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DISTORTION REDUCING ARRANGEMENT

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*Fig. 1*

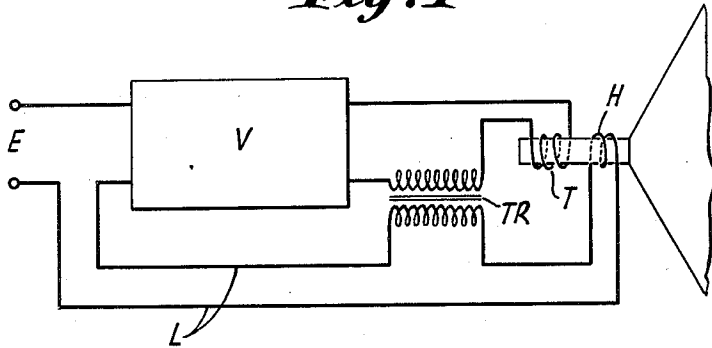


*Fig. 2*

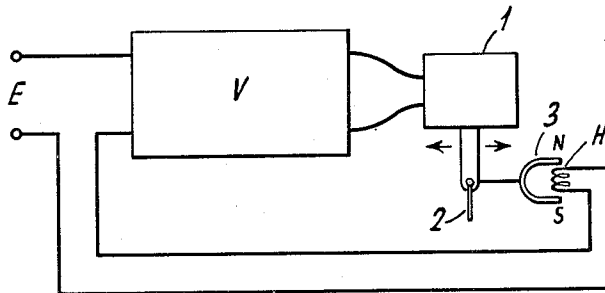
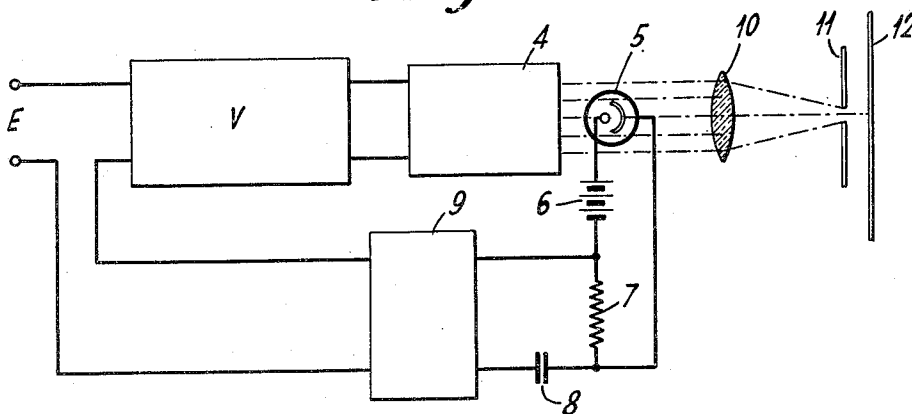


*Fig. 3*



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## DISTORTION REDUCING ARRANGEMENT

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4 Claims. (Cl. 179—1)

It is known in the art that linear and non-linear distortions which arise in an amplifier may be corrected by causing the output current or the output potential to produce a degenerative action also called a negative feedback or negative regeneration upon the input of an amplifier stage. Such negative feedback potential has also been derived from the moving coil of a dynamic loudspeaker fed from an amplifier. In such a scheme the distortions introduced by the output transformer are compensated and corrected, but not those linear and non-linear distortions which arise during the conversion or "transduction" of electrical energy into acoustic energy. The same difficulty and drawback is liable to arise also in the conversion of electrical energy into other forms of energy. To cure this difficulty in an amplifier or receiver with means to correct distortion by negative feedback to the input end of an output potential of a stage thereof, there is used according to the invention an electric voltage obtained from the energy (kinetic, acoustic, or, luminous) into which the amplifier output has been converted or transduced.

The reasons why by an application of the invention such distortions are corrected as arise incidental to the conversion of electric energy, say, into motional energy shall be explained by the practical example of a dynamic loudspeaker. The current put out by the power tube or stage results in a drop of voltage across the loudspeaker coil, and this drop of voltage comprises several components. Because of the low efficiency of a loudspeaker, the voltage components corresponding to the losses are the most important (effective or ohm resistance of moving coil, frictional losses, loss due to leakage inductance of moving coil and to restoring force and mass of the diaphragm), whereas the counter E. M. F. of motion (corresponding to the counter E. M. F. or electromotive force of a motor) amounts to only a small fraction of this voltage. However, inasmuch as the E. M. F. of motion is proportional to the velocity amplitude (amplitude times frequency) and since the radiated energy is a function thereof (and in addition of the radiation resistance), it follows that the voltage arising at the moving coil essentially corresponds to the effective loss or dissipation rather than to the energy radiated off in the form of sound. But if in line with what is shown in the appended drawing and with the exemplified embodiment to be described further below, an accessory or auxiliary coil is disposed adjacent the moving coil, and if a counter or negative feedback potential is derived therefrom,

conditions can be made so that the potential impressed upon the amplifier and the velocity amplitude of the loudspeaker will become proportional to each other. In other words, the linear and the non-linear distortions of the velocity amplitude are eliminated, while the hum due to the mains-supplied field may be bucked or suppressed without providing an additional compensation winding.

To be sure, such distortions as are occasioned by the fluctuations of the radiation resistance are not equalized as a result. As a matter of fact, for this purpose a distinct microphone would have to be mounted in the radiation path of the loudspeaker from which to derive the negative feedback potential. But this, in turn, would necessitate the insertion of means in the negative feedback lead or path adapted to correct the phase shift which is caused by the transit time of the sound through air. However, the frequency response or characteristic of the radiation resistance could be corrected also by including suitable correcter means in an amplifier portion connected in series with the input of the amplifier part comprising degenerative means (negative feedback). From the foregoing, the following is evident:

This invention relates to the reduction of distortion by inverse feedback or degeneration, especially distortion arising in the process of the conversion of energy from one form to another such as from electric to acoustic energy.

It is known that in the case of amplifiers both amplitude distortion and frequency distortion (that is, unequal amplification of different frequencies) may be reduced by feeding back from the amplifier output to its input a voltage opposite in phase to that of the impressed signals. In the case of an audio amplifier feeding a loudspeaker such degenerative feedback in the amplifier may greatly reduce distortion arising in the amplifier but it does not overcome distortion arising in the conversion of electrical energy into sound energy in the speaker itself.

The object of the present invention is to provide a method for reducing distortions arising in any part of a system comprising an energy converting device, especially such a device connected in cascade with an amplifier, by means of overall degenerative feedback from the output of the system to its input.

In accordance with the present invention, means are provided for deriving from the output of such a system as described above a signal of the same nature as the signal input to said sys-

tem but distorted by passage through said system, and further means are provided for impressing said distorted signal upon the input to said system in opposite phase to the original signal impressed thereon. The operation of the invention will be explained with particular reference to a system comprising an audio amplifier whose output actuates a dynamic loudspeaker. Let us suppose that by means to be described later, a voltage is developed that is proportional to the velocity of the speaker voice coil and independent of everything else. For the sake of definiteness let us suppose that with normal output this voltage is one volt. Now let this voltage be impressed on the amplifier input in opposite phase to the signal input. Obviously, the signal input must exceed one volt in order that there should be any resultant voltage to be amplified. This resultant voltage must be sufficient to drive the speaker to normal output after being amplified in the amplifier. If the amplifier has high gain, very little resultant input voltage is required. Again for the sake of definiteness let us suppose that one millivolt resultant input voltage is sufficient to cause normal speaker output. It then follows that the original signal and the feedback voltage must never differ from each other by any appreciable amount. For if the feedback voltage were to drop appreciably below one volt the resultant input would rise to much more than a millivolt thus causing a much more than normal output and, hence, more than one volt feedback which is contrary to assumption.

On the other hand, if the feedback voltage were to increase appreciably there would be no resultant input voltage so that the output would cease altogether and with it the feedback voltage, again contrary to assumption. It is thus proved that the result of such a feedback is to insure between the coil velocity and the input signal voltage a proportionality which is the more exact the greater the overall gain of the system. This proportionality, or in other words lack of distortion, is obtained in spite of amplitude and frequency distortions arising not only in the amplifier but also in the speaker itself. Ideally therefore, a very high quality audio system could be made up from very inferior components provided only that the gain be very large at every frequency and amplitude. Practically, however, because of phase shifts that inevitably occur at some frequency in a large range, there is always a limit to the amount of gain that can be successfully employed so that it is preferable to start with as low distortion as possible.

It will be noted that hum arising in the loudspeaker from its field supply will be greatly reduced incidentally since the voice coil velocity is maintained proportional to the signal input and there is no hum voltage in the signal.

It has been shown that by the practice of the present invention a close proportionality may be insured between the motion of the loudspeaker voice coil and the audio signal input, but there remains one other way in which the reproduced sound as heard by the listener may depart from faithfulness to the original and that is that the effective loudness of the sound produced by a constant amplitude of motion of the voice coil is not the same over a range of frequencies, or in other words, the radiation resistance to motion of the voice coil varies to some extent with frequency. This variation, however, can be compensated for by the insertion of corrective networks well known in the art, in the signal path

ahead of the input to the amplifier having the degenerative feedback. This correction must take place ahead of the degenerative amplifier because otherwise it would be undone by the degenerative action.

It is possible even to carry the invention one step further and derive the degenerative feedback not from the voice coil motion but from the motion or pressure of the air itself, that is, from the actual sound produced. This would insure complete fidelity but unfortunately if the pick up device used to obtain the feedback voltage is located sufficiently far from the loudspeaker to insure that the sound to which it is exposed is representative of what the listener hears, frequency dependent phase shifting devices must be included in the feedback path to compensate for the different phase shifts caused by the transit time of the sound waves of different frequencies from the speaker to the pick-up device, in order that sound waves of all frequencies will be fed back as voltages of exactly opposite phase to the corresponding frequencies in the original signal.

In the drawing, Figs. 1, 2, 3 show three different modifications of the invention. Before discussing any other applications of the invention, there shall first be explained the exemplified embodiment illustrated in the drawing. Upon the input circuit E of the amplifier V are impressed the alternating (signal) potentials to be reproduced. Associated with the output of the amplifier is the moving coil T of the loudspeaker, the diaphragm of the latter being shown only fractionally.

Now, according to the invention an auxiliary coil H is provided from which the negative feedback potentials are tapped and impressed upon the input end of the amplifier by way of the leads L. To make sure that the negative feedback potential will really correspond only to the motion, a transformer Tr is provided which serves to compensate the potential in the circuit of the auxiliary coil which is due to the inductance between the coils T and H.

The said auxiliary coil H need not oscillate inside the same air gap as the main or moving coil proper, in fact, a distinct air-gap for an auxiliary coil of greater or smaller diameter may be provided, which, however, must be in coupling relation with the diaphragm. It is also possible to mount the auxiliary coil H outside the magnet of the dynamic loudspeaker in a way so as to be in coupling relationship with the diaphragm, though in this instance a separate magnetic field for this coil must be provided.

The said auxiliary potential could be secured also by electrostatic or electromagnetic or piezoelectric ways and means. In the former case, the diaphragm could be furnished with a tenuous metal coat or film, while a mesh or grate-shaped cooperative electrode is mounted so as to face the diaphragm.

The invention is useful also for soundboxes used with phonograph disk recording. In this case, for instance, a small sound pickup system could be accommodated in the box which would serve to supply the negative feedback potential. This arrangement is shown in Figure 2 of the drawing wherein the potentials to be reproduced are impressed upon the input circuit E of the amplifier V which drives the phonograph disk cutting tool 2 through the driver 1. The cutting tool 2 has attached to it in any suitable manner a small magnet 3 which moves with the cutting

tool so that lines of force cut the coil H, thus generating the feedback potential which is impressed upon the input of the amplifier V. It should be noted that the coil H of Figure 2 corresponds to the coil H of Figure 1. In the arrangement shown in Figure 2 no coupling corresponding to Tr, shown in Figure 1, is required as there is no electrical coupling between the amplifier output and the coil H in Figure 2.

The invention will be found serviceable also in a case where electrical energy in the form of an amplifier output is transduced into luminous energy, say, in talking-film work. In the path of the rays of light to impact the film to be made, a photo-electric cell could be inserted from which the negative feedback potential is derived.

An arrangement as described above is shown in Figure 3 wherein the signal potentials are impressed upon the amplifier V through its input E. In this case the amplifier output is fed to a light source 4 which through the medium of a lens 10 and a slitted screen 11 throws the controlled light on the film 12. For the feedback there is provided a photo-electric cell 5, the output of which is amplified through an amplifier 9 and fed back through the input of the amplifier V. The battery 6 is the energizing source for the photo-electric cell 5 and the coupling between the photo-electric cell and the amplifier 9 is through resistor 7 and condenser 8.

I claim:

1. In a system of the type for recording electrical signals on film and comprising a signal amplifier, a light source coupled to the amplifier output circuit, and a film arranged to receive the

modulated light impulses from the said light source; the improvement which includes a light-responsive device arranged to be affected by said modulated light impulses, said device deriving electrical signal impulses from the light impulses, and means for impressing said derived signal impulses upon the amplifier input circuit in degenerative phase.

2. A method of recording electrical signal impulses which includes amplifying the impulses, converting the amplified impulses to signal-modulated light impulses, recording the light impulses on a light-sensitive surface, deriving electrical signal impulses from the said light impulses, and combining the derived and original electrical impulses in phase opposition during said amplification.

3. A method of recording electrical waves which includes amplifying the waves, modulating light with said waves to produce modulated light impulses, exposing a film to the light impulses to make a record thereof, deriving from the modulated light impulses electrical waves, and combining the derived waves with said original waves in opposing phase during said amplifying step.

4. In combination with a source of signal voltage feeding an amplifier, a light source coupled to the amplifier to produce signal-modulated light impulses, a film arranged in the path of the light impulses to record the same, a photo-electric cell arranged in the path of the light impulses, and means for degeneratively feeding to the amplifier input circuit signal voltage derived from the output of said cell.

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