Aug. 2, 1938. P. J. HERBST ET AL 2,125,612

ATTENUATOR

Filed Sept. 28, 1935 2 Sheets-Sheet 1

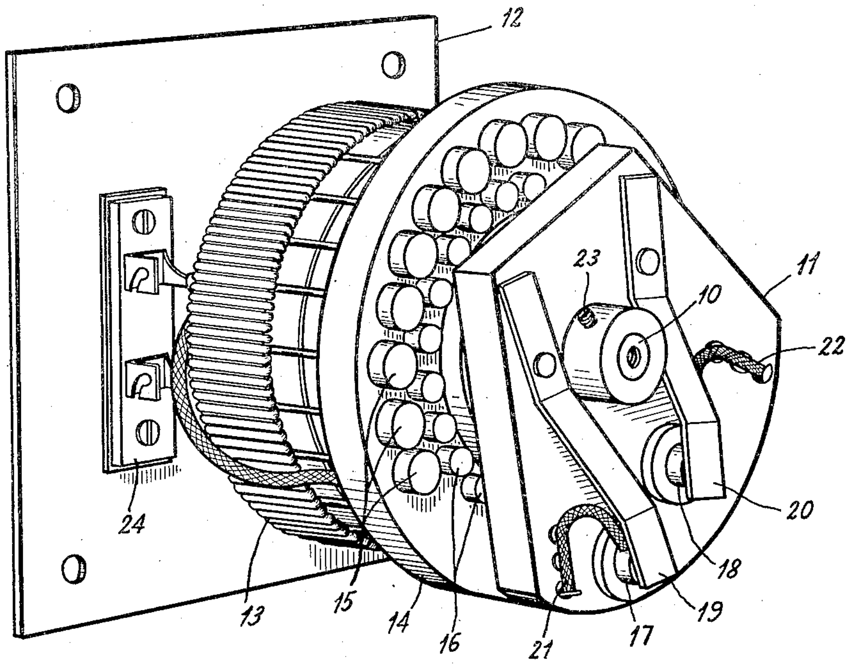
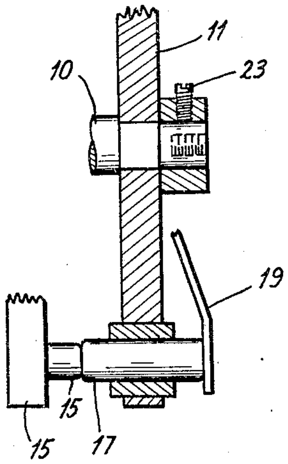


Fig. 1

Fig. 2



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ATTENUATOR

Filed Sept. 28, 1935 2 Sheets-Sheet 2

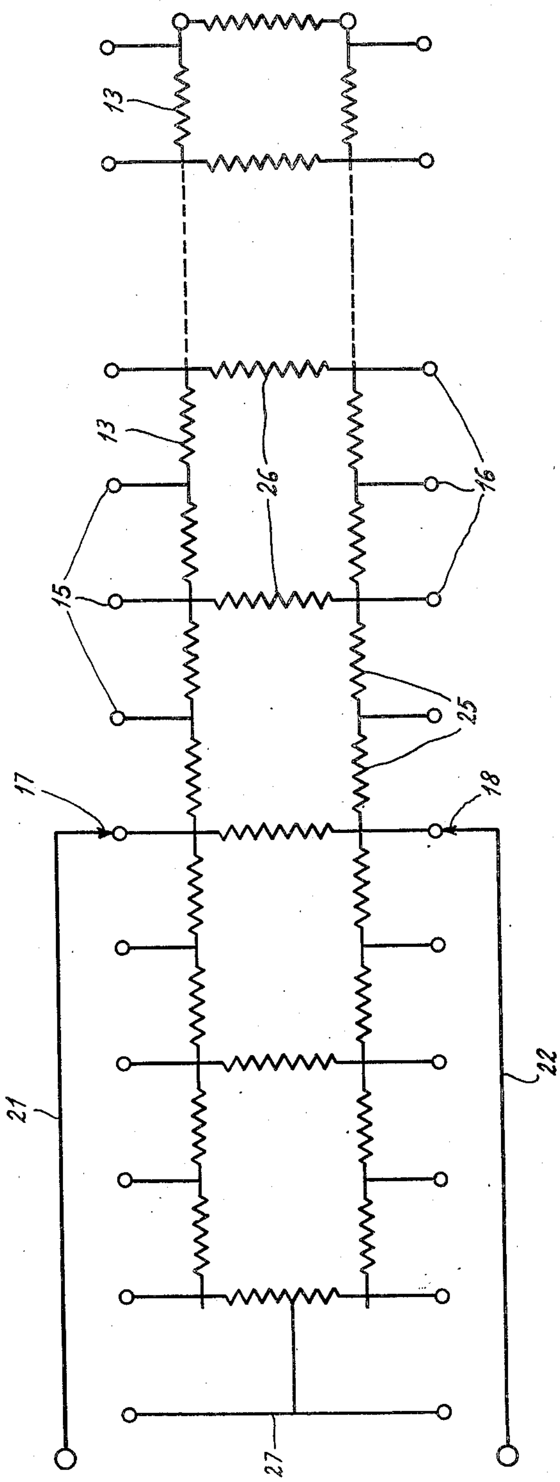

Fig. 3

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ATTENUATOR

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2 Claims. (Cl. 201—55)

This invention relates to attenuator networks such as are utilized in connection with the microphone mixer panels of sound recording apparatus and the like, and has for its principal object the provision of an improved attenuator device and method of operation whereby the construction of such devices is simplified and the extraneous noises incident to their operation is reduced to a minimum.

Attenuator devices usually depend for their operation on the use of moving contacts which tend to generate objectionable noise. The exact cause of such noise is difficult to determine for the reason that its results from a number of causes which tend to mask one another. In general, the three sources of such noise are:

(1) Interruption of existing currents.
(2) Production of electro-thermal currents.
(3) Agitation of the electrons in the contacts.

The noise producing currents resulting from a change in circuit connections may be electro-thermal, may result from leakage or may be due to electromagnetic or electrostatic pick-up. Careful shielding of the attenuator input circuits and the use of blocking condensers in the various leads do not appreciably reduce the noise. It has been observed that a leakage current of a small amount due to the input circuit being at higher potential then ground greatly increased the noise level.

By using two similar metals as contacts such as nickel steel against nickel steel, no electro-thermal currents should be generated as the electro-thermal difference between two such metals is zero. However, such combinations resulted in noise levels which were apparently dependent upon the condition of the surfaces, the nature of the contact and the relative velocity of the metals in contact.

In our investigation of this phenomena a number of different metals were used as contacts in an apparatus consisting of a motor driven insulated disk to which a polished disk of one of the metals to be investigated was bolted and a contact arm carrying two brushes of a second metal. The contact arms were connected in series with 250 ohms to the input of a microphone amplifier. The output of this amplifier was fed into an amplifier, the output of which operated a volume indicator meter. This apparatus was calibrated after each set of readings. The results are tabulated below:

Rotor material	Thermo-electric potential	Specific resist	Brush material	Thermo-electric potential	Specific resist	Noise level (db.)
Brass	+0.140	5 to 7	Nickel steel	−26	30 to 33	−122
Do			Copper	+2.75	1.72	(*)
Do			Brass	+.140	5 to 7	(*)
Do			Phos. bronze			−152
Do			Cop. carbon			−140
Do			Silver	+2.95	1.622	(*)
Copper	+2.75	1.72	Nickel steel	−26	30 to 33	−122
Do			Copper	+2.75	1.72	−145
Do			Phos. bronze			(*)
Do			Cop. carbon			−140
Do			Silver	+2.95	1.622	(*)
Phos. bronze			Nickel steel	−26	30 to 33	−120
Do			Cop. carbon			−145
Do			Silver	+2.95	1.622	(*)
Do			Chromium		2.6	−135
Nickel steel	−26	30 to 33	Nickel steel	−26	30 to 33	−125
Do			Chromium		2.6	Above −100
Do			Iron	+13.7	9.78	Above −100
Do			Silver	+2.95	1.622	−129
Do			Cop. carbon			−123
Chromium		2.6	Iron	+13.7	9.78	−121
Do			Chromium		2.6	−132
Do			Silver	+2.95	1.622	−135
Silver	+2.95	1.622	Iron	+13.7	9.78	−143
Do			Silver	+2.95	1.622	(*)
Iron	+13.7	9.78	Iron	+13.7	9.78	−132
Do			Phos. bronze			−118

*Noise too low to be measured.

Noise level with graphite brushes

Rotor	Hard brush	Soft brush
Phos. bronze	−122	(*)
Nickel silver	Above −100	−125
Iron	−122	−138
Chromium	Above −100	−145
Silver	−142	−147

*Noise too low to be measured.

It will be noted that whenever two metals having high thermoelectric potential difference are used, the resulting noise level is high. However, this does not account for the relatively high noise levels when like metals are used on disk and brushes as in the case of nickel silver, chromium and iron. Even such metals of silver and copper make noisy contacts if the surfaces are not smooth. It will be noted that the noise level is greater for metals of high specific resistance. This fact suggests the inclusion of thermal agitation as a cause of noise. The electrical resistance of the contacts in relative motion is not constant but varies considerably, depending upon the condition of the surfaces, the nature of the contact, the relative velocity and the resistivity of the metals is contact. A simple calculation shows that the thermal agitation voltage in a 250 ohm circuit should be about 0.2 microvolt. This is in the order of the noise originating from the more quiet types of contacts, but is considerably less than is obtained by slightly rough contacts.

The best contacts from the standpoint of noise are of metal of low resistivity, copper, brass, silver. The best form of contact is that which causes the least relative motion, i. e. a pressing contact or a rolling contact. In cases where sliding contacts must be used, the surfaces should be so ground and polished that no scraping results, otherwise the surface is roughened and the contacts become noisy. One of the best contact combinations for sliding contact is brass and copper carbon brush material. However, if the surfaces are not ground true, this contact soon develops relatively high noise levels. The noise level with polished nickel silver brushes and contact studs was reduced to −135 db. by careful working in with "3-in-1" oil. It is interesting to note that any lubricant will reduce the noise level to some extent, particularly with polished surfaces of brass or phosphor bronze.

Brass studs and phosphor bronze brushes were used in another model. In this case, the noise level was reduced to very low levels but the combination has a tendency to wear and the noise level rises rapidly. A heavy lubricant helps considerably in keeping the noise level low.

With respect to mechanical details, it was found that any construction which allows the brush surface to assume a position at an angle to the plane of the studs is decidely harmful. The construction should be such as to assure uniform pressure between brush and studs at all times. Twisting of the brush results in noise, and any tendency to scrape is decidedly harmful. This means that a "wiping" contact is of no use in low level mixing of sound as the nature of the contact must be such that no scraping takes place. Therefore, the action of a wiping contact in scraping the contacts clean is impossible.

The action of silver is particularly noteworthy as the pieces of silver used were not highly polished. With such contacts a very quiet contact could be realized, although the wear might be excessive.

The results obtained in our investigation point to the following items in designing moving contacts for low level mixing units:

Materials.—The materials of contact should be of low specific resistance and with low thermoelectric potential difference between stud and brush. Copper or materials containing high percentages of copper are exceptionally good, silver is excellent, nickel and chromium or their alloys are poor. A material of interest is copper carbon brush material.

Mechanism.—Pressing contact is far superior to sliding contact. In sliding contact, highly polished surfaces with small coefficient of friction are required. Where friction effects are small, they may be helped by the use of a heavy lubricant.

Noise.—The minimum noise level obtained with dry metal contacts (phosphor bronze on brass) was in the order of −160 db. This contact should be lubricated. With self lubricating copper carbon brushes on brass, the minimum noise level was immeasurably small. With nickel steel studs and brushes, the lowest noise level attained when lubricated with oil was −135 db. Copper carbon brushes on brass, when properly made in a pad having twenty studs were subjected to 2,600 passages over the contact without measurable wear of the brush and contact or increase in noise.

In addition to our discovery of this advantageous contact and brush combination, our invention involves the provision of an improved and simplified assembly of the attenuator resistor elements and control contacts.

The invention will be better understood from the following description when considered in connection with the accompanying drawings and its scope will be pointed out in the appended claims.

Referring to the drawings:

Fig. 1 is a perspective view of the attentuator with its cover removed to show its internal construction,

Fig. 2 illustrates the brush and contact relation of the attenuator, and

Fig. 3 is a wiring diagram illustrating the electrical connections of the attenuator.

As viewed in Fig. 1, the attenuator is seen from the rear without its cover which is barrel-shaped and is held in place by a screw extending through the casing bottom into the shaft **10** of the attenuator rotor **11**. The rotor **11** is operated by means of a knob (not shown) mounted at the front of a panel **12** on which the attenuator is mounted.

The attenuator includes a sub-assembly of three concentrically mounted resistor strips, the outer one **13** of which appears in the drawings. These three concentrically mounted strips are rigidly attached to a contact panel **14** which is secured by means of two column supports (not shown) to the panel **12** and which bears two sets of contacts **15** and **16** connected to the input terminals of the attenuator network shown in Fig. 2. Arranged to cooperate with these contacts **15** and **16** are brushes **17** and **18** which are pressed through suitable openings in the rotor **11** by means of phosphor bronze springs **19** and **20** and are provided with input leads **21** and **22**. As previously indicated, the contacts **15** are preferably made of brass and the brushes **17** and **18** of carbon copper.

The rotor assembly is attached to the shaft **10** by means of a screw **23**. Contact is made throughout movement of the rotor by means of contactors and collector rings so that no "pig-tails" are required. Rigidly assembled to the panel 12 are two small terminal boards, only one 24 of which appears in the drawings. Each of these small terminal boards has two soldered terminals. One board is for input and the other is for output connections. There is also a standard ground terminal which is rigidly attached to the panel 12.

The complete device is shielded with a spun aluminum dust cover (not shown). This cover is held in place by means of a knurled thumb screw which engages a tapped hole in the end of the shaft 10. Under the head of this knurled thumb screw is a spring washer in order to insure that the dust cover is definitely held against the rear surface of the nameplate.

The front of the nameplate is etched in such a manner that it indicates 20 steps ranging from zero to 20 in a clockwise direction. The conventional knob with polished nickel pointer is pressed on to the end of the through shaft. The compete assembly is secured to mounting panel by means of four screws located at the corners of the panel 12.

Each of the three concentrically mounted resistor strips is made by securing pieces of terminal wire to a strip of cloth base insulating material such as the phenolic condensation product commercially known as "bakelite". After assembly of terminal wires to "bakelite" strip, the strip is mounted in the conventional resistance winding machine, and the proper number of turns are wound on each of the sections. The resistance wire used throughout was No. 40 "Nichrome". Contact is made between the "Nichrome" resistance wire and terminals by removing the enamel from the resistance wire by means of a fine abrasive, and then by twisting the resistance wire around the terminal wire after which soldering is completed. After the soldering operation, the middle or ladder resistor strip has the resistance wire cut between adjacent terminals where it is desired to obtain an "open". The strip is then bent into circular form, and is held together by means of an eyelet. The circular strip is then immersed in insulating varnish (GE-458-A) so that all of it except ⅜ of an inch on each of the shanks of the terminal wires is completely covered with the insulating varnish. The strips are then baked for one hour at a temperature of 100 degrees F.

The inside strip is then assembled to the "bakelite" terminal board in the following manner. First, all of the terminal wires are inserted in cavities present in the ends of brass terminals. This is done by starting at one end of the circular resistor strip and gradually working all of the terminal wires into the proper cavities. Second, soldering of terminal wire to terminal contact is made all the way around on the inside resistance circle.

Next, the center or ladder resistor is put in position concentrically located with relation to the inside resistor strip. Soldered connections are then made to the terminal shanks of the inside resistor ring.

Third, the outside resistance ring is then assembled in place in the same way that the inside resistance ring was assembled.

Fourth, the remaining terminal wires of the middle or ladder resistance ring are then soldered to proper shanks of terminal wires of the outer resistance ring.

From the foregoing it is evident that the three resistance rings are now in position so that they are all concentric, one with the other, and are in the same plane with relation to the front nameplate. Two pieces of insulation (fish paper) are then inserted between these three resistance rings and these are held in place with three spots of cement.

After the complete assembly of resistance rings to contact panel as already described, the complete contact panel sub-assembly is then "rung on" an arbor and a light skin cut is taken across all of the terminals and both collector rings in order to insure face of these parts being exactly at right angles to the center line of the long through shaft bearing. This cut removes little metal from the face of the parts and is taken slowly enough so that it insures good contacting surface in order to do without necessity of a lapping operation.

The "bakelite" base for the rotor has two through bushings pressed into it. There is also a main bearing which is pressed into the same "bakelite" base. After this, both bushings are carefully reamed parallel to the axis of the hole in the brass bearing. This insures that the copper carbon brushes will move back and forth in a line exactly parallel to the center line of the main through shaft bearing. The copper carbon brushes are carefully machined so that each may move back and forth freely in its bearing with minimum amount of clearance. The brushes are held firmly against brass contacts in contact board by means of phosphor bronze springs. In this manner, an even pressure is exerted on the back end of the copper carbon brush which is, in turn, transmitted through to the front contacting end of the brush. Each brush is drilled and in this drilled hole is soldered one end of a small flexible jumper wire. The other end of this wire is soldered to the "heel" of phosphor bronze contactor which engages a collector ring, which, in turn, is rigidly secured to contactor panel. Assembly of these parts is such that by rotating phosphor bronze spring, the copper carbon brush can be entirely slipped out of its bearing so that examination of contacting end of brush may be made without unsoldering or disassembling any parts.

It is to be noted that when this attenuator pad is used in shielded circuits, that shielded input leads come in through slot in one side of the dust cover to input terminal board, while the shield is grounded by soldered connection on one side of the ground terminal. Shielded output circuit is connected in the same manner with its shield soldered to the remaining side of ground terminal and with the output leads connected to output terminal board. The output leads leave the pad through a second slot diagonally opposite that used by the input leads. In this way a complete shielded circuit is established throughout.

As shown in Fig. 3, the outer resistor 13 is interconnected with the inner resistor 25 through intermediate resistor sections 26 which are electrically isolated from one another as previously explained. At one end of the rotor travel the brushes 17 and 18 are short circuited through a conductor connected to the preceding cross resistor 26 at a point intermediate its ends.

This type of attenuator network has the advantage that

(a) It permits construction of a balanced pad with only two moving contacts.

(b) The values of the elements are identical per step and resistance units wound on strips are therefore feasible.

(c) By making the moving contacts the input of the pad whatever noise is generated is delivered as well as the signal.

This attenuator is a finite number of sections of an infinite ladder structure. It can be designed for either mid series or mid shunt termination. With copper carbon brushes in the form of rods, noise levels in the order of −160 db. are obtained. Such levels are in the order of the hiss generated by thermal agitation and it is possible to measure them only approximately. This is done by comparing the threshold of audibility of a known signal with that for the noise of the pad.

The resistance strips are wound of No. 40 "Nichrome" S. C. C. The resistance of each element is held to ± 5%. The attenuation per step is 2 db. and the allowable variation from a linear attenuation characteristic is ± 0.5 db.

Humidity and life tests made on this pad showed an increase in the noise level for long periods in atmospheres of high humidity. The noise could be readily reduced by cleaning the contacts. The wear on the brushes is very slight, being immeasurable after 60,000 cycles. However, the noise level increases with use and occasional cleaning of the brass studs is necessary for extremely quiet operation.

Since at maximum attenuation, almost all the power entering the pad is dissipated in its terminating resistor, the rating of this element determines the maximum power that can be controlled by this unit. All resistors are wound of No. 40 "Nichrome" so that the limiting factor is the operating temperature of the insulating materials. If this is assumed as 40° C. i. e. 100° F. the current entering the pad should not exceed 25 m. a.

We claim:

1. An attenuator including a stator member provided with a pair of sets of brass contacts, a pair of impedance devices concentrically mounted on said member and each connected to a different set of said contacts at points spaced from one another, a third impedance device mounted concentrically with said devices and provided with sections connected between said devices at points spaced from one another, input terminals, and a rotor member provided with a pair of copper carbon brushes arranged to be moved along said contacts for variably interconnecting said terminals with said devices.

2. An attenuator including a pair of relatively movable members, a pair of sets of brass contacts mounted on one of said members, a pair of impedance devices concentrically mounted on said member and each connected to a different set of said contacts, a third impedance device mounted on said member concentrically with said devices and provided with sections connected between said devices at points spaced from one another, and a pair of copper carbon brushes mounted on the other of said members and arranged to successively engage the contacts of each of said pairs.

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