltage on the plate current of sharp cut-off type of tube (Curve A) and the remote cut-off type of tube (Curve B). The curves of Fig. 16 show the variation of mutual conductance with grid voltage for tubes of the sharp and remote cut-off types, curves A and B respectively.

a fairly high bias; this results in operation near the cut-off point and rectification occurs. . . . The result is distortion and cross-modulation, which is the "riding through" of an undesired station on the carrier of the desired station, etc. If this type of tube is used in the i-f. amplifier, overloading occurs on strong signals and variation of the gain in the system, by means of an

increase of the control grid bias, causes distortion of the modulated wave envelope and this results in a distorted audio output. . . . Such were the complaints of years ago.

Curve B, as stated, is for the variable- μ or remote cut-off type of tube. The plate current characteristic is much longer and, as you can see, plate current flows in the circuit over a very much greater range of control grid voltages. Whereas the sharp cut-off type of tube allows a variation of about 7 volts control bias between zero and maximum plate current, the remote cut-off type of tube allows a variation of control grid bias over a range of over 40 volts between zero and maximum plate current.

This means that the tube is operative over a much greater range of input signals, assuming that the correct bias is applied and, furthermore, allows the application of a very high value of control grid bias so as to reduce the amplification without causing operation of the tube at or past the plate current cut-off point. . . .

Let us now examine the manner in which the mutual conductance (gain) changes with variation of the control grid bias. This is shown in Fig. 16 and the curves A and B are related to the two curves similarly identified in Fig. 15. Note that maximum amplification is available for the sharp cut-off tube (Curve A) when the bias is about 3 volts. However, the amplification falls to zero when the bias is increased to minus 7 volts, so that the range of amplification or gain control is very narrow—as a matter of fact too narrow for normal use. To control amplification by varying the grid bias means a very critical control, because the total range of voltage variation between maximum gain and some point which approaches minimum gain is very small. Furthermore, the control is not applicable to strong signals.

In the case of the remote cut-off tube, the situation is different. The change in gain or mutual conductance is much more gradual over a very much larger range of bias voltages. Operation is just as easily possible with weak as well as strong signals. . . . Full gain is available with a small constant bias upon the tube so that maximum gain is available under ideal conditions. . . . The fact that proper amplification is possible over a very wide range of bias voltages—without fear of changing the operation of the tube from an amplifier to a rectifier—affords suitable control for the very strongest of signals. . . . Such is

the type of tube used in the r-f. and i-f. amplifiers of receivers equipped with a.v.c.

It is evident from what has been shown in Figs. 15 and 16, that if we can provide a negative control grid voltage which varies between a certain minimum and a certain maximum, we can control the gain or amplification available in a single stage of r-f. or i-f. amplification or in a complete r-f. or i-f. amplifier. An effort to do this by hand is out of the question, because it is impossible to follow the received signal intensity variation. . . . A sensitivity control which will set the operating point as desired, is logical—and such a manual control is available in a number of receivers and is supplementary to the automatic volume control. . . . At any rate, we know that if we can supply the required varying control grid bias, we can control the extent of the gain and if this bias is developed as the consequence of the received signal so that the value of the control bias voltage actually depends upon the intensity of the received signal—then we can arrange the condition that when the signal is strong, the bias is high and the gain is low, which means that the sensitivity is low. . . . On the other hand, when the signal is weak, the bias is low and the gain is high, which means that the sensitivity is high.

Nature of the Control Voltage

We now have on hand the means of controlling the overall amplification or gain of a single stage or a complete amplifier by means of a variation in the bias supplied to the control grid. . . . So far so good. . . . But we still lack something. . . .

What we need at the present time is a method for automatically supplying this control voltage. Where shall we find or how shall we produce a varying voltage which will bias the control grids of the i-f. and r-f. tubes in accordance with the signal level at the input to the receiver? . . .

Before answering the above question, it might be well to consider some of the properties which this control voltage must possess. It stands to reason that if this voltage is to act as a bias voltage, it must have d-c. characteristics. We can readily appreciate that it will not always be of constant magnitude. . . . As a matter of fact, it cannot be of constant magnitude because

we deliberately desire a variation in the amount of the bias so as to effect control of the tubes. But since it is to simulate a normal d-c. bias, it must be the equivalent of a d-c. voltage.

The next requirement is that the control voltage must be large when a strong signal is being received and, conversely, the control voltage must be small when a weak signal is being received. . . . This does not necessarily mean that the control voltage must be twice as large for a signal which is twice as strong as another signal. The condition which must be satisfied, however, is that the control voltage developed as a result of the passage of the signal, must vary in such a way that the amplification or gain of the receiver ahead of the second detector is always inversely proportional to the strength of the incoming signal. If this is accomplished, then the output at the second detector will remain constant. The actual variation of the control voltage, as we shall see later, depends upon a number of factors, among which are the character and the number of the controlled tubes.

Another important qualification which the control voltage must satisfy is that when used for automatic volume control its value must depend only upon the value of the received carrier and be independent of the modulation. If we attempt to make the control voltage dependent upon the audio output of the second detector, then the sensitivity control would vary in accordance with the character of the modulation. . . . This is out of the question for a number of reasons. For example, during those periods when the microphone was not being excited, the gain of the receiver would be very great, because there would be no modulation component or audio signal to develop the required control bias. Then again if the receiver were reproducing a passage of music and the control action depended upon the modulation, the soft passages would come through loudly and the loud passages would come through softly. It stands to reason that such operation would comprise the height of distortion. It is, therefore, evident that in order to avoid distortion of this character, the nature of the control voltage used for the a.v.c. action must be such that it is entirely independent of the depth or percentage of modulation.

It might be well at this time to mention that a.v.c. systems which depend upon the audio output have been developed, but these systems are not used for a.v.c. or sensitivity control in com-

mercial broadcast receivers, and hence do not justify detailed discussion in this book.

We do not think it amiss also to make mention at this time that the control voltage fed to the controlled tubes, although admittedly dependent upon the strength of the carrier, must be free of all audio components. Perhaps this is in line with the previous reference to the effect that the voltage must be of d-c. character, but we feel that it might be a good idea to make specific reference to the fact that audio variations must not be present.

Rectifier Output as a Control Voltage

Knowing what we need in the form of a control voltage, it is natural to look about for a source of such a control voltage. . . . The possibility of using the demodulator or second detector connected to the last i-f. stage suggests itself. The primary reason why the second detector tube suggests itself as the source of the control voltage is that it is the only point in the receiver where during normal operation, the carrier strength is sufficiently great to supply the required value of control voltage. This statement should not be construed as signifying that the second detector is at all times the source of the control voltage—because it most certainly is not. . . . But it does suggest itself as a simple expedient and we can investigate the utility of the system with the idea of determining whether it will provide a control voltage possessing the properties mentioned above.

In view of the fact that we are called upon to develop a d-c. voltage varying in accordance with the strength of the received signal—which is an alternating voltage—it stands to reason that some form of rectification will be necessary. D-c. voltages are available in the average radio receiver from the power supply or from the battery—depending upon the type of receiver used—but neither of these sources is suitable for our purpose, because the voltage obtained from these sources is not dependent upon the strength of the received signal. In accordance with what has been said, let us analyze the simple diode rectifier system which is shown in Fig. 17. The rectifier tube is shown connected to the last i-f. transformer in the position which would normally be occupied by the second detector. As a matter of fact, if you can

visualize the secondary winding of this i-f. transformer as being the high voltage winding of a power supply transformer, the complete rectifier circuit consisting of the transformer, the tube and the load resistor R_L , comprises a normal half-wave rectifier system. For that matter, you would do well to consider the average a.v.c. voltage source, which depends upon rectification for the control voltage, as being a conventional rectifier of either half-

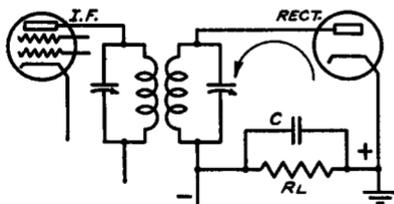
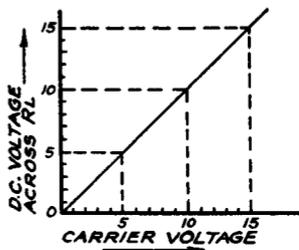


Fig. 17, left. The purpose of this simple diode rectifier is to develop a d-c. voltage for automatic control of the r-f. and i-f. gain.

Fig. 18, right. This curve shows the relation between the d-c. voltage developed across the load R_L , Fig. 17, and the carrier voltage. Note the proportionality between the two.



wave or full-wave character—depending entirely upon the circuit being used. Since we are interested in producing a fairly high d-c. voltage—say up to 40 or 50 volts—and because it is essential to apply a minimum load upon the transformer, so as to minimize detuning and damping of the circuit, a comparatively high value of load resistance is used, which means that R_L is quite large—of the order of several hundred thousand ohms. . . . The by-pass condenser C is included to provide a path for the intermediate-frequency currents so that they will not flow through the resistor R_L .

What rectified voltage can be secured from this arrangement—when the input a-c. voltage is an unmodulated carrier? . . . To start with, the diode rectifier is essentially a linear rectifier. . . . By linear in this case is meant that the output is proportional to the input—which means that a representation of the input—output voltage relations can be shown as a straight line like that in Fig. 18. The horizontal reference line indicates the carrier input voltage and the rectified d-c. output voltage is

shown on the vertical reference line. . . . Note that a variation of the input voltage at all levels causes corresponding variations in the rectifier output, which means that the tube can be used to develop the required d-c. voltage with weak, as well as strong signals.

So far we have referred to unmodulated carrier input into the diode rectifier. . . . Suppose that the carrier is modulated! . . . What then? . . . As it happens it makes no difference as far as the circuit operation is concerned and as far as the input-output relation is concerned. The reason for this is that the rectified current, that is, the direct current in the circuit, is dependent upon the average value of the modulated carrier and this remains the same for any one carrier, whether it is modulated or unmodulated. This is shown in Fig. 19, wherein the average value of a



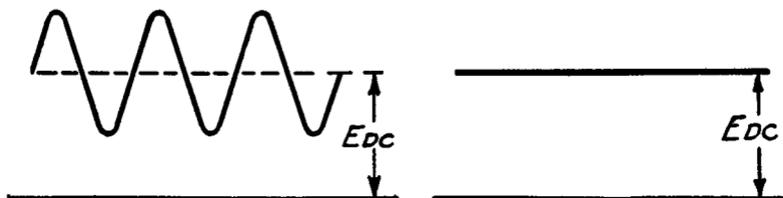
Figs. 19, left, and 20. The average value of the carrier voltage is the same, whether the signal is modulated (Fig. 19) or unmodulated (Fig. 20).

sine wave modulated carrier is indicated to be a straight line. The exact amount representing the average value of a modulated wave is not important at the moment, because it is the same percentage in all cases. . . . All that we are concerned with is the fact that the presence of a modulation component does not alter the condition that the rectified direct current or the d-c. voltage across R_L is dependent upon the carrier intensity and is independent of the modulation component. In other words, the rectifier current or voltage which would be present for the modulated carrier, shown in Fig. 19, would be the same as for an unmodulated carrier having the same average value, as shown in Fig. 20.

So, from what has been said we find that the second detector is a perfectly satisfactory source of the a.v.c. voltage and it fulfills the requirement that the control voltage vary in accordance with the received signal intensity and, furthermore, that it be independent of the nature or character of the modulation. This means that proper control of sensitivity can be had with a modulated or unmodulated carrier on the air.

Necessity for Filter Network

Although, as we have just seen, the same value of d-c. voltage will be across the diode load resistor R_L , regardless of whether the carrier is modulated or unmodulated, there is an important difference in the character of the d-c. voltage for the two conditions named. When the signal or carrier is modulated the voltage across R_L will be a pulsating d-c. voltage, as shown in Fig. 21. These pulsations represent the modulation component. The voltage is a d-c. voltage which rises and falls around an average value shown by the dotted line in Fig. 21. On the other hand, if the modulation is removed from this same carrier, the voltage



Figs. 21, left, and 22. When the carrier is modulated, the voltage across the diode load is a pulsating d-c. voltage, (Fig. 21). With an unmodulated carrier the voltage across the diode load is pure d-c., (Fig. 22).

across R_L will be a steady d-c. voltage, as represented by the straight line in Fig. 22. In each case there is the same average value of d-c. voltage, but in the former case the voltage, as has been said, is of a pulsating nature while in the latter case it is steady.

Now, in actual practice the received signal is, of course, a modulated signal and the question arises as to whether or not we can use the pulsating voltage shown in Fig. 21 just as it is. A little reflection will show you that this is not possible for the reasons which were set forth in connection with the requirements of the control voltage. Variation of this control voltage at an audio rate representative of the modulation component of the carrier, would be the equivalent of applying to the r-f. and i-f. tubes an audio signal and this is, naturally, out of the question. If you examine Fig. 21, you can see that this pulsating voltage consists of two components or two parts. One part is the steady d-c. voltage and the other part is this modulation component. In

other words, the pulsating d-c. voltage is the equivalent of a steady d-c. voltage plus an alternating voltage component, which varies in accordance with the depth or percentage of the modulation and with the character of the modulation. . . . If we can get rid of the a-c. component of the pulsating voltage, the pure d-c. part can be used as the control voltage. . . . Now we must separate the two parts.

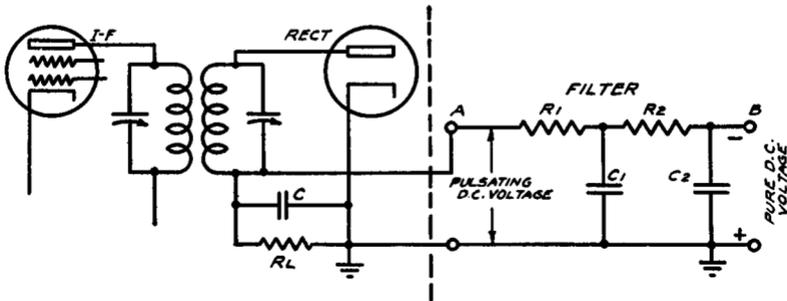


Fig. 23. The function of the filter network (shown to the right of the dotted line) is to remove the audio component in the output of this conventional a.v.c. rectifier.

The manner in which we separate these two is exactly as in any other system wherein a pulsating d-c. voltage exists and we wish to remove the a-c. component. . . . In other words, by means of a filter network. A representation of such a filter network is given in Fig. 23 and you will note that the circuit very greatly resembles the conventional type of filter, such as is used in the normal power supply system. If you examine Fig. 23, you will find that the filter resistors, R_1 and R_2 , occupy a position similar to that normally occupied by the filter chokes in a power supply circuit and that the filter condensers, C_1 and C_2 , occupy the normal filter condenser positions. Considering all facts, the filter system employed in an a.v.c. circuit so as to secure a pure d-c. output, is basically identical to the filter system employed in a power supply device.

Action of A.V.C. Filter

The action of this filter is quite easy to understand. As a consequence of rectification in the diode circuit, a pulsating d-c. voltage exists across R_L in Fig. 23, or between point A and

ground. In other words, between point A and ground a d-c. voltage and an a-c. voltage are found. In analyzing the action of this filter, it is possible to consider the effect of the filter upon each of these parts separately. Let us trace first the action of the filter on the d-c. component.

We know that the purpose of this d-c. voltage is to function as control grid bias. This means that the circuits to which this voltage is applied consume no direct current. Consequently, no direct current flows through resistors, R1 and R2—which means that there is no voltage drop across R1 and R2. Consequently the d-c. voltage at the output of the filter, between point B and ground, is equal to the voltage at the input to the filter or across A and ground. When we refer to points A and ground we are, in effect, referring to the two limits of the load resistance, R_L . The fact that no d-c. flows through the filter system is the factor which permits the use of high resistances in place of the low d-c. resistance filter chokes in the normal power supply filter system.

In the case of the alternating current component, the action is somewhat more complex. In the first place, the capacities of C1 and C2 are so chosen that they offer a low opposition to the flow of the audio-frequency currents. This means that only a very small part of the total a-c. voltage will be developed across the first filter condenser because of the relatively low impedance of C1 with respect to the filter resistance, R1. This small voltage, which is developed across C1, is further reduced in the same way by the action of the R2-C2 combination,—with the result that there is practically no a-c. voltage developed across C2, which means across the output of the filter.

So much for the action of the filter in a qualitative sense. Let us take a simple example to illustrate the effectiveness of the filter network. Expressed in another manner, let us illustrate how a filter is used to eliminate the audio component developed as a result of rectification and which is responsible for the pulsations present in Fig. 21. Suppose that we take a case in which the average d-c. output of the rectifier is 5 volts. Let us assume that the carrier is 100% modulated. Under these conditions the actual output of the rectifier is as shown in Fig. 24. It consists of an average value of 5 volts pure d-c. and a 5-volt peak value a-c. voltage, which combine to form the pulsating d-c. voltage input to the filter. The values of R1 and R2 are 1 megohm and 500,000 ohm, respectively, and the capacities of C1 and C2 are taken to be .05 mfd. each. As the consequence

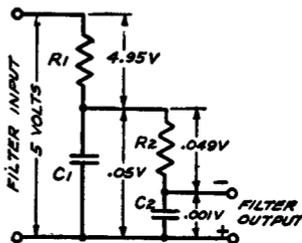
of the modulating frequency and the value of the capacities, the impedance of these condensers is 10,000 ohms each.

What will be the value of a-c. voltage across the first filter condenser—the second filter condenser and the output, under these conditions? To show properly the voltage divider action which takes place, we shall rearrange the circuit of Fig. 23 into that shown in Fig 25. While it is true that the combination of R2-C2 shunts the condenser C1, the combined impedance of R2-C2 is so great with respect to the impedance of C1, that



Fig. 25, right. This diagram shows how the filter network of Fig. 23 attenuates the audio components in the rectifier output. Note the voltage divider action.

Fig. 24, left. The output of an a.v.c. rectifier for a 100% modulated signal. See Fig. 25 for the filter action on this voltage.



we can neglect for the moment, the presence of R2-C2 across C1. Under these conditions and, bearing in mind the resistance value of R1 and the impedance of C1, the 5-volt a-c. component divides between R1 and C1 in such manner that the a-c. voltage across R1 is approximately 4.95 volts and the a-c. voltage across C1 is .05 volt. These values are as stated because the voltage division takes place in proportion to the relative resistances or impedances.

Further examination of the circuit shown in Fig. 25 brings to light that the R2-C2 combination constitutes a voltage divider across C1 and acts to cause a further reduction in the a-c. voltage across C2, which is effectively the output of the filter. The resistance of R2 being 500,000 ohms, and the impedance of C2 being 10,000 ohms, 1/50 of the voltage across C1 will appear across C2. The rest of the voltage is dropped across R2. Accordingly then, the a-c. voltage across R2 is .049 volt and the a-c. voltage across C2, that is, across the output of the filter, is only .001 volt, which is quite negligible. As is evident the filter system has attenuated the a-c. voltage so that at the output of the filter the a-c. voltage is equal to about 1/5000th of the a-c. voltage present in the output of the rectifier.

To continue with this problem, the filter has no effect upon the d-c. component of the detector output, which is the part we seek for automatic volume control purposes. In as much as we have stated that no direct current flows through the filter, the d-c. voltage across the output is approximately equal to the voltage at the input to the filter, which, in this case, is 5 volts.

No doubt you can appreciate that in actual practice the analysis of the filtering action is somewhat more complicated than the illustration we presented. We have simplified matters by considering just one modulation frequency. In actual practice a great number of modulating frequencies are present, so that the pulsating voltage output of the a.v.c. rectifier will contain frequencies ranging from the lowest to the highest audio frequency,—from about 30 cycles to 10,000 cycles. In view of the fact that the impedance of a condenser varies with frequency, it stands to reason that the impedance of C1 and C2 will vary very widely during normal operation. . . . It will be low at the high frequencies, which means that filtering efficiency will be good for the high audio frequencies. On the other hand, the impedance of the condenser will increase for the lower audio frequencies and the filtering efficiency will be materially reduced at these low frequencies. Therefore, it follows that the lower the modulation frequency, the greater will be the percentage of audio voltage present across the output of the filter for any one set of constants used for the filter.

Possibly your first reaction to this condition will be to suggest that the best action would be obtained with large values of C1 and C2. However, there are several considerations relating to the values of C1 and C2 which have not as yet been mentioned. Unfortunately, these considerations make it impossible to use very large values for C1 and C2,—because they influence the *speed of action* of the a.v.c. circuit. This will be discussed in a subsequent part of this chapter.

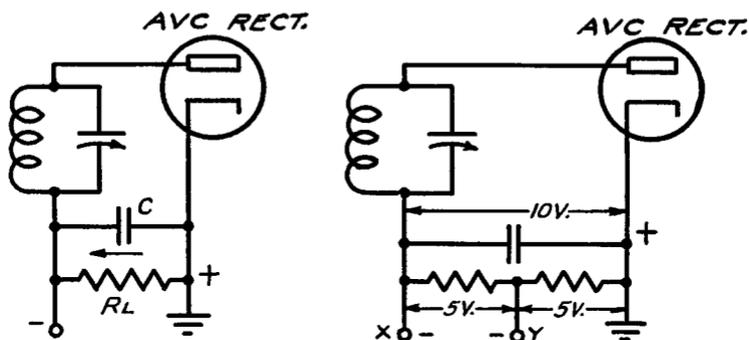
Polarity and Division of Voltage

We have spoken about the development of a d-c. voltage in a rectifier system and also of the filtering of the a-c. component present in this voltage. . . . However, to present the subject properly, it is necessary to make some few comments concerning the polarity of this d-c. voltage.

As a consequence of the direction of electric current flow in the diode rectifier circuit, the voltage developed across the load resistance has a polarity as indicated in Fig. 26. In view of the fact that electric current flows from the plate to the cathode, the

cathode end of the load resistor is positive with respect to the other end. Since, as a general rule, the cathode is grounded and this is the positive end of the a.v.c. voltage supply source, all points along this a.v.c. voltage supply resistor are negative with respect to ground.

In some few instances all of the voltage developed across the a.v.c. voltage supply tube load is not applied to the same tubes. Instead the voltage is distributed among a number of tubes, as will be shown later in this book. This means that the voltage



Figs. 26, left, and 27. The direction of the current flow through R_L is such that the "plate end" of this resistor becomes negative when a signal is being received. If the diode load takes the form of a voltage divider, Fig. 27, varying amounts of control voltage can be distributed to the several tubes, as from the taps X and Y on the resistors making up the diode load. Here both these points are negative with respect to ground.

developed in the a.v.c. rectifier is made available in different values at different taps, as shown in Fig. 27, wherein 10 volts a.v.c. voltage is distributed in two 5-volt steps to the two terminals X and Y. In accordance with what was said before that all points along this divider are negative with respect to the cathode, point X is negative by 10 volts with respect to ground and point Y is 5 volts negative with respect to ground.

A far more elaborate discussion of such division of voltages and polarities of the various points along dividers is to be found in another of this "An Hour A Day With Rider" series, namely, "D-C. Voltage Distribution in Radio Receivers."

The Basic Control Circuit

We are now in a position to see how the control voltage developed in the preceding pages is utilized in a typical simple receiver. The function of the control voltage, as stated in the early part of this chapter, is to vary the gain of the r-f. and i-f. amplifier tubes in accordance with the strength of the signal impressed on the antenna. By distributing this voltage to the control grids of the several controlled tubes, the desired degree of control over the amplification in the r-f. and i-f. systems is obtained.

A typical simple circuit illustrating the coordination of all of the basic elements, which have been discussed so far in the preceding pages, is shown in Fig. 28. This circuit contains an i-f. tube, which is controlled by the a.v.c. voltage, the a.v.c. rectifier, and the resistance-capacity filter. This is the simplest possible illustration and is by no means offered as an example of what would represent a complete circuit. However, it does illus-

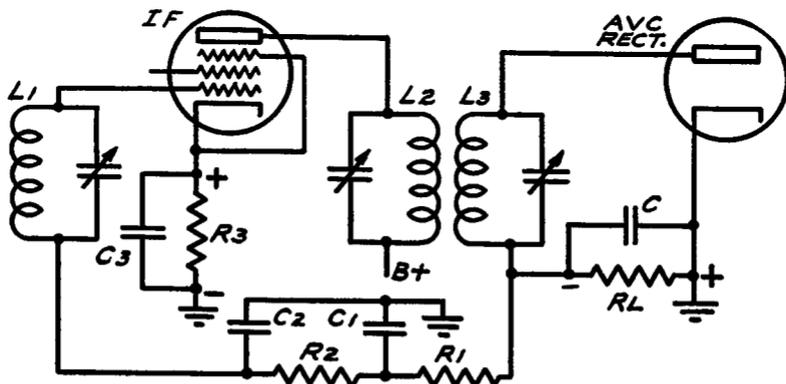


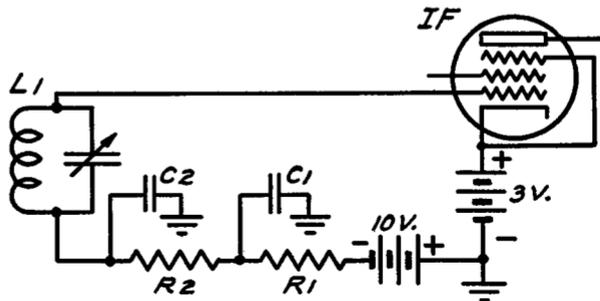
Fig. 28. This simplified a.v.c. circuit shows the basic elements. The control voltage that is developed by the a.v.c. rectifier is fed to the grid of the i-f. tube through the filter, R1, R2, C1, and C2.

trate the relation between the source of control voltage, the filter network and the tube being controlled. . . . What happens in such a circuit? . . .

If we examine this circuit, we find certain significant details present. To start with, the i-f. signal is transferred from the plate circuit of the i-f. tube to the input circuit of the a.v.c. recti-

fier. Rectification takes place and the pulsating d-c. voltage is developed across the load resistor, R_L . The input to the filter circuit is connected to the most negative point along the control voltage supply resistor, which means that the control grid of the i-f. tube is joined to this point. The filter circuit, consisting of R_1 , R_2 , C_1 and C_2 , removes the alternating component of the

Fig. 29. Batteries here show how the a.v.c. voltage (10 volts) and the cathode voltage (3 volts) act in series to form the total bias on the controlled tube's grid.



pulsating voltage, so that a steady d-c. voltage is available as a bias.

Speaking about the bias for the i-f. tube, we note that the cathode of the i-f. tube contains its own biasing resistor. . . . But why should this biasing resistor be in the circuit if we can secure an automatic bias from the a.v.c. rectifier?

The purpose of the i-f. cathode bias resistor is to supply a fixed minimum bias, which sets the operating point of that amplifier stage for its maximum sensitivity position. If we depended solely upon the a.v.c. circuit to supply the entire bias, the i-f. tube would be operating without bias during those moments when the receiver was being tuned between stations and no signal was passing through the receiver so as to develop the automatic bias. By providing a fixed minimum bias, safe operation of the i-f. tube is at all times assured. Such an arrangement is not limited to the i-f. amplifier only—but can also be used in r-f. systems.

Now the polarity of the fixed minimum bias applied to the i-f. tube and the control bias developed by the a.v.c. rectifier when a signal is passing through the receiver, is such that these two voltages are in series—so that the a.v.c. bias is additive to the fixed minimum bias. If we assume the presence of a signal through the system so that the a.v.c. voltage is 10 volts, and if we further

assume that the fixed minimum i-f. bias developed across R3 is 3 volts, and if we further indicate these bias voltages by means of batteries, we have the circuit combination shown in Fig. 29. The reason why we show the minus end of the 3-volt battery joined to the plus end of the 10-volt battery is because the plus side of R_L goes to ground and the minus side of R3 goes to ground, so that the cathode of the i-f. tube is positive with respect to the control grid of the i-f. tube by the sum of the voltages developed across R3 and R_L . When we say that the cathode of the i-f. tube is positive with respect to the control grid by 13 volts, it is the same as if we said that the control grid of the i-f. tube was negative with respect to its cathode by the aforementioned 13 volts.

Let us now analyze in a qualitative way the exact manner in which this simplified circuit functions. We start off with the assumption that a weak signal is being picked up by the antenna. Under this condition the signal voltage is passed on to the i-f. tube and across the secondary winding of the i-f. transformer, which feeds the a.v.c. rectifier, there will be a moderate signal and consequently the control voltage produced across R_L will likewise be moderate in value. This in turn means that the control bias on the i-f. amplifier will be of moderate value and the sensitivity of the receiver will be moderately great. As the input signal to the receiver is increased, the magnitude of the control voltage likewise increases as a result. The effect of this increasing control voltage is to level out the response, because the greater the control voltage, the greater the bias applied to the i-f. tube, and the less its mutual conductance, which can be interpreted in terms of the gain or amplification of the system. This action tends to make the output uniform regardless of the strength of the signal voltage fed to the input of the receiver. The output characteristic which such a system would have if it did not incorporate a.v.c. as against the output characteristic with a.v.c., is shown in Fig. 30. This illustration is similar in content to that which was shown earlier in the book, but we feel that by combining the two conditions we aid comprehension. Note that the output characteristic, even with a.v.c., is far from ideal in that the output is not the same for all values of input, but on the contrary does increase to a certain extent with increasing values of signal input. While it is true that the performance

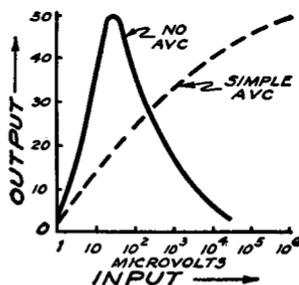
with a.v.c. is not ideal, it is still far superior to the action when the a.v.c. system is absent. . . . So much for generalities. Now for some of the special considerations which must be understood in order to appreciate in full the operation of an a.v.c. system.

Time Delay Considerations

We have mentioned in a number of places in this text that the function of an a.v.c. system is to provide substantially constant output irrespective of changes in the signal input. As far as changes of received signal intensity are concerned, they may be either rapid or slow. *Whatever the condition, the fact remains that the control voltage must be capable of following the fluctuations in intensity of the applied signal. In other words, the control voltage must be able to increase or decrease as rapidly as the occasion demands.*

If you recall, we made some reference to the efficiency of the filter with respect to different frequencies, and you will find that the filter network displays a great deal of influence upon the

Fig. 30. *These two curves show the manner in which the output varies for receivers with and without a.v.c. The dotted curve (that for a set having simple a.v.c.) is smooth, indicating the absence of overloading.*



ability of the control voltage to follow rapid changes in the input signal. However, before we can really understand the nature of the action which takes place in the filter network consisting of R1, C1, R2, and C2 in Figs. 23 and 28, we must investigate some of the fundamental facts relating to the charge and discharge of a condenser through a resistor. As a rule we think of circuits in such a way that if the voltage is changed at one point in a circuit, —then the voltage instantaneously changes in every other part of the circuit in conformity with the initial change. In general this is quite true, but where the circuit involves large values of

resistance and capacity, there is a definite appreciable time lag between the instant that the initial voltage change is made at one point in the circuit and the instant at which the corresponding effect is felt at other points in the circuit.

Charge and Discharge of Condenser

When a condenser, C , is connected in series with a resistor, R , and the series combination is connected across a battery, as shown in Fig. 31, and the switch, S , is closed, the condenser will gradually be charged to the final voltage of the battery. A

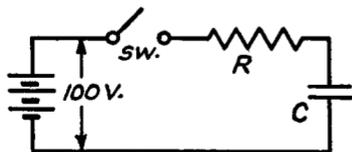


Fig. 31. When the switch is closed, the voltage across the condenser slowly rises to 100 volts, the speed depending on the values of R and C .

definite amount of time is required for the flow of electrons through the circuit, which charge the condenser to the voltage of the battery. The time which is required for a condenser, in series with a resistance, to reach 63% of its final charge after the switch is closed, is known as the *time constant* of the circuit. This percentage is derived from a fundamental electrical equation and holds true for any combination of resistance and capacity, which is explained below. Quantitatively, this time constant in seconds is equal to the product of the resistance, expressed in megohms, and the capacity, expressed in microfarads. For example, a 1-mf. condenser, in series with a 1-megohm resistor and connected across a 100-volt battery, will become charged to 63 volts in accordance with the following equation:

$$T = RC = 1 \text{ megohm} \times 1 \text{ microfarad} = 1 \text{ sec.}$$

As is evident in the equation, the magnitude of the source of voltage is of no consequence inasmuch as this same combination of capacity and resistance will become charged to 63% of its final charge in 1 second, irrespective of the exact numerical value of the final charge. In other words, this same combination will be charged to 63% of its final charge in 1 second if the voltage of the battery is 1 volt, 10 volts, 26 volts, 50 volts or 1000 volts.

If we now assume the control voltage across R_L in Fig. 28 to be the equivalent of the battery in Fig. 31, and the resistance-capacity combination in Fig. 31 to be the equivalent of the resistance-capacity filter in Fig. 28, then there will be a definite time delay between a change in the d-c. control voltage across R_L in Fig. 28 and the corresponding change in control voltage produced at the output of the filter network. In other words, there will be a time delay between the change in control voltage at the a.v.c. rectifier and the application of this changed control voltage at the grid of the tube or tubes being controlled.

If you examine the equation given for the time constant you can readily see that the higher the value of resistance used in the filter and the higher the value of the capacity used in the filter, the greater will be the time constant and the greater will be the time delay. On the other hand, the lower the value of the filter resistance and the lower the value of the filter capacity, the lower is the time constant and the less the time delay. How-

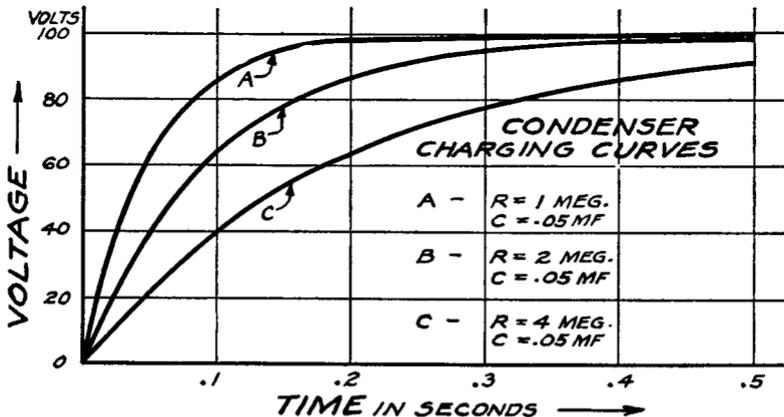


Fig. 32. The larger the value of R (Fig. 31) the more slowly does the voltage across C rise. Each curve is for a different value of R with the value of C the same in all cases.

ever, reducing the resistance and the capacity used in the filter tends to lower the efficiency of the filter, so that it is necessary to find a compromise between filter efficiency and the time delay.

When speaking about the time constant, it is also necessary to mention the discharge of a condenser through a resistor. Just

as a certain amount of time is required for a condenser, in series with a resistor, to reach its maximum charge, just so does a certain amount of time elapse before a condenser, in series with a resistor, is entirely discharged. As far as discharge is concerned, the time constant RC , as previously interpreted, identifies the time required for the condenser to discharge to approximately 37% of its initial value. Several examples of charging curves are

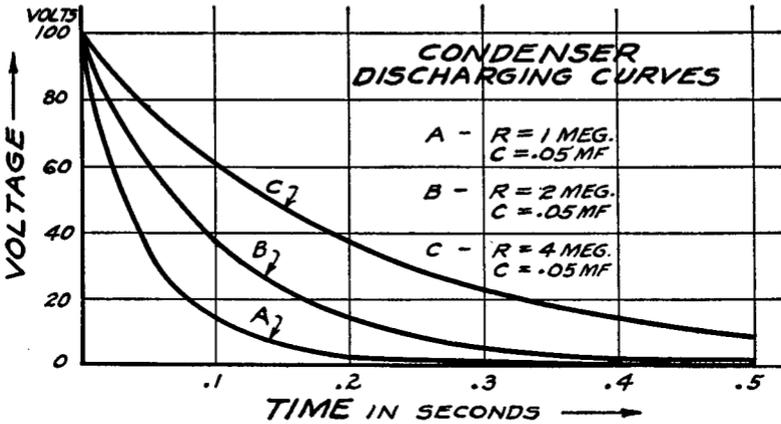


Fig. 33. These curves show the time taken by a condenser to discharge with different values of R in the circuit. The smaller the resistor value, the quicker does the condenser discharge.

shown in Fig. 32 and examples of discharge curves of a condenser in series with a resistor are shown in Fig. 33.

Referring to the filter shown in Fig. 28, the time constant of such a filter would be computed as follows:

Total Resistance =

$$R_1 + R_2 = 1 \text{ megohm} + .5 \text{ megohm} = 1.5 \text{ megohm}$$

Total Capacity =

$$C_1 + C_2 = .05 \text{ mfd.} + .05 \text{ mfd.} = .1 \text{ mfd.}$$

$$T = RC = 1.5 \times .1 = .15 \text{ sec.} = 1/7\text{th of a sec. approx.}$$

This means that the time required for the control voltage at the output of the filter to change in accordance with a shift in the signal level, which means a change in the control voltage at the a.v.c. rectifier, is approximately one-seventh of a second.

Determination of the Optimum Time Constant

While it is not our intention to give design details, we do feel that some such discussion is still required. . . . What is the significance of the time lag? . . . Is it desirable that the filter be so designed that the time lag be small—or should the time lag be great? . . .

Let us first consider the operation of the abridged receiving system shown in Fig. 28, when small values of resistance and capacity are used in the filter circuit—that is for R_1 , R_2 , C_1 and C_2 , and when the time constant RC for the complete filter is small. Specific values are not necessary. Under these conditions the control voltage will find no difficulty in following fluctuations of signal strength, such as those due to fading or to changes in tuning. However, the efficiency of filtering will be materially reduced, because proper operation of the filter requires that large values of resistance and capacity be employed. If the resistance and capacity constants are small, the audio pulsations present across the a.v.c. rectifier load will be present in the control voltage and will influence the amplification of the control tubes at this audio rate and cause distortion. This is especially true at the low audio frequencies, as for example between 30 cycles and, possibly, 200 cycles—because the efficiency of a filter employing small values of R and C is comparatively poor over this portion of the audio range. Consequently we can see that in order to prevent the lower audio frequencies—which, as the consequence of poor filtering, would be present in the control voltage—from taking hold of the control action, it is necessary to use fairly large values of capacity and resistance in the filter.

Suppose that the filter employs large values for the R and C constants . . . What then? . . . In accordance with what has been said, there would be no difficulty as far as the filtering efficiency is concerned. . . . The use of large values for the R and C constants will be very effective in preventing any of the pulsations present across the a.v.c. rectifier load from reaching the output of the filter and hence being present as a part of the control voltage. However, because of these large values of C and R , the time constant of the filter will be large and this acts to make the a.v.c. action very ineffective, in that there will occur an appreciable delay before the controlled tubes will receive the

proper control voltage as a result of the change in the a.v.c. rectifier. When such a condition exists in tuning from a strong to a weak station, it is quite possible that the weak station will be missed entirely, because the original high value of control voltage available at the filter output has not yet changed to conform with the change in control voltage at the a.v.c. rectifier—due to the fact that the receiver is now tuned to a weak signal.

Conversely, when tuning from a weak station, during which time the control voltage is very low and the receiver is very sensitive,—to a comparatively strong signal, the tuning operation will be accompanied by blasting, because the receiver sensitivity is still high and enough time has not elapsed for the control voltage, which now as the consequence of the strong signal input has reached appreciably larger proportions, to change at the output of the filter and thus reduce the sensitivity of the receiver.

From the above considerations, you can see that the optimum value of time constant used in receivers is a compromise value which is large enough to provide adequate filtering and yet small enough so that it can follow varying rapid fading and tuning operations. An analysis of commercial receivers shows that these conditions are achieved when the time constant is of the order of one-tenth of a second. Such a time constant is obtained when the total resistance in the filter is 1 megohm and the total capacity is .1 microfarad. Of course other combinations of resistance and capacity can be used to obtain the same time constant.

It might be well at this time to mention that these details concerning the charge and discharge of condensers and the time constant serve best as an explanation of the relation between the R and C values used in such filter networks and the reason why the constants employed are used.

Chapter III

THE SIMPLE A.V.C. SYSTEM

IN THE foregoing pages we have developed the basic ideas pertaining to the operation of a.v.c. systems and traced the underlying factors upon which the operation of automatic volume control depends. . . . At this time we have reached the point where we are ready to examine a typical simple a.v.c. circuit as found in commercial receivers, and to analyze some of the special considerations of such circuits.

Combined Detector and A.V.C. Rectifier

In our previous discussions of the production of the a.v.c. control voltage, we considered this voltage as being produced by a diode rectifier connected to the last i-f. transformer. In a great many receivers, a circuit is employed which makes use of the fact that both the detector and a.v.c. tubes are essentially rectifiers and are located in the same part of the receiver circuit. . . . In other words, one tube is used to perform the functions of detection and a.v.c. voltage source. A typical circuit of this type is shown in Fig. 34. Basically, this circuit is identical with that shown in Fig. 28 in which the rectifier functions to provide the a.v.c. voltage only. The fact that in the circuit of Fig. 34 the rectifier is used to demodulate the carrier and, therefore, supply the audio voltage and also the a.v.c. voltage—does not introduce any essential differences. . . .

You will note upon examination of Fig. 34, that the diode load resistor, identified as R_1 , is also the audio volume control, which determines the amount of audio output passed on to the audio system. It is by means of this audio volume control that the desired level of volume is obtained, which remains constant once the control is set to one position, regardless of

variations in the input signal to the receiver. In other words, the load resistor R_L has across it the d-c. voltage and also the audio voltage. The condenser, C , is used to bypass the i-f. component present in the rectified signal around the diode load, so that no i-f. voltage appears across the rectifier output. Because of the presence of the regular filter in the system, it is possible to have a pulsating d-c. voltage across the load resistor and to tap off the audio voltage without introducing any complications in the form of control.

The ungrounded end of the diode load resistor R is connected to the first a.v.c. filter resistor R_1 . This filter resistor is then bypassed to ground by means of C_1 , a typical value for which is .05 mfd. From point A in Fig. 34 the a.v.c. voltage is distributed to the r-f. amplifier, the mixer, and the i-f. amplifier, which are the three tubes in the receiver automatically controlled. As is evident in the diagram, the grid of each of these controlled tubes has its own individual filter resistor and filter condenser. These are the R_2 - C_2 combination for the i-f. stage, the R_3 - C_3 combination for the mixer, and the R_4 - C_4 combination for the r-f. amplifier. These resistors and condensers are part of the filter network and act to complete the removal of the audio component from the control voltage.

In this filter network, the greater part of the audio voltage is removed directly at point A , which is the junction of C_1 and R_1 . This is the first filter section and is the most important of the group. As a matter of fact, if you locate such circuits in commercial receivers you will invariably find that the constants of the first filter section are the highest of the group—with a value of 5 or 1 megohm being typical for R_1 . The use of a high value of resistance at this point makes for efficient filtering and at the same time prevents the capacity of C_1 and the remainder of the a.v.c. voltage distribution network, from interfering with the normal operation of the detector. This becomes evident when you realize that the combination of R_1 and C_1 is, in effect, a shunt across the diode load resistor which carries the audio voltage.

Function of Grid Filters

It is possible that by this time you may have given some thought to the fact that the filter network originally stated as being used to remove the audio component, looks somewhat different when shown in Fig. 34. Such is the case, and while it still performs the rôle of preventing audio fluctuations in the control voltage, it also serves to isolate or decouple the several circuits from each other, so that regeneration or feed-back between stages through these mediums will be absent. This rôle is accomplished despite the fact that the bypass condensers, C_3 and C_4 , are part of the r-f. and mixer tuned circuits. The comparatively high values of R_3 and R_4 tend to isolate the circuits from each other.

An example of the utility of such isolation is the following: There are several positions of the tuning dial for which the signal frequency being received is a harmonic of the intermediate frequency. Since the grids of both the r-f. and i-f. tubes are returned to ground through the same control circuit, it is essential to isolate the grids in some manner and this is the function which the individual grid filters perform. The failure to use these resistances or sufficiently high values of resistance at this point would, in general, result in undesirable squeals and improper operation in the neighborhood of the aforementioned frequencies.

Perfectly Flat Response Not Possible

We have stated on numerous occasions that the aim of a.v.c. is to produce a uniform output at the second detector and which output is independent of how strong or how weak the input

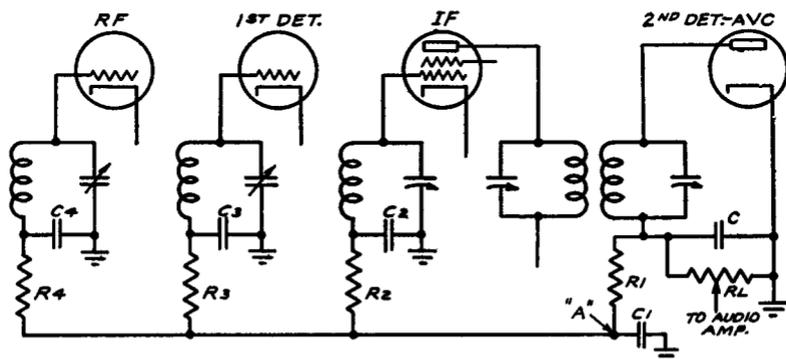


Fig. 34. In this circuit the second detector diode provides the a.v.c. voltage, which is distributed to the four controlled tubes through the individual R-C filters.

signal may be. With the typical simple a.v.c. system shown in Fig. 34, the attainment of such an ideal state is virtually impossible. The reason for this is as follows: If we start off with a weak signal, a certain output will be produced at the second detector and a corresponding value of control voltage. Now, as the input signal is increased, the a.v.c. control voltage must increase in order that the gain of the receiver be cut down so as to keep the detector output unchanged, but—an increase in a.v.c.

control voltage implies that the rectified current in the detector circuit must also increase—which means that the output must increase. In other words, the control action cannot cut down the sensitivity of the receiver unless there is *at least some increase* in the detector output. However, the advantage of the simple type of a.v.c., which we are discussing, over a circuit which does not use a.v.c.—is that although there is *some* increase in detector output to provide the necessary control voltage, *the extent to which the gain of the receiver is cut down is much greater than the comparatively small increase in output which is required to produce the control voltage in question.*

If we express the above in relations of voltage, we can say that the simple a.v.c. system, as described, while not providing a perfectly flat response, is still effective because a change in detector output of from 10 to 20 volts, can be effective in changing the receiver sensitivity by a factor of as much as 40 db. This means that if the signal input voltage varies over a range of from 100 to 1, the detector output will only vary over a range of from 2 to 1. Thus, while we say that a perfectly flat response is not possible, we are still justified in saying that from the practical viewpoint, the a.v.c. circuit does afford substantially uniform output, irrespective of the variation in signal input.

Number of Controlled Tubes

If you examine Fig. 34, you will note that three tubes are controlled by the a.v.c. voltage. This does not necessarily mean that all superheterodyne receivers are similarly controlled. In some receivers of low sensitivity only one tube will receive the control voltage, while in other receivers of high sensitivity as many as four tubes or stages may be automatically controlled.

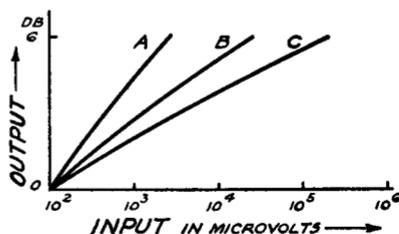
The reason for this variation is that there exists a relation between the number of tubes automatically controlled and the performance of the a.v.c. system with respect to the uniformity of output.

Suppose that we consider first a receiver in which only one tube is controlled. In this case a given increase in output, say a 6 db. change in output, which is the equivalent of a 2 to 1 voltage ratio from 10 to 20 volts, will be accompanied by a certain control voltage that will decrease the sensitivity of the receiver by a definite amount. . . . The exact amount depends upon how much the gain of the controlled stage is influenced by the increased

control voltage. Now, if in this same receiver two tubes instead of one are controlled, then the increased signal input required to produce the same 6 db. increase in output will have to be much greater. This is so because the sensitivity of the receiver is less than in the first case, as the gain of two tubes has been cut down.

What we mean is shown graphically in Fig. 35. This graph illustrates the range of input signals required from minimum to maximum in order to produce a 6 db. change in output or a 2 to 1 change in output voltage

Fig. 35. The three curves show how an a.v.c. system increases in effectiveness, in keeping the output constant, as the number of controlled tubes is increased. The curves A, B, and C are for 1, 2, and 3 controlled tubes respectively.



when one, two, and three tubes are controlled in a typical receiver. Note that with one tube controlled (curve A) with a simple a.v.c. system, a change in signal input of from 100 to 3000 microvolts will produce a change in audio output of 6 db. or a change in audio output equal to a voltage ratio of 2. However, if two tubes are controlled (curve B) an input of from 100 to 25,000 microvolts is required to produce the same change in audio output. On the other hand, if three tubes are controlled (curve C) a variation of from 100 to 200,000 microvolts is required to produce the same 6 db. change in output.

Effect of A.V.C. Selectivity Upon Tuning

Considering further the relations between the a.v.c. system and other parts of the receiver, we find that there is a definite connection between the tuning operation and the a.v.c. circuit selectivity. In spite of the fact that it is possible to use the same diode to perform the functions of both detection and a.v.c. rectification, a great many commercial receivers employ a separate tube to accomplish the latter function. One of the reasons for this practice is that a different degree of selectivity is desired in the source which supplies the a.v.c. voltage from that which supplies the second detector.

To investigate this condition we must consider the action which occurs in a receiver as it is slowly detuned from a signal. If both a.v.c. and second detector have the same selectivity, as is the case when the same rectifier is used to perform both func-

tions, then the following will occur: First, due to the fact that the receiver is slightly detuned, the signal output of the second detector will decrease. At the same time the a.v.c. control voltage will also decrease to the same extent as the signal level. However, a decrease in control voltage means that the receiver gain will be increased, so that the net effect which takes place when the receiver is detuned, is that the receiver output tends to remain the same. In other words, the decrease in output signal as a result of the set being detuned tends to be offset by an increase in receiver sensitivity—as the result of the decrease in a.v.c. control voltage. It is to be understood, of course, that this action occurs when the extent of the detuning is not so great that the signal disappears completely.

This action has a very undesirable effect upon the quality of reproduction, inasmuch as the receiver output in the neighborhood of the signal or carrier tends to remain about the same, the volume or audio level will likewise tend to remain the same despite the incorrect tuning of the receiver. The aural effect of such incorrect tuning is the loss of the lower audio frequencies and the apparent accentuation of the upper audio frequencies. In addition, although the receiver is detuned for the desired signal, it is correctly tuned for some other point near the signal, so that for the band of frequencies covered by the tuning position, the receiver is operating in a highly sensitive condition because of the low control voltage. This in turn means that the receiver will pick up whatever noise voltage is present in that area. We can derive three conclusions from the foregoing discussion. First, that with the simple a.v.c. system a fairly uniform output will be secured despite inaccurate tuning. Second, that inaccurate tuning results in the development of noise. Third, that such inaccurate tuning produces distortion.

A method which is used to overcome these undesirable effects is to decrease the selectivity of the a.v.c. control voltage by using a separate diode for a.v.c. rectification and supplying it with signal voltage from some point in the circuit ahead of the last i-f. winding. It is quite easy to see why this will result in improved tuning operation. When the receiver is detuned slightly from the signal, the receiver output will decrease in normal manner as the consequence of the selectivity action of the tuned circuits. However, the a.v.c. control voltage will not decrease as

rapidly as the output, because the selectivity of the circuit which supplies the a.v.c. rectifier tube is not so great as the selectivity of the circuit which supplies the second detector—consequently the control voltage remains substantially constant with small changes in tuning. It thus follows that *in spite of the detuning*, the desired signal will still maintain control and there will be comparatively little change in receiver sensitivity. In this manner the production of noise is minimized and the drop in volume, which occurs for small degrees of incorrect tuning, facilitates proper tuning.

The previous reference to reduced selectivity in the a.v.c. system should not be construed as meaning that very broad tuning is entirely satisfactory. Too little selectivity in the a.v.c. system will also result in improper operation of the receiver. When the desired signal being received is close to a much stronger signal, this stronger signal may take control of the a.v.c. action and so cut down the sensitivity of the receiver to a point where it is impossible to obtain the desired volume level on the weaker channel. In other words, if, although the receiver is tuned exactly to the weaker signal, the selectivity of the a.v.c. channel is so poor that the control voltage generated by the adjacent strong channel signal is sufficiently great to secure control, the sensitivity of the receiver will be materially reduced. The optimum degree of selectivity desirable in the circuit which feeds the a.v.c. rectifier is a design problem and is determined by a balance between the undesirable effects of too little selectivity and the equally undesirable effects of too much selectivity.

Separate A.V.C. Rectifier

An example of a circuit which employs a separate a.v.c. rectifier with reduced selectivity, is shown in Fig. 36. This circuit is a basic system and a great many variations of this arrangement are to be found, but in general it will serve as an example of the application of the arrangement. You will note that this circuit is similar to that shown in Fig. 34, with the exception that the a.v.c. voltage is obtained from a third winding, L3, on the last i-f. transformer, which is closely coupled to the primary *and which is untuned*. In this way the selectivity of the a.v.c. supply is made less than that of the second detector, which receives its

voltage through the sharply tuned secondary, L2. It might be well to repeat that the function of this circuit is to enable the desired signal to maintain control of the receiver sensitivity despite small amounts of detuning.

As you can readily see the remainder of the circuit shown in Fig. 36 is quite similar to that shown in Fig. 34, hence does not require detailed discussion. However, in addition to the method of using a third untuned winding to supply the a.v.c. rectifier,

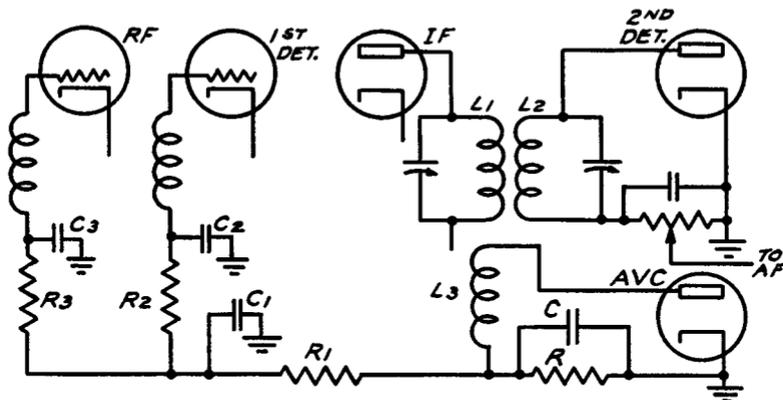


Fig. 36. In this circuit a separate a.v.c. rectifier is used to obtain reduced selectivity in the a.v.c. voltage. The untuned winding, L3, feeds the a.v.c. rectifier.

there are numerous other methods for coupling to the a.v.c. rectifier. Since most of these are used in connection with delayed a.v.c. systems, they will be discussed in a subsequent chapter.

Different Degrees of Control For Several Controlled Stages

It is often desirable to apply only a part of the total control voltage to one or more of the controlled tubes. Such a circuit is shown in Fig. 37. This circuit is similar to that shown in Fig. 34 with the exception that one of the i-f. tubes does not secure any automatic control bias and that different values of control voltage are distributed to the r-f., mixer, and the first i-f. amplifier. You should also note that in this instance the second detector also serves as the a.v.c. tube.

The diode load resistor in this case consists of a series combination of R1 and R2 and these two resistors function as a voltage divider, consisting of two 100,000-ohm resistors, but in accordance with what was previously said concerning voltage and polarity of the a.v.c. control voltage and shown in Figs. 26 and 27, it is evident that the full control voltage is distributed to the r-f. tube and to the first i-f. tube. The mixer tube secures its control voltage from the midpoint of the divider and since the two portions of the divider are of equal resistance, the voltage drop across R1 and R2 is the same. This means that the control voltage supplied to the mixer tube via R4 is equal to $\frac{1}{2}$ of the total control voltage developed across R1 and R2. The two .0001 mf. condensers, C1, serve to bypass the i-f. component in the rectifier output. The condensers C4, C5, and C6 serve as part of the filter system. The resistors R3, R4, and R5 are likewise part of the filter system.

It is also significant to note that each of the controlled tubes has effective upon it a fixed minimum bias which is secured by means of the cathode resistors R6, R7, and R8 and that the combined action of the fixed minimum bias and the control bias is as has been mentioned in connection with Figs. 28 and 29.

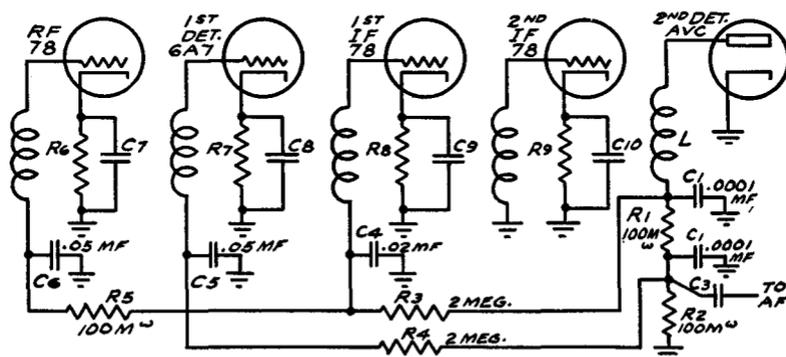


Fig. 37. Different amounts of control voltage are supplied to the several stages. The first detector receives but half the full control voltage and the second i-f. tube is not controlled at all.

At this time you are probably wondering about some of the apparent contradictions which appear in Fig. 37. To start with, we made the statement that the greater the number of tubes controlled in a receiver, the closer the approach to an ideal output characteristic. . . . Yet in Fig. 37 we show one of the i-f. tubes without any a.v.c. voltage. Then again we show that the mixer tube receives half the control voltage applied to the other tubes. While these circuit arrangements do exist, they are not neces-

sarily contradictions of what has been said, because they represent factors which have not as yet been discussed. As far as the second i-f. tube is concerned, it should be appreciated that this tube operates at a comparatively large signal input and it is, therefore, desirable that the tube be able to handle the greatly amplified signal without distortion. As a matter of fact, the signal input to this tube is appreciable even when a large control voltage exists and the receiver sensitivity is pulled down. This is so because this tube receives a signal after it has already been amplified by a number of preceding stages. If a control bias, supplementary to the fixed minimum bias, is applied to this tube, a possibility exists that distortion will develop when a strong signal is being received. It is for this reason that in many receivers very little, if any automatic control voltage is applied to the last i-f. tube—that is, when several i-f. stages of amplification are used.

As far as the mixer tube is concerned, the application of a control bias is found to have an appreciable effect on the noise level. Also, a certain amount of control is desirable to prevent the interference of strong signals with the operation of the oscillator. These considerations point to some degree of control for the mixer—not necessarily the same degree of control as is employed for some of the other stages.

Last, and by far not the least, is the factor of overall receiver sensitivity, which is an important consideration in determining how many tubes are to be controlled and the relative control voltage which each is to receive. We do not take it upon ourselves to stipulate that the various forms of control arrangements given in this book represent the ideal arrangements. As a matter of fact, each type of receiver produced by a manufacturer contains its own problems and there will be found a number of arrangements in these different receivers. However, the schematic diagrams which we include in this book on a.v.c., are offered as being typical of circuit arrangements. Modifications of these arrangements with respect to the number of tubes controlled and the magnitude of the control voltages comprise variations of a basic system.

a.v.c. control tube, which is still used as a rectifier, receives its excitation from the primary winding of the last i-f. transformer. This voltage is coupled to the grid of the a.v.c. rectifier through a small condenser and the grid is returned to the most negative point in the voltage supply through the grid resistor R2. The cathode of the control tube is connected directly to the junction of R3 and R4 on the voltage divider and the voltage drop across R4 supplies the necessary bias for the control rectifier. In other words, this tube functions as a biased rectifier. The plate of the control tube on the other hand returns directly to ground through the plate resistor R1. At first glance it may seem to you that there is no plate voltage on the a.v.c. tube, since its plate connects directly to ground. However, this is not so, because the a.v.c. tube cathode, as you see, is at a negative voltage with respect to the plate because the grounded end of the plate resistor R1 is positive with respect to R4. Because of this connection, the plate of the a.v.c. rectifier is positive with respect to its cathode. (For a full and complete discussion of such polarities, we suggest that you read "An Hour A Day With Rider On D-C. Voltage Distribution In Radio Receivers.)

In a typical circuit the voltage across R3-R4 is of the order of 100 volts and the drop across R4 supplies the grid bias. This bias is determined by the value which is necessary to cut the plate current of the control tube to zero. This means that with no signal the plate is at ground potential. . . . This is so because the plate current being cut off—there is no voltage drop across the plate load resistor R1. Knowing that the grids of the controlled tubes are returned to ground through the plate load resistor R1, it is apparent that the voltage at the plate of the a.v.c. tube is also the voltage applied to the grids of the controlled tubes. Thus, under conditions of no-signal input the automatic control voltage is zero and the normal minimum bias for the controlled tubes is, of course, obtained from the individual cathode resistors shown in the schematic.

When a signal is applied to a receiver so that after due amplification a voltage is impressed on the grid of the control tube through the small coupling condenser C, the plate current of the tube is caused to increase as a result of rectification and the greater the input signal to the receiver the greater is the plate current flowing in the control tube. . . . Now, when plate current

flows through R1, it means that a voltage drop will take place across R1. The greater the input signal into the control tube, the greater is the plate current through R1, the greater is the voltage drop across R1, and the more negative is the control tube plate with respect to ground, and, for that matter, with respect to the cathodes of the r-f., mixer, and i-f. tubes. The overall effect is to provide a suitable a.v.c. action.

The reason why the plate of the control tube is negative with respect to ground during the passage of a signal is, that as a consequence of the position of R1, the direction of current flow through this resistor is away from the ground and towards the plate. This makes the plate negative with respect to ground. . . .

While it is characteristic of the system of a.v.c. just described that a negative voltage, with respect to ground, be available, there is a slightly different circuit arrangement in use which does not require this. In this circuit, the arrangement of the circuit components is exactly as in Fig. 38, but the most negative point on the voltage supply system—the center tap of the power transformer—is grounded. The initial bias for the controlled tubes is obtained by connecting the cathodes to a suitable positive point on the voltage divider. We do not show a schematic of this type of system, because with the exception of the differences just mentioned, it is identical in arrangement and operation with the system just described. Incidentally, when making voltage measurements on such receivers, you should remember that the cathodes of the *controlled* tubes may be above ground by some 50 to 100 volts.

There are some receivers which use a screen grid tube of the 24, 57, or similar types as the control rectifier. The reason for the use of these tubes instead of a triode is that in some circuit arrangements the use of a tetrode or pentode furnishes a more desirable variation in the control voltage with respect to input signal so as to provide a more effective a.v.c. control.

Manual Volume Control in A.V.C. Circuits

In the simple a.v.c. systems considered up to this point, we take for granted that the function of the a.v.c. is to keep the input to the second detector constant and the control of overall volume is accomplished manually by means of an audio volume

control located between the second detector and the audio amplifier. In general, this is the method almost universally used for volume control—but there are some exceptions to this practice. The circuit shown in Fig. 39, which incidentally is a breakdown of the Kolster Models K-90 and K-92, is representative of such an exception. In this circuit the manual overall volume control is a part of the a.v.c. system and the control is accomplished by varying the operating conditions of the a.v.c. tube. You will note that there is no audio volume control in the usual sense, but that the volume control is the 15,000-ohm potentiometer R12, located in the voltage divider circuit.

Certain significant details are of interest in this breakdown diagram. In the first place, a part of the voltage divider is grounded and this ground is positive with respect to the most negative point in the system. Second, the plate of the a.v.c. tube is connected to ground through a 1-megohm resistor, but in view of the fact that the cathode is connected to a point of lower potential along the same divider, this places a positive voltage upon the plate of the a.v.c. tube. Third, the control grid bias is secured from the potentiometer, which provides for a variable negative bias and which enables the selection of any operating point by means of the adjustment of this potentiometer. Fourth, you will note that all the cathodes of the first and second r-f. tubes and the i-f. tube are connected to ground through R2. Fifth, the signal required to excite the a.v.c. tube is fed to the control grid of that tube from the primary winding of the second i-f. transformer through a .0005-mfd. condenser C4.

The operation of this system is best understood by considering two cases. First, we shall take the condition in which a constant signal is applied to the input of the receiver and examine the method by which volume is manually controlled. As a result of rectification in the a.v.c. tube, the plate current of the a.v.c. tube causes a voltage drop across the load resistor R18 and this voltage drop is distributed to the controlled tubes in the conventional manner. When plate current flows through the a.v.c. tube, the polarity of the voltage across R18 and the polarity of the fixed minimum bias across R2 are as indicated. Now you will note that the plus end of R18 and the minus end of R2 are common, which means that the voltage developed across R18 is in series with the voltage developed across R2 and the sum of these voltages becomes the total control bias. When there is no signal applied to the a.v.c. tube, the fixed minimum bias developed across R2 is applied to the controlled tubes.

Manual control over the volume level is accomplished by varying the

decreases and this decrease is communicated to the controlled tubes in the form of a decrease or reduction in the control bias. Because of this decreased control bias, the sensitivity of the receiver is raised automatically to compensate for the initial decrease in signal level. The above indicates the manner in which the a.v.c. action takes place when the signal input to the receiver decreases. As far as an increase in signal input is concerned, the action is similar except that it is in the reverse manner. By this we mean that if the signal input increases, the a.v.c. tube plate current increases—the voltage drop across R18 increases—the control grid bias increases and the net result is a reduction in sensitivity so that the output of the receiver is maintained constant.

So much for the simple type of a.v.c. system. We now are ready for the delayed a.v.c. combinations.

Chapter IV

DELAYED A.V.C. SYSTEMS

THE fact that the simple, conventional a.v.c. system, such as was described in the previous chapter, becomes effective with the weakest signals and thereby reduces the sensitivity of the receiver for such weak signals, was recognized as a disadvantage. The development which followed in order to overcome this defect was known as "delayed a.v.c." and if you recall, this subject did receive mention in the early part of this book. The reference was very meager and we are now going to discuss this subject in more detail and show how the delayed a.v.c. system, which today is commonplace in radio receivers, provides a more effective a.v.c. action without sacrificing the sensitivity of the receiver where it is most needed, i.e., for low values of input signal.

Fundamentally, the action of delayed a.v.c. systems depends upon the fact that the generation of the a.v.c. voltage—and naturally, the application of this a.v.c. voltage—is "delayed" until the input signal to the receiver reaches a certain predetermined value. As an illustration we can say that the ordinary conventional a.v.c. system will become operative and provide a.v.c. action when the input is 1 microvolt or more. The delayed system, however, will not become active or effective unless an input signal of, let us say, 50 microvolts is applied. In other words, in the latter case, the receiver, while responsive to all input signals ranging from 1 to 50 microvolts, will not be a.v.c.-controlled—thereby providing for maximum sensitivity over that band of signal levels which requires maximum sensitivity. These references to actual voltage values should not be construed as signifying that these are the specific values for receivers which employ delayed a.v.c. systems. It is purely a matter of design. Some

receivers will operate over these limits and others are so designed that the a.v.c. circuit functions at less than 50 microvolts input and still others at more than 50 microvolts input.

Referring again to the value of signal strength at which the a.v.c. starts to function, this voltage is known as the *threshold voltage*. For values of input signals below the threshold voltage the full sensitivity of the receiver is available and the only bias which exists upon the control grids of the controlled tubes is the fixed minimum residual bias developed by one or more arrangements—usually by means of cathode bias resistance. However, as soon as the input signal rises above the threshold voltage, the a.v.c. begins to function and the gain is effectively controlled so as to provide an essentially constant output.

This action is illustrated graphically in Fig. 40, in which is shown the relative performance of a receiver which incorporates

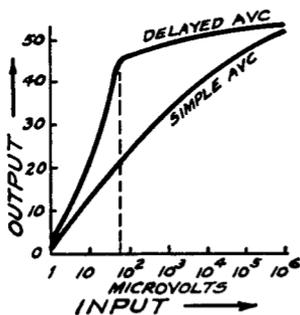


Fig. 40. These two curves show the difference between simple and delayed a.v.c. It should be noticed that delayed a.v.c. in a circuit provides greater sensitivity for low input signals and an output that is more uniform at the higher signal levels.

a simple a.v.c. system as against one which incorporates a delayed a.v.c. system. In this graph the voltage output of the second detector is plotted against the input signal, expressed in microvolts. Let us consider first the curve which represents the performance of the simple a.v.c. system. The effect of the control voltage in cutting down the maximum voltage output for weak signals is apparent. You will observe further that the output of the receiver is appreciably below a desirable value until the input signal reaches a value of the order of 40 or 50 microvolts.

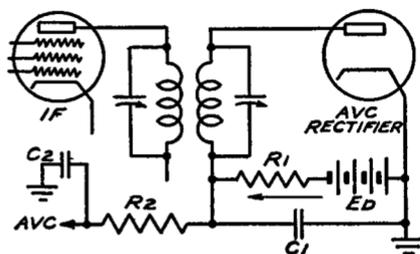
The other curve shows clearly the improved performance which is obtainable by means of the delay action. Note the steep rise in output for input signals up to approximately 85

microvolts, at which point the a.v.c. action begins. This is the threshold voltage for the system in question and the vertical dotted line indicates the location of this value of threshold voltage. With this vertical dotted line as the reference line, it is interesting to note that for voltages below 85 microvolts the output with the delayed a.v.c. system is appreciably greater than with the simple a.v.c. system. Furthermore, the output from the delayed system with an input of approximately 10 microvolts is as great as that available with the ordinary system, when the input is 80 microvolts or 8 times as much. As is evident, both systems provide comparable output when the input signal is approximately 1,000,000 microvolts or 1 volt. It is, therefore, evident that the delayed a.v.c. system provides the required increase in sensitivity at those points where it is most desired—namely, at the low values of input signal. It is also significant to note that for input values above the threshold voltage, the output characteristic with the delayed a.v.c. system is a closer approach to the ideal flat curve than that which is available with the simple a.v.c. system.

Action of Delayed Rectifier

The circuit which is by far the one most commonly used in delayed a.v.c. receivers, is basically similar to that shown in Fig. 41. You will note that a negative voltage is introduced in

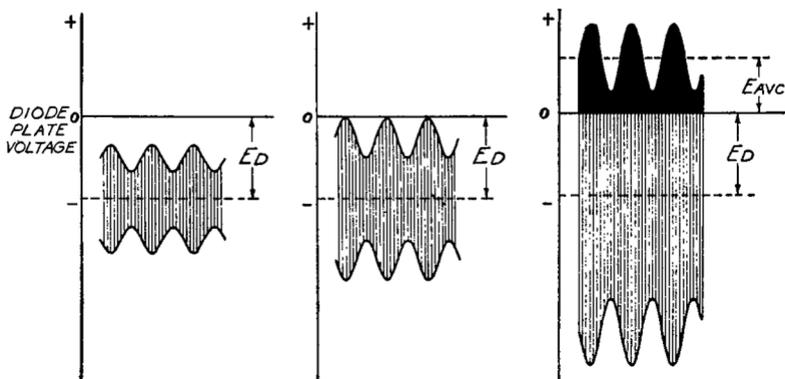
Fig. 41. The basic elements of a circuit that is widely used to obtain delayed a.v.c. action. The bias E_D prevents the rectifier from producing a control voltage until the input signal reaches a certain level.



series with the rectifier load. The direction of this voltage is such that with no signal input the plate of the a.v.c. rectifier is negative by the amount of the voltage E_D , and since the plate is negative with respect to the cathode, no current can flow in the diode circuit. However, when a signal is applied and the peak value of this signal voltage exceeds the value of the delay voltage

E_D , then the plate will become positive with respect to the cathode—rectification will occur, and current will flow in the diode circuit in the direction indicated in Fig. 41.

The conditions under which delayed a.v.c. rectifiers operate are clearly shown in Figs. 42, 43 and 44. Fig. 42 illustrates the action when the peak value of the i-f. input to the a.v.c. rectifier is less than the value of the delay voltage. This input signal volt-



Figs. 42, 43, and 44, left to right. The left-hand waveform shows the action in a delayed rectifier when the peak value of the i-f. input to the a.v.c. rectifier is less than the delay voltage. Fig. 43 shows the peak value of the i-f. input equal to the delay voltage, and Fig. 44 shows the i-f. input greater than the delay voltage. The blackened area of the latter represents the intervals when the diode passes current.

age is represented by the modulated wave which is drawn superimposed on the delay voltage E_D . It follows, from the figure, that the actual voltage at the plate of the a.v.c. rectifier fluctuates between a maximum and a minimum value, as indicated on the diagram, but that at no time does the plate attain a positive potential with respect to the cathode.

As Fig. 43 shows, this condition still holds true when the signal is increased so that the peak value of the modulated wave is equal to the delay voltage. Although the signal does cause the plate voltage to rise to the point where the effect of the delay is overcome, no plate current flows since this is only sufficient to raise the plate voltage from a negative value, E_D , to zero.

However, if the input signal is still further increased, as shown in Fig. 44, then during the positive swing of the signal the diode

plate becomes positive with respect to the cathode and current flows through the diode load R_L . The intervals during which current flows is indicated by the blackened area in Fig. 44. The average flow of current which results in the diode load R_L , as a result of this pulsating current, causes an average value of d-c. voltage drop, which is indicated by the horizontal, dashed line above the zero voltage axis. It is this voltage drop which is distributed to the several controlled tubes in the circuit and which acts as the control voltage.

Separate Detector and A.V.C. Rectifier Necessary for D.A.V.C.

In view of the delayed action of the d.a.v.c. rectifier, this tube cannot be used to perform both the functions of a.v.c. and detection. First, because the d.a.v.c. rectifier does not begin to function until the signal reaches a certain value—hence there would

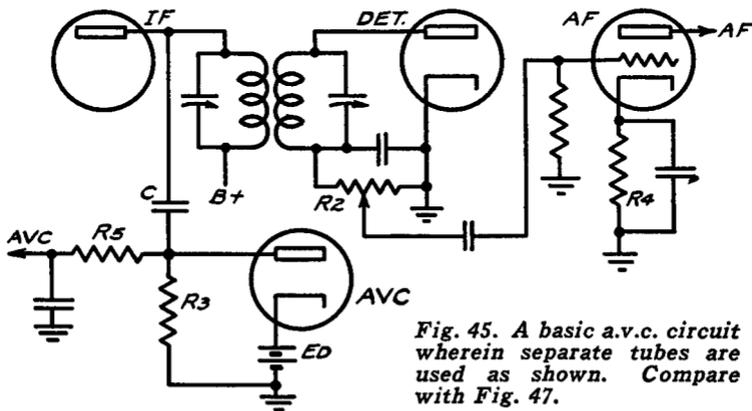


Fig. 45. A basic a.v.c. circuit wherein separate tubes are used as shown. Compare with Fig. 47.

be no output with low input signal. Second, the output of the d.a.v.c. rectifier is distorted under some conditions—particularly when the signal carrier is 100% modulated, which is a commonplace condition in modern transmission. Accordingly, in order to secure proper delay action and an undistorted audio signal, two distinct and separate rectifier tubes must be used to function as the detector and a.v.c. rectifier, respectively.

A typical delayed a.v.c. circuit, which incorporates the principles previously discussed, is shown in Fig. 45. The four sep-

arate tubes function as the i-f. amplifier, second detector, d.a.v.c. and first audio amplifier. The operation of the second detector and audio amplifier tubes, being of conventional nature, require no special discussion. However, examining the a.v.c. circuit, you will note that the a.v.c. rectifier tube is coupled to the primary of the last i-f. transformer through a small condenser C. The load resistor for the a.v.c. diode is the resistor R3. In other words, the signal voltage, which is responsible for the flow of rectified current in the diode circuit, is developed across R3 and, in addition, the d-c. voltage drop, due to the presence of rectified current—which voltage serves as the control voltage, also is developed across the same resistor. *It is for this reason that the customary bypass condenser across the a.v.c. diode load is omitted in this case.* If such a condenser were used—as in the case of the combination a.v.c. and detector, then it would be impossible for the diode to function, since this condenser would act to bypass the i-f. signal.

Another very significant detail present in Fig. 45 is the bias or delay voltage E_D , which is inserted in series with the cathode and R3. This delay voltage places the plate of the a.v.c. rectifier at a negative potential, so that, as previously explained, rectification does not take place until the peak value of the i-f. input signal is greater than the value of the delay voltage. The resulting control voltage is distributed to the controlled tubes in the regular manner through the first filter resistor R5.

As regards the method of coupling to the audio amplifier system, you will note that the demodulated voltage is taken off the detector diode load R2 and fed into the grid of the first audio tube. The bias voltage for the first a-f. stage is secured by means of the cathode resistor R4, which is bypassed with a large condenser to prevent degenerative effects.

Referring once more to the delay voltage, the battery, as shown in Fig. 45, is used to simplify the schematic. As a rule, this voltage is secured from some portion in the receiver as, for example, the cathode bias resistor, a section of the voltage divider, or some other point in the receiver which has across its terminals a voltage equal to that required for the delay action. Examples of such arrangements will appear during the subsequent discussion. As a matter of fact, one illustration of the use

of the voltage developed across a separate cathode bias resistor, as the delay voltage, is shown in Fig. 47.

Multi-Unit. Tubes

If you examine the detector, d.a.v.c., and first audio systems in Fig. 45, you will observe that three tubes are used to perform these three functions. We have included the a-f. amplifier stage in this discussion because of the fact that the combined gain of the diode detector and first audio stage is approximately equal to the gain of an ordinary triode detector. It is for this reason that the use of a diode detector is almost always accompanied by an additional audio stage so as to make up for the lack of gain in the diode detector.

While it is true that three tubes are shown and each of these tubes has an individual function, the development of tubes of the multi-unit type, which incorporate more than one tube within a single glass or metal envelope, has made possible the design of delayed a.v.c. systems without an increase in the number of tubes required to do the full job. Although there are a great many types of multi-unit tubes, the two which are of greatest interest to us at the moment are the duplex-diode triode and the duplex-diode pentode types—both of which are widely used in a.v.c. systems. The arrangement of the elements in these two tubes is shown in Fig. 46. You will note that the former type,

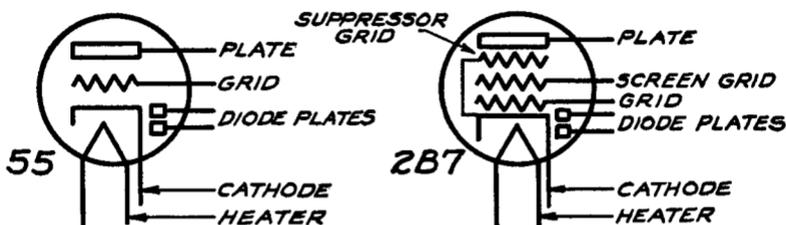


Fig. 46. The arrangement of the elements in the duplex-diode triode, left, and in the duplex-diode pentode tubes. These are widely used in a.v.c. equipped sets.

of which the 55 is an example, consists of two diode units and a triode unit—all of which have a common cathode. The duplex-diode pentode type, of which the 2B7 is an example, consists of two diode units and a pentode unit with a cathode common to all.

These types of tubes are used in a wide variety of circuits, as we shall show in the latter part of this book. At this time we show how the circuit of Fig. 45 with the three separate tubes can be duplicated with a single tube of the 55 type. The revised circuit is shown in Fig. 47.

One of the two diodes (D1) is used for detection. The proper operation of the diode detector is accomplished by returning the detector load resistor R3 directly to the cathode. As is evident, this circuit arrangement differs from that shown in Fig. 45—in that if the resistor R3 in Fig. 47 is returned to ground, as in Fig.

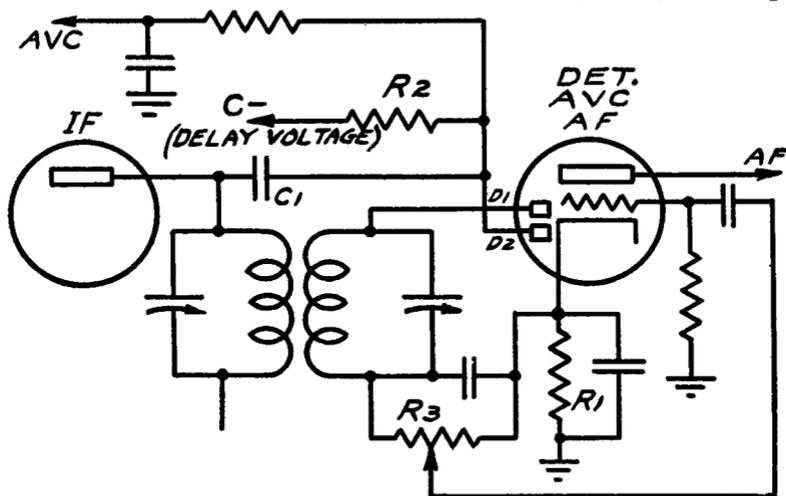


Fig. 47. A duplex-diode triode is employed here as a detector, delayed a.v.c. rectifier, and first a.f. amplifier. Compare with the circuit of Fig. 45, wherein there are separate tubes used for each function.

45, an undesired delay action will be obtained in the detector circuit. As far as the d.a.v.c. rectifier is concerned, the second diode D2 and the common cathode are used. The d.a.v.c. rectifier load resistor is identified as R2 and by returning this to the proper negative point in the receiver system—which may be some point along the voltage divider used in the power supply—the correct value of delay voltage is secured. If you can visualize such a condition, a certain value of delay voltage can be secured in Fig. 47 by connecting the negative side of R2 to ground, which would place the diode D2 at a negative potential with respect to its associated cathode by a value equal to the voltage drop across R1.

ground. This means that the diode plate D1 is 3 volts negative with respect to the cathode and a delay voltage of 3 volts exists upon the a.v.c. diode. Expressed in another manner, this means that the plate D1 does not begin to draw current until the peak value of the signal applied to the a.v.c. circuit is more than 3 volts. On the other hand, the detector diode D2 is returned directly to the cathode through R1 and R2—consequently no delay voltage is introduced in the detector circuit.

Double-Diode Delayed A.V.C. Used in Some RCA Receivers

A form of delayed a.v.c., which is of much interest to us because it is widely used in many RCA receivers manufactured in 1936, is shown in Fig. 49. This circuit, as you will note by

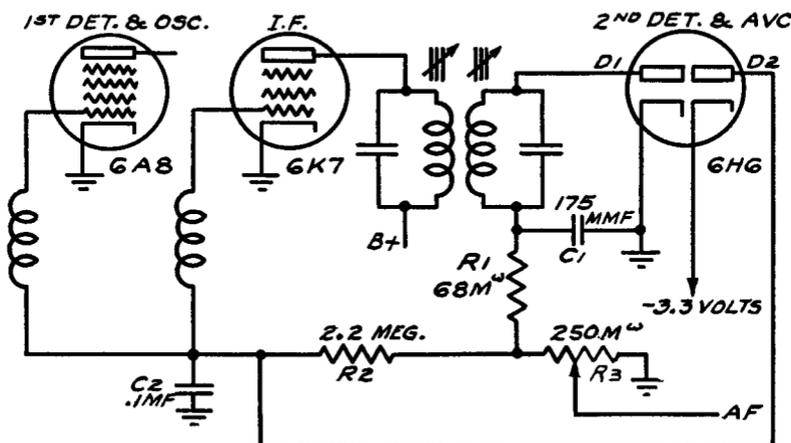


Fig. 49. In addition to the a.v.c. action being delayed, the cathodes of the controlled tubes are grounded and the minimum bias is obtained through the use of the auxiliary diode D2. Compare with Figs. 50, 51, and 52.

reference to the schematic, incorporates some novel features, which differ considerably from the circuits we have previously shown. The most striking feature is that the minimum bias for the controlled tubes is obtained through the a.v.c. feed line in addition to a delayed type of action.

Referring to Fig. 49, a 6HG tube is used as a combined detector and a.v.c. tube. (This tube contains two diode elements within a single envelope, each with its separate cathode and plate connections). D1 is the detector and regular a.v.c. diode, and its load resistor consists of R1 and

R3. D2 is the auxiliary diode. C2 and R2 constitute the a.v.c. filter network through which the control voltage is fed to the first detector and i-f. stages. The cathodes of these tubes are grounded. The cathode of the auxiliary diode D2 in the 6H6 tube is connected to a point on the voltage divider which is 3.3 volts negative with respect to ground. The plate of this same diode is connected to the junction of R2 and C2, that is, to the output of the a.v.c. filter. These facts are quite significant with respect to the operation of the circuit.

To indicate most clearly the manner in which the circuit functions, we deem it most convenient to break down the diagram of Fig. 49 into that shown in Fig. 50. For the sake of simplicity, the two diodes composing the 6H6 are shown in separate envelopes. If you will refer to the schematic, you will note that diode D2, in series with a battery of 3.3 volts, is

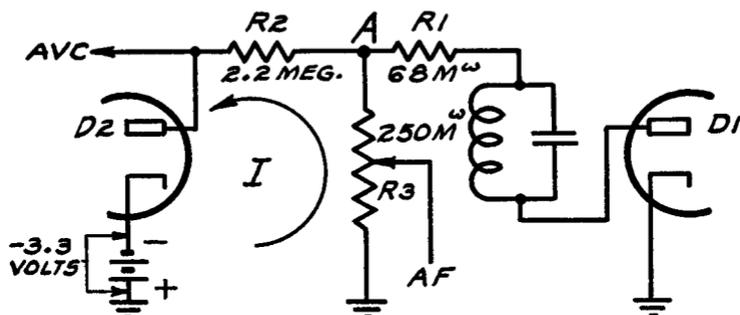


Fig. 50. A breakdown of Fig. 49. The minimum bias voltage (3.3 volts) is fed to the a.v.c. bus through diode D2. The current, I , flows through D2, R2, and R3, and is due to the negative voltage on the cathode, which is represented by the battery.

shunted across the output of the a.v.c. filter. The bias battery is used to simulate the voltage previously referred to as being available from the voltage divider as the result of the connection of the cathode associated with the D2 diode plate.

With no input signal to the receiver, no voltage is developed across the diode load resistors R1 and R3, because no rectified current is flowing through these units. Consequently, the only voltage present in the circuit is the 3.3 volts minus on the cathode of D2. Under this condition of no input signal, a current flow, as indicated in Fig. 50, will take place. This current I is established because the cathode of the diode D2 is negative with respect to its plate—and this is really the equivalent of stating that diode plate D2 is positive with respect to its cathode. . . . Under these conditions, the diode will pass current. Furthermore, since the internal resistance of D2 is very small in comparison with the load resistance, which is in this case more than 2 megohms—there is practically no internal drop across the diode. In effect, this means that the plate D2 is 3.3 volts negative with respect to ground, and as the result of the connection between

D2 and the a.v.c. feed line—the control grids of the mixer and i-f. tubes are 3.3 volts negative with respect to ground. Under the condition of no input signal, the control bias on the controlled tubes, therefore, is the required minimum bias of 3.3 volts negative.

What happens when a signal is applied to the receiver? . . . In the first place, as a result of the rectifying action of the diode D1, a voltage will be present across R3—naturally across R1 as well, but this is not of interest to us at this time. The polarity of this voltage is such that the grounded end of R3 is positive and the junction point between R1 and R3 is negative. The greater the value of the input signal, the greater will be the voltage drop across R3, and the greater will be the negative potential with respect to ground at point A. Since the diode D2 is joined to point A by means of R2, a negative voltage will be applied to this diode and if this negative voltage equals 3.3 volts or becomes more than 3.3 volts, conduction through the diode ceases and, in effect, the diode is no longer present. Under this condition, the current I is, of course, reduced to zero, since the two voltages balance each other. However, the negative voltage supplied to the grids of the controlled tubes is still 3.3 volts.

If the input signal is increased so that the voltage generated across the rectifier load R3 is more than 3.3 volts, a definite change in the mode of operation of the circuit takes place. For one thing, the plate D2 now becomes negative with respect to its cathode, so that no current can flow through the diode D2. As far as operation of the circuit for signal voltages which produce a rectified voltage of more than 3.3 volts across R3 is concerned, we can remove D2 from the circuit since it effectively does not take part in the circuit operation. A simplified version of the circuit when D2 is removed is shown in Fig. 51, and it is important that you understand that this circuit applies only for those cases when the applied input signal is such that the rectified control voltage developed in the detector circuit—that is, the diode D1—is greater than 3.3 volts. With D2 out of the way, the circuit becomes conventional and its operation is similar to that of a receiver which employs an ordinary combined detector and a.v.c. rectifier.

For large values of input signal, the control voltage is fed to the control grids of the controlled tubes through the filter resistor R2 in the conventional manner. The curve shown in Fig. 52 summarizes the action we have just described. In this figure you will note that the control voltage, that is, the a.v.c. voltage, produced at the junction of R2 and C2, is plotted against the input signal to the receiver. For values of input signal up to the threshold voltage, the minimum bias applied to the controlled tubes remains substantially constant at 3.3 volts negative, and there is really no a.v.c. action. For signal voltages above the threshold voltage, the a.v.c. action begins to take place, as indicated by the rise in control voltage.

Perhaps you have wondered at the use of the term “threshold voltage” in connection with the operation of this type of a.v.c. system. You will recall that we introduced this term in connection with the explanation of delayed a.v.c. systems to designate

the signal voltage at which the a.v.c. system begins to function. Although we have not indicated it in so many words, the system which we have just described is essentially an a.v.c. arrangement of the delayed type. This much is evident from the curve in Fig. 52, which shows that a.v.c. action does not take place until the signal input reaches a certain predetermined value. From

Fig. 51, right. Action of the circuit of Fig. 49 at medium and high signal levels. The diode D2 has been omitted as it does not function at the higher signal levels where the voltage developed across the 2nd detector load is more than 3.3 volts.

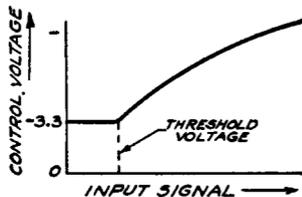
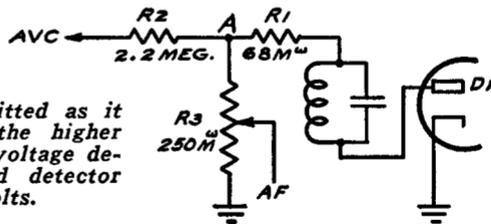


Fig. 52, left. This curve shows the variation of the control voltage with input signal. The control voltage remains at the minimum bias level (3.3 volts) until the threshold voltage is exceeded.

the previous analysis we know that this threshold signal is that input signal which will produce a voltage of 3.3 volts across the rectifier load R3.

Amplified Delayed A.V.C.

Another interesting type of delayed a.v.c. is used in a number of Sears-Roebuck (Silver-tone) receivers. This circuit is of interest because it differs basically from the delayed a.v.c. systems, which have previously been described. If you refer to Fig. 53 you will note that the signal is coupled to the diode D1 of the 6B7 through the small coupling condenser C1. The capacity of this condenser is 25 mmfd. The diode D1 in the schematic functions as a straight rectifier, and its load resistor R1 is returned directly to the cathode, hence there is no delay voltage in this circuit. The rectified voltage produced across R1 is fed to the grid of the pentode section of the 6B7 through the resistive capacitive filter composed of R2 and C2. Inasmuch as the screen

and plate of the pentode portion are tied together and connected to the positive side of the power supply, this part of the tube functions as a triode rather than as a pentode. The cathode of the tube is connected to the center-tap of the high-voltage winding through a 50,000-ohm resistor. Since the speaker field is in

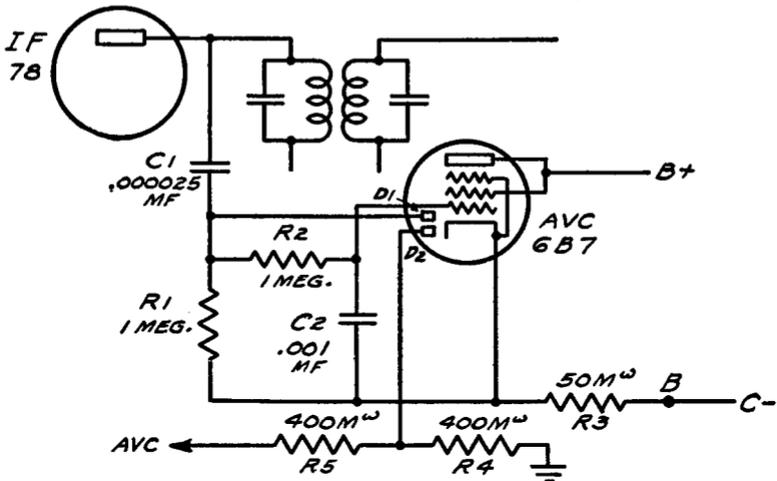


Fig. 53. A type of amplified, delayed a.v.c. The pentode section of the 6B7 (used as a triode) functions as a d-c. amplifier to vary the voltage at the cathode. This negative voltage at the cathode is fed to the controlled tubes through R5.

the negative leg of the power supply (not shown in the figure) it follows that the "B" end of R3 is at all times negative with respect to ground. The plate of the second diode D2 is connected to ground through the 400,000-ohm resistor R4 and at the same time the a.v.c. voltage is taken off through another 400,000-ohm filter resistor R5.

Let us now analyze the action which takes place under varying conditions of input signal. When the incoming signal is very small, the voltage impressed across D1 is also small with the result that only a small amount of negative voltage is fed over to the grid of the pentode section through R2. This small amount of bias results in a comparatively high value of plate current flow through the cathode resistor R3 and the circuit constants are so chosen that the voltage at the cathode is positive under these conditions of large plate current. How does this positive voltage on the cathode affect the operation of diode D2? Well, in the first place, since the diode plate D2 is grounded through R4, you can readily see that

no plate current can flow in this diode circuit through R4 so that there is no voltage drop across R4. This in turn means that there will be no control voltage fed over to the controlled tubes through R5 under these conditions of low signal input.

We see then that under conditions of little or no input signal the diode D2 does not draw current. However, as the input signal to the receiver is increased, the following changes in the circuit conditions take place. First of all the increased signal applied to D1 results in an increased value of rectified voltage fed across R1, which in turn means that the bias of the pentode section is increased. The increased bias on the control grid of the pentode (used as a triode, of course), acts to decrease the value of plate current and this in turn decreases the voltage drop across R3. We have previously observed that the greater the value of plate current through R3, the more positive will the cathode of the 6B7 become. It thus follows that the effect of the *decreased* value of plate current under conditions of comparatively large values of input signal is to make the cathode less positive, or, if you like, more negative. We see then that larger values of input signal result in smaller values of plate current which make the cathode more negative. Thus, as the input signal is increased starting from a small value, the potential or voltage at the cathode also decreases and finally a point is reached where the voltage at the cathode becomes zero. This is the critical value of signal input at which the diode D2 begins to function. For input signals beyond this threshold value, the cathode of the tube becomes more and more negative so that increased values of current flow through the resistor R4. Furthermore, the direction of this current is such that the ungrounded end of R4 becomes negative. It is this negative voltage developed across R4, which serves as the automatic control voltage, and which is distributed to the several controlled tubes through the filter resistor R5.

We might observe that the operation of the circuit just described is really a form of amplified delayed a.v.c. This is true because the initial rectified voltage which is available across R1—the load of the first rectifier D1—is impressed on the grid of the triode and amplified within the triode before it is applied to the controlled tubes. We might further point out that the full amplification of the triode is utilized, since the voltage which appears across R4, is essentially the same as the change in voltage which appears across the cathode resistor R3. As you have no doubt noticed by this time, the plate load for the triode section of the tube is not directly in the plate circuit of the tube, but rather is the resistor R3 located between the cathode and the secondary center-tap on the power transformer. Thus the plate voltage of the tube remains constant for changes in grid voltage and instead the voltage at the cathode fluctuates in accordance

with the grid bias changes. In a later part of this book we shall have occasion to take up some of the troubles which are peculiar to systems of this and other types and to indicate the symptoms associated with defects in various parts of the circuit.

Delayed A.V.C. and Automatic Delay Amplifier

In contrast to the type of a.v.c. system just described, we find a different type, in which amplification is used—but for a different purpose. In the system now under discussion there is no amplification used for the a.v.c. voltage, but instead, the delay voltage is obtained through a stage of amplification and is automatically varied in accordance with the signal level. This is saying a great deal.

In Figure 54 we show that part of the complete circuit of the 1936 model Motorola Golden Voice receiver, which is of interest to us. Upon examination of the circuit you will find that the signal is applied to the diode section of the duo-diode triode 6R7 through the small coupling condenser C2. The load for the two diodes which are connected in parallel consists of R3 and R4. Two additional significant details are evident in the schematic. The first is that the cathode of the 6R7 is grounded through the bias resistor R6. Second, the control grid of the triode portion of the 6R7 tube is connected in such manner that it receives the full a.v.c. control voltage.

Why these unusual circuit connections? What is the purpose of R6? To answer these questions we must investigate the relation between the voltage drop across R6 and the operation of the a.v.c. rectifier. If we assume that the voltage drop across R6 is zero, then the a.v.c. rectifier composed of the two diodes and its associate cathode will function as an ordinary rectifier without any delay voltage. On the other hand, if a voltage drop exists across R6 then the diode section will function as a delayed a.v.c. rectifier,—the delay voltage being that developed across R6.

If we assume for the moment a fixed value of voltage drop across R6, the action of the circuit is substantially similar to that of the basic delayed a.v.c. system described earlier in this text. However—there is a departure from conventionality in the present circuit. This departure is *that the delay voltage is not kept at a fixed value, but the control is varied automatically in accordance with the size of the input signal to the receiver.* Let us see how this is done. When there is no input signal no voltage can be developed across the a.v.c. rectifier load. This means no voltage across R3 and R4—hence the control grid of the triode section as the consequence of its connections to R5, R3 and R4—is at ground potential. During this condition of zero voltage on the control grid of the triode, it stands to reason that the plate current of the triode is high and since the

plate current flows through R6, the voltage across the cathode resistor R6 will be correspondingly high.

What is the effect of this condition? We stated that a positive value of voltage on the cathode means a delay voltage in the diode circuit because the diode load is returned to ground and not to the cathode—hence the diode plate is negative with respect to its cathode. It therefore stands to reason that for conditions

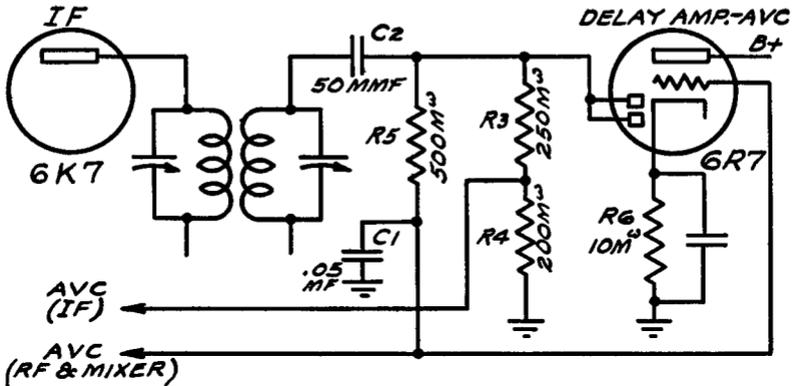


Fig. 54. A system of delayed a.v.c. used in the Motorola Golden Voice receiver in which the delay voltage is amplified and automatically controlled.

of no input signal, there is a large value of delay voltage and the a.v.c. rectifier does not function to supply a control voltage to the controlled tubes. As a matter of fact this same condition prevails for low values of input signal.

What changes take place as the input signal to the receiver is increased? In the first place, as the input signal is increased a value of signal strength will finally be reached when the signal voltage across the a.v.c. rectifier is sufficient to overcome the delay voltage due to the drop across the cathode resistor R6. Rectification will take place and a control voltage will be available across R3 and R4. As the input signal is increased beyond this value, we see the effect which the connection of the triode grid to the a.v.c. line has upon the mode of operation of the circuit. Since the grid is connected to the a.v.c. bus, it follows that when the input signal is increased beyond the threshold value, the control voltage across R3 and R4 is equivalent to a negative

bias, which is applied to the control grid of the triode and as the consequence of this negative voltage upon the grid of the triode, the plate current of the triode section decreases. This decreased value of plate current flowing through R6 makes the cathode of the 6R7 less positive with respect to ground and in this way lowers the delay voltage which is applied to the diode plates.

We see, then, that for increasing values of input signal, the delay voltage, which was effective in making available the full sensitivity of the receiver for weak signals, is removed. The extent to which the delay voltage is decreased becomes greater—the greater the value of input signal. It remains for us to explain why this automatic variation of the delay voltage in accordance with the signal input is desirable. We need hardly comment upon the desirability of a delay voltage for weak values of signal input. But, why it should be desirable to remove the delay voltage as the signal input is increased beyond the threshold voltage is not quite so apparent. There are several reasons why this action is desirable. In the first place, once the threshold signal has been passed, the delay voltage has served its function of preventing a decrease in the weak signal sensitivity of the receiver. Furthermore, you will recall that we previously discussed the effect of delayed a.v.c. in producing distortion at high percentages of modulation and while we stated that the effect was not pronounced in properly designed delayed a.v.c. systems, at the same time the system just described, by removing the delay voltage for increasing values of input signal, minimizes this effect. In addition to reducing the distortion characteristic of delayed a.v.c. systems, the system just described is, on the whole, productive of a flatter response curve than a simple type of delayed a.v.c. since, for the larger values of input signal, the full output of the rectifier is made available as a result of the removal of the delay voltage.

Chapter V

NOISE SUPPRESSION OR QUIET A.V.C. SYSTEMS

IN THE first chapter of this book, we described in general terms, the desirability for a system of a.v.c. which would prevent excessive noise when tuning between stations, and which would reduce the receiver output to zero whenever the signal strength of the received signal was so low as to prohibit satisfactory reception—with respect to signal-noise ratio. . . . Such is quiet a.v.c.—also known by several other descriptive titles.

Having previously discussed the general features of quiet a.v.c. systems, we now want to go into somewhat more detail concerning the more widely used methods for blocking the receiver whenever the signal input falls below a predetermined value—which is generally described as the *squelch level*. In general, this blocking of the receiver can be accomplished in many ways. . . . Any one of the several channels through which the signal passes before it reaches the speaker can be acted upon by a control voltage to prevent the receiver from functioning. . . . For example, in some quiet a.v.c. systems, the last intermediate-frequency amplifying stage is blocked, whereas in other systems, this blocking voltage is applied to the first audio stage. In still other systems, blocking can be accomplished by preventing rectification of the modulated i-f. signal in the second detector tube.

Second Detector Q.A.V.C. Systems

Perhaps the simplest type of quiet a.v.c. to comprehend is that type stated in the heading of this paragraph—namely, the type which depends for its action upon the blocking of the second detector whenever the input signal falls below a pre-established

value. This system is used in a considerable number of receivers and, on the whole, finds its greatest application in auto radio receivers—but it should be understood that it is not necessarily limited to such receivers. Furthermore, a number of variations of this circuit arrangement are to be found and some of these variations will be described in the pages which follow.

The basic circuit, which is characteristic of quiet a.v.c. systems of the blocked second detector type, is shown in Fig. 55. The circuit as shown has been stripped of all of its non-essentials and for this reason appears to contain but few components.

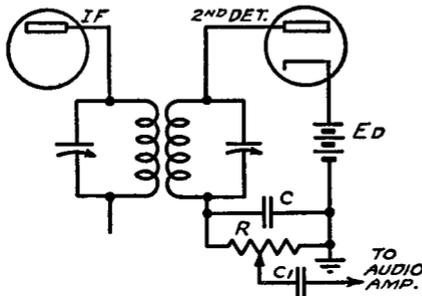


Fig. 55. The partial schematic at the left is the basic circuit of noise suppression systems, which function by means of a delay voltage, E_D , in series with the diode of the second detector.

However, you will observe that the circuit is similar in character to that which has been illustrated as being typical of a delayed a.v.c. circuit. The signal from the last i-f. stage is fed to the second detector and a voltage, designated as E_D , is inserted in series with the cathode. The effect of such a voltage in series with a rectifier circuit, and with the cathode made positive with respect to ground or its plate, has been previously discussed in connection with the explanation of delayed a.v.c. action. However, in this case, the purpose of the delay voltage is contrary to that intended in a delayed a.v.c. system. Here, the purpose of the voltage is to prevent rectification of signals *until the input signal voltage exceeds the value of this delay voltage*. You will recall that in connection with delayed a.v.c., the function of delay voltage was to prevent the development of an a.v.c. control voltage until the received signal was greater than a certain predetermined value. Rectification, on the other hand, was accomplished by another tube and an output signal was at all times available. In this case, however,—there being no rectification until the input signal is greater than a predetermined value—the

receiver is quiet, or silent, until a signal of proper value is tuned in. The magnitude of the required signal is slightly greater than that of the delay voltage. In arrangements of this type, the tube is generally utilized solely for the purpose of detection and a.v.c. control voltage is generated by some other means. The value of the voltage E_D is, therefore, the factor which permits the choice of the minimum signal level at which the receiver will operate.

In view of the usual importance of sensitivity, you will be tempted to say that such a circuit arrangement will tend to lower the sensitivity of a receiver since it becomes impossible to obtain any output until the input signal reaches an appreciably high value so as to overcome the delay voltage. This is correct, except for one fact—namely, that the design of the usual receiver is such that the delay action is not experienced with the normal run of signals—even weak signals, because the amplification available between the antenna and the second detector is such as to provide a reasonably strong input into the second detector and thereby overcome the delay voltage. However, since it is possible that extremely weak signals of unsatisfactory value may be tuned in, the q.a.v.c. system provides freedom from noise during such time. These items are points of interest in connection with design rather than service work. Consequently, we do not deem it necessary to go into a detailed discussion concerning the effect of the second detector delay voltage upon sensitivity or distortion.

Delayed Second Detector Circuit in Atwater Kent 776

An example of the basic circuit shown in Fig. 55 is illustrated in commercial form in Fig. 56, which is a schematic of the second detector and a.v.c. system used in the Atwater Kent 776 receiver. You will note that the circuit employs a duplex-diode triode tube to perform the functions of delayed a.v.c., delayed second detection and audio amplification. Considering the delayed a.v.c. circuit first, D1 is used as the a.v.c. diode and the diode load is the resistor R1. The a.v.c. voltage is distributed to the controlled tubes through the filter network composed of R2 and C2. As to the delayed a.v.c. action, the a.v.c. delay voltage is that which is developed across R3 and R4 in series. Inasmuch as these re-

will begin to function. If the signal supplied to the D2 diode is less than 6 volts, there will be no audio output. This is the contrast to the fact that the a.v.c. action does not begin until a signal input of approximately 12 volts is applied. Thus in between the squelch signal level and the a.v.c. threshold voltage level, there is no a.v.c. action.

Optional Quiet A.V.C. in Stromberg Model 33-A

In Fig. 55 we showed the rectifier delay voltage as being secured from a battery. In Fig. 56 we showed this rectifier delay

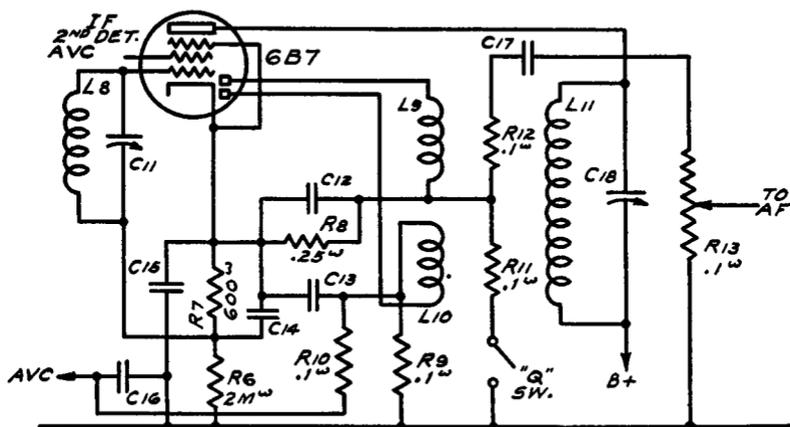


Fig. 57. The delay voltage of this "Q" circuit is introduced in the detector circuit when the "Q" switch is closed, by means of the voltage drop across R8.

voltage as being secured by means of the voltage drop across the cathode bias resistor. Another arrangement, and one which provides for optional quiet a.v.c., is shown in Fig. 57. This is a partial schematic of a Stromberg Carlson 33-A auto receiver. While the previous systems described did not incorporate a manual adjustment for permitting a choice of quiet or conventional a.v.c., you will note that the circuit shown in Fig. 57 is equipped with what is designated as a "Q" switch, which permits either ordinary a.v.c. or quiet a.v.c., depending upon whether the "Q" switch is open or closed.

Let us examine the general circuit arrangement. The pentode section of the 6B7 functions as the i-f. amplifier, and the i-f. transformer in the plate circuit of this tube has the conventional primary winding, L11, and two secondary windings, L9 and L10. The winding L9 feeds the signal into the upper diode section, which section operates as the second detector. The load for this diode is resistor R8, bypassed by condenser C12. In this connection you should note carefully that R8 is returned directly to the cathode, so that when the "Q" switch is open there is no difference in potential between the cathode and the plate, consequently there is no delay action. The audio voltage developed across R8 is fed to the audio volume control, R13, through the series combination of R12 and C17. Rectification takes place irrespective of the value of the input signal.

As to the a.v.c. circuit, the signal voltage is fed to the lower diode through the coil L10, and the load for this a.v.c. diode is resistor R9. Since R9 is returned directly to ground and the cathode of the 6B7 is above ground, due to the voltage drop across resistors R6 and R7, it therefore follows that the a.v.c. action is of the delayed type—and that the delay voltage is equal to the drop across these two cathode resistors. . . . So much for the second detector and a.v.c. action when the "Q" switch is open. . . .

What happens when the "Q" switch is closed? . . . We now have a different state of affairs. To start with, closing the "Q" switch places R8 and R11 in series and in shunt with the two cathode resistors, R6 and R7. We stated that the cathode is above ground by the sum of the voltage drops across R6 and R7. This voltage is due to the flow of current through these two resistors. With the "Q" switch closed, the current will naturally divide between the series combination of R6 and R7 and the series combination of R8 and R11. Since there is current flow through R8, it stands to reason that a voltage drop will take place and the polarity of this voltage will be such as to make the cathode positive with respect to the upper or second detector diode. Consequently, the second detector will not begin to function until the signal input across L9 is greater than the voltage drop across R8. In this way, with the "Q" switch closed, the second detector is inoperative for weak signals or all signals lower in value than the drop across R8.

It is important to understand that the voltage drop across R8, utilized as the delay rectifier voltage, is due to the current in the cathode circuit and which current, as has already been stated, divides between the two parallel branches, R6 and R7, and R8 and R11—when the "Q" switch is closed.

Variable Delay Voltage in Second Detector Circuit

In all the circuits of the delayed second detector type, which we have considered up to this time, the squelch signal cannot be varied once the magnitude of the bias voltage is set. In other

words, to vary the squelch voltage, it is necessary to vary the delay bias voltage. In locations where the noise level is quite high, which place or places are located in proximity to powerful broadcasting stations, it would, in general, be desirable that the squelch signal be adjusted for comparatively high value. This would make it possible to receive properly the desired stations and at the same time eliminate the annoying noise between stations. On the other hand, in locations which are remote from transmitting stations, and where it is necessary to utilize the maximum sensitivity of the receiver, a low value of delay bias voltage is desired. Now, in view of the fact that practically each and every location is of dual character—that is, has its nearby stations, and it is still desired to receive distant stations—it would be advantageous to have some means whereby the magnitude of the squelch signal can be definitely controlled at the receiver. In other words, it would be advantageous to provide noise suppression which can be adjusted to operate at various levels.

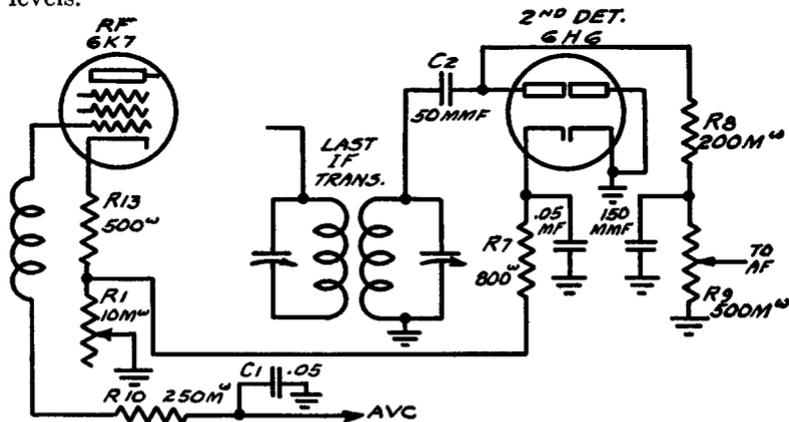


Fig. 58. This circuit makes possible both a manual and an automatic variation of the second detector delay voltage, as explained in the text.

An interesting circuit which makes it possible to set the squelch signal to fit the conditions under which the receiver is to be operated and which, at the same time, provides a certain measure of automatic control over the delay voltage, is shown in Fig. 58. The unique feature of this circuit is the connection

of the 6H6 second detector cathode so that it returns to ground through the resistance of the sensitivity control R1, which is placed in the cathode circuit of the first r-f. amplifier tube. As the consequence of the connection of the 6H6 second detector cathode to R1, as shown, the voltage drop across R1 serves as the rectifier delay voltage. Before we can analyze the manner in which the automatic variation of the second detector cathode voltage is accomplished, the operation of the sensitivity control R1 must be understood.

When the resistance of this control is set at zero, there is a minimum bias voltage on the first r-f. amplifier, and consequently the maximum sensitivity of the receiver is available. Furthermore, since the cathode of the 6H6 second detector is also returned to ground through R1, it follows that when the resistance of R1 is zero, the delay voltage in the second detector circuit will likewise be zero. On the other hand, when the full sensitivity of the receiver is not necessary, the resistance of R1 is set to some value greater than zero and the voltage drop across R1, as a result of the plate current flow through this resistor, increases the bias applied to the r-f. tube and, likewise, becomes the delay voltage or squelch voltage in the second detector circuit.

The action, which has just been explained, is in keeping with the type of performance which is desired—in that no squelch action is obtained under conditions of maximum sensitivity. Furthermore, when the full sensitivity of the receiver is not desired, the squelch action automatically comes into play. Last, but by far not the least, the magnitude of the squelch action is increased as the required sensitivity is decreased. As you no doubt have noted, the variation of the sensitivity control R1 is a manual operation. However, there is also automatic variation of the squelch voltage in accordance with the magnitude of the input signal to the receiver. This can be understood by analysis of the following considerations. If we assume, for a moment, a given value for the resistance of R1, that is, assuming that the sensitivity control is set at some value other than zero, then when the receiver is tuned to a strong signal, the a.v.c. action will operate to increase the bias of the first r-f. stage and, consequently, the plate current of the first r-f. stage will be still further reduced. This, in turn, means that the voltage drop across R1 will be small; consequently, the delay voltage applied

to the second detector circuit in the form of a squelch voltage will likewise be small. We see then that regardless of the setting of the sensitivity control—under conditions of strong input signal, the a.v.c. action will always operate to keep the delay voltage in the second detector circuit at a minimum. This is a very desirable condition, in that the second detector delay voltage does not function when the signal is being received and, as a result, there is little possibility of distortion being introduced from this source during detection.

On the other hand, as the receiver is detuned from a signal, the a.v.c. action decreases the bias on the first r-f. stage, and the plate current of this stage rises. As a result, the bias voltage developed across the sensitivity control increases and this means that an increased delay voltage is applied to the second detector and, as a result, will block the receiver. However, as soon as the receiver is retuned to another carrier, the a.v.c. action takes place—the voltage across R1 decreases—and this results in a decreased delay voltage in the second detector circuit, and normal detector operation is again secured. We can thus see that in the circuit described, which happens to be that used in the Motorola Golden Voice, the delay voltage in the second detector circuit functions only during periods when the applied signal is small.

Blocked Audio Type of Quiet A.V.C.

Another type of quiet a.v.c. is that which depends for its action upon the blocking of the audio amplifier rather than the second detector whenever the input signal fails below a certain value. In general, circuits of this type depend upon the application of a control voltage to reduce the voltage amplification in the first audio stage to a point where no signal reaches the speaker. The element to which this control voltage is applied may be either the plate, the screen grid, the suppressor grid, or the control grid, depending of course upon the circuit design.

The circuit shown in Fig. 59 is representative of the manner in which blocked audio noise suppression circuits function. This is the quiet a.v.c. circuit used in the Philco Model 810 PA receiver. You will note that the diode section of the first 75 tube is used as the second detector and also as the a.v.c. tube. The a.v.c. voltage is fed to the controlled tubes through the filter con-

sisting of R4 and C3, while the negative voltage, which is applied to the grid of the triode section of the 75, is taken directly from the high side of the second detector load, R3. The plate of the triode section, which serves as the "Q" tube, is connected to a positive point on the voltage divider through a 1.0-megohm resistor, R2. The diode section in the second 75 tube is not used.

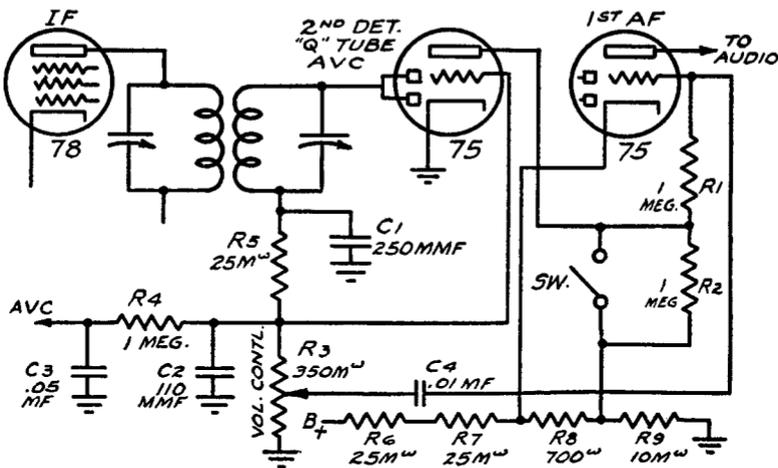


Fig. 59. The q.a.v.c. circuit used in the Philco 810 PA and which is representative of the blocked audio type. The increased voltage developed across R2, during intervals of low input signal, blocks the first a-f. amplifier.

The triode section of this tube is the first audio stage, which is controlled. From the connection of the cathode of the first audio tube to the voltage divider at the junction of R7 and R8, it is clear that an initial bias is placed on the first audio tube equal to the voltage drop along R8.

To examine the noise suppression action which is present, it is necessary to examine the bias on the first a-f. tube under varying conditions of input signal. When the input signal is high, then the voltage developed across the detector load will also be high. Furthermore, with this high negative voltage applied to the grid of the 75 tube, the plate current of the "Q" tube will be very small. This in turn means that there will be practically no voltage drop across R2 as the consequence of the "Q" tube plate current, with the result that the bias on the first a-f. tube is not increased but is equal to the normal value established by the voltage drop across R8.

As the input signal falls to weak values, the bias on the "Q" tube is also decreased so that the plate current of the "Q" tube increases. This in turn results in an appreciable voltage drop across the 1-megohm resistor R2. The direction of current flow being into the plate of the tube, the bias on the first a-f. tube will be increased to the extent of the drop along R2. Since the 75 first audio tube is of the high- μ type, the circuit design is such that the increased bias is sufficient to cut off the plate current of the first a-f. tube and to reduce the amplification to zero. This naturally blocks the receiver and produces an effective noise suppression action.

With the "Q" switch closed so as to short R2, no additional bias is impressed upon the grid of the controlled tube under conditions of low input signal, so that the "Q" circuit is inoperative, and the receiver then functions at maximum sensitivity with no noise suppression action.

There are many other variations of this basic type of "Q" circuit which depends for its operation upon cutting off the first a-f. stage for low values of input signal. However, we feel that the explanation of a typical system coupled with the similarity in operation of these circuits to others, which have been explained in great detail, will suffice to enable the comprehension of other circuits without the necessity for further elaboration.

Blocked I-F. Amplifier Noise Suppression

It remains to discuss a third type of noise suppression, which depends for its operation upon the blocking of the i-f. amplifier

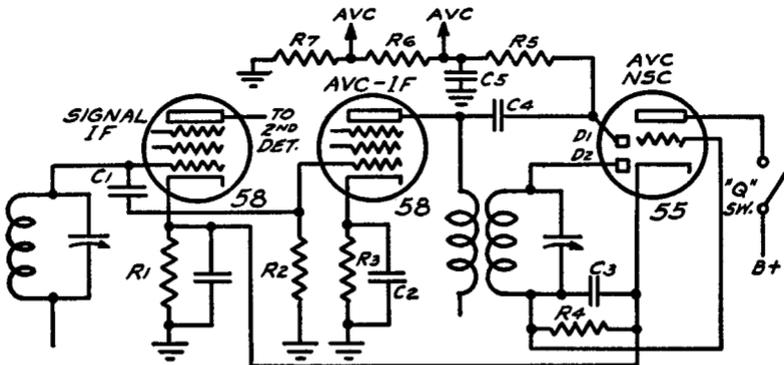


Fig. 60. A system of noise suppression which acts by blocking the signal i-f. amplifier stage. This is done by the voltage drop across R1, due to the large plate current of the triode section during periods of low input signal.

during those periods when the input signal falls below a certain value.

The circuit shown in Fig. 60 is a partial schematic of the

RCA Model R-78, showing the essential parts of the a.v.c. and noise suppression circuit. If you examine the schematic you will note that there are two i-f. amplifier stages, one of which is used to amplify the signal and which connects to the second detector and the other which is used to amplify the voltage which feeds the a.v.c. rectifier.

Each of the two diodes in the type 55 tube are used for separate purposes. The diode designated as D1 is the a.v.c. rectifier and receives its voltage from the primary winding through the small coupling condenser, C4. The a.v.c. voltage is fed to the controlled tubes from the voltage divider composed of R5, R6, and R7. The second diode, D2, is connected to the secondary winding of the i-f. transformer and the load for this diode is the resistor, R4, which is bypassed for i-f. by means of the condenser, C3. You should observe that this resistor is returned directly to the cathode, whereas the a.v.c. load is returned to ground. From the connection of the a.v.c. diode load to ground it follows that the magnitude of the a.v.c. delay voltage is equal to the voltage at the cathode of the 55. This is also the voltage at the cathode of the signal i-f. amplifier stage, since the cathode of the 58 is tied in with the cathode of the 55. The plate of the triode section of the 55 is connected to B+ through the switch designated as the "Q" switch. . . . Let us now analyze the operation of the circuit.

As the figure shows, when no signal voltage is impressed on the receiver, no voltage is produced across R4, the load of the noise suppression diode D2. Since the triode section receives its bias from the voltage across R4 it follows that under conditions of zero or very small input signal, the triode section operates at zero bias. Under this condition the plate current of the triode is very large and approximately equal to 10 ma. Since this plate current flows through the cathode resistor R1, which is common to both the signal channel i-f. amplifier and the a.v.c. tube, this 10 ma. plate current will develop a positive voltage on the cathode of the i-f. tube. Since the resistance of R1 is 4500 ohms, the voltage drop across R1 will be 45 volts and this voltage is sufficient to reduce the amplification of the i-f. stage to a point where no signal voltage will reach the second detector.

Under conditions of larger signal input, the increased bias, which is developed across R4 as a result of the increased input signal, acts to reduce the plate current of the triode section and hence to reduce the R1 bias on the signal channel i-f. stage. In this way the sensitivity of the i-f. amplifier is restored under

conditions of larger input signal and the receiver functions in the usual manner.

Selectivity Considerations in "Q" Circuits

In a previous chapter we discussed the relation between the selectivity present in the a.v.c. system and that in the signal channel and showed that to obtain smooth tuning and to prevent the accentuation of the upper audio frequencies for small degrees of detuning from the signal, it is desirable that the selectivity of the a.v.c. channel be less than that of the signal channel. What about the "Q" circuit? Is it desirable that the selectivity of the channel, which supplies the noise suppression rectifier, be large or small to produce the best overall performance?

The answer to this problem is most easily obtained by considering the action which is desired when the receiver is detuned slightly from the carrier. Under this condition the a.v.c. action will be such as to raise the gain of the receiver so that *if the noise suppression action is to be effective for small degrees of detuning, then the selectivity of the channel feeding the noise suppression rectifier must be greater than that of the a.v.c. channel.* It is for this reason that in Fig. 60 the voltage supplying the a.v.c. rectifier is taken from the primary side of the i-f. transformer, while the voltage which feeds the noise suppression rectifier is taken from the sharply tuned secondary winding. In this way the noise suppression channel takes control of the amplification for small degrees of detuning and acts to reduce the possibility of objectionable noise.

Automatic Tone Control—Noise Suppression

Another method which is related to noise suppression but also involves some other considerations—yet belongs in this chapter—is that which employs the dynamic input capacity of a tube as a means of tone control and noise suppression. Among the receivers which utilize this system are the Model 110 Stewart Warner and the Model 105 Emerson. For extremely low input signals, the system functions to shunt a capacity across the second detector load which is sufficiently great so that the output

of the receiver is substantially zero—hence noise suppression. As the input signal is increased, the value of this shunt capacity is reduced proportionately with the result that the receiver functions but with a reduced output at the higher audio frequencies. For medium and stronger values of input signals the design of the complete system is generally such that the added shunt capacity is negligible so that there is no loss in the higher audio frequencies.

Basically the action of such circuits depends upon the fact that the input capacity of a tube, which is the capacity between the control grid and the ground, is dependent upon the capacity between the grid and plate of the tube and the amplification constant of that tube—when the load impedance is fixed. This input capacity is a reflected capacity. By varying the grid bias applied to the tube and all other operating potentials held constant, it is possible to create across the control grid and ground a varying capacity, the value of which changes in proportion to the change in amplification constant or mutual conductance. For high values of grid bias the amplification constant is low, while for small values of grid bias the amplification constant is high—consequently the input capacity will be low when the bias is high and will be high when the bias is low. By connecting the control grid of the noise suppression tube to the a.v.c. network it is possible to vary the grid bias in accordance with the strength of the incoming signal and in this way to obtain a varying input capacity which is directly dependent upon the strength of the incoming signal.

If you will refer to Fig. 61 you will note how these principles have been applied in the Model 110 Stewart Warner receiver. The a-f. and a.v.c. circuits are quite conventional and do not require comment. However, turning our attention to the type 35 tube, which is used as a noise suppression tube, we note that the input circuit to this tube is shunted across the second detector load resistor, R1. This means that the input capacity of this tube is shunted across the load resistor R1. We further note that a .0001-mfd. condenser C is connected between the grid and plate of the noise suppressor tube, the purpose of which is to increase the range of the variable capacity effect developed across the control grid and ground of the noise suppressor tube.

Because of the connection of the grid of the 35 to the high side of R1, a variable bias is applied to the grid and this bias is in accordance with the strength of the incoming signal. For small values of input signal, the bias on the 35 is sufficiently small so that the capacity which is reflected

Chapter VI

TROUBLESHOOTING IN VARIOUS TYPES OF A.V.C. SYSTEMS

THE outstanding characteristic which affects troubleshooting in a.v.c. circuits is the high resistances involved in the circuit. It is safe to say that in no other part of receiver circuits is it generally necessary to make resistance measurements which are so high in value. A.v.c. rectifier load resistances, filter resistances, isolating resistors, voltage dividers, etc.—all these units which are found in a.v.c. circuits have resistance values which are seldom less than 100,000 ohms and often more than one megohm. This means that you must be able to measure resistances of this order with ease and accuracy. Aside from the effect upon the measurements, the fact that high resistances are used in these circuits makes it important that leakages in filter condensers and other parts of the circuit be avoided. These can have disastrous effects upon the operation of the a.v.c. system even when the leakages are as low as several megohms.

Leakage in A.V.C. Filter Condenser

A more or less common defect which takes place in a.v.c. circuits is a leak in one of the control voltage supply circuit filter condensers. If this leak is constant, that is, not intermittent, then it follows that there will be a reduction of the control voltage which is fed to the controlled tubes. The effect of this, insofar as the operation of the receiver is concerned, will be to cause more or less serious overloading and distortion, depending upon the extent of the condenser leakage. The effect will not be so noticeable for weak and medium strength signals, but there will definitely be overloading and distortion for strong values of input signal. As for example when listening to strong local stations. This is due to the fact that the leakage in the condenser makes it act as a resistance with the result that a voltage divider is formed across the a.v.c. rectifier load.

The manner in which leakages in the a.v.c. distribution filter system act to cut down the available control voltage is indicated in Figs. 62 and 63. Fig. 62 shows a typical a.v.c. distribution circuit in which the first filter resistor has a value of 2 megohms and the other resistors are 100,000 ohms each. What will be the effect if a 500,000-ohm leak develops in the first filter condenser? To analyze this we can consider the a.v.c. rectifier as

producing a certain control voltage, say 30 volts, and in Fig. 63 this is represented by the battery E_{AVC} . The resistors R_2 and R_3 are indicated as leading to the two controlled tubes, but no complete path is shown since these taps go to the grids of the controlled tubes and consequently under normal operation they do not supply any current. As regards the 500,000-

Fig. 62, right. The dotted resistor, R_{C1} , represents a leaky condition in the first filter condenser, C_1 . The effect is to reduce the available control voltage, making for distortion and overloading.

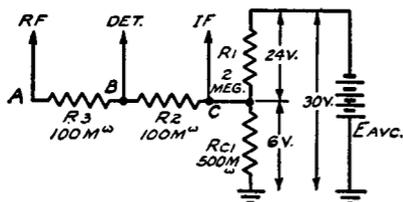
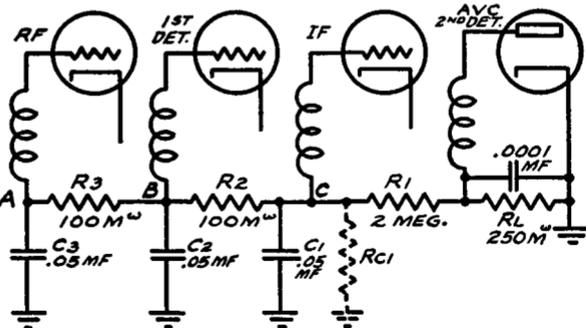


Fig. 63, left. This breakdown diagram shows how a leak in C_1 (Fig. 62) forms a voltage divider across the a.v.c. voltage supply and reduces the control voltage from 30 to 6 volts.

ohm leak in C_1 , it is indicated in the figure by a 500,000-ohm resistor R_{C1} . This is permissible since from the point of view of d-c. voltage distribution the capacity of the condenser is of no importance and it is merely the leakage resistance which is the determining factor. For a further clarification of this important point we refer you to the first volume of this series, "An Hour A Day With Rider on D-C. Voltage Distribution."

Returning to the problem at hand we want to determine how the voltage at A, B, and C is affected by the leakage in condenser C_1 . First of all we know that if there are no leaks in the circuit, then the voltage at A, B, and C will be the same and equal to the voltage developed by the a.v.c. rectifier, which in this case was taken to be 30 volts. This is true because no current is drawn at any point in the network and there is thus no voltage drop in the network. On the other hand, with the values of resistance that have been assumed in this problem, the effect of the leaky condenser would be to reduce the voltage at the grid of each of the controlled tubes from 30 volts to 6 volts. This follows because of the voltage divider which R_{C1} forms in conjunction with R_1 .

While for the purpose of illustration we have examined the case in which the first filter condenser is leaky, it is quite apparent that, referring again

to Fig. 62, a leak in either C2 or C3 would have a similar effect in reducing the available control voltage. Therefore when a.v.c. problems occur—check the leakage resistance of the a.v.c. circuit filter condensers. As a general rule the normal leakage resistance of such condensers approximates 1000 megohms per microfarad.

Effect of Open Circuit in Filter Condenser

We have just examined the effect of a leak in a filter condenser in the a.v.c. circuit and have shown how it acts to reduce the control voltage. What is the effect of an open circuit in one of the filter condensers? Referring again to Fig. 62 we can see that the effect of an open circuit in C1 will be to reduce the filtering efficiency and will result in the appearance of a considerable a-f. component in the a.v.c. voltage. Not only this, but an open circuit in C1 will reduce the decoupling action so as to produce unstable operation. Since most of the filtering is accomplished by R1 and C1, an open in C2 or C3 will not affect the a-f. filtering action appreciably. However, it will act to couple the r-f. and i-f. circuits and as a result may be productive of miscellaneous squeals, motorboating and oscillation.

Intermittent Opens and Leaks in Filter Condensers

In those cases in which the leakages or open circuits in the a.v.c. filter condensers are intermittent in nature, the symptoms, which we have described, will naturally follow the variation in the extent of the leakages or open circuits. There are no hard and fast rules which can be given for detecting defects of this nature. However, where the trouble has been localized to the extent that only several units are suspected, these can be checked under abnormally high conditions of d-c. voltage so as to show up a defect of the intermittent type. A method, which often has proved successful, is to subject the condenser in question to a very large r-f. current by placing it in the tuned circuit of an r-f. power oscillator. This subjects the condenser to an abnormally high temperature and if there is a weak or intermittent connection in the condenser, the unit will open permanently so that the suspected defect can be definitely established.

Open Circuit in Filter Resistors

A defect which is not uncommon is to find that a filter resistor in the a.v.c. distribution circuit either increases in resistance appreciably or becomes definitely open circuited. Referring again to Fig. 62 we can see the effect of this upon the operation of the system. First of all it is important to appreciate that the grids of the several controlled tubes are returned to ground through the a.v.c. filter resistors and that this provides the only connection to ground to complete the grid return. The effect of an open in one of the filter resistors is thus to open up the grid circuit of one or more of the controlled tubes, depending upon the location of the defective resistor. Thus in Fig. 62, we can see that if R1 is open, then the grids of the r-f., first detector, and i-f. tubes will be left free. On the other hand,

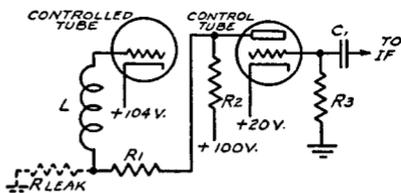
if R2 is open, then the first detector and r-f. grids will be free, while if the R3 is open, then only the r-f. tube will be affected. Regardless of which resistor opens up, the result will be improper and unstable operation, which is always characteristic of a circuit in which the grid of a vacuum tube is free. Fortunately, such open circuits are easy to detect, in that it is only necessary to measure the control voltage developed at each of the grids in order to establish whether the circuit is complete. Or if a high impedance vacuum tube voltmeter is not available for making this measurement, then an ohmmeter can be used for checking the continuity—provided the ohmmeter is sufficiently sensitive to measure resistances of the order of megohms.

Leakage between I-F. or R-F. Coils and Ground

You will recall that we described a type of triode a.v.c. in which the cathodes of the controlled tubes are above ground or chassis potential by the amount of the plate voltage required for the a.v.c. control tube. This necessarily places the grid coils of the controlled tubes above ground by some 50 to 100 volts and it sometimes happens that a leakage resistance develops between the grid coil and the chassis. This leakage may be due to actual contact, but is sometimes due to excessive humidity. Let us examine the effect which such a leak would have upon the operation of the receiver.

A typical voltage distribution circuit for this type of a.v.c. is shown in Fig. 64, in which you will note that only one controlled tube is shown.

Fig. 64. A leak in one of the a.v.c. filter condensers or between the grid coil and ground, may completely block the receiver, since the cathodes are more than 100 volts above ground in this type of a.v.c. circuit.



This may be either the r-f., first detector or i-f. amplifier. You will note that in accordance with the method of operation of this type of a.v.c., the cathode of the *controlled* tube is 104 volts above ground,—the cathode of the a.v.c. or *control* tube is 20 volts above ground, and the grid of the a.v.c. tube is grounded. With no input signal and with no leakages in the circuit, the voltage at the grid of the controlled tube is, of course, 100 volts, which leaves a net minimum bias of 4 volts on the grid. With larger values of input signal the bias is increased by the amount of the rectified voltage across R2. So much for the normal operation of the circuit.

Under conditions of leakage at some point in the voltage distribution circuit, which may be due to one of the filter condensers or possibly to leakage between the grid coil L and ground, there is created effectively a shunt resistance indicated on the figure by the dotted resistor R_{LEAK} . This leakage resistance, in conjunction with R1 and R2, forms a voltage divider across the 100-volt tap on the power supply and as a result, the voltage at

the grids of the controlled tubes will be appreciably less than 100 volts. In the extreme case where the leakage is a dead short, then the voltage at the grid will be zero and since the cathode is at 104 volts, the tube will be completely blocked due to an effective bias of 104 volts. *It is for this reason that in a.v.c. systems of this type a leak in one of the filter condensers or in one of the grid coils results in a completely dead receiver, whereas in the receivers having conventional diode a.v.c. the effect of a leak is to raise the sensitivity of the receiver rather than to lower it.*

As in the previous cases, the method of troubleshooting is to locate the leak by suitable resistance and voltage measurements. In general the progress of the procedure should be indicated by the symptoms which are interpreted by working from the breakdown diagram.

Defective A.V.C. Tube

One of the essential things to be checked when troubleshooting in a.v.c. circuits is the a.v.c. or control tube itself. Defective operation of a.v.c. circuits is often due to a gassy or otherwise defective control tube and in the long run it will save time if this point is checked at the outset. Unless an exceptionally good tube checker is available, it is most convenient to replace the suspected tube with one known to be in good condition. If this does not correct the operation of the receiver, then it can be assumed, for the time being, that the tube is not at fault.

No Control of Volume

A condition which sometimes arises in a.v.c. circuits is that the manual volume control provides insufficient, or no control over the volume. As a general rule, this does not occur in a.v.c. circuits where the manual volume control is in the input to the a-f. amplifier. In those cases where it does, the trouble is quite definitely due to a defect in the volume control unit itself and not the a.v.c. system. However, this type of trouble, which we are now discussing, is characteristic of the type of a.v.c. circuit in which the manual volume control does not directly control the input to the first a-f. stage, but rather *controls the a.v.c. tube itself*. The operation of a typical system of this type was explained in connection with Fig. 39.

For circuits of this type, lack of proper volume control action is most often associated with the control tube circuit proper. The reason for this condition is evident when we consider that the manual volume control generally changes the bias on the *control* tube and in this way changes the amplification of the *controlled* tubes, as we previously explained. If this action is not obtained, then the failure may be due to a number of different causes. *The first thing to be checked is the a.v.c. tube itself*. If this does not correct the condition, then the next step is to check the a.v.c. action directly. For this purpose a vacuum tube voltmeter should be connected across the a.v.c. plate load resistor (R18 in Fig. 39.) Under conditions of zero input signal, with the volume control fully advanced, the measured voltage drop across the plate resistor will be approximately zero. However, if the signal generator is connected to the receiver, the voltage at the plate

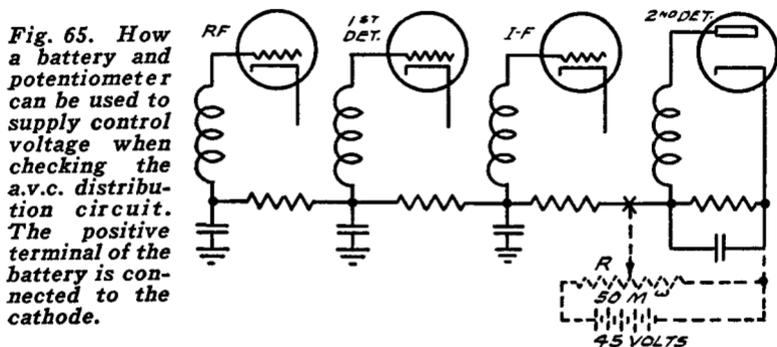
of the control tube should become more and more negative as the input signal is increased. Furthermore, still using the circuit in Fig. 39 as a reference, if the volume control is decreased, then the voltage at the plate should become still more negative as the volume control is *retarded*. In this way it is possible to check both the automatic control action by varying the signal input and noting the change in control plate voltage, and also to check the manual control action as well.

Where a vacuum tube voltmeter is not available, the action can be checked by inserting a low-range milliammeter in the plate circuit of the a.v.c. tube. Although a more sensitive instrument is indicated, an 0-1 milliammeter can be used to obtain a rough idea of the voltage being developed. With the conventional 1-megohm plate load, a current indication of .02 milliamperes, generally the first division on the scale, would indicate a voltage drop of 20 volts across the plate resistor (R18 in Fig. 39), or a control voltage of 20 volts. While this method is not as sensitive or as quick as the vacuum tube voltmeter method, it will furnish an indication of the control circuit operation when the latter is not available.

It should be mentioned that the above test of the operation of the a.v.c. tube should be made with the lead from the plate of the a.v.c. tube to the distribution network disconnected. This precaution is taken to establish definitely the operation of the a.v.c. tube itself and to prevent any possibility of a leak in the distribution or filter circuit from producing a false conclusion. Should the operation of the control tube and its immediate circuit prove to be satisfactory, then it follows that the defect is in the distribution circuit and this should next be checked for leakages and open circuits.

Checking the A.V.C. Distribution Circuit

In many cases it is desirable to determine definitely whether faulty a.v.c. operation is due to improper operation in the control circuit *proper*



or in the circuit which distributes the a.v.c. voltage to the several controlled tubes. For this purpose it is convenient to substitute temporarily for the automatic voltage a variable C-battery bias which is manually controlled.

The manner in which this substitution is made is indicated in Fig. 65. You will observe that the a.v.c circuit has been opened at the point X and the 50,000-ohm potentiometer and battery, which is shown in dotted lines, has been added. It is important that the low positive side of the C battery be returned to the low side of the resistors across which the a.v.c. voltage is developed. For simple diode systems this is generally the cathode of the diode, while for triode type of a.v.c., it generally is the point on the voltage divider to which the plate resistor is returned. An inspection of the schematic should be made to indicate the point at which this connection of the battery circuit should be made. A 45-volt battery is satisfactory since it will supply bias voltages to the controlled tubes up to 45 volts.

By means of the potentiometer, R, the voltage applied to the controlled tubes is varied to suit the strength of the signal which is applied to the receiver. If the operation of the receiver appears to be satisfactory with the separate battery bias, then it indicates that the section of the a.v.c. circuit which includes the filter circuit and the controlled tubes is operating properly, insofar as the leakages or open circuits are concerned. This procedure naturally does not check the time constant of the a.v.c. circuit. The procedure which is mentioned here is sometimes used in connection with alignment to stop the operation of the a.v.c. action. The necessity for this under certain conditions is discussed in "An Hour a Day with Rider on Resonance and Alignment."

An indication of the procedure which is useful in checking the control circuit proper, is given in one of the preceding sections. In this connection we should mention that lack of control voltage may sometimes be due to lack of excitation or signal voltage on the control tube. This may be due to an open coupling condenser or possibly to improper alignment of the i-f. transformer which feeds the control tube—if a separate transformer is used.

Gas or Leakage in Controlled Tube

The effect of gas or leakage in one of the i-f. or r-f. tubes which is controlled, is just as disastrous as far as the operation of the a.v.c. circuit is concerned, as is a defect in the control tube proper. This can easily be appreciated from the fact that a gassy tube shows a low resistance between its control grid and cathode. This low leakage resistance acts to short circuit the a.v.c. voltage and produces overloading and lack of control.

Incorrect Time Constant in A.V.C. Circuit

In an early part of this book we discussed the effect of the size of the filter resistors and condensers upon the speed of the a.v.c. action and upon the filtering efficiency. Without again going into these relations, we want to state that sluggish a.v.c. action can sometimes be traced to a partially open first filter resistor. While this does not greatly affect the final control voltage which is delivered to the several tubes, it does affect the time required for the change to take place and hence the speed of the a.v.c. action.

In this connection when it becomes necessary to replace an open filter resistor or a filter condenser, the correct value should always be used because of the effect upon the time lag in the a.v.c. action. We especially emphasize this precaution because ordinarily it makes no difference whether, for example, a .05-mf. cathode bypass is replaced with a .1-mfd. condenser. However, such a substitution in the case of a condenser in the a.v.c. filter circuit would double the time constant of the circuit and in some cases would result in a noticeable time lag in the a.v.c. action. For this reason the replacement condenser or resistor should have the value indicated by the manufacturer within the usual tolerance limits.

A.V.C. Tube Removal

In a.v.c. systems which use a separate a.v.c. tube, a certain amount of information can generally be obtained from the effect which the removal of the a.v.c. tube has upon the operation of the receiver. For example, if with medium input signal—say 10 millivolts—the receiver is completely dead, then the a.v.c. tube should be removed to note the effect upon the operation. In some cases it will be found that the removal of the tube restores the operation of the receiver. If this is so, then it points to a defective a.v.c. tube, incorrect voltages on the a.v.c. tube, or possibly a leaky coupling condenser to the grid of the control tube. At any rate it definitely localizes the trouble as being in the control tube circuit. This test is chiefly of value when the removal of the control tube restores operation and it is not especially significant when operation is not restored.

Quiet A.V.C. Systems

In Chapter V we described the various types of noise suppression systems, which are commonly used. Naturally the type of circuit which is used will influence the line which the servicing procedure will follow. However, regardless of the system which is used, the function of the noise suppression circuit is to block some part of the signal channel, whether it be the i-f. amplifier, the second detector, or the first a-f. stage. Where the receiver being serviced is very insensitive to weak signals or is completely dead, the trouble may be due to improper conditions in the noise suppression circuit. Among the possibilities are improper voltages on the noise suppression tube due to defective resistors in the voltage divider circuit, etc., defective "Q" tube, defective circuit elements (condensers and resistors, etc.) in the "Q" tube circuit, and possibly leaky coupling and blocking condensers.

A.V.C. in All-Wave Receivers

In a number of receivers of the all-wave type, you will find that the a.v.c. circuit is different in the several bands. You should take this into account when troubleshooting and be sure that the band-changing switch is in the proper position.

General Observations on Troubleshooting

For reasons which must be apparent to you, we have not attempted to cover all the possible defects and conditions which can arise in a.v.c. circuits. Such a treatment is well nigh impossible and furthermore, to our way of thinking, is a very poor way to attack the problem.

What we have tried to do in this book is to describe the fundamental operation of the types of a.v.c. systems which are in common use, so that you will be able to draw your own inferences and conclusions from the symptoms which the receiver shows and the results of the measurements which you make. Such a method is far superior to one which attempts to give a great many rules for meeting different conditions, inasmuch as the manifold conditions which can arise in radio receivers are so complex and varied that the only successful way in which they can be met is by understanding the basic mode of operation. This background we have tried to give you in this book.