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# The Functions of C and R in A.V.C. Circuits

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THERE are numerous varieties of automatic volume control circuits but all work on the same principle. It is therefore the purpose of this article to present the theory whereon the circuit is based which should enable the reader to understand modern a.v.c. circuits in all its variations.

The arrangement, popularly misnamed "automatic volume control" is intended to maintain the strength of the signal arriving at the detector nearly constant, thus compensating for different signal strengths of different stations and for fading. It does this by varying the sensitivity of the r.f. and i.f. amplifiers and consequently the proper name should be "automatic sensitivity control". The volume is of course not kept constant because it depends on the percentage of modulation at the transmitter. This is being varied in accordance with the volume of the transmitted sound and music. To try keeping this constant would be ruining the effect of music consequently it would not be desirable to make a true "automatic volume control". In the following discussion the popular terms automatic volume control and a.v.c. will be retained.

Figure 1 illustrates an a.v.c. system often used in up-to-date sets and perhaps the easiest to explain. Forgetting for a moment the grid return resistors in the r.f. circuits, let us begin with the detector. The signal is rectified by a diode. Current can flow only when the diode becomes positive and the coil must then be considered as the generator. This will perhaps help to explain why the resistor R1 will carry a current in the direction of the arrow, making the point P negative with respect to the cathode and the chassis. This point seems to be difficult to understand for many. The current flowing between P and the chassis consists of a direct current component, a radio frequency component and an audio frequency component. The condenser C1 has been placed across the resistor to pass most of the radio frequency currents and the audio frequency component is of course taken off to be applied to the grid by means of the coupling condenser C. The steady voltage at P which is proportional to the strength of the incoming signal must now be fed back to the r.f. and i.f. amplifiers but the a.f. component must be filtered out and precautions for interstage coupling should be taken. This is accomplished by the network of resistors and condensers of Figure 1. Since the grids of the amplifying tubes are never drawing current, it does not matter, within, limits how much resistance there is between the point P and the individual grids. No voltage drop can be across them because there is no current except in the case of overloading where very high values of resistance may cause tube blocking. Resistor R2 and condenser C2 form a resistance capacity filter which smoothes out most of the audio frequency fluctuations. That it does so is best seen from a consideration of the laws of alternating currents. Since the condenser which is in series with the resistor R2, forms a path for alternating currents, a great part of the audio signal will pass through C2 in preference to following the paths through R3-C3, R4-C4, R5-C5. The percentage of the original audio voltage appearing across C2 is found as follows. Supposing R2 to be 1 megohm and C2 .05 mfd, which are popu-

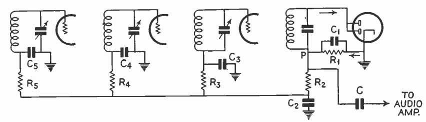


Fig. 1

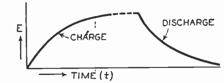


Fig. 2

lar values, the impedance of the condenser at 50 cycles would be 64000 ohms. Adding this value vectorially to the 1 megohm, we have

$$Z = \sqrt{1000000^2 + 64000^2}$$
$$= 1002000 \text{ ohms approx.}$$

The percentage of the original audio voltage appearing across C2 is then 100 x 64/1002 = 6.2%. At higher frequencies the percentage is lower. This is the first filtering stage. The resistor-condenser combinations in the grid returns each form a second filtering stage which again may reduce the

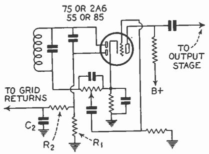


Fig. 3

audio voltage to a few percent of the remaining 6 percent, thus bringing the final audio voltage down to .1 percent of the original or even less. The question is now how much resistance and capacity is required and is there such a thing as having too much of it. Yes, there is.

Looking again at the calculation of the filter above, it will be seen that halving the resistor R2 and doubling the condenser C2 would have given exactly the same degree of filtering. Consequently, it is the product of C and R which determines the filtering efficiency and any two values of C and R whose product is the same will give the same filtering. Also, the larger the product CR, the better the filtering.

## TIME CONSTANT

The product CR is called the time constant of the resistor condenser combination and for the following reasons. When a condenser is charged through a resistor, the voltage across the condenser increases relatively slowly following the logarithmic equation

$$E = E_{MAX}\left(1 - e^{-\frac{t}{RC}}\right)$$

where E max is the voltage of the source and $e = 2.718$

Similarly, when a condenser discharges through a resistor, the voltage drops according to the law

$$E = E_o e^{-\frac{t}{RC}}$$

where Eo is the initial voltage across the condenser

Curves, showing the voltage plotted against time for both charge and discharge are shown in Figure 2. It can be shown mathematically that the general shape of these curves is always the same regardless of the size of the condenser or the resistor. It is then a relatively simple matter to calculate the time required for any degree of charge or discharge. The equations show that the only term which determines this duration is the product CR.

So, for instance, when t = RC, the fraction of the exponent becomes equal to —1 and in this time the charge of the condenser is up to 63% of its maximum value, or, the discharge is down to 37% of the original value. The time constant of a resistor-condenser combination then, is the time required to discharge the condenser through the resistor down to 37% of the original charge or to charge it to 63% of the voltage of the source.

Another definition which also follows from the equation gives it as the time wherein the condenser would charge or discharge completely if it kept charging or discharging at the initial rate.

Returning now to the a.v.c. circuit of Figure 1, if the strength of the incoming signal is suddenly changed, the negative voltage at the point P

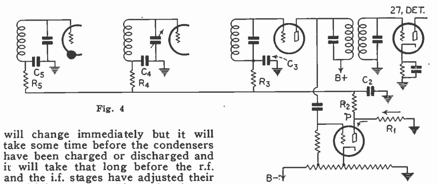


Fig. 4

will change immediately but it will take some time before the condensers have been charged or discharged and it will take that long before the r.f. and the i.f. stages have adjusted their sensitivity. When this period is too long it becomes extremely difficult to tune the set because tuning past a strong station to a neigboring weak one, the sensitivity of the receiver is still lowered due to the strong carrier and the weak station will not be heard unless extremely slow tuning is practiced. Similarly, when tuning to a strong station it will take some time before the receiver adjusts itself and during that time the set will overload.

The correct time constant is a compromise between the best filtering and the desired speed of following signal strength variations. The best values are between one tenth and one twentieth of a second. For this circuit the time constant is equal to the product of R2 plus R3 and C2 plus C3. When the resistance is given in megohms and capacity in microfarads the time is in seconds.

Slight variations of the circuit of Figure 1 will be found in most of the present day receivers. The diode tube is then generally a double-diode-triode or pentode which serves at the same time as the first audio stage. Sometimes a separate diode is employed for the detector. The two diodes are then coupled by a small con-

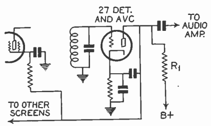


Fig. 5

denser as shown in Figure 3. It will also be found that some of the resistors R3, R4, and R5 may be absent. It depends on how much filtering the designer found necessary. These filters, of course, also serve to isolate the grid circuits of the different stages. But when the stages work at different frequencies (r.f. and i.f.) bypass condensers seem to be sufficient.

## SEPARATE A. V. C. TUBE

Before the advent of the double purpose tubes, it was necessary to provide a special tube for the a.v.c. circuit. Sometimes this tube required a voltage supply delivering up to 70





volts negative with respect to the chassis. Such a circuit, employing a triode tube—like a 27—is shown in Figure 4. The same can of course be done with screen grid tubes or pen-

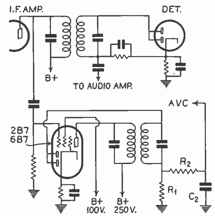


Fig. 6

todes (types 24A, 57 or 6C6). The signal is picked from the plate or grid circuit of one of the i.f. stages and coupled to the grid of a.v.c. tube through a small condenser. The tube rectifies the signal because the grid bias is adjusted to practically cut-off of the plate current. This will cause plate current to flow through the resistor R1 and the point P again becomes negative with respect to the chassis. This negative voltage is passed along to the amplifying tubes through the usual filter.

## VARYING THE SCREEN VOLTAGE

Sometimes in the past it became necessary to vary the i.f. gain by lowering the screen voltage. This was done especially before there were any variable mu tubes and in some dry battery sets. The manner of doing it is illustrated in Figure 5. The screen currents and the detector plate current pass through a common resistor R1. As soon as a signal comes in, the detector plate current increases, thereby increasing the voltage drop across the resistor and lowering the screen voltage. The system is not so successful with 24A, 32 or 22 tubes because the amplifying stages will rectify with a low screen voltage and this causes cross talk. It can be used however with variable mu pentodes.

## DELAYED A.V.C.

The systems thus far discussed will bring the circuit into action for even the weakest signals. So, as soon as the precious weak signal enters it is cut down again by the control action. Thus sensitivity is lost. It would be much more convenient if the circuit would not begin to work until the incoming signal exceeded a certain level. The sensitivity would then remain and the cutting down of sensitivity would happen only to strong signals which can stand it. Such a system is called delayed a.v.c. and should not be confused with the time constant.

It is accomplished by biasing the a.v.c. diode plate negative with respect to the cathode so that no current will flow in the diode circuit until the incoming signal's peak voltage exceeds this bias. The most convenient way to introduce the system to the circuit of Figure 1 is by placing a bias resistor in the cathode circuit and returning R1 to ground; but that would introduce the delay to the detector also. Therefore the separation like in Figure 3 is necessary. Figure 3 shows a bias resistor in the cathode circuit and this is delayed a.v.c. In the circuit of Figure 4, delay can be introduced by adjusting the grid bias to below plate current cut-off.

## AMPLIFIED A.V.C.

In numerous cases it has been found that the generated control voltage is not large enough to properly equalize the incoming signals of different stations. The remedy then is to amplify the control voltage by an extra stage. It can be done by means of an extra stage of i.f. or r.f. amplification. It is also possible to employ a d.c. amplifier, but this system has not be-

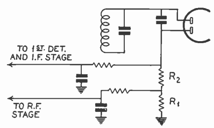


Fig. 7

come popular. An example of amplified a.v.c. is shown in Figure 6. A single tube serves as the amplifier and the diode rectifier. The pentode section first amplifies the signal and it is then coupled through an i.f. transformer to the diode. Delayed action can again be introduced if desired.

## TAPPED A.V.C.

There are various reasons why it is desirable to deliver a different amount of a.v.c. voltage to different tubes. The r.f. stage might for instance receive only one half of the a.v.c. voltage while the other tubes are controlled by the full voltage. The reason is that the receiver will work with less noise if the signals impressed on the mixer tube are relatively large and so it is desirable to have some more gain in the r.f. stage.

A voltage divider system has to be employed to deliver the correct proportion to each tube and each tap

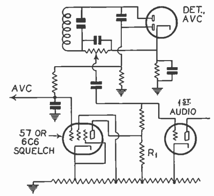


Fig. 8

must have its own resistance capacity filter. The idea is illustrated in Figure 7. R1 and R2 form the voltage divider and the voltage across R1 alone is applied to the grid of the r.f. stage while the voltage across both R1 and R2 is applied to the other tubes.

## QUIET A.V.C.

When a receiver with a.v.c. is tuned from a station to a spot on the dial where nothing is received, the sensitivity is suddenly turned up full and the set appears very noisy. This interstation noise is objectionable to many users. The various schemes to eliminate it would fill a good sized book. However, here are two of the commonest. A manual sensitivity control can be added to the automatic. The setting of this manual control then limits the maximum sensitivity the receiver can have in-between stations. The listener should retard the manual control until the noise stops being objectionable.

Another scheme is shown in Figure 8. An extra tube is so connected as to cut off the audio amplifier until a signal of a given strength is coming in. When no signal is coming in, the grid of the "squelch" tube is at the same potential as the cathode and plate current flows. This plate current causes a voltage drop across R1 which is large enough to bias the first a.f. tube to cut-off. As soon as a signal is received, the grid of the "squelch" tube becomes negative, cuts off the plate current and restores normal bias to the audio stage. The "squelch" tube is generally a pentode like the 57 which has a steep curve with a sharp cut-off.