AUDIO, POWER SUPPLY, AND SPECIAL CIRCUITS OF COMMUNICATIONS RECEIVERS

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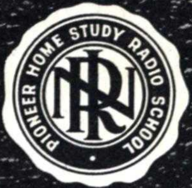
finished Jan 19, 1960

NATIONAL RADIO INSTITUTE
ESTABLISHED 1914
WASHINGTON, D. C.



STUDY SCHEDULE NO. 35

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind, then answer the Lesson Questions for that step. Study each other step in this same way.

☐ 1. The Audio Amplifier .... Pages 1-10

You study types of distortion, typical voltage amplifier circuits, and typical power amplifier circuits, phase splitting, negative feedback, and audio filters. Answer Lesson Question 1.

☐ 2. The Power Supply .... Pages 11-13

This section discusses sources of power, the bleeder and voltage divider, voltage regulation, and power-line filters. Answer Lesson Question 2.

☐ 3. Special Circuits .... Pages 13-21

Here we take up the various automatic volume control circuits, squelch circuits, noise limiter circuits, tone control, and volume control. Answer Lesson Questions 3, 4, and 5.

☐ 4. A Modern Communication Receiver .... Pages 22-36

This gives a detailed description of the National NC-2-40D Receiver. Answer Lesson Question 6, 7, 8, 9, and 10.

☐ 5. Start Studying the Next Lesson.

FM1M957 1958 Edition Printed in U.S.A.

AUDIO, POWER SUPPLY AND SPECIAL CIRCUITS OF COMMUNICATION RECEIVERS

The Audio Amplifier

THE signal available from the second detector is not sufficient to operate even a sensitive pair of headphones at a satisfactory level. An audio amplifier is used to build up the power to the desired value. For headphone operation, an output of several milliwatts is all that is necessary. For speaker operation, a level of about one watt or more is desirable. The amplifier should be capable of delivering somewhat more power than is actually needed, to reduce the possibility of overloading it, and causing excessive distortion.

Of course, the distortion in the audio amplifier should be at a minimum for good intelligibility of signals. The fidelity or perfection of response does not have to be as good as that of a high-quality entertainment receiver in order to be satisfactory for communication purposes. It is, however, common practice to keep the audio distortion of a communication receiver low, and limit response to the frequencies actually needed.

TYPES OF DISTORTION

Frequency Distortion. The three types of distortion possible in an audio amplifier are called frequency distortion, amplitude distortion, and phase distortion respectively. Frequency distortion is unequal amplification of different frequencies contained in the signal. It increases with the band width which must be uniformly amplified, and with the total amplification. An example of frequency distortion is shown in Fig. 1B, where the "dip" in the input wave of Fig. 1A has been eliminated. This dip is due to the presence of higher frequencies, which the amplifier failed to amplify the proper amount.

Amplitude Distortion. Amplitude distortion is caused by a non-linear relation of voltage and current at either the input or the output of an amplifier stage. At the input this may be due to overload which drives the grid positive. The grid draws current,

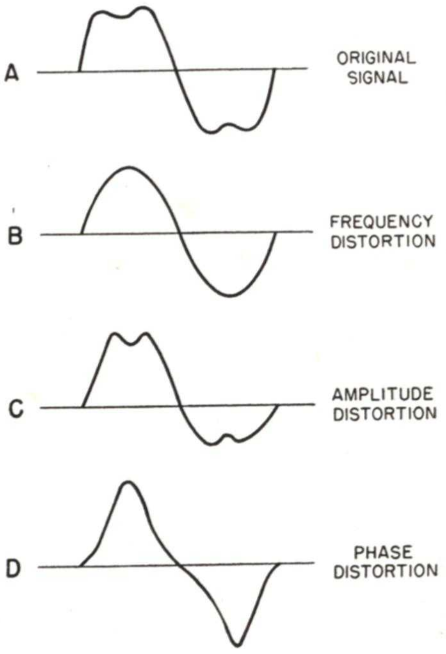


FIG. 1. Effects produced by different types of distortion in audio amplifiers.

lowering the grid-to-ground resistance, and the input voltage drops, causing distortion. Output distortion is due to curvature of the tube characteristic, which can be minimized by having proper operating voltages on the tube elements. This type of distortion produces output frequencies not present in the input, as shown in Fig. 1C, where the "dip" has been exaggerated, and the two halves of the wave are no longer of equal amplitude.

Phase Distortion. Phase distortion is caused by high frequencies passing through the amplifier at a different speed than lower ones. They combine with low frequencies which started out at a different time, producing a wave with different shape than that at the input. Phase distortion is shown in Fig. 1D, where the high-frequency component has shifted so that it adds to the low-frequency one, giving a peak instead of a dip. Phase distortion is not usually noticeable to the ear, which is tolerant as to relative time of arrival of various frequencies, but it is very serious in facsimile, television, and certain types of pulse communication systems, where the "piling up" of frequencies would tend to destroy the signal intelligence.

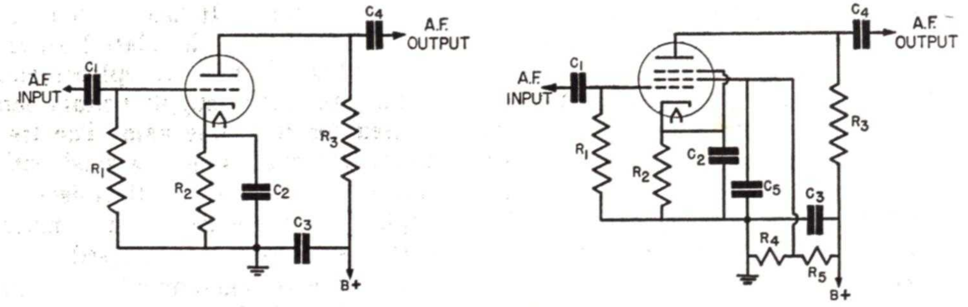
In modern a.c.-operated receivers, there is always the possibility that a.c. hum may get into the audio amplifier from the heater supply, or by induction into any transformers used, as well as by stray pickup on unshielded leads. A certain degree of care in design and layout of the amplifier is required to keep the hum down to a reasonably low level. Usually this is at least as low as 1/100 of the maximum receiver voltage output (40 db or more down). The power supply must be well filtered to reduce hum, and in addition, the voltage amplifiers usually have resistance-capacity filtering.

Either triode or pentode tubes may be used as audio amplifiers. In general, triodes give less voltage gain than pentodes, and have lower plate resistance. A high voltage gain is often desired between the second detector and the grid of the output stage, at least for weak signals. A high power gain, accompanied by a low plate resistance is desired in the output stage.

Low plate resistance makes possible the proper matching of the tube impedance to the output load with practical transformers, and "damps" the load, so that transients (sudden changes of signal or noise) do not cause the speaker or phones to continue vibrating long after the transient has passed. Pentode power output tubes are commonly used in spite of their high plate resistance, because of their high power gain and relatively high efficiency. Either the poor transient response, and relatively high distortion are accepted, or negative feedback is used to lower the effective plate resistance at the expense of gain.

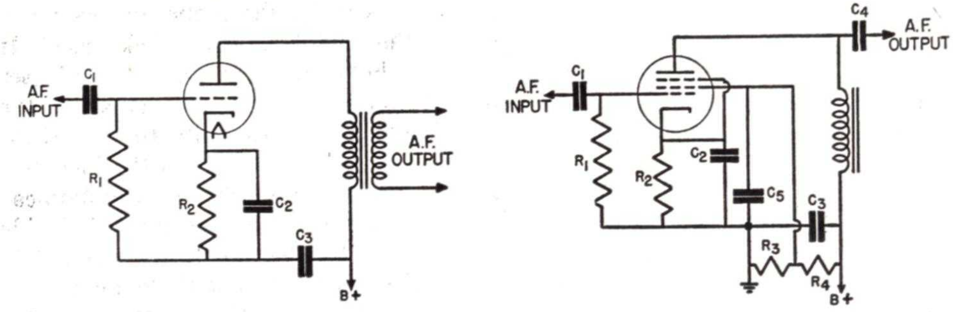
Audio voltage amplifiers are always operated class A, so that no grid current is ever drawn, and no power is required to drive the stage. This method of operation also gives the lowest possible distortion. The efficiency is low, but this is of no concern, as the power level is negligible.

Audio power amplifiers for receiver use are usually operated class A, but may be operated class AB, where grid current is drawn on peaks, and the output and efficiency are considerably increased. True class B audio amplifiers are usually used only for public address or transmitter modulator applications, where high power and improved efficiency are required, and where a power supply of exceptionally good voltage regulation can be provided.



Ⓐ TRIODE, RESISTANCE-COUPLED

Ⓑ PENTODE, RESISTANCE-COUPLED



Ⓒ TRIODE, TRANSFORMER-COUPLED

Ⓓ PENTODE, IMPEDANCE-COUPLED

FIG. 2. Audio voltage amplifier circuits.

TYPICAL VOLTAGE AMPLIFIER CIRCUITS

Typical single-stage audio voltage amplifier circuits are shown in Fig. 2. That in Fig. 2A has a resistance-coupled triode, with the audio input coupled from the second detector to the grid by condenser C_1. Grid leak R_1 provides a d.c. grid return to ground so that bias voltage can be impressed on the grid. It is usually a very high value (between 0.1 and 1.0 megohm) to reduce loading on the preceding stage. The cathode is grounded through R_2, and the flow of plate current through this resistor causes a voltage drop across it which is of proper polarity and magnitude for grid bias. This resistor is by-passed by C_2 for the lowest frequency to be amplified, so that an excessive audio loss will not occur across it along with the d.c. drop. The variations of plate current caused by the input signal flow through output load resistor R_3, producing useful audio output across it. The output voltage is coupled to the next stage through condenser C_4. Condenser C_3 makes certain that the lower end of R_3 is at a.f. ground potential to keep audio out of the power supply. It may be the last filter condenser in the power supply. If resistor R_3 is too large, the d.c. plate voltage drop in it will be excessive, and the tube will draw little plate current and will give little gain. If R_3 is too small, there will be too little audio drop across it, and the gain will be low. It should be comparable with the tube plate resistance, and is usually several times larger to get maximum voltage gain. This usually means a value between 50,000 and 250,000 ohms.

A pentode resistance-coupled amplifier stage circuit is shown in Fig. 2B. Its performance is similar to that of the triode, except that it usually has a considerably higher gain, and R_3 is somewhat higher. The screen is fed from voltage divider R_4-R_5 across the power supply, and is by-passed for audio by C_5. A sharp cut-off tube is used.

A transformer-coupled triode stage is shown in Fig. 2C. An iron-core audio transformer is substituted for the plate load resistor of Fig. 2A. This reduces the d.c. voltage drop while the high primary inductance maintains the audio impedance. The tube is thus able to give somewhat more output, or to give the same output with a lower power-supply voltage. More voltage gain can be obtained by having a step-up ratio of the transformer feeding the next stage. Usually this is about 3 to 4 times. If it is made higher, it is difficult to provide a reasonably good frequency response. A rather expensive transformer must be used to give comparable frequency response to that obtained with resistance coupling, even with low transformer ratios.

It is not practical to use transformer coupling with pentodes because the plate resistance of pentode voltage amplifier tubes is about a megohm, and no transformer can be built to work out of such a load and still give reasonably wide frequency response. A lower impedance transformer provides a poor match for the tube, and most of the developed voltage is lost inside the tube, giving a low gain, and thus nullifying the advantage of the pentode. A typical impedance- or audio-choke-coupled pentode amplifier circuit is shown in Fig. 2D. The choke has a high impedance at the lowest frequency to be amplified, which usually requires it to have about a 500-henry inductance. It has much lower d.c. resistance than the plate load resistor of Fig. 2B, which it replaces, and thus a lower power-supply voltage can be used for the same gain. The frequency response is not as good with impedance coupling as with resistance coupling, and the gain is not much greater, so it is not often used.

In all the voltage-amplifier circuits shown in Fig. 2 the low-frequency response is limited by the reactance of the input and output coupling condensers or by the inductive reactance of the transformer or choke used. If the choke, transformer, or condenser is made very large, the effect of the shunt or stray capacity to ground increases, which by-passes the high frequencies excessively. In communication receivers it is usually not desirable to pass frequencies below about 100 cycles, as they contribute no intelligence, load up the amplifier power handling capability, and invite hum trouble. The high-frequency response is limited by the shunt capacity to ground. This is partly due to the necessary wiring and socket capacities, and partly due to the input and output capacities of the tube. The reactance of this stray capacity decreases with frequency increase until it becomes much lower than the load resistance, effectively by-passing it. With usual precautions, this effect does not become serious until about 10,000 cycles, which is higher than is required for good intelligibility.

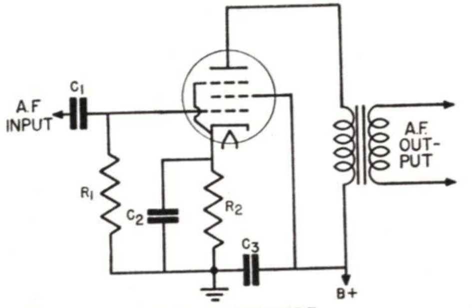
TYPICAL POWER AMPLIFIER CIRCUITS

A typical single pentode audio power amplifier output stage is shown in Fig. 3A. The bias and input coupling arrangement is similar to that of a pentode voltage amplifier. The screen is made to operate at the same or slightly higher d.c. voltage than the plate, which is the full output of the power supply with no dropping resistor. Screen by-pass condenser C_3 is usually the last filter condenser in the power supply. The output transformer is designed with the proper turns ratio and materials to give maximum undistorted output to the load, which is usually the loudspeaker voice coil. The d.c. resistance of the transformer primary is fairly low so that the heavy tube plate current does not produce an excessive voltage drop across it. The transformer must be large in cross section or have an air gap in its magnetic circuit to prevent saturating the iron from the heavy direct current flowing in the plate circuit. Saturation would reduce the inductance and give severe distortion and lack of low-frequency response.

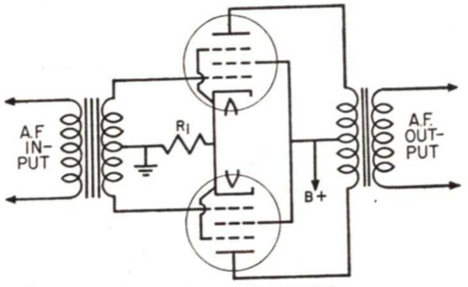
A circuit with two pentodes in push-pull is shown in Fig. 3B. A center-tapped input transformer is used to excite the grids in opposite phase, so that when one is positive with respect to ground, the other is negative. Since the audio signals flowing in the cathode circuits are out of phase, no audio voltage appears across cathode bias resistor R_1, and no by-pass condenser is required. The plates are similarly connected to the center-tapped primary of the output transformer. As the plates are in opposition, the hum from the power supply tends to cancel out, and this stage can be fed from a point having less filtering than is required for the rest of the receiver. The direct plate current for the two tubes flows in opposite directions in the output transformer, and its magnetic effect cancels out, so saturation of the core is not a factor as it is for the single-ended circuit. Even harmonic distortion (2nd, 4th, 6th harmonic, etc.) is canceled in the output transformer. These advantages have led to frequent use of the push-pull output stage even when the increased power output may not appear necessary.

PHASE SPLITTING

One of the common problems in the audio amplifier is the provision of some method of phase splitting or phase inversion to derive two input signals 180 degrees out of phase to drive the two grids of a push-pull output stage. One method of changing from a single-ended to a push-pull stage by means of a transformer with a center-tapped secondary has just been described for the circuit of 3B. Other methods of accomplishing this result are shown in Fig. 4.



Ⓐ SINGLE PENTODE



Ⓑ PUSH-PULL PENTODES

FIG. 3. Audio power amplifier circuits.

The system shown in Fig. 4A uses a transformer without a secondary center tap. The secondary is bridged with two equal series resistors whose junction is grounded, giving an effective center tap. The resistors place a load on the transformer which is reflected to the plate of the driving tube, and may load it to the point where excessive distortion is produced. To avoid this, the resistors are made as high as can safely be used in the grid circuit of the output tubes. If these grids are driven positive on peaks, the distortion due to load change will be much more severe than if a low-resistance center-tapped transformer were used.

The method shown in Fig. 4B uses a center-tapped audio choke as an auto-transformer. The two halves are tightly coupled by their common iron core. This circuit is not as good as one using a well designed transformer, as perfect symmetry between the two grids is not obtained, and there can be no gain in the coupling device.

The method shown in Fig. 4C uses a vacuum tube instead of an iron-core choke or transformer. Such a system is capable of giving excellent fidelity at much lower cost and weight than a transformer system. Either a triode or a pentode tube can be used. Resistor R_4 in the cathode circuit is made equal to R_5 in the plate circuit, and as they are in series, an equal audio voltage appears across each of them. The voltage at the ungrounded end of R_4 has the same phase relation as that on the grid, but the plate voltage is 180 degrees out of phase with that at the grid, and thus the grids of the power output tubes are driven with equal voltages 180 degrees apart in phase, as with a center-tapped transformer. As the input is applied between grid and ground, the drop in audio across R_4 produces degeneration, reducing the gain to either grid to slightly less than one. The negative feedback improves the fidelity and decreases distortion. The input impedance is about 10 times that of R_2, enabling C_1 to be a rather small size. Heater-to-cathode capacity of the phase-splitting tube causes more by-passing of high frequencies from the bottom output tube grid than from the top one. This effect is negligible up to several thousand cycles. Cathode bias resistor R_3 is not by-passed, as it gives negligible loss compared with the drop through R_4 and R_5. The cathode should not be by-passed to ground, as this would by-pass also the input to the bottom output tube grid and cause distortion. As the phase splitting tube cathode is above ground audio potential, hum may be troublesome if the leads are not kept short. It may be desirable to operate the heater from a separate filament winding whose center is connected to the junction of R_3 and R_4 to reduce heater-to-cathode hum leakage.

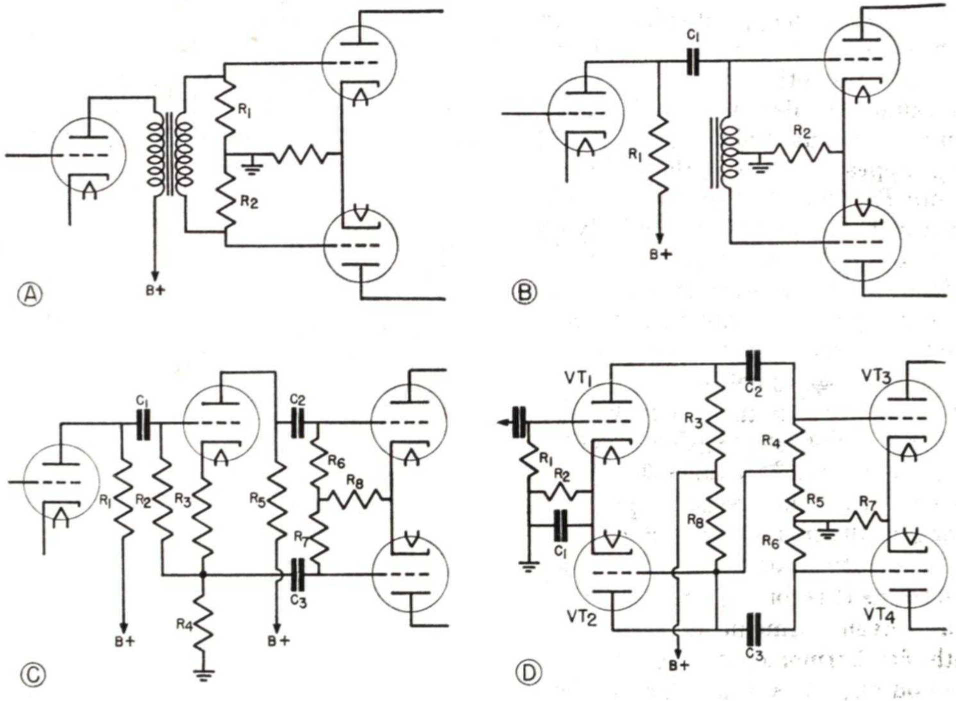


FIG. 4. Phase-splitting arrangements.

Another frequently used tube phase-splitting arrangement is shown in Fig. 4D. VT_1 is the regular driver tube, and VT_2 is the phase splitter. The input voltage for VT_2 is obtained by tapping off a portion of the output of VT_1 in its plate load of R_4 plus R_5. The values of R_4 and R_5 are chosen so that the voltage applied to VT_2 is the same as that applied to VT_1 when the two tubes are of the same type. Adjustment of R_5 to obtain balance is usually done under working conditions to get correct balance between the two sides. The effective gain of VT_2 is then one, and it merely reverses the phase, because its plate voltage is 180 degrees different from its grid voltage, which is in phase with the plate voltage of VT_1. Resistors R_3 and R_8 are equal and R_6 equals R_4 plus R_5. This circuit is quite satisfactory when once properly adjusted, and as the cathodes of VT_1 and VT_2 are nearly at ground a.f. potential, there is little hum trouble.

NEGATIVE FEEDBACK

Negative feedback is feedback from the output to the input of one or more stages which has a component out of phase with the input voltage. When it is applied to an audio amplifier, the noise, harmonic distortion, and phase distortion *in the amplifier stages in the feedback path* are reduced. There is no reduction of these effects occurring before or after this portion of the amplifier. The stability is improved, and variations in performance due to tube or voltage changes are reduced. The frequency response is improved. The equivalent internal resistance is decreased (with negative voltage feedback). All these advantages are obtained at the expense of voltage gain or power sensitivity. Negative voltage feedback occurs when the voltage which is fed back is proportional to the voltage across the output load. This decreases the effective internal amplifier resistance. Negative current feedback occurs when the voltage which is fed back is proportional to the current through the output load. This increases the effective internal amplifier resistance.

The simplest method of producing negative current feedback is to leave the cathode resistor unby-passed as shown in Fig. 5A, or to by-pass only part of it when less feedback is desired. The drop across the cathode resistor is in series with that across the output load resistor, and of a polarity to oppose the input voltage, giving negative feedback. This system is not usually employed on pentode output tubes, because it raises the apparent plate resistance, which is already too high to give proper damping action for good transient response.

Negative voltage feedback as applied to a transformer-coupled amplifier is shown in Fig. 5B. The feedback

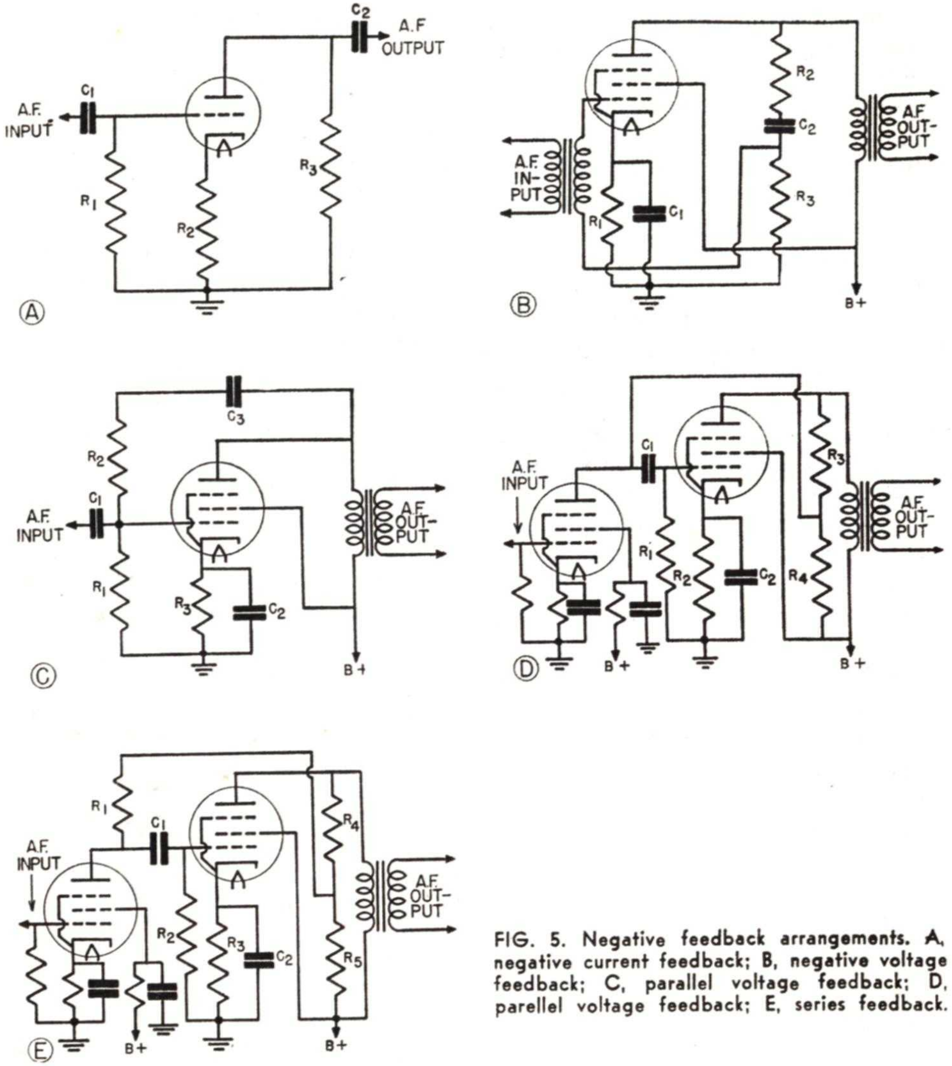


FIG. 5. Negative feedback arrangements. A, negative current feedback; B, negative voltage feedback; C, parallel voltage feedback; D, parellel voltage feedback; E, series feedback.

is determined by the ratio of the two resistances in the voltage divider consisting of R_2 and R_3. Condenser C_2 has negligible reactance and is used to keep the d.c. plate voltage off the feedback tap. A portion of the output voltage is thus fed back to the grid, and as the plate and grid voltages are of opposite phase, the feedback is negative.

A parallel voltage feedback circuit used with a single resistance-coupled stage is shown in Fig. 5C. Condenser C_3 is a blocking condenser to keep d.c. plate voltage out of the grid circuit, but it has low audio reactance. The negative voltage feedback to the grid is determined by the voltage divider consisting of R_2 in series with the combination of R_1 and the previous stage plate load resistor and tube plate resistance in parallel. This circuit makes the equivalent input impedance of the stage very low, and C_1 must be a very large capacity to give good low-frequency response.

The circuit of Fig. 5D is similar to that of Fig. 5B in its operation, but no input transformer is required.

A series feedback circuit is shown in Fig. 5E. This is the same as Fig. 5D except for the addition of plate load resistor R_1 for the driver tube. This is a very satisfactory circuit.

Negative feedback may be applied over two or three stages, but care must be taken that at very low or very high frequencies, the cumulative phase shifts do not become sufficient to change from negative to positive feedback and produce oscillation of the amplifier.

In the average communication receiver in which fidelity is of minor importance, feedback is not generally used.

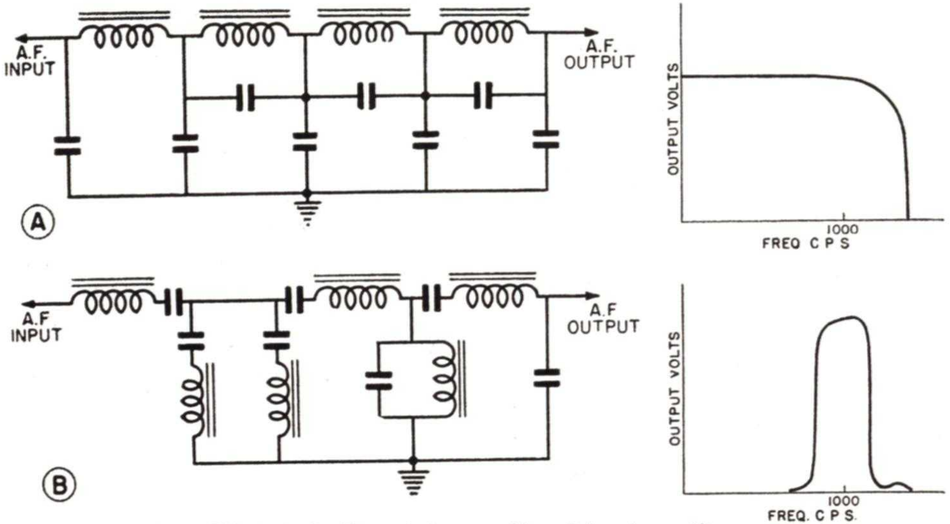


FIG. 6. Audio filters. A, low-pass filter; B, band-pass filters.

AUDIO FILTERS

We have found that for optimum intelligibility, there is a maximum high-frequency response, beyond which the increase of noise is a greater disadvantage than the advantage of a slight increase in signal fidelity. It would be desirable if the response would suddenly fall to zero at this high-frequency limit, and would remain zero at all frequencies above this value. A shunt condenser across any point of the audio amplifier by-passes high frequencies more than low ones, but does not have the desired rapid drop. This arrangement is often used to give a poor approximation of the desired characteristic. The circuit of about the best commercial filter obtainable to give sharp cut-off is shown in Fig. 6A. This is known as a "low-pass filter," as it passes all frequencies from zero (d.c.) up to its "cut-off frequency" where the output falls very rapidly as shown in the response curve at the right. This is about as close to the ideal vertical drop as can be obtained at a reasonable cost and size. A typical code filter of this type gives half the low-frequency voltage response (6 db down) at 1350 cycles, and one-hundredth this voltage response (40 db down) past 1350 cycles. This shows the extent of the drop once cut-off starts. All beat notes from zero up to about 1350 cycles may be used with this filter, but no high-frequency noise components reach the output. The cut-off frequency may be extended to use this filter for voice work by changing the values of the components.

For extreme selectivity such as that needed for code reception in the 15 to 200 kc. range where signal channels are 150 cycles apart, a very sharp audio filter is very helpful. Audio filters can provide the required selectivity more readily than even a crystal filter in the i.f., because the percent of frequency difference is so much greater at audio frequencies. Tuned audio circuits can be used, but it is difficult to build such circuits with a Q greater than about 20, and the sides of the selectivity curve are thus not very steep. A special filter designed to have more nearly the ideal rectangular selectivity curve is known as a "band-pass" filter. The circuit for an excellent commercial unit of this type is shown in Fig. 6B with a typical response curve at the right. With the filter set to pass a 1000-cycle beat note for c.w. reception, the band width is 6 db down from optimum response at 215 cycles, and is 40 db down at 425 cycles, showing the great steepness of the sides. This gives selectivity comparable with the greatest obtainable with a crystal i.f. filter, with no maintenance or alignment adjustments, as all components are of commercial tolerance, and all are sealed into a single container having only an "input," an "output," and a common "ground" terminal brought out to easily accessible points.

Audio filters of this type must have proper resistance terminations at input and output to give proper response characteristics. The input may be designed to work out of the plate resistance of a suitable audio amplifier tube, and the output load with the addition of a suitable resistor may be the grid leak of the next stage. The usual location of such audio filters is between the second detector and the first audio amplifier, so the signal level in the filter is kept as low as possible. Strong static pulses or code keying will cause a filter like that of Fig. 6B to "ring" at its center frequency for several cycles after the sudden input change is past. This causes keying to "run together" and be hard to separate at high speeds, and the spaces between characters are "filled in" by static ringing the filter, still further reducing readability. This effect is also obtained when a crystal filter is employed in its sharp selectivity condition, and under some conditions this selectivity cannot be used. This is when the low-pass filter may be most useful. Provision must be made to switch the filter in or out of the circuit, or to broaden its response when necessary. A good filter introduces very small loss at its resonant or optimum frequency. Those of Fig. 6 can be made to have about a 6 db or less loss.

The Power Supply

BATTERIES

The modern superheterodyne receiver requires electrical power to operate the filaments of the various vacuum tubes, and a steady source of d.c. voltage of the proper potential for their plates, screens, and control grids. In the early days of vacuum tube receivers, all these required voltages were supplied by batteries. Other power sources have since been developed, but batteries are still used in many communications sets, particularly in those used in mobile services. Dry cells are frequently used for portable and emergency receivers. Large storage batteries are used in aircraft, aboard ship, and in other mobile installations, and some small types are popular for portable use.

D.C. POWER LINE

In some localities, commercial d.c. power is available at about 115-volts potential. This is sometimes used to power receiver heaters by placing all heaters in series and using a series resistor to make up the difference between their combined voltages and 115 volts. The power line potential is used directly, or usually after some filtering, as plate and screen voltage. Bias or C voltage is usually obtained by the drop in cathode resistors or between the negative supply terminal and the chassis. Receivers which will operate on either a.c. or d.c. are connected in this manner, but a plate supply filter of larger capacity is fed through a rectifier tube. If the d.c. polarity is wrong, the rectifier does not conduct, and the receiver does not operate, but no harm is done. Reversal of the power plug at the wall outlet reverses the polarity and permits the rectifier to conduct. The chassis must be insulated from ground, because usually one side of the power line is grounded, and inserting the power plug in the wrong way would short-circuit the line; d.c. power is sometimes converted to a.c. by use of a motor-alternator or vibrator-transformer (sometimes called an inverter) as when the storage battery is used. The a.c. is then used to operate receivers designed for a.c. operation. The d.c. power line eliminates the possibility of portable operation, and frequently gives large voltage variations which affect performance. Appreciable filtering of ripple and noise components is usually required. Power cost is low and there are no life or maintenance difficulties.

A.C. POWER LINE

By far the most common source of power for operating radio receivers is the commercial a.c. power line supplying a voltage of from 105 to 125 volts at frequencies of from 25 to 60 cycles per second, the latter being the most prevalent. This power source has the advantages of large power capability, ease of conversion to both high and low voltages, and freedom from maintenance requirements. It is so universal that even a considerable degree of portability is possible, as a similar power source is often available at the desired alternate location of the receiver. To use an a.c. supply for B and C power, a rectifier and filter system is necessary, and usually a transformer in addition, except for a.c.-d.c. receivers. These required components are relatively heavy and space consuming, although remarkable progress in reducing these factors has been made.

The actual circuits employed are

standard, and as they have been covered in detail elsewhere, this information will not be repeated here.

THE BLEEDER AND VOLTAGE DIVIDER

The regulation or steadiness of voltage output from the B supply filter under varying line-voltage and receiver-current changes due to a.v.c. or gain-control manipulation, is improved by the use of a constant resistance load on the power supply in addition to the receiver load. This load usually takes no more than 10% of the total output, and is called a bleeder resistance. It makes certain that the filter condensers discharge after the receiver is turned off, and keeps the voltage from building up to dangerous values across the filter condensers when the receiver is first turned on, and before the tubes have had time to warm up enough to draw their normal current. The bleeder may serve another function as a voltage divider. Any voltage less than the maximum may be tapped off on the bleeder and used for screen voltage or plate voltage of some of the stages.

VOLTAGE REGULATION

To improve the stability of the local and beat oscillators, the voltage applied to them should not vary when the line or receiver load varies. This characteristic can be improved by the use of several types of voltage regulators. The simplest and most widely used is the cold cathode gas tube regulator whose circuit is shown in Fig. 7. The filtered power supply output is fed to the load circuit through resistor R_1. The regulator tube is in parallel with the load. This tube requires a certain voltage to cause it to conduct, whereupon it emits a colored glow. Under this condition, increasing the voltage applied to the input of the resistor causes more current to flow through the resistor and the tube, but the load current and voltage tend to remain the same, and the voltage increase appears as an increased drop across R_1. In other words, the voltage across the regulator tube remains constant for rather wide variations of current through it, which is not in accordance with Ohm's Law. The tube will not work properly with less than about 5 milliamperes flowing through it, and will be damaged or its life will be seriously shortened if the current through it exceeds about 40 milliamperes. The receiver current is the difference between the tube current and the total current. R_1 must be chosen to keep the tube within safe limits. In some cases, two or more regulator tubes are connected in series, or in parallel, to give different regulated voltages or greater range of regulation. There are elaborate vacuum tube regulator circuits which hold the voltage within remarkably close limits, but these are relatively complex and are not often used in receiver power supplies. No examples of such circuits will be given here, but you may find them in some receivers where exceptional stability is required without the use of crystal control.

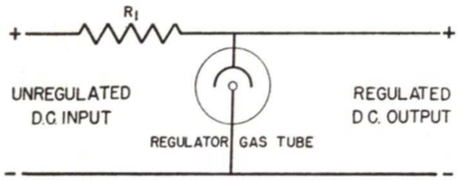


FIG. 7. Cold-cathode voltage-regulator circuit.

POWER-LINE FILTERS

A sensitive communication receiver may receive signals which are picked up on its power line and which leak through stray capacities into the input or i.f. circuits. A power-line filter which will not pass r.f. signals while passing the power frequency is often used to reduce this effect. A very simple filter consists of a condenser from each side of the power line to ground to by-pass incoming disturbances to ground, regardless of which way the power plug is polarized. A more elaborate filter may employ one or two shielded inductances and three or four shunt condensers in each side of the line. Such filters are very valuable when transmitters are operating near by.

Special Circuits

AUTOMATIC VOLUME CONTROL

Because of the wide variations in strength of different signals encountered, and because of the variations of a given signal due to fading, an automatic volume control (abbreviated a.v.c.) which makes all signals deliver approximately the same receiver output is often very desirable for voice-modulated signals. Such a control should vary the receiver gain in inverse proportion to the signal strength. A.V.C. is accomplished by rectifying the i.f. carrier and applying the negative average d.c. voltage obtained as bias to the r.f., i.f., and often the mixer grids, in addition to the bias obtained in other ways. Since the a.v.c. bias is proportional to the average signal amplitude, the receiver gain is reduced as the signal strength increases. It is not possible to overcontrol by this method. In other words, the output will still be somewhat greater on strong signals than on weak ones. The difference becomes less, or the control becomes better, the greater the number of stages and the greater the gain of the stages which are put on the control.

Delayed A.V.C. It is usually desirable for a.v.c. action not to commence until a certain signal level is reached. This permits the full receiver gain for weak signals, but gives normal a.v.c. gain reduction for strong ones. This action is called delayed a.v.c. It is obtained in a diode detector by placing a negative delay bias on the a.v.c. diode plate, so that no rectification, and hence no a.v.c. bias, is developed until the signal voltage is enough to overcome the delay bias. Delay bias must not be used on the same diode which is used to give audio output, or excessive distortion or lack of output on weak signals will result. Separate a.f. and a.v.c. diode plates are used with delayed a.v.c.

A.V.C. Time Constant. The time constant of a circuit consisting of a condenser fed from a source of voltage through a resistor is the time it takes to charge the condenser up to 63% of its ultimate value. This time in seconds is the product of the condenser capacity in farads and the resistance in ohms. If the time constant of the condenser and resistor filter used to remove the audio variations from the rectified i.f. carrier is too fast low, the audio variations are not eliminated, and when applied to the r.f. and i.f. grids, the effective modulation percentage is reduced, and distortion is introduced.

slow

If the time constant is too high, the a.v.c. voltage cannot follow relatively fast signal fading, and much of its utility is lost. The usual time constant is from one to two tenths of a second. This is obtained by using 0.1 microfarad and one megohm or 0.2 microfarad and one megohm. Considerable leeway from these values will be found in various receivers. A much slower time constant may be used for c.w. code reception to hold the gain relatively constant between characters. When a.v.c. is used for c.w. reception, the beat oscillator voltage must be kept low to avoid its biasing the a.v.c. system and reducing the sensitivity just as a very strong signal would.

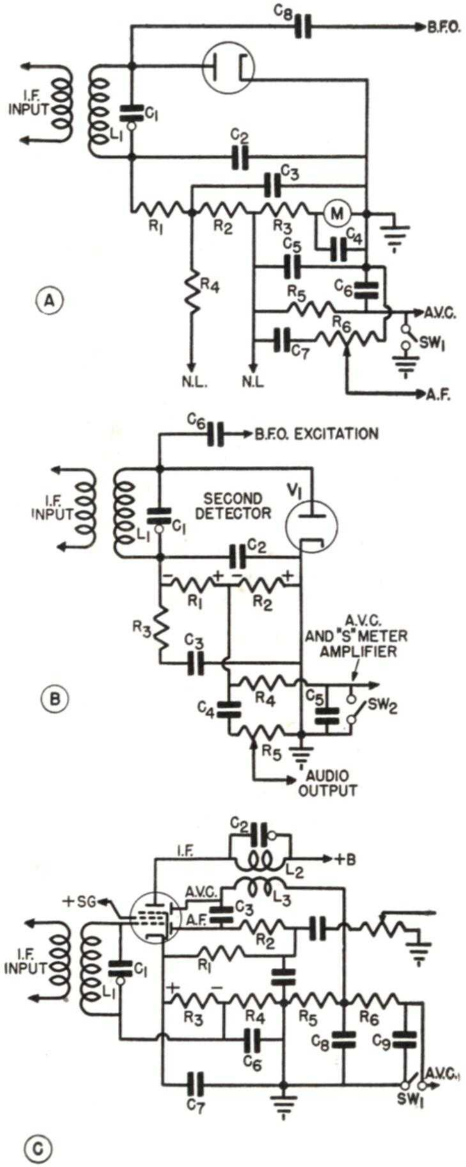


FIG. 8. Typical a.v.c. circuits. A, Hammerlund HQ-120 second detector circuit; B, Hallicrafter SX-28 second detector circuit; C, RCA AR-60-S second detector circuit.

Typical A.V.C. Circuits. Typical a.v.c. circuits are shown in Fig. 8. Those at A and B are essentially the same, a single diode is used for a.v.c. and audio. A.V.C. voltage is taken from a tap on the diode load, and is filtered by a series resistor and a shunt condenser. A switch shorts the a.v.c. to ground to disable it for c.w. reception, but this does not short the audio, because of the large decoupling of the filter resistor. The circuit of Fig. 8C uses a separate diode for a.v.c. and for audio. The audio diode load R_1 returns to the cathode, so it has no appreciable bias. The cathode returns to ground, and about 12 volts bias is developed across R_3 and R_4 by the plate and screen current of the pentode section of the tube. This bias is applied as delay voltage to the a.v.c. diode, whose load R_5 returns to ground.

In Fig. 9A, a circuit is shown which has a single diode for both audio and a.v.c. output. A second diode is used as a delay tube. The delay bias is obtained by the entire receiver plate and screen current flowing through a 50-ohm resistor from the negative plate supply terminal to ground. The plate of the delay tube is connected to the a.v.c. line, and its cathode is connected to the negative delay bias, placing a positive voltage on its plate and rendering it conductive. With no signal input, the conductivity of the delay tube causes the a.v.c. system to assume the potential of the delay bias. This bias is held on the a.v.c. system until the d.c. voltage in the signal diode load exceeds it, whereupon the delay tube becomes non-conducting, and the a.v.c. system operates in the usual manner. This arrangement does not bias the second detector appreciably on weak signals, because of the isolation of the 2-megohm a.v.c. filter resistor, and distortion is very low. The delayed a.v.c. system shown in Fig. 9B has separate a.v.c. and detector diodes, and is similar to that of Fig. 8C except that the delay bias is obtained by the drop of the entire receiver plate and screen current from the negative power supply terminal to ground as in Fig. 9A instead of by the drop of a single tube's current in its cathode resistor.

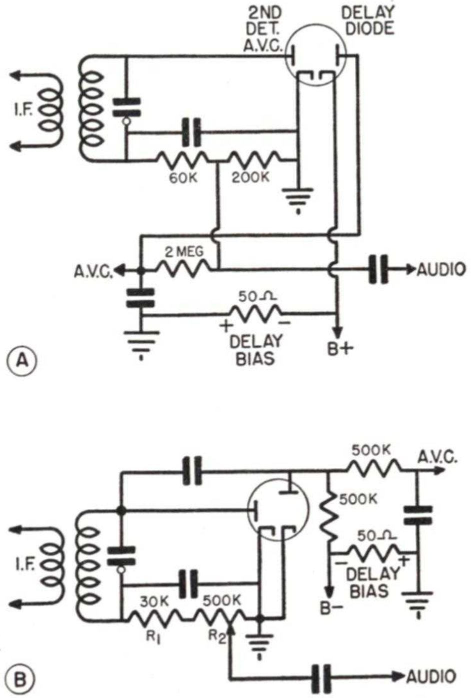


FIG. 9. Delayed a.v.c. systems. A, single diode second detector and a.v.c. with special delay diode. B, separate audio detector and delay-biased a.v.c. diodes.

To help clarify the action of a receiver with no a.v.c., ordinary a.v.c., and delayed a.v.c., the curves of Fig. 10 are shown. These curves show what happens to the audio output when the strength of a resonant signal is varied from below that usable up to one volt. With no a.v.c., the i.f. amplifier overloads and blocks shortly after maximum output is reached. With ordinary a.v.c., the gain continuously decreases as the signal strength increases, and there is no straight-line portion. With delayed a.v.c. there is an appreciable linear portion, and the output is greater for the same signal strength from 1 to over 10,000 microvolts input than it is for ordinary a.v.c. The threshold where the delay ceases to hold is at about 12 microvolts.

A.V.C.-Controlled Tubes. The tubes which are controlled by a.v.c. must be of the remote cut-off type, which operate in a linear manner over wide variations of bias. Otherwise they would cut off on strong signals, and severe distortion or complete loss of output would result. The last i.f. stage is sometimes left off the control, or is fed a reduced a.v.c. voltage, as it is subjected to such a large grid swing that increasing its bias with a.v.c. might drive it off the linear portion of its characteristic curve and produce distortion.

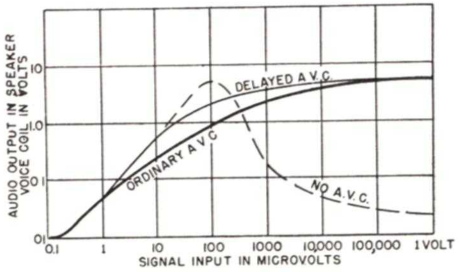


FIG. 10. Typical resonant overload curves for the same receiver with no a.v.c., ordinary a.v.c., and delayed a.v.c.

Tuning Indicators. When a.v.c. is used, it is found that when a signal is slightly off tune, reception sounds noisy and distorted. This is because there is less signal, giving less a.v.c. bias, and the receiver gain is increased to an off-tune signal. One set of side bands is amplified more than the other, producing distortion, but the total volume may be about the same. A broader a.v.c. working through less of the receiver selectivity is one solution to this problem, and it has been used in commercial receivers. This may cause a desired weak signal near a strong one to be missed. The preferred arrangement is some indicating device which shows when exact resonance is obtained. The simplest device of this sort is a d.c. meter in series with the diode load, which gives a reading proportional to carrier strength. The tuning is adjusted for maximum meter reading on each signal, regardless of the value of the maximum itself. Such an arrangement is shown in the circuit of Fig. 8A. Often such a meter is connected to read the plate current of the last a.v.c.-controlled tube or of several a.v.c.-controlled tubes. As this current decreases when a.v.c. voltage increases on stronger signals, the current minimum indicates resonance. The meter may be mounted upside down, or a bridge circuit may be used to get its pointer to move from left to right for stronger signals. In some cases, a special d.c. amplifier tube operating off the a.v.c. line, drives a d.c. meter in its plate circuit. This enables a less sensitive (and less expensive) meter to be used.

The "magic eye" tuning indicator is very popular. It is a small cathode-ray tube usually incorporating a d.c. amplifier, in which the angle of luminous glow increases when the bias on the d.c. amplifier increases. By operating this amplifier from the a.v.c. line, the receiver tuning is optimum for greatest "closing" of the eye, or for maximum luminous area. The tuning meter can be calibrated to measure input signal strengths, and is often used for this purpose. The calibration is generally made in "S" units to enable the operator to judge the relative strength of different signals. Visual tuning aids are also a help in aligning the front end of the receiver.

SQUELCH, SILENCER, OR "CODAN" CIRCUITS

When a sensitive receiver with an effective a.v.c. system is tuned, the noise becomes objectionably high between stations, because the a.v.c. increases the receiver gain to the maximum. Circuits which eliminate this interstation noise, or which require a predetermined signal strength before any receiver output will be obtained, are called squelch, silencer, or CODAN (carrier operated device, anti-noise) circuits.

A simple squelch circuit is shown in Fig. 11A. The second detector and a.v.c. circuits are conventional. A 12-volt positive potential obtained from the power supply by the voltage divider R_{11}-R_{12} is applied to the squelch tube plate through R_8. With no input signal present, the drop across R_8 is of proper polarity and magnitude to bias the first audio tube to cut-off, giving no receiver output. When a sufficiently strong signal is received, the a.v.c. voltage drives the grid of the squelch tube sufficiently negative to cut off its plate current, and no bias appears on the first audio tube because of the drop in R_8, which is then zero. The audio tube then operates normally with cathode bias determined by its cathode current flowing through R_7.

A more elaborate circuit which gives a much sharper cut-off with less audio distortion near the cut-off point is shown in Fig. 11B. The second detector circuit is conventional except that the first audio stage has a small amount of a.v.c. Silencing action takes place when the plate current of the silencer amplifier tube which flows through resistor R_{15} in common with the silencer diode, reduces the diode plate voltage to cut-off. Audio signals that are too weak to exceed the cut-off level, determined by the plate current from the silencer amplifier, are not passed through the remainder of the audio amplifier.

There is thus no output when too weak a signal is present. The plate current of the silencer amplifier is determined by both the a.v.c. voltage ap-

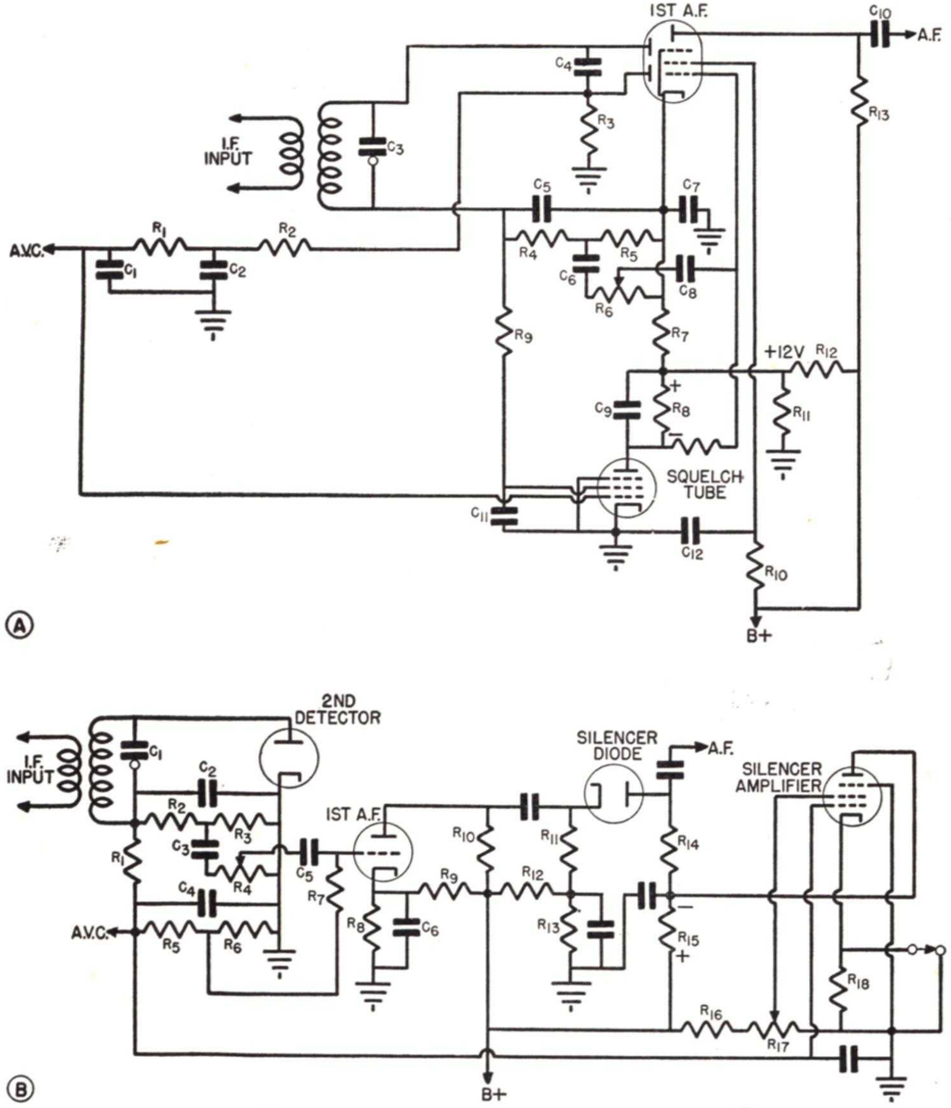


FIG. 11. Squelch Circuits. A, broadcast interstation noise-suppressor circuit. B, circuit giving sharp "knee" of squelch characteristic and wide range of level at which squelch begins.

plied to its grid and its screen voltage controlled by R_{17}. This screen voltage is the main factor in cutting off the diode because of its effect on the silencer amplifier plate current. The same sharp silencing action can be obtained over a range of several orders of input by properly setting R_{17} for the minimum signal strength it is desired to receive. When the cathode switch of the silencer amplifier is opened, this amplifier is biased nearly to cut-off, and silencer action ceases, permitting the weakest signals to operate the audio amplifier.

Squelch circuits are very valuable in mobile police cars, airport control towers, and point-to-point voice circuits which are used only intermittently, to avoid subjecting the operator to a constant roar of background noise when no signal is on the circuit. When he hears output from the receiver, he can pay attention to it, and at other times he is not bothered. The interstation noise suppressing feature is usually of more interest for broadcast receiver applications.

NOISE LIMITER OR SUPPRESSOR CIRCUITS

The noise present in the receiver output may consist of clicks, pops, or other separated impulses of high amplitude and short duration, or it may consist of hissing, humming, or roaring noise made up of many overlapping small pulses. Some of the hiss originates within the receiver due to thermal agitation and electron shot effect, and the hum is usually due to lack of complete shielding and filtering of the power supply. A considerable proportion of the noise is usually picked up on the antenna along with the signal, and much of it is of man-made origin. Hiss or roaring noise may be caused by high speed series motor commutator sparking, mercury vapor rectifier "hash," and power line insulator leaks. Impulse noise may be caused by lightning, auto ignition systems, and all sorts of electrical switching operations.

The best method of reducing man-made noise if the source cannot be located and corrective measures applied to it, is to place the receiving antenna as high and as much in the clear as possible, and to use a transmission line which does not pick up noise, or which cancels the noise picked up. The use of a directive receiving antenna reduces noise which would otherwise be picked up from the unused directions. The smaller the receiver band width, the less noise passed, but impulse noise may "ring" the receiver when the band width becomes too narrow, as has already been pointed out. Short of this procedure, little can be done to reduce the effect of steady hiss or roaring noise. Impulse noise can be clipped off at, or even below, signal level with appropriate peak noise limiter or suppressor circuits, giving a great improvement in signal readability because the noise impulse usually produces shock excitation effects on the circuits and reproducer, which last many times the original pulse length.

Peaks which exceed the signal level may be prevented from producing more output than the signal by means of an audio output limiter such as that shown in Fig. 12A. The audio output pentode is operated with variable screen voltage set by limiter control R_1. The screen voltage can be adjusted so that the tube can deliver only the desired output with maximum audio gain and a strong input signal. No peak can exceed this, and thus all peaks exceeding the signal are clipped off. There is considerable distortion in the limiting process if the level is held down, so this system is useful mainly for c.w. reception where this distortion is of no particular importance.

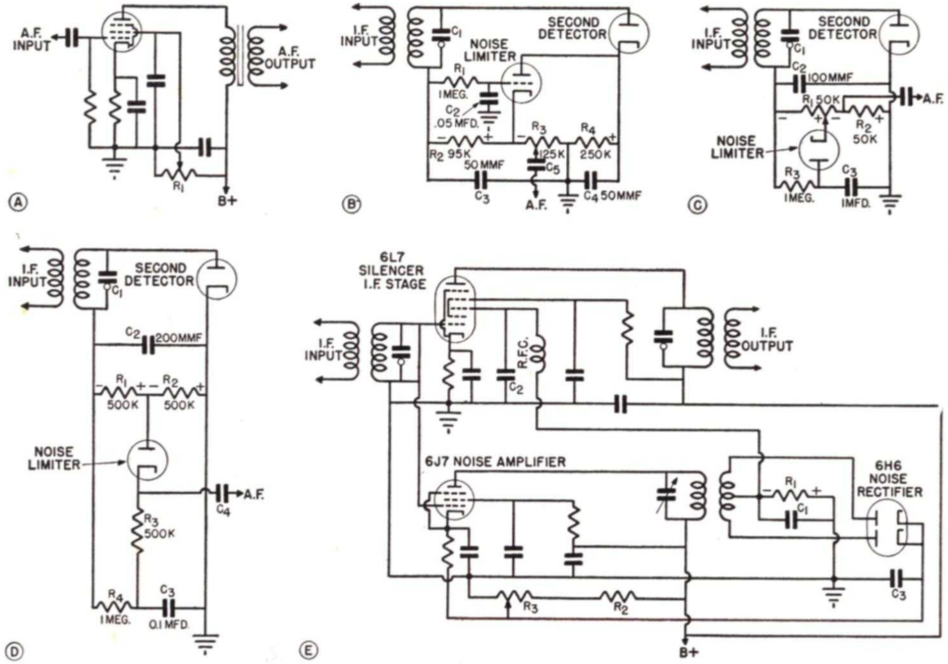


FIG. 12. Noise limiter circuits which are effective on peak or impulse noise. A, audio output limiter; B, shunt noise limiter; C, shunt noise limiter; D, series noise limiter; E, i.f. feedback (Lamb) noise silencer.

The system shown in Fig. 12B employs what is called a shunt limiter across the audio output from the second detector. The diode load consists of resistors R_2, R_3, and R_4 in series, and audio is taken from the movable tap on R_3. The plate and cathode of the noise limiter shunt diode load resistors R_3 and R_4 across which audio voltage is developed. The grid of the noise limiter tube is returned to the negative end of the diode load through R_1 which is a high resistance. As the carrier increases, the bias for the noise limiter is the d.c. drop across R_2. The plate voltage is the d.c. drop across R_3 and R_4 in series. As the relative increase of bias and plate voltage is constant, the tube stays cut off during slow carrier changes. A sudden noise pulse raises the plate voltage, but although the voltage across R_2 rises by the same percentage, it does not vary the bias immediately because of the large time constant of R_1 and C_2. By the time C_2 begins to charge up appreciably, the noise pulse has ceased. This sudden increase of plate voltage with the same grid bias causes the tube to conduct, and its low plate resistance shunts the input to the audio amplifier, loading it heavily, and greatly reducing the effect of the impact on the following circuits.

Another type of second detector shunt noise limiter using a diode tube is shown in Fig. 12C. The diode load consists of R_1 and R_2 in series. Audio is taken from the junction of these resistors. By moving the variable tap on R_1, various values of negative voltage may be applied to the diode plate for any given carrier level. The diode is thus normally cut off or non-conducting, and slow changes of signal level keep it in this condition. A sudden pulse makes the cathode more negative with respect to ground than before, but the plate is not immediately made more negative because it takes considerable time to charge C_3 through R_3 because of their large time constant, and the diode plate becomes positive with respect to its cathode. The diode then conducts, and its low plate resistance in series with the low reactance of C_3 shunts the diode load from the tap on R_1 to ground, greatly reducing the peak amplitude. Before C_3 can charge up to the pulse amplitude, the pulse has ceased, and normal cut-off diode operation is resumed. Shunt limiters cannot completely cut off noise pulses, and although they are easily added to existing receivers, the series limiter requiring no more components and giving better performance, is usually employed in modern communication work.

The circuit of a series peak noise limiter which is more effective than the shunt type is shown in Fig. 12D. The audio output from the tap between diode load R_1 and R_2 is fed to the audio amplifier in series with the noise limiter diode. No voltage will be fed to the audio amplifier unless the diode is in a conducting state. It will be noted that the circuit is practically the same as the shunt limiter shown in Fig. 12C with the diode reversed. The d.c. drop across R_1 places a positive voltage on the diode plate, so that it is normally conductive with any level of signal and for slow changes of signal strength. The cathode potential cannot change rapidly because of the large time constant of R_4 and C_3. The application of a large pulse makes the plate much more negative with respect to ground, and thus the diode becomes non-conducting and opens the input to the audio amplifier. This limiter begins to limit even the signal modulation peaks when they exceed 40% modulation. The distortion does not sound objectionable to the ear on signals which hit 100% modulation on peaks, and the improvement in readability is quite noticeable over that obtained when cutting takes place at 100% modulation. The point at which cutting begins can be regulated by changing the relative values of R_1 and R_2. As 40% has been found the optimum percentage, this setting is usually fixed. The limiting level is automatically set by the carrier level, so no adjustment is required. Operation is quite effective even on c.w. reception because average bias is retained by the charge on C_3. This limiter is the most effective of any in use, and works on more different types of noise under more different receiver adjustment conditions than any other.

The circuit of the Lamb or i.f. feedback noise silencer is shown in Fig. 12E. A special noise amplifying i.f. stage is fed in parallel with a regular i.f. stage with the special 6L7 mixer tube as a pentode with an injection grid. The noise amplifier drives a push-pull noise rectifier, whose negative output voltage feeds the regular 6L7 injection grid, cutting off this tube whenever a noise peak exceeding a predetermined value is received. The noise rectifier has an adjustable delay bias applied by means of R_3, fed from the power supply through R_2. This also places more bias on the noise amplifier at the same time the delay bias is increased. This setting must be made for each signal level and type of noise. The time constants of all i.f. circuits and of the injection grid circuit must be kept low to avoid excessive blocking after the cessation of a noise pulse. Under some conditions, the increase of distortion does more harm than the noise limiting does good. The timing must be such that the silencing does not occur either ahead or behind the pulse itself. For most communication receiver applications this limiter is not as desirable as the simpler and adjustment-free series type.

TONE CONTROL

The use of various series and shunt condenser and resistor combinations to extend or reduce the frequency range of the audio amplifier is common in broadcast receivers, so that the listener can adjust the response to suit his personal taste or the acoustic properties of the room in which the receiver is located. Such controls are sometimes found on communication receivers, but are usually considered merely "gadgets" by commercial operators. The response should be just as good as necessary for intelligible reception to reduce noise to a minimum. If this is not inherent in the receiver, or if the proper band-pass filters are not available, the tone control may partially accomplish the desired result. The usual tone control consists of a variable resistance in series with a condenser connected between a high impedance point in the audio amplifier and ground. There is little shunting effect of the higher frequencies with all the resistance in the circuit. As the resistance is decreased, the condenser becomes more and more effective in by-passing the higher frequencies, and the effect is as though the lower frequencies were accented. This condition is often helpful in receiving voice signals through severe static or peak noise, much of which consists of higher frequency components.

VOLUME CONTROL

In modern communication receivers, it is usual to have both an audio gain control following the second detector and also a common r.f. and i.f. gain control which is manually controlled. This is usually a potentiometer fed from the plate supply, with a variable tap connected to the cathode returns of all the r.f. and most of the i.f. stages. The r.f. gain is usually left full on when a.v.c. is in use, and output is controlled with the audio gain control. When a.v.c. is not used, the audio gain control is usually left full on, and gain is controlled with the manual r.f. control. This usually gives optimum sensitivity, optimum signal-to-noise ratio, and freedom from overload.

A Modern Communication Receiver

DESCRIPTION

A schematic diagram of the National NC-2-40D Receiver is shown in Fig. 13. This is a twelve-tube superheterodyne covering the continuous frequency range from 490 to 30,000 kc. This receiver was designed to give the amateur a maximum of bandspreading, and combines mechanical bandspreading on all bands with additional electrical bandspreading of the 10, 20, 40, and 80 meter amateur bands. The receiver also incorporates very stable high-frequency circuits, because of the high-frequency oscillator circuit design which eliminates the detuning effect of the r.f. gain control, and the even more undesirable motor-boating or fluttering which occurs in some receivers when tuning in strong high-frequency signals. Perhaps the best way to prove the exceptional performance of this type of circuit is in the 10-meter band where a line-voltage shift from 100 to 120 volts produces less than 1000 cycles change in tuning. This is a variation of less than .003 per cent. Frequency drift has been reduced to a minimum through the use of temperature compensating capacitors, not only in the high-frequency oscillator circuits, but in the r.f. and first detector circuits as well.

The sensitivity is particularly high, an input signal of only 1 microvolt providing 1 watt of audio output. Well designed r.f. coupling circuits have made possible the maintenance of full sensitivity up to the highest frequencies covered by the receiver. Moulded polystyrene coil forms are used in all circuits, both r.f. and i.f., thus assuring the freedom from circuit losses or detuning which might otherwise be caused by humidity effects. Variable condenser insulators, tube sockets, etc., are of Isolantite.

Circuit. The circuit used on all bands consists of one stage of radio-frequency amplification, a separate first detector and stabilized high-frequency oscillator, two intermediate frequency stages, an infinite impedance second detector, a self-balancing phase inverter and audio amplifier, and a push-pull audio output stage.

The second detector utilizes one set of elements of a dual triode; the other set of elements is utilized for a series type noise limiter. Separate tubes are used in the automatic volume control and beat frequency oscillator circuits. The latter is coupled to the second detector for c.w. reception.

A crystal filter is connected between the first detector and first i.f. amplifier tubes.

All voltages required by the receiver circuits are supplied by a built-in power supply.

Tuning System. The three-gang tuning capacitor C_{1A}, C_{1B}, and C_{1C} and six sets of coils are used to tune to 490 to 30,000 kilocycle range of the receiver. By means of a highly developed band-change mechanism, four of these same coil sets are made to spread the 10, 20, 40, and 80 meter amateur bands uniformly over the major portion of the tuning dial. All ten ranges are calibrated. For simplicity Fig. 13 shows only one set of coils.

All transformer coils of the r.f. amplifier, first detector, and h.f. oscillator stages with their associated padder and air-dielectric trimmer capacitors are mounted in a rigid aluminum casting which slides the length of the chassis, being moved by the main tuning control. The various coil assemblies are

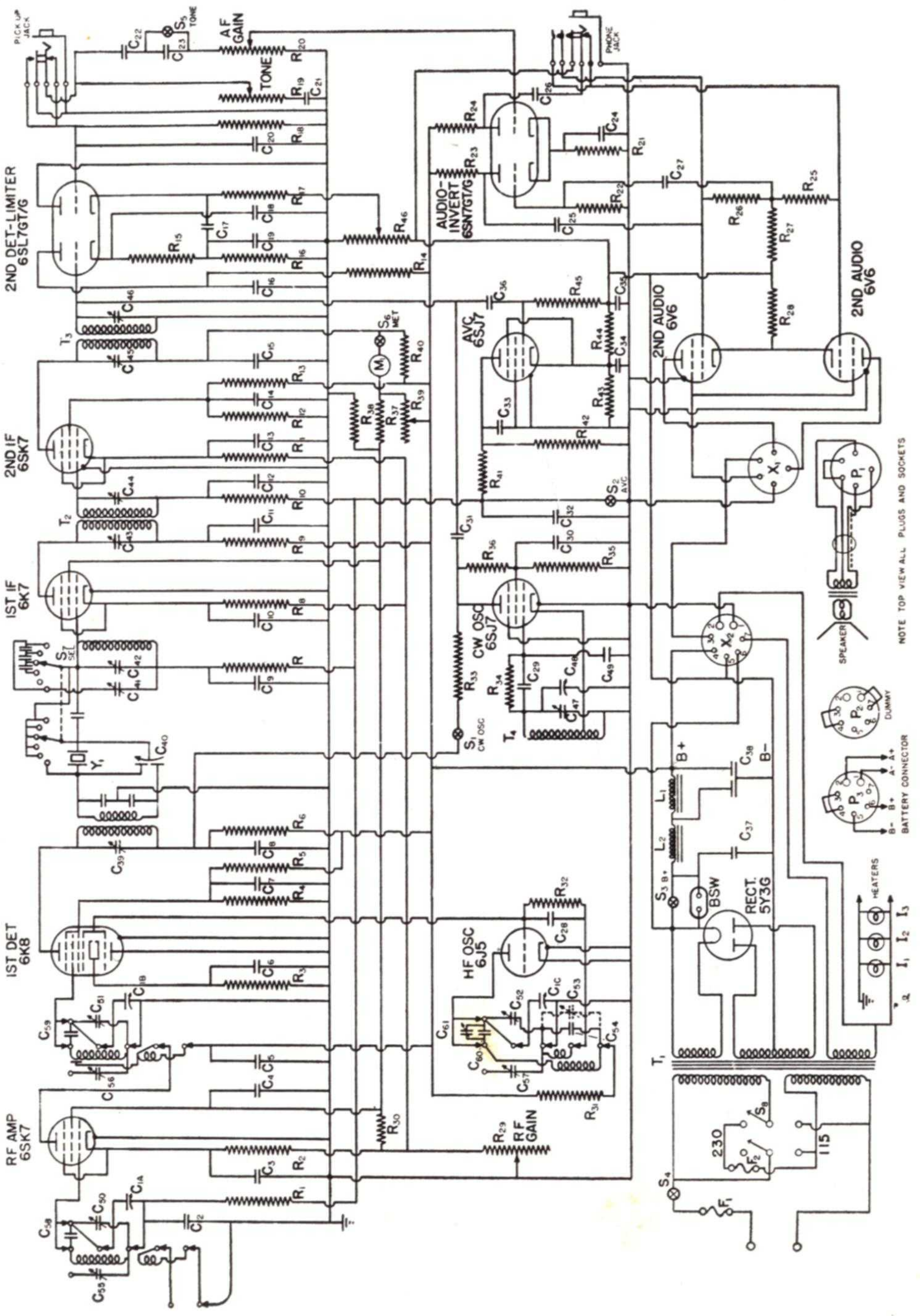


FIG. 13. This is the manufacturer's schematic of the National NC-2-40D receiver.

fitted with heavy contact pins which engage spring contactors mounted immediately under the variable tuning capacitor. This system permits thorough shielding of each individual coil while, at the same time, the coils in use are moved to the best position in the chassis, giving shortest leads to the tubes and master tuning capacitor, and all other coils are completely disconnected from the circuit.

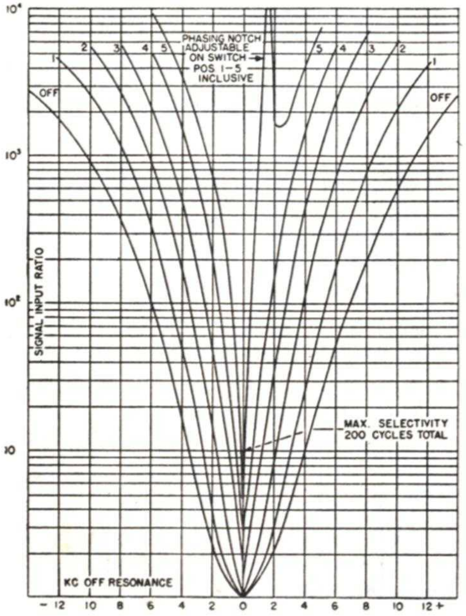


FIG. 14. Typical selectivity characteristics.

Crystal Filter. Six uniform steps of selectivity, as shown in Fig. 14, and a variable phasing control allow the receiver to be adjusted to almost any operating condition, a highly desirable feature for both short-wave communication and broadcast reception. The curves show that any degree of selectivity between that of full single signal operation and wide-band broadcast reception is available, the ratio between the two being almost forty to one.

Noise Limiter. The simplified circuit is shown in Fig. 15. The action is as follows. An adjustable voltage from potentiometer R_3 is connected to the diode elements (the cathode and grid, since the plate is grounded and does not perform any function) through resistors R_4 and R_5. The polarity of this voltage is such that a current is maintained between the diode plate (the grid) and the cathode. The diode elements are therefore in a conducting condition and will allow audio voltages to pass from the cathode to the grid, and the circuit from input and output will be complete as long as the diode "plate" remains positive with respect to the cathode.

If, however, a noise peak of sufficient amplitude is impressed upon the input circuit, the diode immediately becomes non-conducting and prevents the noise pulse from reaching the audio amplifier.

Tone Control. The tone control is used to vary the frequency characteristic of the audio amplifier as shown in Fig. 16. The control is particularly helpful when receiving weak signals through interference, as will be explained.

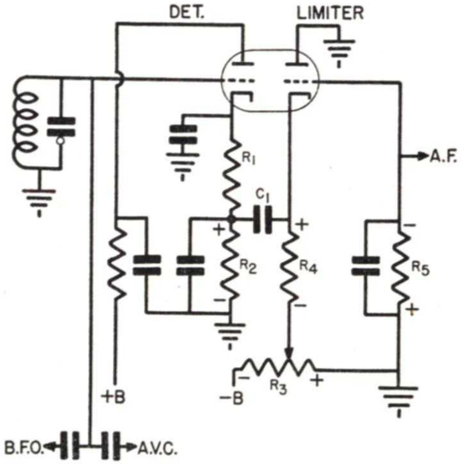


FIG. 15. A simplified circuit of a noise limiter.

Signal Strength Meter. A 0-to-1 milliammeter, serving as a signal strength meter, is front-panel mounted. It is fitted with a scale graduated in S-units from 1 to 9 and in db above S_9 from 0 to 40 db. The bridge circuit, in which the meter is connected, makes possible accurate signal input readings from below 1 microvolt to 1,000 microvolts.

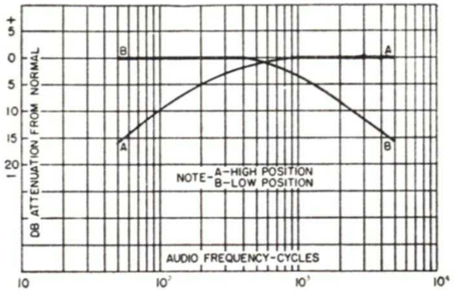


FIG. 16. Tone-control action.

Antenna Input. Antenna input terminals are located at the rear of the receiver chassis. The input circuit is suitable for use with a single-wire antenna, a balanced feed-line or a low-impedance concentric transmission line. Average input impedance is 500 ohms.

Audio Output. Two audio output circuits are provided:

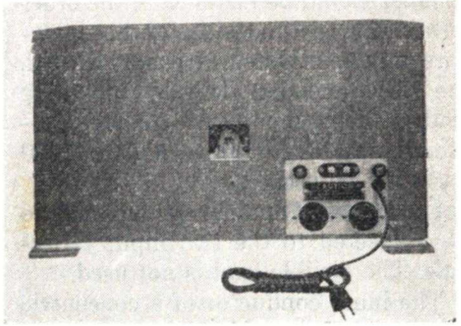
(1) A headphone jack is mounted on the front panel and is wired so as to silence the loudspeaker when the phone plug is inserted. The correct load impedance for the headphone output is 20,000 ohms, this being the usual impedance of phones having a d.c.-resistance of between 2000 and 3000 ohms. Maximum audio output available at the phone jack is 15 milliwatts.

(2) A five-prong speaker socket (X_1 in Fig. 13) as shown in Fig. 17 is provided at the rear of the receiver chassis. To this socket are brought the audio output leads. The proper load impedance (total) for the output circuit is 10,000 ohms. Maximum undistorted audio power output available is 8 watts.

Power Supply. The receiver is designed for operation from a 110/120-volt, or 220/240-volt, 50/60-cycle power source. A toggle switch is provided in the dual primary circuit of the power transformer to permit operation from either voltage. Normal power consumption is approximately 100 volt-amps. The built-in power supply delivers all voltages required by the heater and B supply circuits—4.5 amperes at 6.3 volts and 100 milliamperes at 250 volts, respectively. One side of the a.c. input line is connected through a 2-ampere fuse and a 1-ampere fuse housed in extractor posts mounted at the rear of the receiver chassis. The 2-ampere fuse is used in the circuit for 115-volt operation. Both 2- and 1-ampere fuses are used for 230-volt operation.

This receiver is equipped with a seven-prong plug and socket combination to permit portable or emergency operation from batteries.

Loudspeaker. The loudspeaker supplied with the receiver is of the permanent magnet field type having a diameter of 10 inches. A coupling transformer, mounted on the loudspeaker chassis, matches the voice coil to the output impedance of the receiver. A



Courtesy National Company, Inc.

FIG. 17. This is a rear view of the NC-2-40D receiver.

shielded three-wire cable and plug is furnished for connection between the loudspeaker and the receiver.

A cabinet, finished to match the receiver, houses the loudspeaker for table mounting. The cabinet interior is lined with sound absorbent material to avoid any undesirable mechanical resonance.

A 10½ × 19 inch panel of ⅛ inch steel is used to support the ten-inch loudspeaker chassis in a relay rack installation.

Pick-up Jack. A pick-up jack mounted on the front panel of the receiver may be used to connect auxiliary apparatus, such as a phonograph pick-up, to the audio system of the receiver. This input circuit is high impedance and feeds into the 6SN7GT/G audio amplifier-phase inverter tube. The TONE and A.F. GAIN controls are operative with this connection.

INSTALLATION

Antenna Recommendations. When a single-wire antenna is used, the lead-in should be connected to one antenna input terminal, and the short flexible lead, which is attached to the chassis, should be fastened to the other terminal. The dimensions of the single-wire antenna system are not critical, the recommended length, including lead-in, being from 75 to 100 feet, although any length between 25 and 200 feet may be used.

Feed-lines of doublet systems should be connected to the two input terminals. The flexible lead is not used.

The inner conductor of a concentric transmission line should be connected to one input terminal. The outer conductor and the flexible grounding lead should be connected to the other terminal.

An external ground connection to the chassis may or may not be necessary. It should be used unless it reduces signal strength.

A.C. Operation. To put the receiver in operation, the following procedure is used:

1. Make sure tubes are firmly in their sockets.
2. Insert the dummy connector plug (P_2 in Fig. 13) in the seven-prong socket (X_2). (See Fig. 17.)
3. Insert loudspeaker plug P_1 in the five-prong audio output socket X_1 of the receiver.
4. Connect antenna feed line.
5. Set primary selector switch for line voltage to be used, i.e. 115 or 230.
6. Plug a.c. line cord in proper source of supply.
7. Set controls as recommended for reception of signals.

Battery Operation. The NC-2-40D may be operated in portable or emergency service by connecting batteries to the terminals of battery connector plug P_3 and inserting it in socket X_2 in place of plug P_2. See Fig. 17. For normal operation with somewhat reduced loudspeaker output, a 6-volt heater supply (storage battery) should be connected to terminals 1 and 2 of plug P_3, in Fig. 13, and a 180-volt B supply should be connected to plug terminals 5 and 6. The jumper between terminals 3 and 4 (of P_3) completes the plate and screen supply circuits of the 6V6 output tubes. It may be omitted, with greater battery economy, when operation with headphones only is desired. A suggested refinement is to connect a switch between terminals 3 and 4, thus permitting the 6V6 B supply to be opened at will. Alternatively, removal of speaker plug P_1 from socket X_1 will open the 6V6 B supply in the same manner, without harming the output tubes. A further economy of battery power may be effected by removing the 6V6 tubes from their sockets.

Filament power save

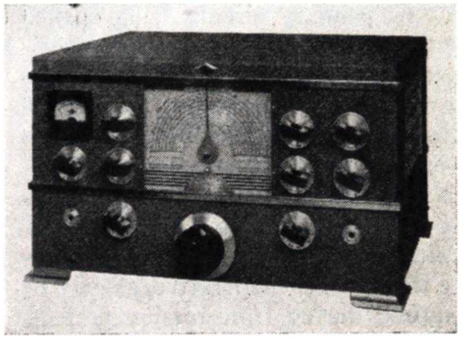
Do not attempt to use plug P_2 for battery connection, since the jumper between terminals 1 and 7 would be incorrect.

Loudspeaker. If the installation is such that the loudspeaker will be placed close to the receiver, the most desirable position is at the side. Placing the loudspeaker on top of the receiver is not desirable since vibration from the speaker might possibly introduce microphonic noises which would not otherwise be noticeable.

Controls. The MAIN TUNING control knob shown in Fig. 18 is located at the middle of the front panel and operates three-gang variable capacitor C_{1A}, C_{1B}, C_{1C} (Fig. 13) through a 60 to 1 ratio reduction drive mechanism. The main dial has ten accurately calibrated scales, the scale in use being definitely indicated by band markers appearing at the scale ends. A dial pointer shows the frequency to which the receiver is tuned. The accuracy of the general coverage calibration can be relied upon to be better than plus or minus 1%. Immediately behind the pointer is a vernier dial which may be used to log incoming signals accurately.

The tuning system is single control; in fact, the MAIN TUNING control referred to above is used for band changing as well as tuning. To select either a general coverage or bandspread coil range, the MAIN TUNING control knob is pulled out about ¼ inch. When this is done, the dial and capacitor drive mechanism is disengaged, and the knob is geared to the coil casting. As the knob is turned, the coil carriage is moved across the chassis until the proper coil pin contacts engage the circuit contactors, as indicated by the scale markers. Approximately one full turn of the MAIN TUNING knob is required to change from one general coverage range. Approximately one quarter turn of the knob is required to shift from a general coverage range to the associated bandspread range near the high-frequency end. After the desired range has been selected, the tuning knob is pushed in to its original position, engaging the capacitor drive and disengaging the coil carriage rack.

The LIMITER control, at the left-hand side of receiver panel, is used to adjust the d.c. potential applied to the elements of the series type noise limiter tube. The limiter circuit is thus provided with an adjustable threshold at which limiting starts. Any audio voltages, or peaks, in excess of this threshold are prevented from reaching the audio amplifier. With the LIMITER control set at 0, the limiter circuits will pass all but the strongest audio peak voltages; when the control is set at 10, the threshold is lowered to a point where the audio signal will be distorted due to suppression of the positive peaks.



Courtesy National Company, Inc.

FIG. 18. Front view of the NC-40D receiver.

The R.F. GAIN knob is located below and to the right of the LIMITER knob. It is used to adjust the amplification of the r.f. amplifier and two i.f. amplifier tubes. Amplification increases as the control is turned clockwise toward 9. When the knob is set at 10, the meter switch is closed, and the signal strength meter is connected.

A CONTROL SWITCH is mounted above the R.F. GAIN control knob. In the AVC position, the automatic volume control circuits are in operation; in the MVC position, automatic volume control is turned off; in the CWO position, the beat-frequency oscillator is turned on and automatic volume control is turned off.

The POWER SUPPLY control knob is directly above the CONTROL SWITCH. In the counterclockwise position, OFF, the receiver is turned off, the primary circuit being opened by the a.c. line switch; in the mid-position, B + OFF, the a.c. line switch is turned on but the B supply circuits are incomplete since the B+ switch is open; in the clockwise position, B + ON, the B+ switch is closed, completing the B supply circuit. The B+ OFF position may thus be used for rendering the receiver inoperative, as may be required during transmission periods.

The PRIMARY SELECTOR SWITCH of the power transformer is mounted on the receiver chassis to the right of the power transformer. This switch selects the proper circuit arrangement of the dual primary for operation from either a 115 or a 230-volt power source. There is a shield provided to prevent unintentional throwing of the switch.

The A.F. GAIN control knob is located to the right of the MAIN TUNING control. It is used to adjust the audio amplification of the receiver. Audio amplification increases as the control is turned toward 10 on the scale.

The PHASING and SELECTIVITY controls, located above the A.F. GAIN knob, are part of the crystal filter. When the SELECTIVITY control is set at OFF, the crystal is switched out of the circuit. With the crystal switched out, the phasing control has little influence on receiver performance. With the SELECTIVITY control knob set at any point between 1 and 5, inclusive, the crystal filter is in operation, selectivity increasing as the knob is advanced to 5. See Fig. 18. The PHASING control is then used to balance the crystal bridge circuit and eliminate interfering signals or heterodynes.

The C.W. OSC. control knob located to the right of the SELECTIVITY control is used for varying the frequency of the beat oscillator. At 0 on the C.W. OSC. scale, the beat oscillator is tuned to the intermediate frequency.

A TONE control knob is located above the C.W. OSC. knob and is used to vary the frequency characteristic of the audio amplifier as previously described.

A BSW terminal panel is mounted at the rear of the receiver chassis as shown in Fig. 17. The terminals are connected in parallel with the B+ switch. If external (remote) stand-by control is desired, it can be accomplished by connecting a switch or relay to these terminals.

Phone Reception. After the equipment is properly installed, it is placed in operation by turning the POWER SUPPLY switch to B + ON. The LIMITER control should be set at 0. The CONTROL SWITCH should be set at AVC. The PHASING knob should be set at 0; the SELECTIVITY at OFF; the TONE control should be set to give the desired audio characteristic; the R.F. GAIN control should be advanced to some point between 8 and 10, depending upon receiving conditions; the A.F. GAIN control should be set at the point providing the desired audio volume. The receiver is now adjusted for the reception of phone signals and will tune to the frequency indicated by the MAIN TUNING dial. The C.W. OSC. knob has no influence on receiver performance under these conditions.

With the CONTROL SWITCH set in the AVC position, as recommended, the R.F. GAIN knob should be advanced as far as receiving conditions permit, or until background noise becomes objectionably loud. Audio output should be adjusted entirely by means of the A.F. GAIN knob. The operator must remember that automatic volume control action will be restricted unless the R.F. GAIN knob is fully advanced.

The CONTROL SWITCH may be set at MVC, in which case the operator must be careful not to advance the R.F. GAIN knob to a point where i.f. or audio amplifier overload occurs. Such overload is indicated by distortion. In general, the A.F. GAIN control may be set about halfway on, i.e., at 5, and the audio output adjusted by means of the R.F. GAIN control.

If a signal is weak and partially obscured by background noise and static, best signal-to-noise ratio will be obtained by turning the TONE control towards the LOW position. The most effective setting must be determined by trial as too much attenuation of high audio frequencies will impair the intelligibility of speech.

When a signal is accompanied by static peaks or noise pulses of high intensity and short duration, the best signal-to-noise ratio will be obtained by advancing the LIMITER control toward 10. The best setting must be determined by trial, as too much limiter action will impair audio quality. If static peaks and noise pulses are extremely strong or if they are of fairly long duration, the effectiveness of the limiter will be best with the CONTROL SWITCH in the MVC position. In such cases both R.F. GAIN and LIMITER controls must be carefully adjusted for optimum signal-to-noise ratio.

The selectivity of the receiver may be adjusted by means of the crystal filter. The normal setting of the SELECTIVITY control in phone reception is at one of the positions affording broad selectivity. Position 1 or 2 is recommended. Selectivity may be progressively increased by turning the SELECTIVITY control to positions 3, 4, and 5 although advancing the control too far will increase selectivity to a degree where phone signals become unintelligible.

The PHASING control is used to eliminate or attenuate heterodynes. The normal setting of the PHASING control in phone reception is at 0 on the scale. If, after a signal has been tuned in, an interfering signal causes a heterodyne or whistle, the PHASING control should be adjusted until the interference is reduced to a minimum. The setting of the PHASING control which provides maximum attenuation of the heterodyne will depend upon the pitch of the heterodyne whistle. If the beat note is above 1000 cycles, the optimum PHASING control setting will be near 0; if the beat note is 300 or 400 cycles, the optimum PHASING control setting will be near one end of the scale or the other, depending upon whether the interfering signal has a higher or lower frequency than the desired signal.

It is recommended that the TONE control be set in the HIGH position when using the crystal filter in phone reception. The resulting attenuation of low audio frequencies tends to compensate for the side-band cutting action of the crystal filter.

C. W. Reception. The initial adjustment of the receiver for c.w. reception is as described for phone reception, except that the CONTROL SWITCH must be in the CWO position. The C.W. OSC. control should be set at mid-scale.

The sensitivity of the receiver should be adjusted by means of the R.F. GAIN control, care being taken not to advance the control to the point where strong signals will cause I.F. or audio amplifier overload, as indicated by excessive thumping.

The action of the TONE and LIMITER controls will be similar to that already described. When receiving c.w. signals, it will be possible to advance both TONE and LIMITER controls considerably farther than is possible in phone reception, since audio distortion is relatively unimportant.

Turning the C.W. OSC. control will change the characteristic pitch of the receiver background noise. The pitch will become higher as the beat frequency oscillator is detuned from the i.f. amplifier. With the C.W. OSC. control set at 2 or 3 (on either side of 0), the characteristic pitch of the receiver background noise will be in the neighborhood of 2000 cycles. Under these conditions, the audio beat note of any c.w. signal will show a broad peak at approximately 2000 cycles. This peak will appear on one side of the carrier only, and the other side, where the audio beat note is around 2000 cycles, will be considerably weaker. This characteristic "semi-single signal" is helpful in receiving weak signals through interference.

The selectivity of the receiver may be adjusted by means of the crystal filter, the action of the SELECTIVITY and PHASING controls in c.w. reception being similar to that described. It is possible, however, to utilize the full range of crystal filter selectivity in c.w. reception. Maximum selectivity is obtained with the SELECTIVITY control set at 5. With this setting the single-signal effect, outlined above, becomes very pronounced; in other words, the audio beat note is very sharply peaked at a definite audio frequency which is determined by the setting of the C.W. OSC. control. The operator may have difficulty in finding the audio peak when first attempting to use the crystal filter. After a signal has been accurately tuned to give peak response, the R.F. GAIN control may need to be retarded in order to prevent i.f. or audio overloading. With the receiver tuned to "crystal peak," an interfering signal may be attenuated by proper setting of the PHASING knob since this control does not appreciably affect the desired signal.

Measurement of Signal Strength. To make a measurement of signal strength by means of the S-meter, the R.F. GAIN control must be advanced to 10, and the CONTROL SWITCH set at the AVC position. The crystal filter should be turned OFF by means of the SELECTIVITY control; the PHASING knob set at 0. The TONE, LIMITER and A.F. GAIN controls do not affect the meter reading.

Tuning the receiver to a signal will cause the meter to read, indicating the signal input in S-units or in decibels above the S_9 level.

With no r.f. input to the receiver, or with the antenna disconnected, the S-meter should read 0, plus or minus 1 S-unit. If it does not, the S-meter circuit requires adjustment.

Measurement of the signal strength of c.w. signals cannot be made with the beat-frequency oscillator in operation.

SERVICE AND TEST DATA

Tube Failures. Failure of a vacuum tube in the receiver may reduce the sensitivity, produce intermittent operation, or cause the equipment to be completely inoperative. In such cases, all tubes should be checked either in an analyzer or similar tube-testing equipment, or by replacement with tubes of proved quality. All tubes should be marked as they are removed from the receiver so that they may be returned to their original sockets thereby reducing the necessity for realignment.

Individual tubes of the same type will vary slightly in their characteristics and it is well to remember this fact when replacements become necessary. Even though the circuit is designed to reduce the effect of such variations to a minimum, the high-frequency oscillator and i.f. tubes should be selected with some care. A replacement high-frequency oscillator should be checked in the receiver to make sure that the inter-electrode capacities are the same as those of the tube originally employed. This is easily determined by noting any change in dial calibration, particularly in the amateur bandspread ranges.

Substitution of new tubes in the i.f. amplifier may possibly alter over-all gain and selectivity characteristics. Instructions for realignment will be given in detail.

One other point should be checked when trying the new high-frequency oscillator; a fairly strong steady signal should be tuned in, preferably on some frequency above 10 mc.; the beat-frequency oscillator should be turned off; jarring the receiver, or lightly tapping the tube, should not produce noise in the output.

Circuit Failures. Excluding tubes, the most common failure will probably be some defect in a capacitor or resistor. Measurement of voltage will no doubt show where failure has occurred. A by-pass capacitor which has failed may cause overload of associated resistors. These resistors should be checked for any change in resistance. An open capacitor, often the cause of loss of sensitivity or oscillation, may be checked by temporarily connecting a good capacitor, of about the same size, across it. If this clears up the trouble, the condenser under test is defective and should be replaced. Intermittently poor connections can usually be located by lightly tapping each part with a piece of insulating material.

Stage-Gain Measurements. The sensitivity measurements listed below are made with equipment set up as specified later in the section on alignment. The CONTROL SWITCH should be set at MVC, the A.F. GAIN at 10, the SELECTIVITY at OFF and the PHASING at 0. The signal generator should be adjusted to deliver a test signal of 455 kc., plus or minus 2 kc. either modulated or unmodulated. The high output lead should be attached to the grid of the tube specified in the table below and the ground lead connected to the receiver chassis.

With 1 milliwatt output at the phone jack, the test signal should be within the limits specified below.

Terminal	Test Signal
First Det. Grid	50 ± 10 Microvolts
First I.F. Grid	250 ± 50 Microvolts
Sec. I.F. Grid	50,000 ± 10,000 Microvolts
Sec. Det. Grid	Over 1 volt

Voltage Tabulation. All measurements of voltages should be made with the equipment connected for normal operation with an a.c. supply of 115-volt, 50/60-cycle or 230-volt 50/60-cycle. Except as noted, the R.F. GAIN knob is set at 9, the LIMITER knob set at 0 and the CONTROL SWITCH knob set at MVC. A d.c. voltmeter of at least 1000 ohms-per-volt sensitivity should be used. The following table must not be considered as a list of the actual operating voltages since loading effects of the measuring instrument will disturb many of the circuits and later alter normal voltage distribution. A meter having a higher ohms-per-volt rating will give a truer picture of the actual operating voltages. All voltages are measured between specified terminal and chassis.

Tube Terminal	DC Volts ± 15%
R.F. Amp. Grid	0
R.F. Amp. Cathode ..	3 A
R.F. Amp. Cathode ..	25 A*
R.F. Amp. Screen ...	80 B
R.F. Amp. Plate	230 B
First Det. Grid	0
First Det. Cathode ...	1 A
First Det. Screen	80 B
First Det. Plate	225 B
H.F. Osc. Grid	C
H.F. Osc. Cathode ...	0
H.F. Osc. Plate	90 B
First I.F. Grid	0
First I.F. Cathode ...	3 A
First I.F. Cathode ...	25 A*
First I.F. Screen	80 B
First I.F. Plate	225 B
Sec. I.F. Grid	0
Sec. I.F. Cathode ...	5 A
Sec. I.F. Cathode ...	25 A*
Sec. I.F. Screen	95 B
Sec. I.F. Plate	225 B
Sec. Det. Grid	0
Sec. Det. Cathode ...	8 A
Sec. Det. Plate	225 B
Limiter Grid	—3 A
Limiter Cathode	4.5 A
Limiter Cathode	0 D
Limiter Plate	0
AVC Grid	—25 AE
AVC Cathode	—45 AE
AVC Screen	0 E
AVC Plate	0 E
B.F. Osc. Grid	C
B.F. Osc. Cathode ...	0 F
B.F. Osc. Screen	10 AF
B.F. Osc. Plate	25 AF
Amp.-Inv. Grids	0
Amp.-Inv. Cathode ..	4.5 A
Amp.-Inv. Plates	115 B
Audio Grids	—20 A
Audio Cathodes	—40 A
Audio Screens	230 B
Audio Plates	215 B
B + Common	230 B
B — Common	—50 B

A—0 to 50-volt meter scale
B—0 to 250-volt meter scale
C—Accurate measurement cannot be made
D—LIMITER knob set at 10
E—CONTROL SWITCH knob set at AVC
F—CONTROL SWITCH knob set at CWO
***—R.F. GAIN knob set at 0**

ALIGNMENT DATA

General. To determine the necessity for realignment, the receiver should first be carefully checked against its normal performance. In no case should realignment be attempted unless tests indicate that such realignment is necessary. Even then, it must be remembered that a communications receiver should not be serviced or realigned by any individual who does not have a complete understanding of the functioning of the equipment.

The coil group which is plugged into the circuit at any time is the one directly underneath the three-gang master tuning capacitor. The coil nearest the front panel of the receiver is in the h.f. oscillator circuit, the middle coil is in the first detector circuit, and the coil nearest the antenna input terminal panel is in the r.f. amplifier circuit.

All coils have individual general coverage trimmer capacitors. The h.f. oscillator circuits of broadcast ranges E & F have, also, general coverage variable series padding capacitors. All coils of ranges A, B, C, and D have band-spread trimmer capacitors. Variable series padding capacitors are used in all h.f. oscillator band-spread circuits.

Adjustment of general coverage circuits affects the alignment of the band-spread circuits. On the other hand, band-spread circuit adjustments have little effect on general coverage circuit alignment. This fact must be kept in mind when any high-frequency circuit is adjusted. A screw driver having a metal shaft may be used to make adjustments in the high-frequency circuits, but capacity effects will be noticeable, and the shaft should not touch any part of the aluminum casting.

Before proceeding with the alignment of any circuit of the receiver, the equipment must be set up for operation, except that the antenna lead-in or transmission line must be disconnected. An output meter having a 20,000-ohm resistive load should be connected to the phone output jack. The POWER SUPPLY knob should be set at B + ON and the R.F. GAIN knob set at 9. The TONE control knob should be set at N, and the LIMITER knob should be retarded to 0.

Alignment of the equipment which is typical, may be divided into three major steps:

(1) I.F. Amplifier Alignment
(2) General Coverage Alignment
(a) H.F. Oscillator
(b) First Detector and R.F. Amplifier
(c) Tracking of H.F. Circuits
(3) Band-Spread Alignment
(a) H.F. Oscillator
(b) First Detector and R.F. Amplifier
(c) Tracking of H.F. Circuits

The circuits MUST be tuned in the above order when complete alignment is necessary.

I.F. Amplifier Alignment. The intermediate frequency of the NC-2-40D Receiver is 455 kilocycles, plus or minus 2 kilocycles. The exact frequency is determined by the quartz crystal resonator Y_1.

Tuning capacitors are provided on the crystal filter and on each i.f. transformer. These capacitors are designated by symbol numbers C_{39} and C_{41} to C_{46}, inclusive, in Fig. 13.

The high output lead of an accurately calibrated signal generator should be connected to the grid terminal of the first detector tube and the grounded lead to any convenient point on the chassis. The flexible lead need not be disconnected from the grid of the tube. Connection is made directly from the output jack of the signal generator, a dummy antenna being omitted. The CONTROL SWITCH of the receiver should be in the CWO position and the modulation of the signal generator turned off to provide a steady c.w. test signal. The PHASING control of the receiver should be set at 0 and the SELECTIVITY control at 5. The A.F. GAIN control should be fully advanced.

Adjust the output attenuator of the signal generator to provide a signal of approximately 100 microvolts, and vary the tuning control of the signal generator slowly between the frequencies of 453 and 457 kilocycles. At some frequency between these limits, the i.f. amplifier of the receiver will show a very sharply peaked response, as indicated on the output meter. The output attenuator of the signal generator has been tuned to the i.f. peak in order to avoid i.f. or audio overload; the C.W. OSC. control must be set to provide an audio beat note in the middle of the audio range (between 400 and 1000 cycles).

The i.f. tuning capacitors C_{39} and C_{43} to C_{46}, inclusive, should each be carefully adjusted to give a maximum reading on the output meter. The order in which the adjustments are made is not important. While making i.f. amplifier adjustments, it will be necessary to retard the attenuator of the signal generator if the readjustment increases i.f. amplifier gain to the point where overload occurs.

The crystal filter SELECTIVITY knob should then be set at 1 and the signal generator detuned between 3 and 4 kilocycles either side of the crystal frequency. Capacitor C_{42} should be tuned for maximum output meter reading. After this adjustment is made, the SELECTIVITY knob should be set at OFF and the signal generator retuned to exact crystal frequency. Compensator capacitor C_{41} should then be adjusted for maximum reading on the output meter.

The performance of the i.f. amplifier and audio circuits may be checked against the stage gain data after alignment has been completed. Selectivity may be checked against the curves of Fig. 14.

After alignment of the i.f. amplifier has been completed, the C.W. OSC. control should be set at 0, at which setting the c.w. oscillator should be at zero beat with the test signal. If zero beat does not occur at 0, readjust capacitor C_{47} of transformer T_4.

The quartz crystal resonator Y_1 may be checked at the conclusion of i.f. amplifier alignment as follows: The SELECTIVITY control should be set at 5, and the signal generator tuned to the crystal frequency. The output meter reading should be noted. When the SELECTIVITY knob is turned to OFF, the meter reading should decrease 1 to 2 db provided the PHASING knob is at 0. An increase in meter reading can, in most cases, be traced to an improper adjustment in the i.f. amplifier, since the crystal resonator is mounted in a sealed holder, and it is rather unlikely that trouble will be had from that source.

General Coverage Alignment. This is effected as follows:

(a) H.F. Oscillator

With the coil range to be aligned connected in the circuit, the MAIN TUNING dial should be set near the high-frequency end of the range. A signal generator should be connected to the antenna input terminals and accurately tuned to deliver a signal of the same frequency as that indicated by the receiver dial setting. If, when this signal is tuned in, the dial reading is too high, the capacity of the h.f. oscillator general coverage circuit trimmer C_{52} should be decreased to make correction. Conversely, low dial readings are corrected by increasing the capacity of trimmer C_{52}.

It is imperative that the high-frequency oscillator circuits operate at a higher frequency than that of the first detector and r.f. amplifier circuits. This can be checked by tuning in the image signal, which should appear at a dial reading approximately 910 kilocycles below that of the real signal. The image signal should be considerably weaker if the r.f. amplifier is correctly aligned, and a stronger test signal may be required before the image can be found. If the image does not appear at the lower frequency dial setting, the h.f. oscillator circuit is incorrectly adjusted, and the capacity of the h.f. oscillator trimmer capacitor in question must be decreased until the real signal and image signal appear at the proper points on the dial.

455 IF

OSC. is above sig separated by i.f. value & below sig value on image reception separated by if value – if no preselector is used sig. stron[g]

if presel. used image [illegible] weak

(b) First Detector and R.F. Amplifier

With the signal generator adjusted to deliver a modulated signal near the high-frequency limit of the band to be checked, the receiver should be tuned to give maximum output, as indicated by the output meter. The first detector and r.f. amplifier trimmer capacitors C_{51} and C_{50} respectively, should then be varied until the output meter reads maximum. On the highest frequency bands, adjustment of the first detector and r.f. amplifier trimmers may change the calibration of the high-frequency oscillator, necessitating retuning of the MAIN TUNING dial. If these trimmers should require considerable realignment, it may be necessary to readjust the high-frequency oscillator trimmer C_{52} in order to maintain correct calibration.

A very simple and quick method of first detector and r.f. trimmer alignment may be used if a signal generator is not available. This method consists of setting the trimmers at the adjustment which provides maximum circuit or background noise. It will be found that trimmer settings under this method are sufficiently sharp to provide good alignment, although the adjustment must be made with care to avoid alignment to the image frequency.

(c) Tracking of H.F. Circuits

After the h.f. oscillator, first detector, and r.f. amplifier trimmers have been properly set at the high-frequency limit of the range, the receiver should be tuned to a frequency toward the low-frequency end. Tracking at any point up to the low-frequency limit may be checked by adjusting the signal generator to the proper frequency and testing the settings of the first detector and r.f. amplifier trimmers for maximum gain. Calibration may be checked also at these points. After such a test, all trimmers checked should be reset at the high-frequency end of the band since their settings are most critical at this point.

Errors in tracking near the low-frequency limit of the band can be caused by defects in any of three circuit elements.

(1) The tuning capacitor section.

(2) The circuit inductance.

(3) The h.f. oscillator series padding capacitor.

In order to determine if one or more sections of the master tuning capacitor C_1 are the cause of any mistracking present, it is necessary to make the check described above on two or more different bands. If the same tracking error appears on all bands, the master tuning capacitor is definitely at fault. The error should be corrected by permanently bending the rotor or stator plates to provide the proper capacity.

If the tracking error appears only in the r.f. amplifier or first detector stage and on only one band, the inductance of the tuned circuit of the stage is incorrect. If the tracking checks indicate that the h.f. oscillator circuit of a particular band is at fault, either the inductance of the circuit, the series padding capacitor, or both may be responsible.

After any change or readjustment is made to any high-frequency circuit inductance or series padding capacity, it will be necessary to realign the associated trimmer at the high-frequency limit of the coil range. Tracking should then be rechecked.

Band-Spread Alignment. This is effected as follows:

(a) H.F. Oscillator

The method of adjusting the h.f. oscillator band-spread trimmer C_{57} of any band is the same as that described above. As stated previously, the adjustment of the general coverage trimmers must not be altered at this time.

(b) First Detector and R.F. Amplifier

The method of adjusting the band-spread trimmers C_{59} and C_{58} of the first detector and r.f. amplifier circuits is the same as that previously described.

(c) Tracking of H.F. Circuits

After steps (a) and (b) have been completed, the MAIN TUNING control should be turned to the low-frequency band limit, and the accuracy of the dial reading checked. If the dial reading is too low, the capacity of the series padding capacitor C_{61} should be increased until the dial reading is correct, and vice versa. The MAIN TUNING control should then be reset at the high-frequency band limit, and step (a) repeated. Recheck the low-frequency dial reading and repeat the whole procedure if necessary.

The detector and r.f. amplifier stages have fixed band-spread padding capacitors. These circuits will, therefore, track properly with the h.f. oscillator stage, provided that the general coverage circuits are properly aligned and that the band-spread h.f. oscillator circuits are accurately tuned.

S-Meter Adjustment. The S-meter balancing resistor R_{39}, is used to obtain zero meter reading in the absence of signal input to the receiver. The adjustment is as follows: Set the R.F. GAIN control at 10, CONTROL SWITCH at MVC, and disconnect the antenna leads; adjust R_{39} until the S-meter reads zero.

Band Indicator Adjustment. An adjustment for centering the band indicator markers in the horizontal slots of the dial face is located in back of the MAIN TUNING knob. It is recommended that the MAIN TUNING knob be pulled out to engage the band changing mechanism, and turned clockwise to the last position before the stop. The red band marker should then indicate 28 to 30 mc. (10 meter) band-spread. To make the adjustment, simply remove the tuning knob and set the ¼″ hexhead screw as may be required. The screw is self-locking.

Lesson Questions

Be sure to number your Answer Sheet 35RC.

Place your Student Number on *every* Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next Lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time or you may run out of Lessons before new ones can reach you.

1. What is the simplest method of producing negative current feedback?
2. If an a.c.-d.c. receiver in good condition does not operate when first plugged into a d.c. power line, what should you do?
3. Why is it that sometimes a.v.c. is not used on the last i.f. stage?
4. If a meter is placed in the cathode circuit of an a.v.c.-controlled tube, will it indicate an increase or a decrease in cathode current when tuning from a strong station to a point where no signals are received?
5. Which type of peak noise limiter, the shunt or the series type, is more effective?
6. In Fig. 13 is the right or the left-hand section of the 6SN7GT/G tube the phase inverter?
7. Draw a schematic diagram of an infinite impedance second detector and series diode noise limiter.
8. What is the purpose of the phasing control in the National NC-2-40D receiver?
9. Why should tubes ahead of the second detector, even if they are the same type, be returned to their original sockets in a communications receiver after they have been tested as good?
10. What are the three major steps in aligning a typical communications receiver?

UNDERSTANDING

"Happv is the man that findeth wisdom,
and the man that getteth understanding.
For the gaining of it is better than the gaining of silver.
And the profit thereof than fine gold.
Understanding is more precious than rubies:
And none of the things thou canst desire are to be compared unto it.
Its ways are ways of pleasantness,
And all its paths are peace.
It is a tree of life to them that lay hold upon it.
And happy is every one that retaineth it."

—*Adapted from Proverbs.*

The world is yours. Stored in your subconscious mind is knowledge acquired through your own efforts, plus abilities bequeathed by all the centuries of the past. Once you truly understand the tremendous capacities which are within you — once you realize your responsibility to others in the world — once you acquire the knowledge needed for success in your own chosen field — *you can be as great as anyone who has ever lived before you!*

J. E. SMITH