SECTION 3

SPECIALIZED BROADCAST RADIO ENGINEERING

AUDIO CONTROL EQUIPMENT

308 E

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AUDIO CONTROL EQUIPMENT

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SCOPE OF ASSIGNMENT

The previous technical assignment dealt with the audio components to be found in a broadcast studio, such as the microphone pre-amplifier, mixer, Program Amplifier, etc. The present technical assignment will concern itself mainly with the switching and control circuits associated with the above equipment. It is here that the greatest lack of standardization is to be found, and rather than discuss any one special broadcast station's layout, it will be preferable to discuss and analyze the various methods and means of control in general use today.

In general, the following topics will be discussed:

- (a) Normal and Emergency Channel Connections
- (b) Fundamental Relay Circuits
  - (1) Setup and Holding
  - (2) Methods of Interlocking
- (c) Studio Switching Systems
  - (1) Microphone-to-Fader Control Circuits
  - (2) Interlocking of studios
  - (3) Talk-back Systems
- (d) Master Control Room Switching
  - (1) Control of Studio Connections
  - (2) Pre-setting
- (e) Miscellaneous Considerations
- (f) Care and Maintenance
- (g) Operational Technique

CONTROL COMPONENTS

CHANNEL CONNECTIONS.—The actual connections between the various audio components must be arranged so that a defective piece of equipment can be replaced by one functioning satisfactorily with a minimum of delay. The connections must also permit changes in component groupings to be made to fit unusual program requirements. The usual method of connection is by jacks and plugs and patch cords.

JACKS AND PLUGS.—A separate jack and plug is used for each side of the circuit, which is generally balanced to ground. The two plugs, however, are part of one mechanical assembly and act as a unit. Similarly the two jacks are fabricated and mounted on the relay panel as one unit. They are shown in cross section in Fig. 1.

As may be noted from the figure, the tip of each plug is insulated from the shell. The two shells are held in a holder which may be either of metal or of insulating material. The shells are connected to the copper shield surrounding the two conductors of the patch cord by means of the grounding wires shown, so that the shells are either grounded or else ground the shield, depending upon where the system is connected to ground.

The inner conductors pass through the shell and connect to the inner portions of the plug that ultimately form the tips. In this way the plug acts not only as a connecting means, but also as a grounded shield for the tip portions. The copper shield of the patch cord is usually covered with a cotton braid that acts as a protection for the copper shield and prevents it from catching onto the shields of other patch cords, clothing, or the hands of the operator.

The two corresponding jacks are mounted on a panel or a jack strip, together with other such pairs to form a jack strip assembly. Note that the supporting framework for the jack contact springs forms a grounded shell, too. Upon inserting the plug into the jack, the two shells make contact and thus afford continuity of the ground circuit as well as a continuation of the shields.

other as shown, so that the circuit is closed through them when the plug is not inserted.

Upon insertion of the plug, the above 'normalled' circuit is broken, and the connection to the longer spring is continued through the plug tip to the corresponding wire in the patch cord instead of to the other spring.

PATCHING PROCEDURE.—A simplified schematic representation of a plug and jack connection is shown in Fig. 2. Here a line amplifier is shown connected to the 6 db isolation pad between it and the telephone line to the transmitter. It is to be noted that the normalled connections are an ordinary shielded pair, laced in with the other audio

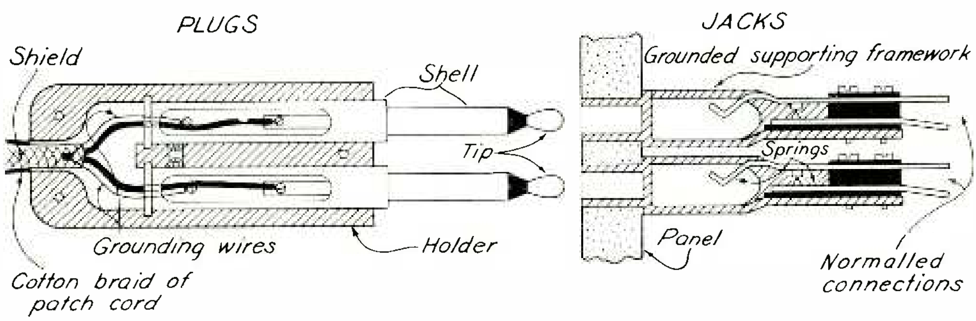


Fig. 1.—Cross Section of Plug and Jack Assembly.

The tip of the plug makes contact with the longer spring in the jack. The curved hook of the latter causes it to move away from or to other adjacent springs when the plug tip engages it. While there are a wide variety of jacks and plugs made, the usual type employed in broadcast work is as shown in Fig. 1, i.e., one insulated tip in the plug, and two springs in the jack. These two springs normally contact each

circuits in the rack, and soldered to the jack contacts. Patch cords, on the other hand, are portable, terminate in plugs, and are used to break the above normalled connections and make new connections, as desired (patching).

An example of patching procedure is illustrated by Fig. 3. Here Line Amplifier #1 is normalled through the 6 db pad to the telephone line. Line Amplifier #2 is a spare, to be used in case of an emergency. Note that the schematic of Fig. 2 for the normalled connections has been still

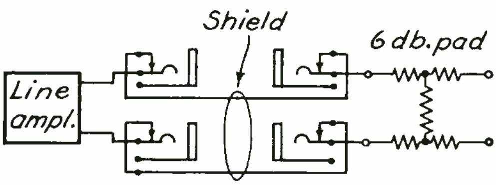


Fig. 2.—Schematic Representation of Normalled Connection.

further simplified in Fig. 3, and that furthermore, two normalled connections appear on each side of each amplifier. If Amplifier #1 becomes noisy or otherwise defective, Amplifier #2 may be substituted for it by means of patch cords.

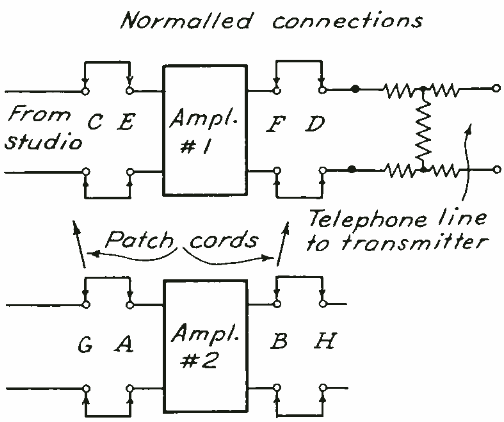


Fig. 3.—Use of Patch Cords for Emergency Connections.

The proper procedure is as follows: insert the plugs of the two patch cords at A and B, respectively. This lifts the input and output of Amplifier #2 off the normalled connections, and puts them on the patch cords. Then the plugs on the other ends of the patch cords are inserted into jacks C and D respectively (not E and F).

If the plugs had been inserted into E and F, the two amplifier inputs and outputs would have been merely tied in parallel with one another and at the same time disconnected from their normalled components. With the connections made to C and D, the studio now feeds the input of Amplifier #2 instead of Amplifier #1, and the telephone line is fed from the output of Amplifier #2 instead of #1.

On the other hand, if Amplifier #2 is the defective unit in its chain of connections, Amplifier #1 may be substituted for it by patching E to G and F to H. That is why there are two normalled connections between each pair of components: one is for the *output* of the *first component* and the other is for the *input* of the *second component* in cascade with the former. Also note the order in which patching is made: first the substitution unit is lifted off its normalled connections and transferred to the patch cords, then the defective unit is patched out of the circuit. This minimizes the 'outage' time in patching. To avoid click and similar noises, both patch cords should be inserted simultaneously into their respective jacks.

MULTIPLE CONNECTION.—In addition to the normal connection, another jack may be added to furnish a multiple or parallel connection. This is shown in Fig. 4. By this means a db meter, or an oscilloscope, or any desired device may be plugged into the multiple connection, thereby placing it in parallel with the normal connection. Sometimes a special setup is required, as for test purposes, where the amplifier is to be terminated in the proper impedance, and the output measured on a meter, or distortion measurements made, etc. Multiple connections are

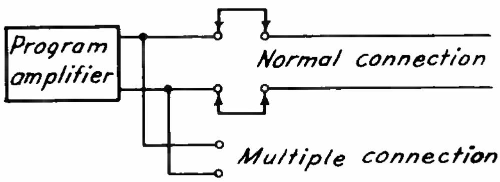


Fig. 4.—Use of Multiple Connection.

then of great utility, as they obviate the need for soldering or cliping on to existing connections.

PUSH BUTTONS AND KEY SWITCHES.- In a subsequent technical assignment on transmitter control circuits, large switches, such as knife switches, circuit breakers, and power relays will be discussed. For audio control circuits, however, it will be found that much smaller switches and relays are employed, since the power-handling requirements are much less, and much more compact structures are possible. Nevertheless, often a push button may be employed as the starting point for a sequence of power switching operations that ultimately involve a large power relay or circuit breaker, but the push button in itself is never called upon to break the main circuit, as may be the case in audio work.

PUSH BUTTONS.—In Fig. 5 is shown a type of push button favored in telephone and broadcast work. Note that unlike the ordinary push button used for ordinary door bells, etc., this push button is characterized by a long body and small panel area. This is characteristic of most telephone and broadcast equipment, and facilitates the grouping of a large number of controls on a single panel. The springs shown are forced out by the conical end of the button and either make or break contact with a shorter spring not actuated by the contact with a shorter spring not actuated by the button. If pressing the button separates the springs and opens the circuit, then the button is known as a 'closed circuit' type.

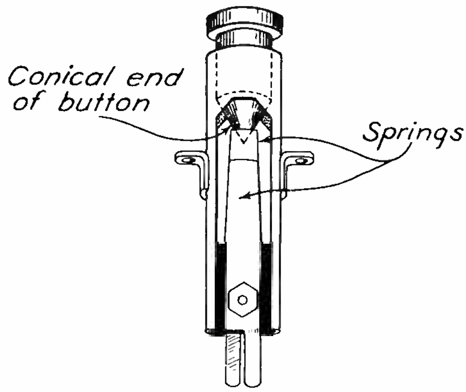


Fig. 5.—Typical Push Button.

TYPES OF SWITCHES.—The types of connections that can be made by a push button, and particularly by the more complicated type of switches known as key switches and relays, are shown in schematic form in Fig. 6. In (A) is shown a simple form of normally closed circuit push button, in which a 'break' in the circuit occurs when the button is pressed. In (B) it is clear that the springs *make* contact when the button is pressed.

More involved switching operations are involved in the next four types shown. Thus in (C), one circuit is broken as the button is depressed, and then—as the middle spring continues moving to the left,-the second circuit is closed. This is a Break-Make push button. In (D) it is clearly shown how one circuit is first closed before the other circuit is finally opened. In many cases it is necessary that this sequence of operations occur.

In (E) one circuit is opened, the next closed, and the third then opened. As stated in the figure, this is a Break, Make Before Break type of push button. Finally in (F) is shown a locking type push button. The previous buttons immediately restore the original circuit connections when the pressure on the button is removed. This requires a locking contact for a relay—as will be explained presently. In (F), on the other hand, a mechanical locking arrangement holds the button locked in the down position even after the finger is released. The spring—as is clear from the picture—fits into a recess of the button and prevents it from rising. To release, usually some auxiliary means, such as an actuating bar, is required to push the spring out of the recess in the button thus permitting it to snap up once again.

KEY SWITCHES.—The size of the push button and the type of actuating mechanism—that of a conical end to the button—precludes its use except for the switching of very simple circuits. Where more than one circuit is to be switched simultaneously, a more robust structure known as a key switch is employed. An example of this type of switch is shown in Fig. 7. The handle can be rotated through an angle in either direction as shown by the arrows. In doing so it pivots on axis P, and swings a pair of insulating rollers C (one behind the other) around so as to raise the upper *or* the lower springs, thus opening either contacts A or B. In more complicated arrangement several sets of springs are actuated.

There are thus two sets of springs, one alongside the other, above the center frame D, and another pair below the center frame. Each set of springs is called a 'pile-up'; a key switch has four pile-ups. A maximum of 13 springs per pile-up is permitted, although only two per pile-up are shown in Fig. 7. Thus

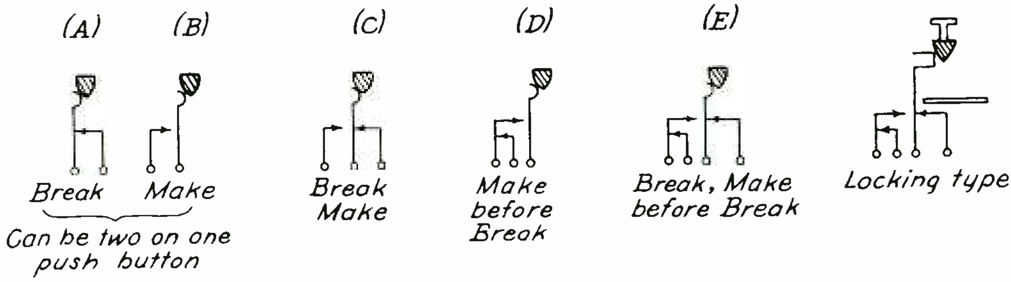


Fig. 6.—Various kinds of Switching Operations Possible.

a maximum of 4 × 13 = 52 springs can be handled by one key switch, and this represents a large number of

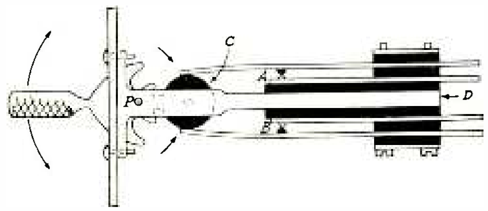


Fig. 7.—Typical Key Switch.

circuits that can be controlled by the switch.

As in the case of the push button type of switch, the key switch is usually represented in simplified form in a schematic diagram. Fig. 8 shows a pile-up of seven springs, of

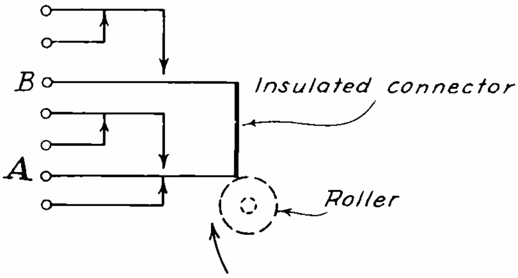


Fig. 8.—Example of a Pile-up.

which two are actuated by a roller on the key, and are accordingly called armatures. Note that the roller, (shown in dotted lines and normally omitted in a schematic diagram) actuates armature A. An insulating connecting rod mechanically transmits the motion to armature B as well, while maintaining electrical isolation between the two armatures, since these may be in separate circuits.

The top three springs constitute a make-before-break combination; the bottom four a break, make-before-break combination. The armatures are actuated when the roller swings upward (key is swung downward). When the roller swings downward, this pile-up is unaffected, and maintains the connections shown. The same is true of the second pile-up in back of the one shown in Fig. 8.

In Fig. 9 the schematic for a complete key switch is shown. The upper half represents two sets of

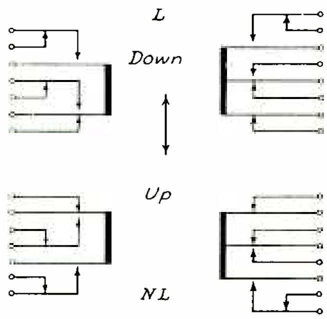


Fig. 9.—Schematic for a Complete Key Switch.

pile-ups that are actually one alongside of the other; similarly the lower half represents two such pile-ups. When the key moves DOWN, the rollers move up, as is clear from Fig. 7, and the upper pair of pile-ups are actuated. When the key moves UP, the rollers move down and actuate the lower pair of pile-ups.

The letters L and NL refer to locking and non-locking, respectively. Normally, when pressure is released on the key, the armatures bent back to the natural position and the switch is non-locking. On the other hand, it is also possible (and quite common) to have a mechanical arrangement whereby the key remains set in the position to which it is actuated, and the switch is then of the locking type. The letters in Fig. 9 indicate that the switch is locking in the DOWN position, and non-locking in the UP position. Any combination of locking and non-locking is available.

INTERLOCKING PUSH BUTTONS.—An interesting type of switching arrangement is that of an assembly of interlocking push buttons. This is shown in Fig. 10 where, for simplicity, only two buttons are shown.

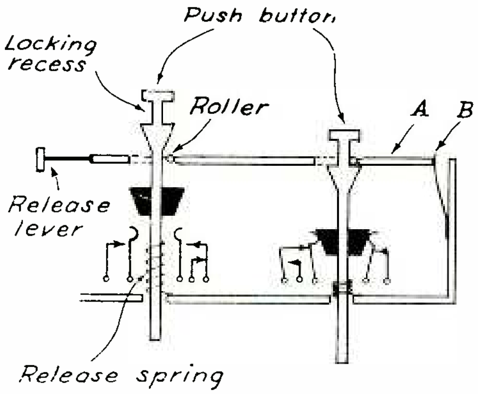


Fig. 10.—Interlocking Assembly of Push Buttons.

The right-hand button is shown in the depressed or actuated position, and the armature springs have been forced outward by the insulating conical section, so that they contact their respective stationary springs. The button is locked by the roller on the actuating bar A riding over into the locking recess in the button. A spring B holds A in this position.

If it is desired merely to release the button, the release lever can be pushed to the right, forcing the roller away from the locking recess, whereupon the release spring forces the button up out of engagement with the armature springs. The latter may not be strong enough to perform this function in this particular mechanical design.

The interlocking feature comes from the fact that if any other button is pressed, such as the left-hand one shown in Fig. 10, then the actuating bar is momentarily moved to the right by the conical section directly underneath the button, and thus moves the roller out of engagement with the locking recess on the right-hand button, thereby permitting the latter to jump up. Thus, when the left-hand connections are made, the right-hand connections are broken, and vice versa; the two sets of connections cannot be both made simultaneously, and the associated circuits are said to be interlocked.

Of course, if both buttons are deliberately pressed simultaneously, both circuits will be made and held, but in normal operation, where the operator presses only one button at a time, only one circuit or the other can be made. Thus, for example, if one button connects studio A to the transmitter, and the other connects studio B, then in normal operation there is no danger that both studios will be simultaneously connected to the transmitter.

It is possible to make any button non-locking by simply slipping a sleeve over the release spring, as shown in Fig. 11. This sleeve limits the travel of the push button to an amount insufficient to bring the locking recess into line with the roller on the actuating bar, i.e., the roller cannot get above the conical section underneath the button. In this case the button actuates its armatures only when depressed. However, the button also moves the actuating bar to the right when depressed, and thereby releases any other button previously depressed. Hence the button may very well function solely for release purposes instead of the release lever shown in Fig. 10, and is usually preferred because of the better mechanical arrangement.

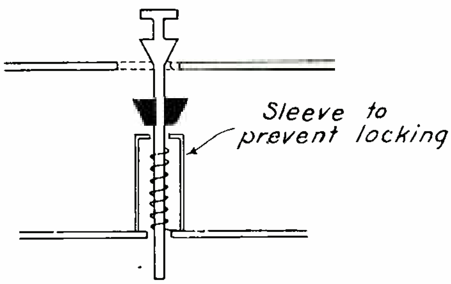


Fig. 11.—Non-Locking Type of Push Button.

Later on a means of interlocking using relays will be shown, in which the interlocking is by electrical means. However, the above arrangement for interlocking depends upon mechanical means, and in one form or another is in wide use in telephone practice, receiver push-button tuning, as well as in broadcast practice. Station WOR of Newark, for example, has used this interlocking push-button system in their studios with satisfactory results.

RELAYS.—Push buttons and key switches are relatively simple mechanically, but require the circuits which they control to be brought to their location. In a great many instances it is preferable to locate such switches where the circuits normally are run, and to control the operation of the switches from a remote point. A remote-control switch is generally one in which a magnet actuates the armatures and springs, and is known as a relay. The magnet is energized by a battery through some form of manually operated switch, such as a push button, located at a point convenient to the operator. (A. C.-operated relays are also available, but not desirable near low-level audio circuits.)

CONSTRUCTION.—One form of relay is shown in Fig. 12. A magnet

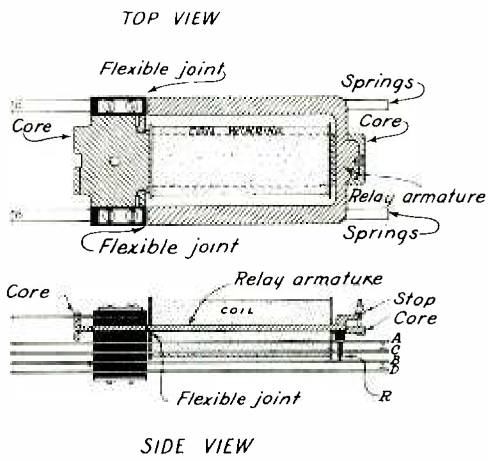


Fig. 12.—Representative Type of relay.

coil surrounds a flat iron core. At the back, two flexible steel joints connect the movable relay armature with the core and form a fairly low-reluctance magnetic circuit. The armature is an iron stamping, and is in the form of two strips or arms, joined at the front by an arched cross piece, as shown. The latter arches over the relay core projecting out of the core at that end. When the coil is energized, the core attracts the arched portion of the relay armature above it and pulls it down into contact with itself, thereby bending the flexible joints connecting the armature arms to the core at the rear.

The movement of the relay armature causes an insulating rod R attached to it to press down on contact with the springs C and D directly beneath them in their pile-up. Note that the insulating rod passes through a hole in C and thus does not press it down. In a similar manner the motion can be transmitted through several stationary springs to several movable armatures.

CHARACTERISTICS.—Since the magnetic actuating force is comparatively weak compared to that produced in manual operation, only two pile-ups are employed in a relay. The number of ampere-turns in the relay coil depends upon the number of springs and the required speed of closing. Usually this varies from .002 sec. to .005 sec., and the opening or release time generally varies in *inverse* manner through the range of .025 to .005 sec.

The relay winding has one end near the core on the innermost layer, and the other on the outside layer remote from the core. Generally the inner end is connected to the minus side of the actuating battery, so as to make any electrolytic action of the current owing to moisture in the insulation such that metal is deposited on the surrounding grounded structure. The reason is that normally fine copper wire is employed, and the inner end near the grounded core would ultimately, after a year's operation or thereabouts, be corroded-away, thus opening the coil.

There are several kinds of relays employed in broadcast practice, which follows telephone practice fairly closely, but the various types are best described in connection with the several kinds of relay circuits in use. Accordingly, an analysis of the different types of relay and other switching circuits will now be made.

CONTROL CIRCUITS

SETUP AND RELEASE CIRCUITS.—The relay is actuated from a remote point by push buttons. These are normally of the non-locking type, and would open the relay coil circuit as soon as the finger is removed from the button. It is therefore necessary to make the relay lock or hold its own coil circuit closed after the actuating button is released. This is done by means of a pair of locking contacts on the relay, and will be clear from Fig. 13.

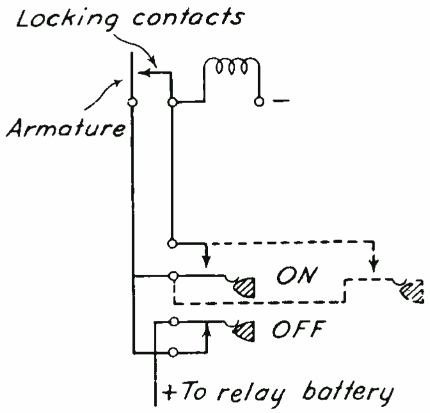


Fig. 13.—Locking Circuit.

SETUP LOCKING CIRCUIT.—The relay is shown in schematic form at the top of the figure. Actually other springs are present, but only the pair that produce locking of the relay are shown. When the ON push button is pressed, its contacts close and connect the plus side of the relay battery, through the close-circuit OFF push button, to the left-hand terminal of the relay coil, thus energizing it. The armature is pulled over to the right, thus closing the locking contacts, whereupon it will be observed that an alternative path is offered to the battery other than the ON button. Hence if the latter is released, the relay will nevertheless remain closed through its own locking contacts.

To release the relay, the battery circuit is broken by pressing the OFF button, thereby separating its normally closed contacts. It is also possible to turn on or off the relay from several points. As indicated by the dotted lines in Fig. 13, another ON button can be connected in parallel with the first, or several can be so connected. In the case of the OFF buttons, these must all be of the closed-circuit type, and must be all connected in series. If the relay is to be controlled from several points, this means several contacts in series and therefore the possibility of high contact resistance.

RELEASE RELAY.—To obviate this effect, a separate relay, known as a release relay, is usually employed where multiple control is desired. This is shown in Fig. 14. The switching relay, which is part of the Setup Circuit (that makes or breaks the normal audio circuits) is actuated by the ON button. It locks itself in the closed or energized condition through its locking contacts, which are now in series with the normally closed contacts of the release relay instead of the OFF push button, as was the case in Fig. 13.

When the switching relay closes, it not only locks itself closed, but also usually lights an indicating lamp, as shown. This is located at the remote point where the ON and OFF push buttons are installed, and serves to indicate to the operator there whether the control circuits are functioning properly. For example, if the lamp lights only when the ON push button is pressed, it indicates that the locking circuit is not operating. This may be owing to poor contact at the locking or at the release contacts. Under normal operation the lamp remains lit after the ON button is released.

To release the switching relay the OFF button is pressed. Note that this is an open-circuit type, just like the ON button. The release relay is energized and pulls the armature spring over to itself to the left, thereby opening the locking

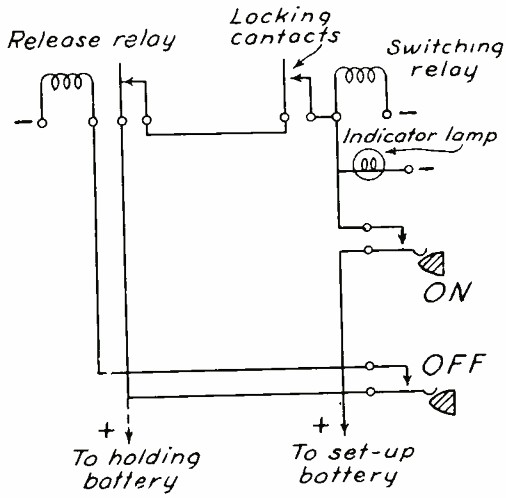


Fig. 14.—Use of Separate Release Relay.

circuit. The switching relay then opens its locking contacts, the indicator lamp goes off, and when the OFF button is released, the switching relay remains inoperative.

For reliability of operation, the release relay in large stations is often fed from a separate battery, called the Holding Battery. Connection to such a battery is indicated by the dotted line, to be used in lieu of the solid cross connection to the Setup Battery.

Note that only one normally closed pair of contacts is required, —those on the release relay. If control is desired from several points, additional open-circuit ON and OFF buttons can be connected in parallel to the two shown. For this reason a release relay is used on all but the simplest control circuits. It is to be emphasized once again that what is shown in Figs. 13 and 14 are the control circuits, and that the *controlled* audio circuits are connected to *additional* springs on the switching relay. For example, the simple circuit shown in Fig. 13 may be used to connect a microphone to its pre-amplifier, with the ON and OFF buttons located on the console panel in the Control Booth.

OTHER TYPES OF RELAYS.—Occasionally a different type of relay may be encountered. This is not often the case in broadcast practice where only a relatively few relays are used, but is more common in telephone practice. In Fig. 15 is shown a combination setup relay that has a high-current actuating coil A and a low-current holding coil B, both wound on the same core. When the relay armature presses against the relay core, the air gap is essentially eliminated, the reluctance of the magnetic circuit is greatly decreased, and hence less ampere-turns are required to hold the relay armature closed than to pull it to this position from its normally open position.

Coil B therefore has many more turns of *much finer* wire than coil A, and draws considerably less current. The saving of current for holding is important only where a

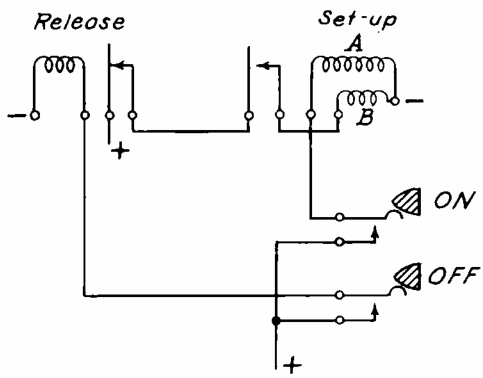


Fig. 15.—Western Electric Type of Relay.

large number of relays are involved, and this is seldom the case except in a large broadcast system. Note that coil A is fed through the ON button, but that the holding coil is independently fed through the locking and release contacts.

Another type of relay occasionally encountered is a differentially wound arrangement, shown in Fig. 16. This combines the set-up and release features in one structure, and therefore represents a saving in cost. Coil A, energized through the ON button and held by the locking contacts, actuates the relay. To release the relay, the OFF button is pressed, thereby passing current through coil B, which is wound opposite to coil A. The two mmfs thus developed oppose and cancel one another, and the relay armature is pulled away from the core by the relay spring. Owing to residual magnetism present, this relay tends to release more slowly than

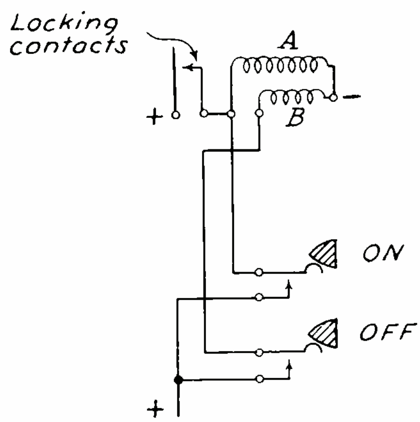


Fig. 16.—Differentially Wound Relay.

the ordinary relay, and has not found extensive use in the broadcast field.

INTERLOCKING CIRCUITS.—A mechanical system of interlocking push buttons was described previously. Such a system prevents two studios, for example, from being inadvertently connected to the same outgoing telephone line, and thus helps to minimize human errors. Usually interlocking systems are electrical in nature, and a typical example is shown in Fig. 17. Here both the *control and controlled* (audio) circuits are shown.

Basically, a switching and a release relay are required for each studio. The locking and release contacts, known as interlock contacts, are required on each switching relay. In analyzing and designing a relay system, it is important to grasp the basic plan underlying the system of connections in order that the wires themselves do not confuse the operation.

In Fig. 17 it is desired that if Studio A, for example, is already connected through relay A to the transmitter, then Studio B must be able to be connected through relay B when its ON button is pressed. This clearly requires cross connections between the ON buttons and the opposite relays. This is provided by the interlock contacts.

If the circuits be traced, it will be found that the 'A' ON button is connected in series with the normally closed interlock contacts of relay B; and the 'B' ON button is connected in series with the interlock contacts of relay A. Thus, if either relay is already energized, its interlock contacts are opened, and as a result the ON button of the other relay cannot energize its circuit. Otherwise the circuit is identical with that of Fig. 14. The OFF buttons operate their respective release relays and thus de-energize their switching relay without any reference to interlocking, since none is needed for the OFF position.

If both ON buttons should be pressed simultaneously, then whichever relay closed first would cut the other out. If both closed simultaneously they would stay closed owing to their locking contacts, which are not interlocked, but simultaneous operation is too remote a contingency to cause any concern. However, it is intended to emphasize here that in designing relay circuits, great care should be exercised to see that the system operates properly under all possible conditions that will be encountered in practice.

The audio circuits employ simple double-pole single-throw springs on The arrangement of Fig. 17, while simple, is however, confined to two studios because of the excessive number of interlocking contacts con-

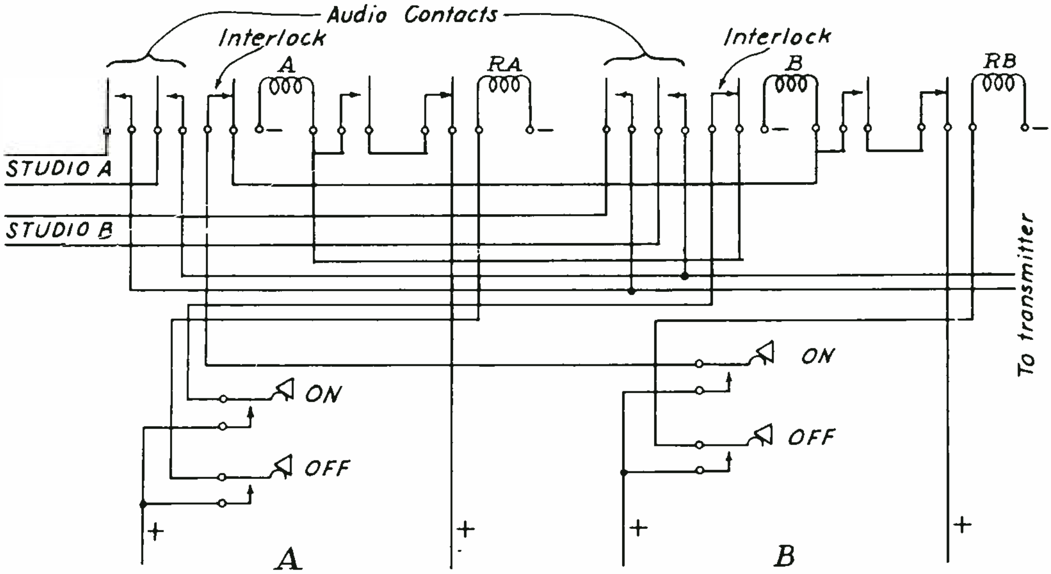


Fig. 17. — Interlocking Between Two Studios and a Transmitter.

the two switching relays so that whichever relay is energized connects its studio to the one feed, namely the transmitter. It is to be noted that these same springs could just as well be mounted on a pair of mechanically interlocking push buttons described previously. The arrangement would be much simpler and cheaper, but would require that the audio circuits be run to the point of control, and only one control could be used.

The relay system is clearly more flexible. The ON and the OFF push buttons can also be located at the announcers control box, if used. *nected in series* that would otherwise be required on the switching relays.

INTERLOCKING OF SEVERAL STUDIOS. — Where three or more studios have to be interlocked, a more complicated arrangement is necessary to avoid several normally closed contacts in series. At least one solution can be devised on the same basis whereby closed-circuit OFF buttons are eliminated. There a release relay replaces the closed-circuit OFF button, and the latter then becomes an open-circuit type that can be paralleled many-fold.

THREE-RELAY CIRCUIT. — A similar solution exists here: replace the *normally closed interlocking contacts* on each switching relay by a third relay having only *one normally closed* pair of contacts, and which may be considered an interlocking relay. It is controlled by *normally open* contacts on the other switching relays. When any of these close, they close the latter contacts, energizing all the *other* interlocking relays and thus preventing the corresponding switching relays from being closed.

There are thus *three* relays required for each studio: a switching relay, a release relay, and an interlocking relay. The circuit is shown in Fig. 18. Only three sets of relays represents the switching relays for the various studios; the second row, the interlocking relays; and the third row, the release relays. Since three studios are involved, there are 3 - 1 = 2 interlocking contacts on each switching relay. The basic idea is that if any one switching relay is on, its interlocking contacts are closed and energize *all the other interlocking relays*. Their normally closed contacts are therefore opened, and since these are in series with their respective ON buttons, the corresponding switching relays cannot be energized.

Specifically, suppose Studio A

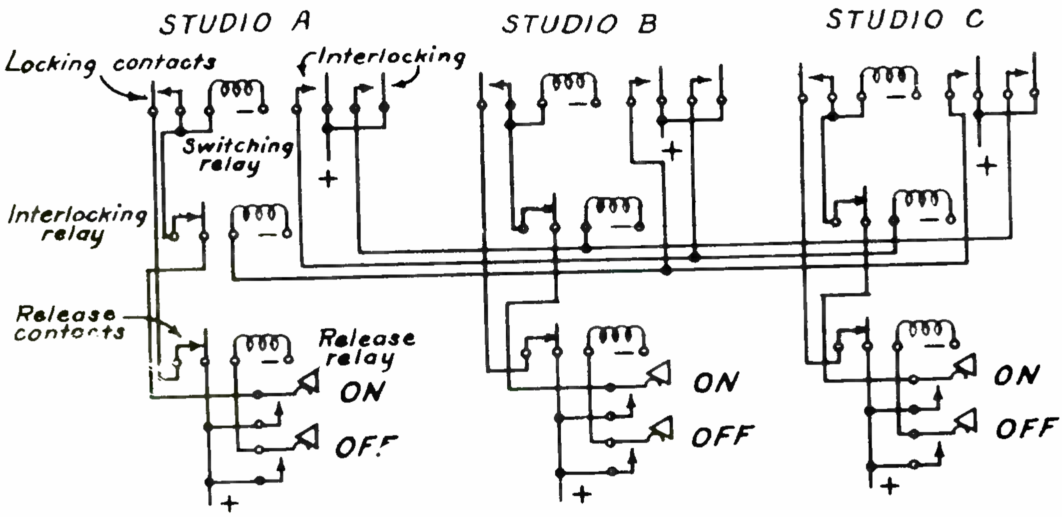


Fig. 18.—Interlocking Circuit for Three or More Studios.

lays (studios) are shown, but the extention to any number of relay sets is obvious. The number of interlocking contacts required on each switching relay is one less than the total number of studios involved.

In Fig. 18 the first row of re- is to be connected to the outgoing line. Pressing its ON button closes the circuit to the (top) switching relay through the normally closed contacts on the interlocking relay. Since by hypothesis no other switching relay is on, the interlocking relay for Studio A is de-energized and its contacts therefore closed, as stated above. When the 'A' switching relay closes, it does two things:

(1) It closes its own locking contacts and thus holds itself energized, and

(2) It closes its two interlocking contacts, thereby energizing the interlocking relays for Studios B and C, whereupon their normally closed contacts open. This breaks the ON circuits for Studios B and C, so that pressing their ON buttons cannot energize their switching relays. Thus these studios are interlocked and cannot function, until the 'A' OFF button is pressed which momentarily energizes the release relay, opens its contacts in the locking circuit, and thus de-energizes the 'A' switching relay. This in turn de-energizes the other two interlocking relays, thereby giving either of the other two studios a chance to be connected to the outgoing line.

From the symmetry of connections, it is clear that the same is true for any other studio. Indeed, a test of the correctness of the design is that the circuit should be perfectly symmetrical, if all components are to function in a similar manner. This is clearly the case for Fig. 18.

The *controlled* (audio) circuits have not been shown, but are identical with those shown in Fig. 17. Indeed, the problem is not that of designing the audio switching circuits, but rather that of interlocking the control circuits. Another point to note is that all ON and OFF push buttons are of the open-circuit type, and can be paralleled as much as desired. In the case of several studios, a Master Control Room is generally used, and multiples of all the ON and OFF buttons will be installed here. From the preceding description it is clear that no studio can come on the air until the studio already on releases its connections. Should the control room engineer or announcer of that studio fail to press his OFF button, the master control operator can do so at his location, and should the next designated studio be tardy in coming on the air, he can press his multiple of its ON button and thus switch it on.

TWO-RELAY CIRCUIT.—As a general rule, there is no single or unique solution to a relay problem. The best solution is that which is most foolproof under all possible operating conditions, and uses a minimum number of parts. An examination of Fig. 18 reveals that the release relays can be eliminated by adding another set of normally closed contacts to the interlock relay, and connecting the OFF push buttons to this relay. This is shown in Fig. 19.

The release and interlock contacts on the lower relay are indicated for Studio A, and it will also be noted that the OFF button connects directly to this lower relay. If the lower relay is already energized by the contacts on another switching relay, no harm will occur if the OFF button is pressed; on the other hand, if its studio is connected to the outgoing service, pressing the OFF button will, by energizing the lower relay, open the locking circuit of the corresponding switching relay at the release contacts and thus disconnect the studio.

SEVERAL STUDIOS TO SEVERAL SERVICES.—A more complicated setup is that where several studios are required to feed several services. For example, suppose three studios, A, B, and C, are to feed either the local transmitter or a network chain. Thus, suppose that Studio A is to be connected to the local transmitter, and Studio C to the network. Interlocking will be required so that after A is connected to the local transmitter, neither B nor C can be inadvertently connected to it, and similarly, with C connected to the network, neither A nor B can be connected to it.

The solution is essentially an expansion of the previous circuit, such as that of Fig. 19. Two such interlocking sets of relays and push buttons can be used. Each set is interlocked exactly as shown in Fig. 19, and hence need not be drawn again. The only point of interest observed that each studio feeds the upper and lower sets of contacts of its switching relay in parallel. There will also be two ON and two OFF push buttons for each studio, as mentioned above. One pair will be designated as the Transmitter, and the other pair as the Network buttons, or Line #1 and Line #2.

Suppose ON push button 'A' Transmitter is pressed. Then switching relay A will operate, its audio contacts will close, and it will be connected to the transmitter through Line Amplifier 'A' transmitter energized, neither relay B nor C will be operative if their ON buttons are pressed, owing to the interlocking features in this circuit, as shown in Fig. 19.

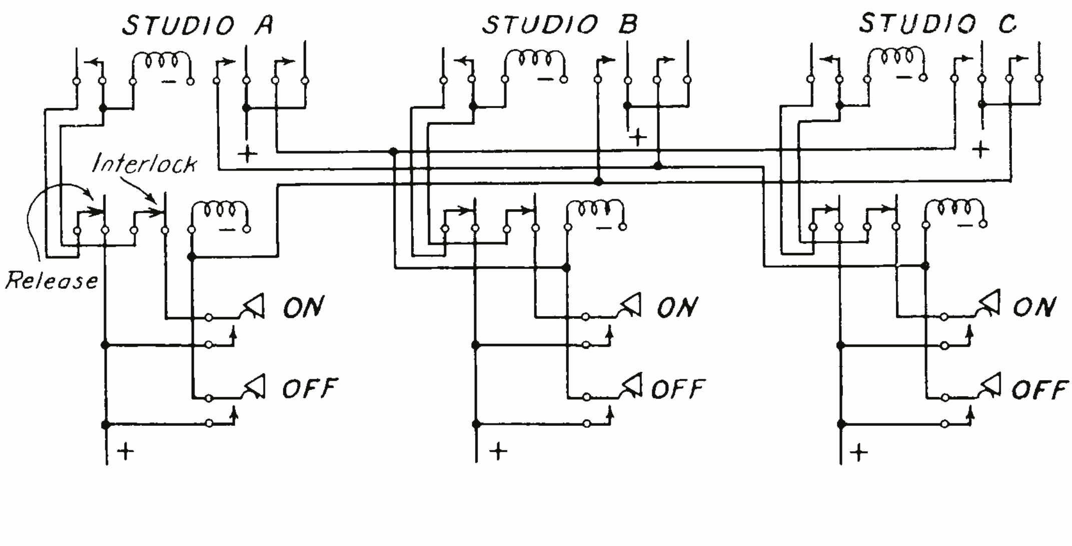


Fig. 19.—Interlocking Circuit for Three or More Studios Using Two Relays per Studio.

now is the audio or controlled circuits, hence only the contacts on the two sets of *switching relays*, which control the audio circuits, are shown in Fig. 20. It will be

However, in the lower set of switching relays, the ON push button, 'C' Network, can be pressed and the corresponding switching relay will connect Studio C through the multiple feed to the network. At the same time, owing to the interlocking features present here too, neither Studio A nor B can now be connected to the network until, of course, C is released. It should also be clear from the diagram that any one studio can be connected to *both* services, whereupon neither of the other two can be connected to either service.

If more than two services are involved, more rows of the relays and push buttons are required, but the method of connection is exactly the same as that for Fig. 20. Also, if more studios are involved, each row is expanded to take care of the additional studios. The system is therefore completely flexible as regards number of studios and services to be handled.

MECHANICAL INTERLOCKING.—The system of mechanically interlocking push buttons described previously can be used. The advantage is a simpler and cheaper mechanical system as compared to the large number of relays required in the electrical system. The audio springs shown in Fig. 20 can be mounted on two or more tiers or rows of push buttons, with the individual buttons in each tier interlocked so that only one audio circuit (studio) can be connected to the service entering that tier.

One disadvantage is that these tiers can be located and hence controlled *from but one point*, probably the Master Control Room or its equivalent, whereas the ON and OFF buttons in the relay system can be multipled for control from as many locations as desired.

Another disadvantage is that the audio circuits must be brought to the panel where the buttons are mounted, and this may be a location remote from their normal course. To obviate this, it is possible to use the interlocked push buttons to control relays that are located where

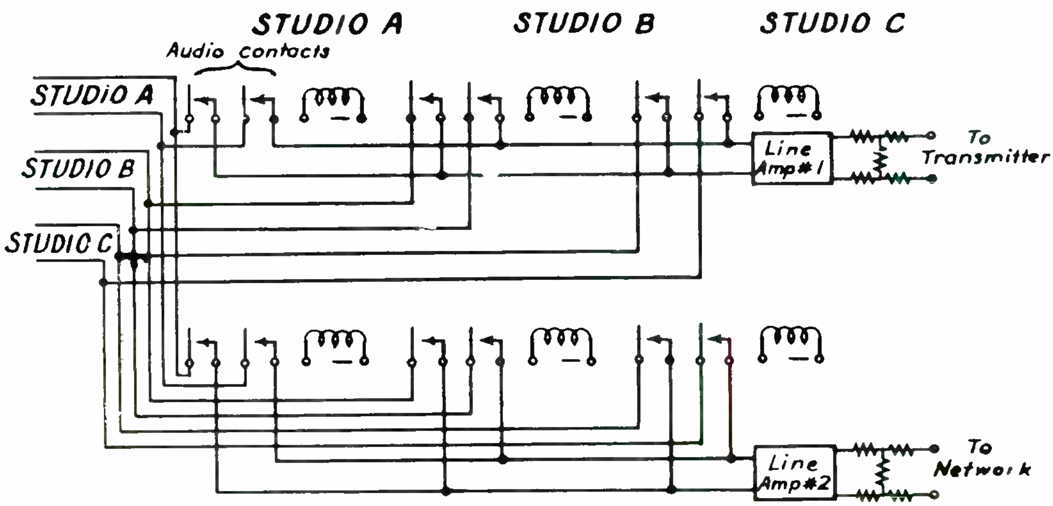


Fig. 20.— Audio Circuits From Three Studios to Two Services.

the audio circuits run, and thus retain this advantage together with the advantages of simplicity and cost that the mechanical interlock system has over the electrical relay-type interlock system. However, the disadvantage of control from only one point still holds for the push button system.

The arrangement is shown in Fig. 21 for the case of three studios and two services. Two sets or tiers of three mechanically interlocked push buttons are used: two tiers for two services, and three push buttons for three studios. In either tier, when one push button is pressed, it releases all others and connects its studio to the service. The operation differs from the previous relay system in one important respect: in the relay system no new studio can connect to the service until the studio already connected relinquishes the service. In the mechanical system, on the other hand, if the push button for any new studio is pressed, it automatically disconnects the studio already connected and feeds the service instead. This may or may not be desirable; however, if the buttons are located in a master control room and all studios controlled from there, then it is immaterial since the operator there will do all the switching required and no studio engineer can put his studio on the air in place of another.

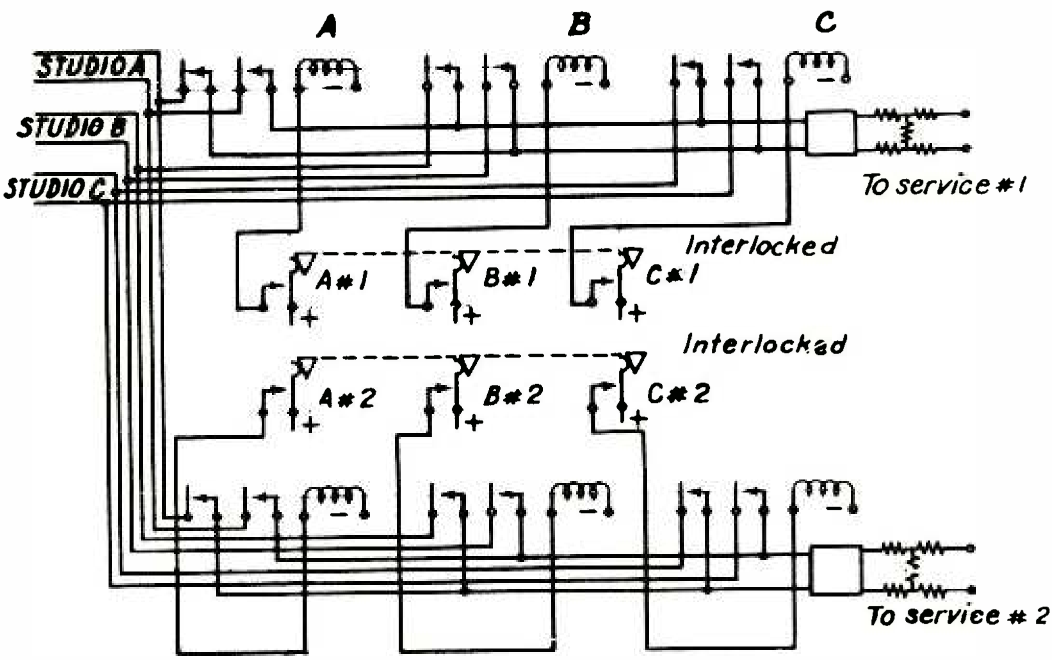


Fig. 21.—**Mechanically Interlocked System for Three Studios and Two Services.**

The mechanical interlock system

has been gaining in favor lately, and is satisfactory, provided the mechanical assembly is made sufficiently sturdy and accessible. As stated previously, it provides a simple and cheap way of interlocking circuits either directly, or through the use of relays. The trend toward simplicity in control circuits is a welcome relief from the complexity of some of the control systems in the very large broadcast stations.

PRE-SETTING.—The function of pre-setting has been described in previous technical assignment. Briefly, it enables studios to be connected in one arrangement to the associated services for one program, and the arrangement for the following program in the meantime to be set up (pre-set) by operation of a duplicate set of push buttons or switches, and the changeover can then be made instantly at the proper moment by actuating but one master switch.

MASTER CONTROL KEY SWITCH.—The circuits described previously can easily be expanded to provide presetting. For example, take the case of the three studios and the two services shown in Fig. 21. Suppose the outputs went to one side of a four-pole double-throw master switch instead of directly to the services, and suppose further that a duplicate arrangement of the push buttons and relays went to the other side of the above switch. Then depending upon which way the master switch was thrown, either arrangement of studio connections would be made to the actual services, and the changeover would be made instantly, while either selection or arrangement could be made at a leisurely rate.

A suggested circuit is shown in Fig. 22. Only the master four-pole double-throw switch need be shown, as the feeds to it may be from the outputs marked Service #1 and #2 in Fig. 21, or from Transmitter and Network of Fig. 20, depending upon which type of interlocking is employed. The master control switch shown is of the key type. Position I refers to the arrangement chosen for one program; Position II, the arrangement for the next program. Associated with it are four interlocking circuits of the type shown in Figs. 19 and 20, or Fig. 21, as desired.

Suppose there are four studios A, B, C, and D, and for the first program Studio A is to be connected to Service #1, which may be a network, and Studio D is to be connected to Service #2, which may be the local transmitter or another network. The studios are suitably interlocked as indicated above, so that when the ON button 'A' #1 is pressed, Studio A is connected to the #1 Service line, and none of the other three studios in this group can be connected to this service. Such interlocking is illustrated by Figs. 19 and 20 for the electrical type of interlocking, or by either group of Fig. 21 for the mechanical type of interlocking. The output of such a circuit then becomes the input labeled #1, Position I, in Fig. 22.

In the second set of interlocked circuits, ON button 'D' #2 is pressed. This connects Studio D to Service #2, and prevents the relays of the other studios in this group from being connected to Service #2. The output then becomes the input labeled #2, Position I, in Fig. 22. If now the key of the master switch is thrown DOWN, the top set of contacts is closed, and #1 Position I feeds Service #1, while #2 Position I feeds Service #2, as may easily be checked by tracing the circuits in Fig. 22 for this position of the key switch. Hence, by the combination of two interlocking circuits and the master key switch, Studio A is connected to Service #1 and Studio D is connected to Service #2, as is required.

Now suppose that in the next program Studio C is to feed Service #1, and Studio B is to feed Service #2. If the pre-set arrangement were not used, then at the end of the first program the master control operator would first have to press OFF buttons 'A' #1 and 'D' #2, and then ON buttons 'C' #1 and 'B' #2. While in this simple example the operations required are only four, it is apparent that mistakes could occur, and such a possibility is even greater for a larger number of studios and services.

With the pre-set arrangement, the operator can during the first program 'punch up' the second set of connections on the remaining two interlock groups. Thus the ON button for 'C' #1 would be pressed in the third group of interlocked relays, whose output becomes the input labeled #1 Position II in Fig. 22, and the On button for 'B' #2 would be pressed in the fourth group of relays, whose output becomes the input labeled #2 Position II in Fig. 22.

There the connections would wait, as it were, until the end of the program, when the master control operator could flip the key up. The upper set of contacts would thereupon open, disconnecting Studios A

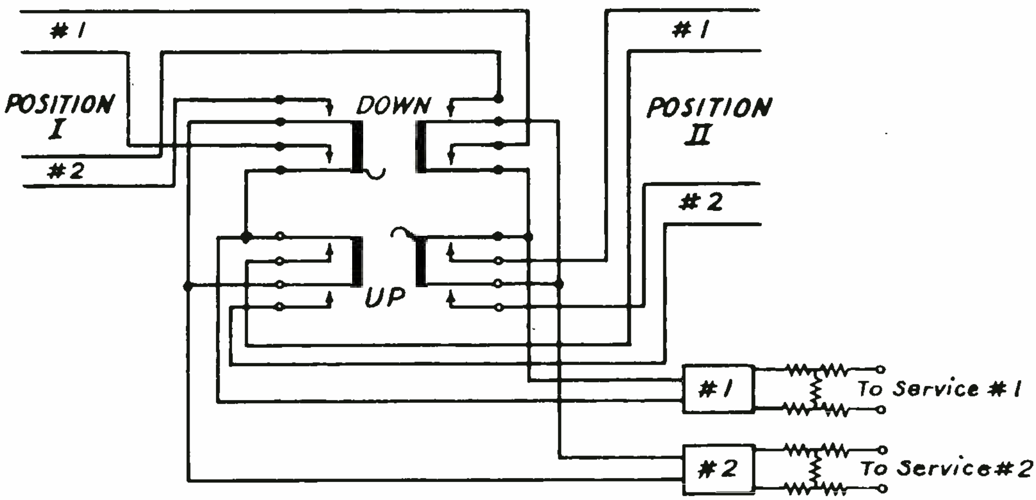


Fig. 22.—Connections to Four-Pole Double-Throw Master Control Switch for for Pre-Setting.

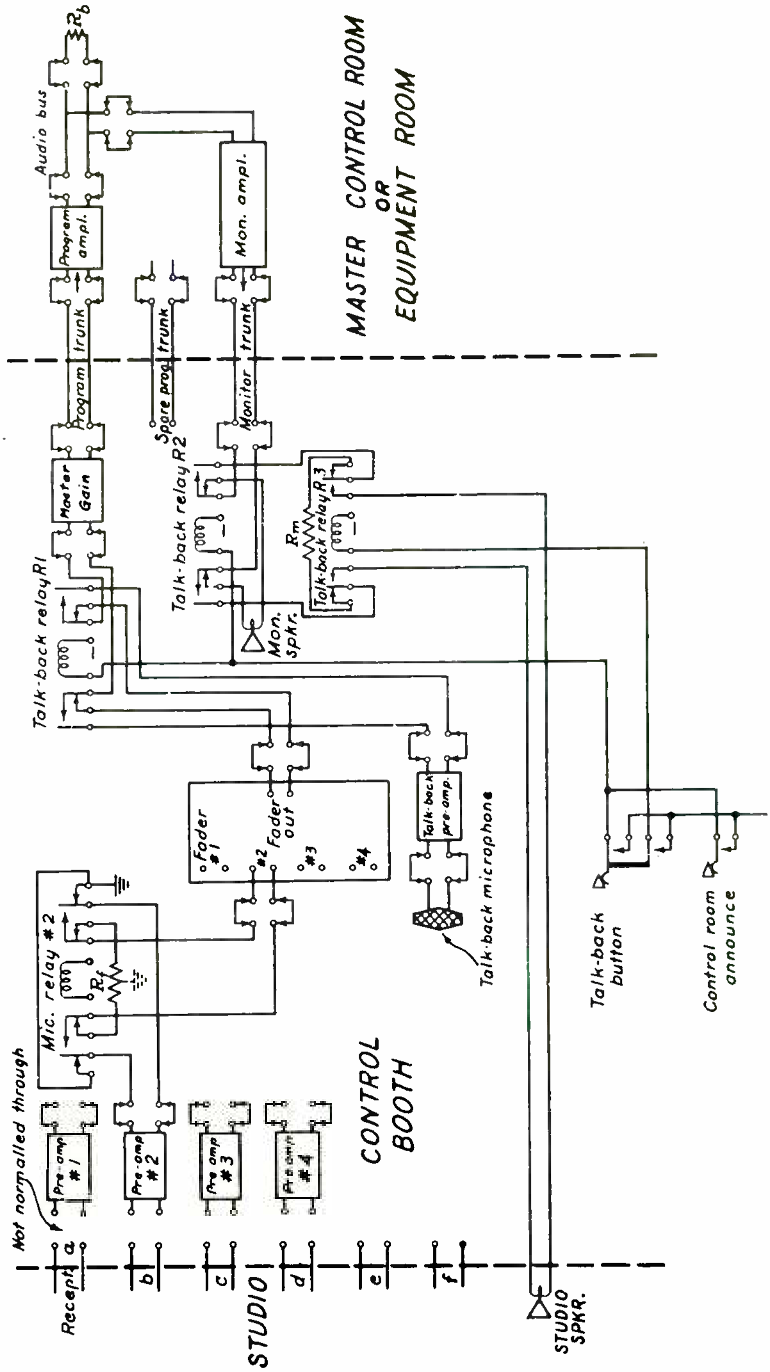


Fig. 24.—Studio Electrical Layout Showing Talk-Back System.

and D, and the lower set of contacts would close, whereupon the pre-set connections between Studio C and Service #1, and between Studio B and Service #2 would be completed. Also note that the key switch has a neutral position, in which neither set of contacts is closed. This permits even the very first program of the day to be set up in advance and held in abeyance until the broadcast starts.

If more than two services are involved, then more springs are required on the key switch. For example, six services will require 12 springs per pile-up, which is just one less than the maximum permitted. This, however, is no particular objection. But, as indicated previously, the need for routing the audio circuits up to the key switch may be undesirable.

MASTER CONTROL RELAY SWITCH.— The solution is as before: the use of relays. Not only can these be remote-controlled from many positions, but also the arrangement is more flexible, although more expensive. The reason for the increased flexibility is that if too many springs are required for one pile-up, two or more relays whose coils are connected in parallel can be employed and controlled by one push button. Thus any number of circuits, such as the services above, can be controlled as a unit.

In employing relays for the master switch, an arrangement such as that shown in Fig. 23 is desirable. Here two relays are employed, one for each position or pre-set arrangement. Each relay has four pairs of audio contacts or springs, one pair of locking contacts, and one pair of interlock contacts. Three buttons are shown: an ON button for each position, and a common OFF button.

The audio contacts are exactly the same as those used in the key switch of Fig. 22, but the other control contacts will warrant some discussion. Note that each ON swtich connects directly to its relay, so that the relay is sure to be energized if the button is pressed. The locking circuit of either relay, which maintains the relay energized after its ON button is released, is interlocked with the other relay. Hence, if the relay for Position I is energized, and ON button for Position II is pressed, the relay for Position II closes. In doing so, its normally closed interlock contacts open, thus opening the locking circuit for the first relay, whereupon it opens.

In this way either relay may be used to open the other at the same time that it closes, which is similar in action to the mechanically interlocking push buttons. These, by the way, could be used to operate the two relays instead of the On and OFF buttons shown. In that case the relays would require only the audio contacts. The OFF button is of the closed-circuit type and is in series with both interlock and locking contacts. Hence if it is pressed, *both* relays are de-energized, as is necessary at the end of the day's broadcasting.

There are, of course, other ways of obtaining pre-setting, such as by selector relays, (used, for example, by NBC at Radio City, New York), but the circuits shown above are representative of the systems used in a large number of stations, rather than special circuits for special installations. The important things to grasp are the principles involved, for then the specific means employed can be understood from a study of the connection diagram.

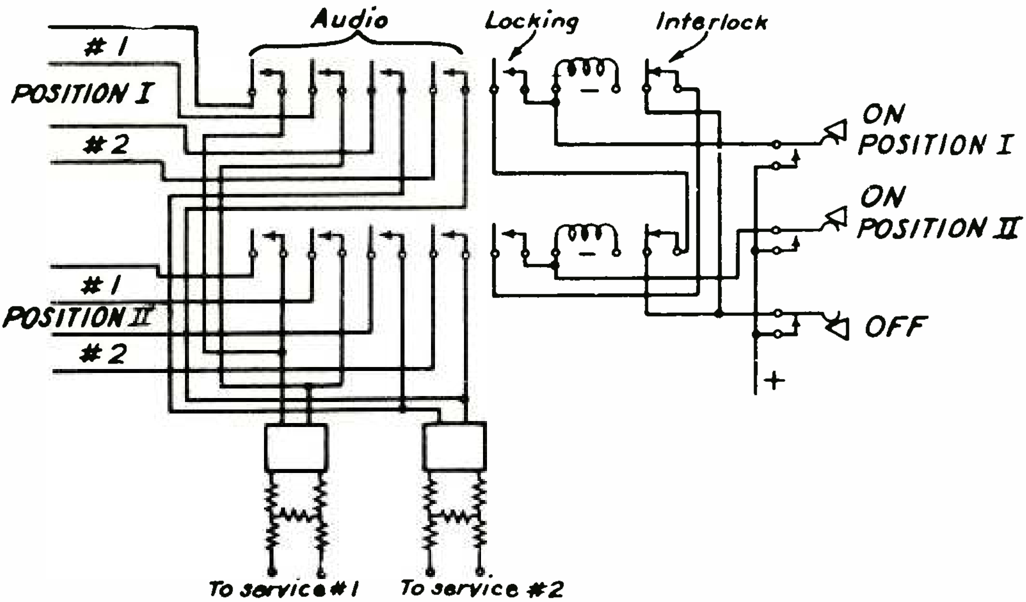


Fig. 23.—Relay Type of Master Control Switch for Pre-Setting.

TALK-BACK SYSTEM.—It will be instructive to analyze the circuits employed for talk-back and control room announce purposes, as these bring out some interesting features of the audio design. In Fig. 24 is shown a talk-back system that employs the monitoring amplifier to operate the studio loudspeaker or the monitor loudspeaker, as desired, or else only the talk-back microphone for control room announce purposes.

The system is shown in considerable detail so that features common to studios in general can be seen here as well as the talk-back circuits. In the first place, the studio has receptacles around the wall and in the floor into which microphones can be plugged as desired. Depending upon the program, one or more of these receptacles will be used, and it is therefore not possible to normal any one receptacle into any one pre-amplifier. Hence, as indicated in the diagram, the desired receptacles must be patched to pre-amplifiers, and jacks are provided in the control room rack to enable this to be done.

Four pre-amplifiers are shown, corresponding to four fader positions in the mixer. Each pre-amplifier is normalled through to the corresponding fader position via a microphone relay. In order to enhance the clarity of the figure, the details for only Pre-amplifier #2 are shown. The other three pre-amplifiers are connected to their fader positions in exactly the same manner.

Referring to pre-amplifier #2, note that if the microphone relay is not energized, the output of the pre-amplifier is shorted and grounded, and the input to fader position #2 has a resistor R_f connected across it to match the impedance of the fader pad, as discussed in the section on mixer circuits. By pressing the ON button for this pre-amplifier, the relay is energized, the short-circuit is removed from the output of the pre-amplifier, and the latter is connected to fader position #2 in place of R_f. The details of the control circuit have been omitted because they are essentially those shown in Fig. 13 or in Fig. 14.

Note, in addition, how jacks interposed between each unit, as between the pre-amplifier and the relay, the relay and the fader position, the output of the four faders and the master gain control, etc. All these jacks are normalled through, but a spare unit can be patched around any unit in this sequence that proves defective. Note further the *multiple* jack off the audio bus, through which the Monitor amplifier is normalled. The multiple jack permits the amplifier to bridge across the bus, while the latter is terminated in its matched impedance R_b. Other multiple jacks (not shown) serve to feed the various line amplifiers, volume indicator, etc., from this bus.

TALK-BACK CONNECTIONS. — When the control room engineer wishes to talk to the studio personnel, as during a rehearsal, he presses the 'TALK-BACK BUTTON'. This actuates all three talk-back relays, — R1, R2, and R3. Relay R1 is a low-level relay; i.e., it controls an audio circuit of low level, that of the Fader Out circuit; R2 and R3 are high-level relays, because they control the amplified output of the monitor amplifier. It is preferable to use separate relays in order to isolate the high-and low-level circuits from one another, thus preventing feedback and possible regeneration.

Relay R1, when energized disconnects the master gain control from the Fader Out terminals and connects it instead to the output of the talk-back pre-amplifier. Thus the talk-back microphone will feed in sequence the master gain control, the program amplifier, and the monitor amplifier. It will also feed any line amplifiers bridging across the audio bus, but these are not supposed to be connected, as the studio is assumed being used for rehearsal or audition purposes.

The output of the audio bus represents the studio output, and is the point where interlocking with the outputs of other studios occurs. This feature has been previously described. If it is desired, the talk-back push button circuit can also be interlocked with the studio output switching relay, so that if the studio is connected to a service via the switching relay, the talk-back circuit is simultaneously opened. This will prevent any possibility of the control room engineer being able to talk to the studio during a regular program; however, it would appear to be an unnecessary precaution since the management should be able to rely upon the engineer's not committing such a gross and obvious error.

The talk-back button also energizes R2. This disconnects the output terminals of the monitor amplifier (now being fed by the talk-back microphone) from the monitor speaker and transfers them to contact on R3. It is imperative that the monitor speaker be disconnected as otherwise acoustic feedback between the speaker and the talk-back microphone would occur, since both are in the control booth.

Since R3 is also energized, it will be found upon tracing the circuits of Fig. 24 that the output of the monitor amplifier, transferred by R2 to R3, does not feed R_m—a terminating resistor—but instead feeds the studio loudspeaker, which is the desired arrangement for talk-back purposes.

CONTROL-ROOM ANNOUNCE CONNECTIONS.—When it is desired to make an announcement over the air from the control room, the talk-back amplifier is connected to the studio output ahead of the master gain control as before, but now *neither* loudspeaker must be operative. Hence the control-room announce push button is wired to actuate only relays R1 and R2 *and R3 is inoperative.* The output of the monitor amplifier therefore feeds R_m instead of either speaker. The use of a terminating resistor R_m is advisable in order that the voltage across the plates of the output tubes and the primary of the output transformer of the monitor amplifier does not reach such a large magnitude as to damage these components. (The voltage is the normal d.c. plate-supply voltage plus the superimposed audio voltage, which can rise to abnormally high values on open-circuit of the secondary of the output transformer.)

It is to be observed in passing that the control-room announce push button circuit should *not* be interlocked with the studio output switching relay, since it is desired that the announce signal get on the air.

MISCELLANEOUS CONSIDERATIONS.—The foregoing discussion of control circuits cannot possibly hope to cover completely so extensive a field, but it should afford the reader a general view of the fundamental methods and circuits employed in broadcast practice. There will now be considered those miscellaneous items that did not come under any of the previous topics discussed.

RELAY ARCING.—When the relay coil circuit is opened, an arc will normally occur across the contacts that break the circuit owing to the inductive nature of the relay coil. Once current is established in the coil, any attempt to reduce it results in an inductive rise in voltage in the coil tending to oppose such reduction in the current.

At the moment of the break, the coil tends to maintain the current at the previous magnitude. If the contact resistance suddenly jumps to infinity as the contacts open, an infinite voltage drop will suddenly appear across them as the above current tries to flow through this infinite resistance. Actually, as the voltage rises, the air breaks down (ionizes) thereby reducing the resistance to a finite value, and the current arcs across. In doing so, the current decreases exponentially until it is insufficient to maintain the arc and the circuit is thereupon opened.

This action takes place not only in a relay circuit, but in any inductive circuit, such as that of a loudspeaker magnetic field winding, and the induced voltage when the circuit is opened, particularly in the latter case, may be sufficient to break down the coil, as well as cause a heavy arc across the switch contacts. In the case of a relay coil, the inductance is not very great so that coil breakdown is improbable, but the arcing of the contacts will in time tend to impair their functioning. Moreover, the sudden break in the circuit tends to set up a surge and hence noise in the audio system.

This effect is decreased to a certain extent by the presence of the indicator lamp across the relay coil, as shown in Fig. 25. This

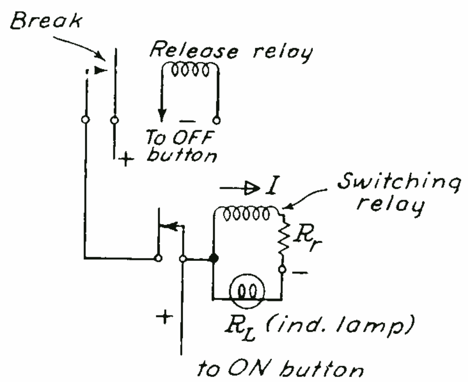


Fig. 25.—Suppression of Arc at Relay Contacts by Indicator Lamp.

permits the relay current I to flow through the lamp resistance R_L, instead of through the relay battery and the release relay contacts, to the positive side of the switching relay coil.

The peak voltage developed across the relay coil (or any other coil) at the instant the circuit is opened, is equal to

$$E_m = E_r \frac{R_L}{R_r} \qquad (1)$$

where E_r is the d.c. relay voltage and R_r is the resistance of the relay coil. Examination of Eq. (1) shows that if the external resistance, such as R_L, is very high, then the initial peak voltage E_m will be very high, although it then decreases exponentially to zero. If $R_L = R_r$, $E_m = E_r$, so that the voltage across the coil will be no greater than normal, and the voltage across the contacts will then be $2E_r$, since the battery voltage is in series with E_m with respect to the contacts.

However, for R_L to equal R_r, the indicator lamp will normally draw as much current as the relay. If the lamp is very small, so that R_L is much greater than R_r, then when the relay current I attempts to flow through the lamp, it may burn it out. Hence a better procedure is the following (normally acting in conjunction with the lamp).

In Fig. 26 is shown an R-C com-

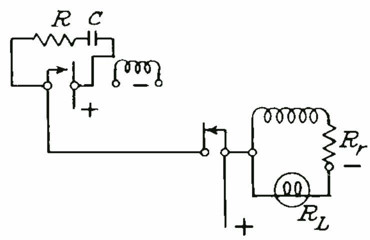


Fig. 26.—Use of R-C Combination to Suppress Arcing.

bination, which can be connected across the contacts, as indicated in the figure, or alternatively across the relay itself (in parallel with R_L). To any sudden change in voltage, the capacitor C acts essentially as a short circuit, so that in effect it is as if R alone were connected across the contacts. It therefore absorbs the arc just as the lamp does, but since C prevents it normally from carrying current, there is no steady d.c. power loss entailed, and it can be of sufficient wattage to withstand the surges.

Typical values are C = 1 mfd. and R = 400 ohms. It is a method used fairly extensively by Western Electric and RCA, and can also be applied to loudspeaker field circuits, although here a much larger value of C may be required. The value of R is such that

$$R \gg \sqrt{L/C} \qquad (2)$$

where L is the coil inductance. The circuit is then more than critically damped, and oscillatory currents in the combination are thereby avoided.

CLICK FILTER.—Another device used in broadcast circuits is the 'click' or 'static' suppressor or filter, used to minimize clicks produced in an audio circuit when it is switched on or off. This is shown in Fig. 27, where only the audio contacts are indicated. The click filters are simply the two resistors

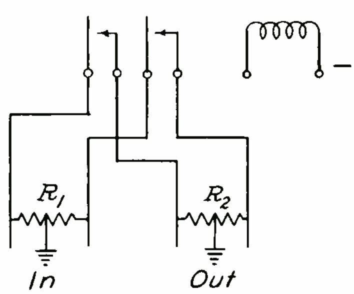


Fig. 27.—Use of Click Filter.

R_1 and R_2. If the circuits are balanced to ground, as is normally the case, then R_1 and R_2 may be grounded at the center-tap, as shown.

They vary from 10,000 to 50,000 ohms in value (NBC uses 40,000 ohms), and are mounted close to the contacts, to absorb any surges set up as the contacts are suddenly made or broken. They are not very effective if too high in value; on the other hand, they incur too great an insertion loss if they are low in value, particularly if there are many such contacts in series in the circuit, even though they are more effective. Another expedient that is helpful is to employ make-before-break contacts wherever possible so that, for example, the second source is switched to the circuit before the first source is disconnected.

CARE AND MAINTENANCE

Normally, the only care required by broadcast equipment is periodic checks and replacements, and keeping the equipment clean. Dirt not only prevents such delicate units from functioning, but may also hide a poor connection. The chief engineer of one broadcast station requires all new employees, regardless of their engineering qualifications, to start in by dusting all amplifier terminals, etc. The idea behind this is that in so doing, the employee may come across a poor or loose soldered connection, or other defects that would otherwise escape detection.

RELAY CONTACTS.—Among the items that must be kept clean are the relay contacts. Ordinarily they need burnishing at periodic intervals. A simple tool that is employed for this purpose is shown in Fig. 28. The flat steel spring is inserted between the two relay contacts to be cleared, and pulled back and forth between them. Its

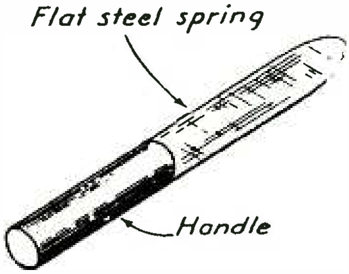


Fig. 28.—Burnishing Tool for Relay Contacts.

smooth surface polishes the contacts and removes any dirt or oxide film between them. Care must be exercised to see that the contacts are 'dead' while this is being done in order to prevent any dangerous short circuits in the associated circuit.

If the contacts are badly pitted, it may be necessary to smooth them down with a strip of crocus cloth. This contains a very fine abrasive, and the strip is pulled back and forth between the contacts until they show a smooth shiny surface. Subsequent burnishing may then be of advantage. In any event, all dust and dirt should be blown out of the relay structure.

RELAY ADJUSTMENTS.—As a general rule relays can operate for as long as a year at a time without requiring any attention other than blowing out dirt from between the contacts. Reference is here made to the small audio relays that usually carry minute currents. The larger power type, such as those used at the transmitter, require more frequent checking. Sometimes, however, a relay is damaged in shipment or when installed as a replacement unit for a defective relay. In many instances the springs are bent or some other part thrown out of adjustment.

To adjust a spring, use long-nose or preferably duck-bill pliers. The pliers are held in a vertical direction, and clamp the armature spring, lying in a horizontal direction, between their jaws, as indicated in Fig. 29. Starting near

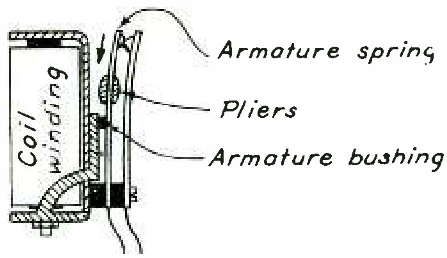


Fig. 29.—Use of Pliers to Set a Relay Spring.

the contact end, and with the jaws given a slight twist as shown, the pliers are slowly drawn down from the contact end until they almost touch the armature bushing.

This puts a concave twist or bow in the armature spring, as shown. The spring is then grasped by the pliers about one third of the way from the contact end and given a slight opposite twist *at that point* to remove the bow in the spring. However, in the process of doing so, the tension of the spring against the armature bushing is increased, which provides the normal pressure desired. The same procedure should be followed with respect to all the other armature springs. Then the stationary springs should be bent so as to provide the proper clearance for normal operation.

One other adjustment that may have to be made is that on the armature residual screw. This adjustment should also be made before adjusting the springs. Note, however, that it cannot be made on the type of relay shown in Fig. 12, for which the setting is fixed in manufacture. First the armature residual screw, Fig. 30, should be loosened until it

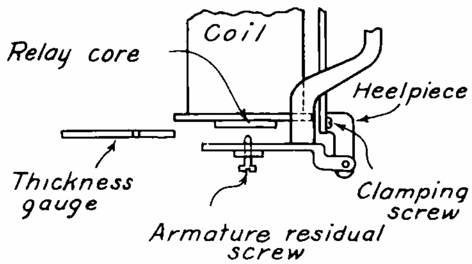


Fig. 30.—Adjustment of Armature Residual Screw.

no longer projects through the armature. Then .002" gauge is placed against the relay core and the armature pressed against it. The clamping screw is loosened, thereby permitting the heel piece to shift until the armature presses uniformly all over against the .002" gauge. This means that in the *closed* position the armature will be parallel to the core, so that these will be a minimum air gap all over and consequently maximum magnetic flux and pull. The clamping screw is then tightened.

The gauge is then removed, and the armature pressed directly against the core. The clearance ('airline') should be barely perceptible to the eye, and in no case should it exceed .004", owing to shifting when the clamping screw is tightened.

The residual screw is then set so that it now protrudes through the armature. A special thickness gauge, as shown, is now placed between the armature and the relay core in such a manner that the residual screw passes through the hole in the gauge. The armature and gauge are pressed against the core, and the residual screw tightened against the core until the gauge is just snug. The locking nut is then tightened. A gauge .001" thicker than the specified one should now fit tight when partially inserted, and a gauge .001" thinner should be loose.

The purpose of the residual screw is to prevent the armature from making actual physical contact with the core. Such physical contact tends to make the armature stick in the closed position owing to residual magnetism, even when the relay coil is de-energized. A slight air gap, such as that provided by the residual screw, prevents this and obviates a slow opening time. A similar method may be noted in electric bells, in which case a copper plate or cap is placed over each magnet pole.

FADER CONTROLS.—As stated previously, fader controls should be kept clean and coated occasionally with a special oil known as Davenoil. One item will prove of interest here: that of adjusting the contact surface of the fader arm. This is generally constructed of individual leaf springs, as shown in Fig. 31. The edges should be filed at a small angle to the face of the contact stud, as shown. In this way, when the springs are forced into contact with the stud, they will separate from one another and have individual freedom to seat properly on the stud regardless of any small irregularities of its surface.

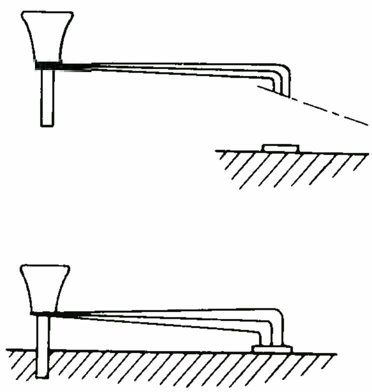


Fig. 31.—Adjustment of Fader and Potentiometer Arms.

AMPLIFIER AND TUBE CHECKS.—Amplifier channels and tubes are normally checked at monthly or quarterly intervals, although a skeleton check may be made daily. The procedure varies from one station to another. Of course it is understood that if any part of the equipment suddenly breaks down an immediate repair is made, but such sudden break-downs are precisely what the periodic checks seek to eliminate.

Three types of tests are made:

(1) Frequency run.

(2) Distortion test.

(3) Noise level.

These three tests may be made as often as every morning before the station opens, on a channel that is in daily use, or as seldom as once a month on one channel at a time, so that any one channel may not be tested again until three or four months later. Where daily tests are made, more detailed monthly tests are also made of a similar nature on each individual component.

The tubes are generally checked for plate current and plate voltage possibly once a day, and once a month they are removed and tested in a standard tube checker for emission and transconductance. In addition, they are inherently checked for noise or distortion when the channel is tested for these characteristics.

FREQUENCY RUN.—In Fig. 32 is shown a typical setup for a frequency run. The unit to be measured may be a single amplifier, or an entire channel, in which case the input may be to a microphone pre-amplifier, and the output that of the line amplifier or even the transmitter end of the telephone line. The audio oscillator furnishes the signal at a high enough level to be read accurately on an ordinary V.I. or output meter, and then the attenuation box

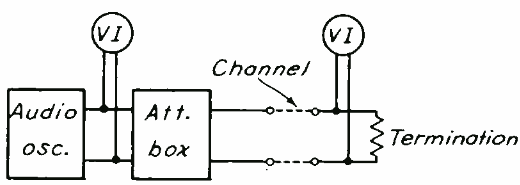


Fig. 32.—Setup for Frequency Run.

attenuates the signal to the desired low level that can be fed into the channel without overloading any amplifier in that channel. (The safe input level to a high-gain channel is far too low to be read directly by a V.I. meter.) At the output of the channel, however, the level is once again high enough to be read by such a meter.

Usually the audio oscillator has several output terminals such as 50, 250, 500, and 5000 ohms, and the proper impedance should be chosen to match the input to be fed from it. One precaution that should be exercised is to use a balanced pair of output terminals in the audio oscillator if the input of the channel is balanced to ground, and an unbalanced pair if the input is unbalanced to ground. This will be clear by referring to Fig. 33. Balanced-to-ground outputs are obtained by using

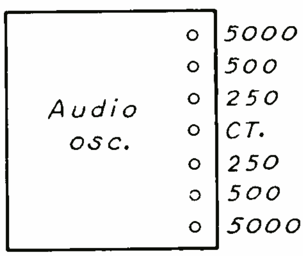


Fig. 33.—Output Terminals of a Typical Audio Oscillator.

similarly marked terminals that are symmetrically disposed with respect to the center-tap. For example, the 500-500-ohms terminals represent a balanced-to-ground output impedance of 500 ohms. On the other hand, the impedance looking back into one of the 500-ohm terminals and the C.T. terminals will be one-quarter of this or 125 ohms, since one-half of the 500-500 winding is involved and the impedance varies as the square of the turns ratio. Moreover, the output will be unbalanced to ground.

The attenuation box may be a single variable pad capable of a large range of attenuation, or it may be a collection of fixed pads mounted in a box, and arranged so that they can be connected in any sequence between the input and output terminals of the box. The usual arrangement is to have eight pads, 1 db, 2 db, 3 db, 4 db, and 10 db, 20 db, 30 db, and 40 db. Such a set can be connected in cascade to give any attenuation from 0 to 110 db *in 1 db steps*.

The pads should be H-pads for balanced-to-ground inputs, and Tee pads for unbalanced-to-ground inputs. However, it is possible to employ an H-pad for unbalanced input if an isolation transformer is interposed between the two, or if one-half of each pad is used for half of its normal impedance. If the pads and the input are both balanced or unbalanced to ground, but differ in impedance, than a taper pad (discussed in Section II) can be interposed to match the two impedances. In such a case the insertion loss of the taper pad should be added to that required in the attenuation box to give the total attenuation.

The output is normally terminated in its image or matched impedance, but if not, the proper terminating impedance, together with the V.I. meter, can be connected through the multiple jack provided for the purpose. As an example of the readings that may be obtained, suppose the input V.I. reads +3 db and the input impedance is 250 ohms; the output reading is +11 db and the output impedance is 500 ohms.

The gain of the channel is then found as follows: V.I. or output meters are generally calibrated to read correctly across a 500-ohm circuit. This comes about from the fact that the meter is inherently a voltmeter, and its scale can be calibrated to read power, or ten times the logarithm of the power (db), only across a chosen value of circuit impedance. The value normally chosen is 500 ohms.

Since the meter is actually reading across a 250-ohm circuit, a correction factor must be added. This is simply 10 log (500/250) = 3 db; i.e., if R_s represents the standard impedance circuit for which the meter has been calibrated, and R_c the impedance of the circuit to which it is actually corrected, then the correction factor is

$$\text{C.F.} = 10 \log (R_s/R_c) \qquad (3)$$

In the above example, 3 db must be added to the input reading, so that the true input to the attenuation box is 3 + 3 = 6 db. The input to the amplifier is lower in level by the attenuation in the box, or

Amplifier Input = + 6 - 90 = - 84 db

The output level is read across a 500-ohm circuit, so that the C.F. is zero, and the true output level is that read, namely, +11 db. The gain of the channel is therefore simply

$$+11 - (-84) = 95 \text{ db}$$

The gain is measured in this manner at various frequencies in steps, starting with about 30 c.p.s., and ending with 12,000 to 15,000 c.p.s. A satisfactory response for a channel (including the telephone line) is one which does not deviate from a flat response by more than ±2 db from 30 to 10,000 c.p.s. The individual components, such as the program amplifier, are therefore flatter than this, and may be flat to 12,000 c.p.s. or higher.

DISTORTION MEASUREMENT.—The distortion measurement is made with the aid of a distortion meter. The reading of this device represents the *total distortion*, rather than any one component. There are various designs available. In one type, Fig. 34, the input and output terminals are connected to the device, and the magnitude of the input voltage adjusted within the meter to

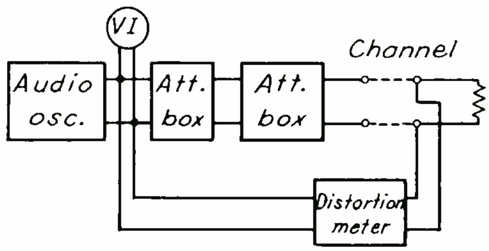


Fig. 34.—Distortion Meter.

equal that of the fundamental component in the output. In addition, the phase of the input wave is adjusted by a phase-shifting device within the meter so as to be 180 degrees out of phase with the fundamental output.

When such balance is obtained, the voltage remaining to register on the meter is solely that of distortion developed in the channel plus noise. Ordinarily the noise is so low that the reading of the distortion meter is substantially that of distortion itself. The action is illustrated in Fig. 35. An output wave assumed to have a strong second harmonic component is shown, (solid line). The input wave, amplified without appreciable distortion within the meter, and adjusted to be 180 degrees out of phase with the fundamental in the output wave, is shown as a dotted line. The *algebraic* sum of the two waves leaves only the second harmonic, which registers on a meter.

In operation, the desired level for the channel is chosen, since the distortion varies with the level, and the input wave from the oscillator adjusted to a calibrated value within the meter. Then the output.

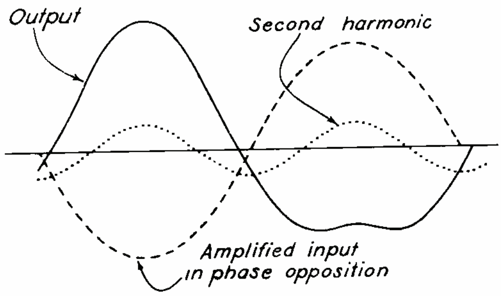


Fig. 35.—Cancellation of Fundamental Component, Leaving Second Harmonic.

wave amplitude of the channel to the meter is adjusted until the reading on the meter is a minimum. Further phase adjustment in the meter still lowers this reading until the lowest reading possible is obtained. This represents the complete cancellation of two fundamental components, each of a pre-determined amplitude. The resulting reading on the meter is therefore the distortion products, and by proper calibration of the meter scale, is read on a percentage basis. Fig. 36 shows such an instrument.

In another type only the output connections need be made. Within the device is a bridged-tee pad made up of active (L and C) and resistive elements. By suitable adjustment of the resistance, a balance is obtained on this pad at any *one* frequency desired, so that there is no output at that frequency. The action of the pad is therefore similar to that of a Wheatstone bridge, but the bridged-tee pad is inherently unbalanced to ground, and therefore can be readily fed from a single-ended vacuum tube amplifier in the device, since a single-ended amplifier is inherently an unbalanced-to-ground source.

The output of the pad is composed of the distortion products, since the pad is not balanced to these frequencies, and these components are read on the output meter as a percent of the input. An ingenious means is used to vary the null position of the pad in the frequency range. This requires the variation of an inductance, and for this purpose a reactance tube is employed similar to that used in F.M.

The percent distortion in a well-designed studio broadcast system should not exceed about 3 percent, and actually should be much lower, (less than one percent). Any undue increase can generally be traced to a defective tube, so that this test is also an indirect check on the tubes.

NOISE MEASUREMENTS.—The noise measuring meter is essentially a calibrated amplifier with a V.I. meter connected to its output. It can be and often is part of the distortion meter. The noise meter is connected to the output of the channel or line under test. First a signal of normal level is impressed on the channel, and the noise meter's amplifier gain adjusted until its meter reads to a prescribed mark.

Then, with no signal impressed, the output reading is noted. This reading is due to the noise developed in the channel. Acceptable values are 60 db below the normal program level. Such a low level is possible even when the telephone line between the studio and transmitter is included in the test, provided that a low-noise line has been specially leased from the telephone company. In general, excessive noise is also usually the result of a defective (noisy) tube, although dirty relay or other switch contacts can be the cause.

LOUDSPEAKERS AND MICROPHONES.—As a general rule the average broadcast station does not have the facilities to test loudspeakers and microphones except in the most general sense. A defective microphone can be detected by poor quality of reproduction in a monitor system known to be satisfactory, and also by the fact that the output level may be too low.

Loudspeakers can be checked by a similar listening test. Any rattles or 'fuzzy highs' can thereby be detected. Often a broken cone spider is the cause, or improper centering of the voice coil in the air gap, and the cone is therefore either replaced or recentered, as required. In making the frequency run, the loudspeakers and their associated amplifiers can be connected to the system under test, and defects at any frequency thereby noted.

(Courtesy of RCA)

Fig. 36.—RCA Type 69C Distortion Meter.

OPERATIONAL TECHNIQUE

MONITORING.—Although switching operations are part of the duties of the control room engineer, the major portion of his time is devoted to monitoring the program. This means adjusting the fader and master gain controls so as to avoid over-modulation and overloading of the equipment on loud passages, and insufficient modulation by the very quiet passages which will produce too low a signal-to-noise ratio.

Contradictory considerations and interests make any precise procedure difficult to establish and to follow. Orchestral music has a particularly wide volume range: the ratio of maximum to minimum sound intensity may be as much as ten million to one (70 db). An estimate of the overall volume range of sounds encountered in a broadcast studio is 100 db.* This must be reduced at the output of the mixer to a range of 55 db at most, and often the range is much less. At any rate, the lowest level sounds must be 'brought up out of the mud', and the peak sounds must be cut down in the monitoring process.

In Fig. 37 is shown the output of the Line Amplifier when monitored, and also if no monitoring were employed. If no monitoring were employed, the volume range of a program could be as much as 100 db. (Note that V.U. refers to 1 mw. as 0 V.U. and db level refers to 6 mw. as 0 db. *Difference* in level, such as gain or attenuation, is expressed in db, and comes out the same whether the levels are measured in V.U. or db).

If the loudest sounds are reduced or compressed in level by 17 db, and if the quietest sounds are raised or expanded in level by 28 db, then the volume range after such monitoring will be only 55 db instead of 100 db.

The above represents the theoretical principle of monitoring.

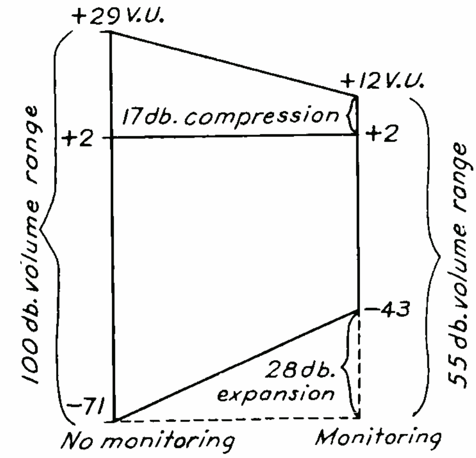
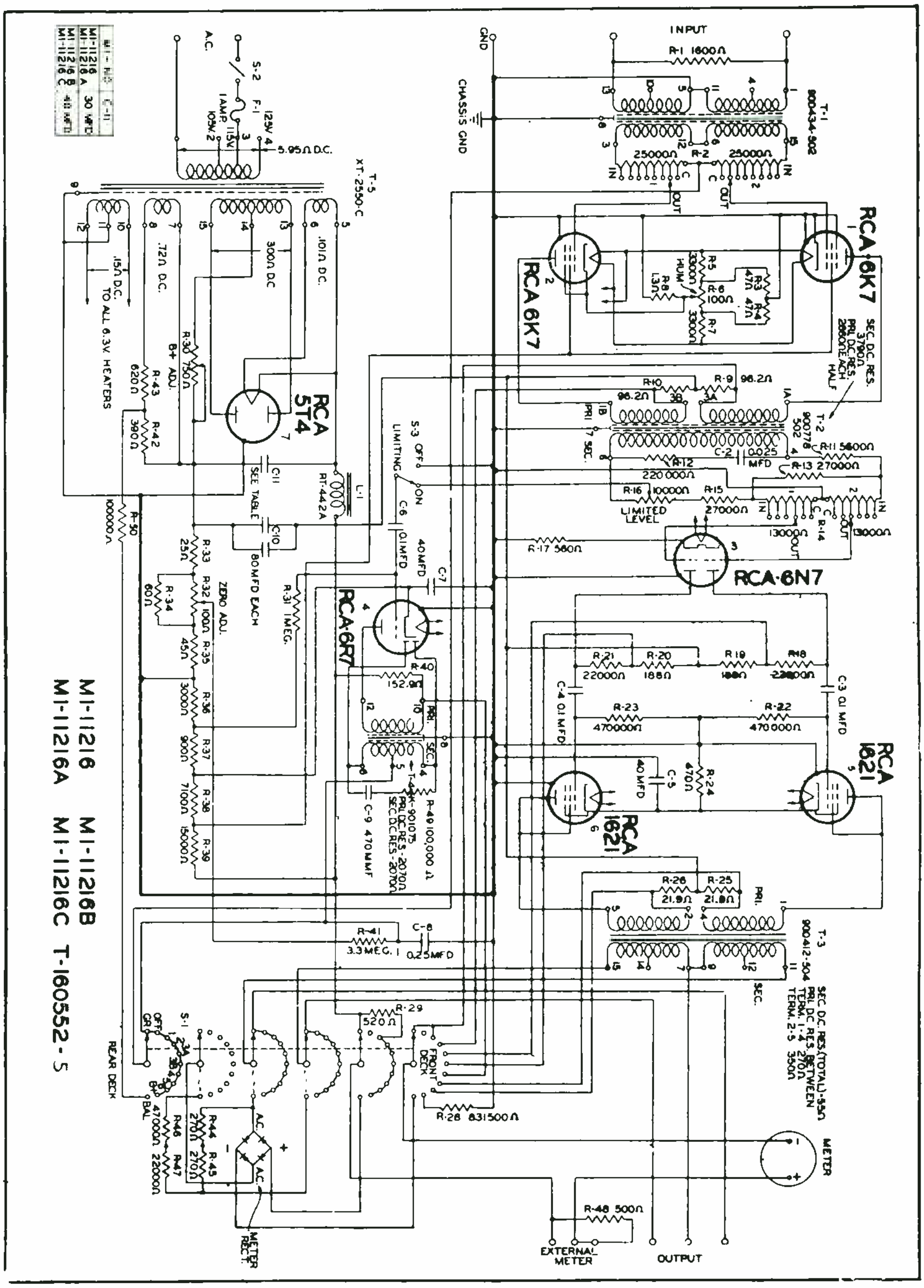


Fig. 37.—Effect of Monitoring on the Volume Range of a Program.

In practice a volume range of 50 to 45 db may be used, and actually for ordinary programs the level is held as near maximum as possible, so that the transmitter is operating at as near 100 per cent modulation as possible. Such operation is desirable from the viewpoint of broadcast coverage, and is fairly readily obtained in the case of speech programs, which are the bulk of broadcast material.

In the case of music, if the volume range were reduced to a very small value, then one of the essential qualities of the music would be lost, and it is here that compromises must be made between coverage and quality of program. One such compromise is as follows: a program is carefully rehearsed so that the engineer becomes acquainted with the

*See Taylor, J.P., "Selecting Speech Input Equipments", *Communications, April, 1938.*



(Courtesy of RCA)

Fig. 38. — Schematic Diagram-Type 86-A1 Limiting Amplifier.

music and can anticipate sudden loud passages. He accordingly begins to reduce the gain *slowly* ahead of time so that the reduction in volume of the preceding quieter passage is not noticed particularly. Then, when the loud passage occurs, the gain has already been reduced to a point where overloading is avoided, and yet the contrast in volume is so great that it sounds as if the program had not been monitored.

Such monitoring calls for a good deal of skill and practice. Ordinary programs are usually monitored so that the needle of the V.I. meter 'kicks' every few seconds or thereabouts, and seldom registers at the low end of the scale. Exceptionally loud passages are cut down, and exceptionally quiet passages are raised in level, but the more usual volume range is allowed to proceed through the mixer without further change.

Such monitoring is satisfactory where very loud and very quiet passages are infrequent. Consider, for example, a radio play, where, except for an occasional shout or cry, the level is reasonably constant. Owing to the possibility of a sudden loud sound, the monitor engineer is constrained to operate say at 60 percent modulation normally. If a device could be built that would automatically decrease the gain when the signal level exceeded the permissible value, then the engineer could safely operate at 90 percent modulation normally, and this would correspond to an average increase in power of $(90/60)^2 = 2.25$ or more than double. This is very worthwhile.

LIMITING AMPLIFIERS.—A device that accomplishes this is available, and is known as a Limiting Amplifier. In one model it operates essentially the same as a delayed A.V.C. circuit in a receiver; i.e., the input signal, when it exceeds a certain value, varies the bias on a supercontrol tube and reduces its gain. Such is the principle of operation of the RCA Limiting Amplifier Type 86-A1. The circuit is shown in Fig. 38. The main circuit has three push-pull stages; as has been mentioned previously with respect to electronic gain controls, a push-pull circuit avoids 'thumps' in the output when the bias is suddenly varied.

The triode section of the 6R7 tube amplifies the signal developed across R-16, and the diode plates then rectify the output (secondary of T-4), and develop a voltage across R-41 which is connected to a point (Zero Adj.) considerably negative to the 6R7 cathode. Thus a delay action is obtained; the signal must exceed a certain level before limiting takes place. The d.c. voltage developed across R-41 is in proportion to the signal amplitude, and is applied with negative polarity to the control grids of the two 6K7 tubes in the first stage, thus decreasing their transconductance as the signal amplitude increases.

The amplifier can be adjusted by means of the input volume control R-2 to start limiting at any level. Vernier adjustment is obtained by means of the 'Limited Level' R-16. The output control R-14 will then set the output level at which limiting begins. Note that since the rectifier channel applies the A.V.C. bias ahead of R-16 where it taps off, it tends to cut down the signal applied to itself as it begins to limit. This is characteristic of the ordinary A.V.C. circuit too, and the significance of this action is that the limiter can never reduce the output level below the input level, as might occur if the bias were applied to a stage *following* R-16. Thus there can be no incongruous action whereby the music becomes softer instead of louder.

However, extreme limiting is not desired. The desired action is shown in Fig. 39. Note that as the input level goes up to +10 V.U., the output level goes up in direct proportion to +10 V.U., but then rises more slowly with increased input level, so that when the latter is +14.5 V.U., the output, instead of being about +14.5 V.U., is about 3 db less, or actually 11.15 V.U. Thus at an input level of +14.5 V.U. there is reached a point of slightly more than 3 db gain reduction.

Attention is also called to the 'attack' and 'release' time of the device. Upon a sudden crescendo in the music, the rectifier almost instantly increases the bias, or the 'attack time' of the limiter is very short. Owing to the action of C-8, which charges up through the rectifier, but discharges through the much higher resistance of 3.3 megohms, R-41, the limiting action does not cease immediately after the cessation of the loud passage, but holds on for about 2 seconds before 90 per cent of the initial gain has been recovered.

This is called the 'release time', and is purposely made slow so that the limiter will not tend to follow the individual cycles of low-frequency audio notes and thus distort them. However, under severe overload, the release time may be sufficiently long to amplify insufficiently a subsequent low-level passage, and a 'hole' in the program may result. This can be obviated by reducing R-41, but generally such effects are due either to an unprecedented surge that occurs very infrequently, or else to too much compression (limiting) of the program.

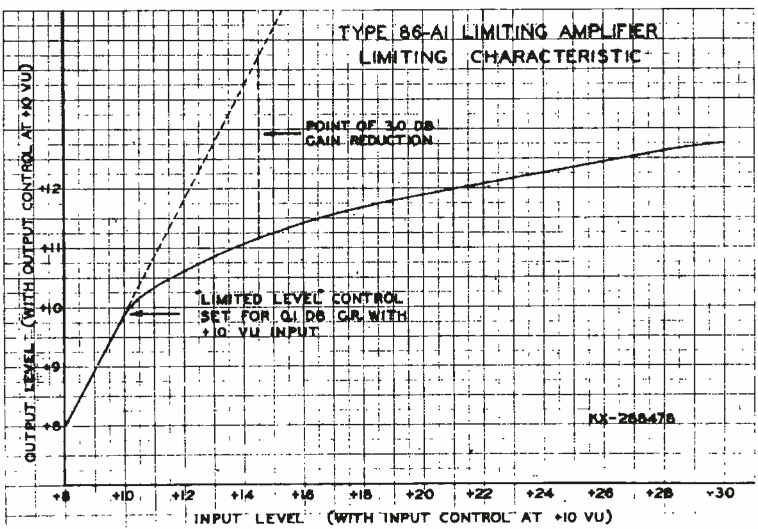


Fig. 39.—Gain Reduction Characteristic - Type 86-A1 Limiting Amplifier.

In the latter case the limiting action should be reduced, as otherwise the program will, in general, suffer from too much loss of dynamic contrast or volume range.

Another type of limiting amplifier is the Type 110-A manufactured by the Western Electric Company. This amplifier operates on a slightly different principle: that of an attenuation pad interposed between two stages, and which functions to vary the gain by having its resistance elements varied electrically. A simplified schematic diagram of the principle features are shown in Fig. 40. While batteries are shown

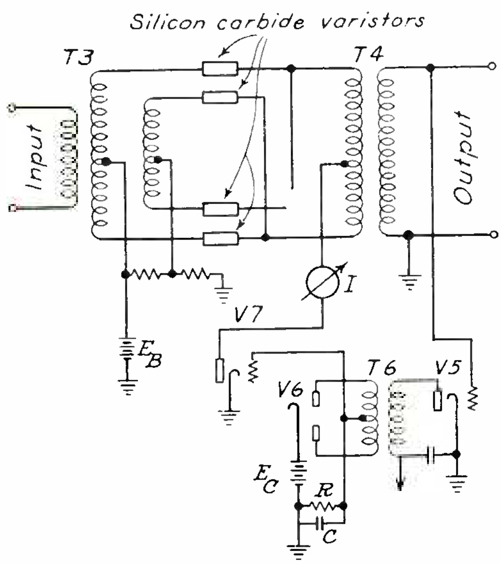


Fig. 40.—**Simplified Schematic Diagram of Volume Control Network and Control Circuit.**

for simplicity, an a.c. power supply is actually used.

As will be noted from the figure, the OUTPUT circuit feeds the grid of V5 with audio signal. This signal is derived from a stage ahead of the INPUT terminals. The audio signal is amplified by V5, and then is rectified (full wave) by V6. As a result, a d.c. voltage appears across R and C in parallel, such that the right-hand side of these is negative to the left-hand side (ground).

The bias E_C renders diode V6 inoperative until the audio signal exceeds a certain minimum value; this provides the delay feature of the system; i.e., limiting does not begin to take place until the signal rises above a certain minimum level.

The grid of V7 becomes more negative when V6 begins to rectify the audio signal, and this causes the plate current of V7 to decrease. Note from Fig. 40 that the plate current is obtained from E_B through the circuitous path involving transformers T3 and T4 and the silicon carbide varistors. These have the property of lowering their resistance with increase of current through them. Hence, if the plate current (d.c.) of V7 *decreases* with increase of audio signal, then the varistors increase their resistance to the superimposed a.c. or audio currents flowing through them.

An increase in the a.c. resistance of the varistors permits less audio current to get to the output transformer T4, so that the gain is reduced. Thus, as the signal input increases, the signal output increases at a slower rate, and limiting is obtained. The balanced or push-pull connection of the transformers and the varistors not only cancels even harmonics produced in the varistors, but also permits the d.c. plate current of V7 to cancel its magnetic effects in the transformers, thus preventing their cores from saturating.

The attack time is determined by the charging of C through the diode V6, and is very short, whereas the release time is determined by C and R, and since the latter is much higher than the internal resistance of V6, the release time is on the order of a second or so. A switch provided in the actual equipment to permit the operator to select either of two values for C and thus one of two values of release time, depending upon the nature of the program.

Limiting amplifiers are employed in place of the regular program amplifier in many small stations. In the larger stations its preferred location is at the transmitter just ahead of the modulator unit. This is a somewhat more preferable location in that there is less audio gain following the limiting amplifier, and hence less possibility of variation in gain beyond that point. Thus the settings of the limiting amplifier to determine 100 per cent modulation in the transmitter are less apt to be thrown off by change in gain in the audio components following it. Its use removes a considerable cause of strain and fatigue on the part of the control room engineer, and enables him to operate the audio system at a considerably higher level without fear that sudden peaks will open the circuit breakers in the transmitter. For that reason most large and medium size stations, as well as a number of small stations, employ this unit.

LINE EQUALIZATION.—When a remote program is picked up, it is transmitted to the studio over a telephone line, and may then be fed through one of the mixer channels to the Program Amplifier, etc. and thence to the transmitter and/or network. Ordinarily the remote pick-up is only a few miles away from the studio, and hence an ordinary telephone line is employed, together with an equalizer to flatten its frequency response.

Usually two telephone lines are leased for the occasion: one is called the Program Pair (of wires) or Program Line; the other, the Order Pair or Order Line, and serves as a means of communication between the operators at the two ends of the line. The Program Line is equalized, although sometimes both are so treated in order that the program can be switched to the Order Pair in case of failure of the Program Pair.

Equalization has been treated in Section II, and hence this topic will be merely reviewed and then amplified here. For short distances, such as 10 miles or less, the ordinary telephone line is but a fraction of a wavelength and hence appears essentially as a capacity, together with the ohmic resistance of the wires. The effect of the capacitive reactance is to attenuate the higher frequencies, and equalization consists in attenuating the lower frequencies by means of a suitable network (equalizer) so as to obtain an overall flat response.

The ordinary equalizer consists of a simple L-C resonant circuit together with an adjustable resistance. It may be of the series- or of the parallel-resonant from, illustrated in Fig. 41. The parallel type is better suited for balanced lines, since in the case of the series type, two such circuits are required, one in each side of the line. The action is essentially the same in either case.

The inductance L and capacity C

are turned to the highest frequency to which it is desired to equalize. For example, if the highest frequency of interest is 8,000 cycles, then so that their effect at the higher frequencies is negligible. Hence only C_L lowers the voltage at the higher frequencies, and the equali-

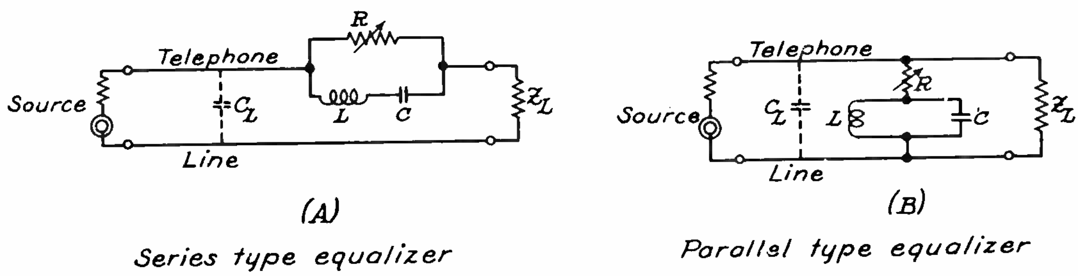


Fig. 41.—Two Simple Forms Of Equalizers.

L and C are initially designed to resonate at that frequency. Representative values are L = .0022 H., C = .171 μ f, and R = 1,000 ohms, in the case of the parallel type equalizer. Below 8,000 cycles the reactance of L is much less than that of G, so that the combination has a net inductive reactance, and draws considerable current from the line. This current must travers R. By adjusting the latter, the current drawn through the line from the source (usually the Line Amplifier and 6 db pad following it) can be regulated so that the voltage drop in the source and in the resistance of the line decreases the lower frequency voltage at the load Z_L to the same value that the line capacity C_L lowers it at the high frequencies owing to the charging current it draws.

At the higher frequencies, particularly 8,000 cycles, however, L and C draw very little line current, zer lowers it at the lower frequencies, by an amount determined by the setting of R. At intermediate frequencies each element has an intermediate effect, and by suitable design of the equalizer, the total attenuation at intermediate frequencies can be made about the same as at the high and low ends of the spectrum.*

While strictly speaking such compensation is more nearly perfect for some particular length of line and hence a particular value of C_L, actually in practice the same equalizer can effect satisfactory compensation for a large range in line length. For very long lines, say

*Perfect compensation is possible at three frequencies only. By suitable choice of these, satisfactory compensation is obtained over the entire range.

more than 15 miles in length, such elementary means of equalization is insufficient, although more complicated networks are available. One factor that begins to be more and more prominent is that of line noise. For very long lines this may be so great, and the desired equalized signal so weak that the signal-to-noise ratio may be inadequate. However, in such cases the telephone company is relied upon to furnish satisfactory transmission. The equalizer discussed above is primarily adapted for short lines, such as between a remote pickup point and the studio, or between the studio and the transmitter.

The procedure in equalizing a line will be clear in the light of the above preliminary discussion. In practice the engineer at the remote point has enough to carry in the way of microphones, the remote amplifier unit, etc., and is not expected to carry test equipment as well, although today very light audio test oscillators are available. It will therefore be assumed that the audio source or oscillator is located in the studio, and it is desired to equalize the line.

This can be done very simply by the use of the Order Pair. The set-up is shown in Fig. 42. The audio test oscillator feeds a signal through the unequalized Order Line to the remote amplifier, which then sends this signal back to the studio via the program line. The remote operator keeps the output to the program line constant by adjustment of his master gain control, and uses his V.I. meter to indicate such constancy of output signal. For example, if the test oscillator sends out an 8,000-cycle note, the remote operator will have to increase the gain of his remote amplifier considerably before his V.I. meter will read the same level (about +8 V.U.) as it will for a 50-cycle note, owing to the increased attenuation of the 8,000-cycle note by the Order Line.

Ordinarily the highest frequency (say 8,000 cycles) is sent first, and after the remote operator adjusts the gain until the desired level is being fed into the program line, the studio engineer notes the reading on his V.I. meter. Then he sends a 50-cycle note, for example, to the remote point. The operator there adjusts the gain of his amplifier so that the output into the program line is the same as it was at 8,000 cycles.

The studio engineer then decreases the resistance in the equalizer until the 50-cycle reading on his V.I. meter is the same as it was for 8,000 cycles. Thus, at 50 cycles, by reducing the resistance, the equalizer is permitted to draw a current equal to that drawn by the line capacity at 8,000 cycles, so that the voltage drops in the system are the same for the two frequencies, and hence the voltages delivered to the studio are equal.

However, the reduction in resistance may have slightly altered the 8,000-cycle reading. The effect should be small, especially if an isolating pad of about 6 db attenuation or greater is interposed between the line and the equalizer so as to prevent any tuning between the line capacity and the equalizer inductance. However, a check is made by transmitting the 8,000-cycle tone once again, noting the return reading at the studio, then sending the 50-cycle tone, and readjusting the equalizer resistance so that the 50-

cycle reading will now check the slightly altered 8,000-cycle reading. The readjustment required is so small that it will not in turn still further alter the 8,000-cycle reading.

If the shape of the equalizer attenuation curve is reasonably complementary to that of the line, satisfactory equalization over the entire range can be obtained.

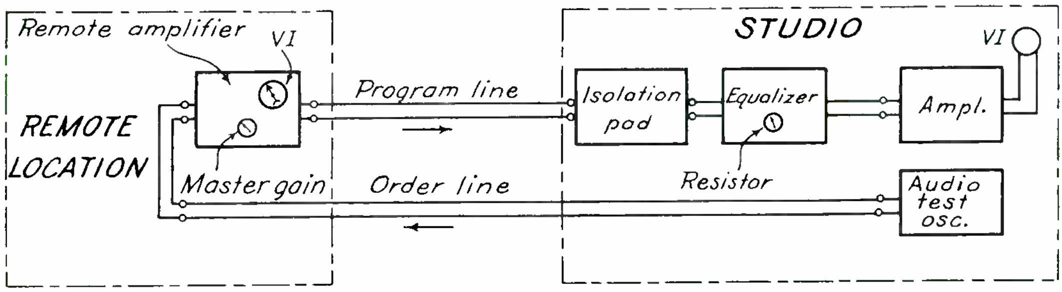


Fig. 42.—Setup for Equalizing a Telephone Line.

Finally, as an overall check, a complete frequency run from 50 to 8,000 cycles or higher is made. The response should be flat within about 2 db over the entire range. In Fig. 43 is shown the equalizer and line

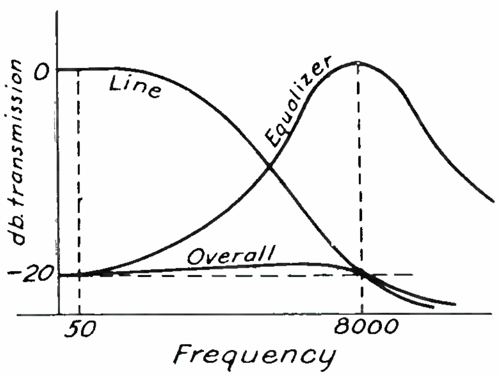


Fig. 43.—Line, Equalizer, and Overall Response Characteristic.

frequency response characteristics.

In the case of equalizing the line between the studio and transmitter, signals are fed from the audio oscillator (located in the studio) at constant output to the line, and the equalizer (located at the transmitter) is adjusted for flat transmission. The setup is, of course, very much simpler because the feeding of test tones in this case is *from* the studio instead of to the studio.

SUMMARY

This concludes the technical assignment on audio control circuit. This consisted of four major subdivisions:

(1) The first part dealt with a description of the jacks and plugs, and then of the various types of switches employed in controlling the audio paths in a broadcast system. These switches varied from the simple

push button type to the more elaborate key switches, mechanically or manually interlocking push button type, up to the remote control type known as a relay.

(2) The next part dealt with the manner in which combinations of the above could be arranged to provide locking, and pre-setting of the relays. This referred essentially to the types of *controlling circuits.* Then *controlled audio circuits* were discussed, and an analysis of a typical studio lay-out was given, showing the methods of obtaining talk-back and control-room announce operations.

(3) The third part discussed the care and maintenance of switches, relays, and volume controls, followed by a discussion of the various tests performed, such as tube checking, frequency runs, distortion measurements noise measurements, and simple microphone and loudspeaker tests.

(4) Finally the fourth part dealt with the operational technique employed in monitoring, together with a description of limiting amplifiers, and the method of equalizing the telephone line between a remote pickup point and the studio, or between the studio and the transmitter.

AUDIO CONTROL EQUIPMENT

EXAMINATION

1. (A) What is a normalled connection?

(B) Describe the proper procedure in patching a new unit for a defective unit during a program.

(C) What is a multiple connection?

2. (A) When are key switches used instead of push buttons?

(B) When would a push button be preferable?

(C) What is the maximum number of springs in the pile-up of a key switch?

(D) What is the maximum number of pile-ups?

3. (A) What important advantage does a relay possess over a push button or key switch?

(B) What precaution should be exercised in connecting the relay coil winding to the battery?

4. (A) What is the advantage of using a release relay instead of a closed-circuit OFF push button?

4. (A) *(Continued)*

(B) What is the basic function of an interlocking relay system?

(C) Can such operation be obtained mechanically? Explain.

(D) Give one advantage and disadvantage of either system.

5. Given three studios and two services. It is desired to interlock and pre-set the connections by means of relays and a master key switch. Devise a circuit to do this, and show *all* connections in a neatly drawn diagram.

6. (A) Refer to Fig. 24. Why are the microphone receptacles in the studio generally patched rather than normalled to the pre-amplifiers in the control booth rack?

(B) Where does the talk-back microphone switch into the studio system?

(C) Why is relay R3 *not energized* when it is desired to make a control room announce?

(D) Why are separate relays R1 and R2 employed?

7. (A) How is arcing of the contacts that open the relay coil circuit minimized?

(B) What is the normal care of relay contacts? What procedure is followed if they are badly pitted?

(C) How are volume control arms fitted to the contacts?

8. (A) A frequency run is to be made on a channel having a 250-ohm *unbalanced-to-ground* input and a 500-ohm *balanced output*. Two V. I. meters are available, (calibrated for 500-ohm circuits), also a 500-ohm H-type attenuation box, and a beat frequency oscillator with two terminals having an internal output impedance of 1,000 ohms, balanced to

ground. Show how you would connect this equipment, particularly the attenuation box, use only the items given.

(B) The V.I. reading at the output terminals of the audio oscillator is +5 V.U. The attenuation in the attenuation box is 83 db, and the output level is +15 V.U. What is the db gain of the channel?

9. (A) Describe the principle of the RCA Distortion and Noise Meter when used for measuring distortion.

(B) What part of a monitor loudspeaker may become defective in time?

10. (A) Describe *briefly* but completely the action of the electronic type of Limiting amplifier.

(B) How does it permit greater station coverage?

(C) Describe the method of equalizing the telephone line between a remote pickup and the studio.