May 24, 1949. P. M. G. TOULON 2,471,252

SINGLE-STAGE, HIGH-GAIN AMPLIFIER

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Fig. 2.

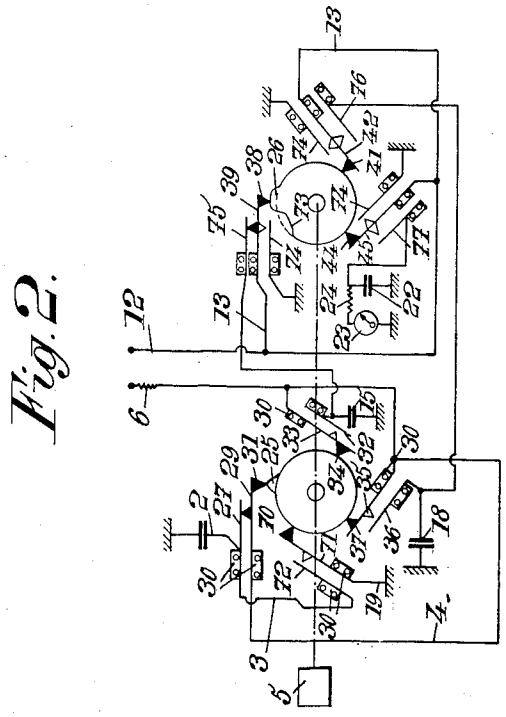

Fig. 1.

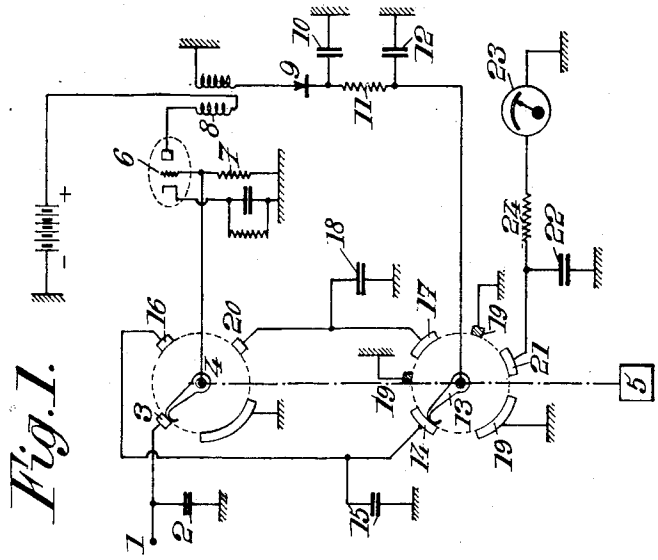

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Fig. 3.

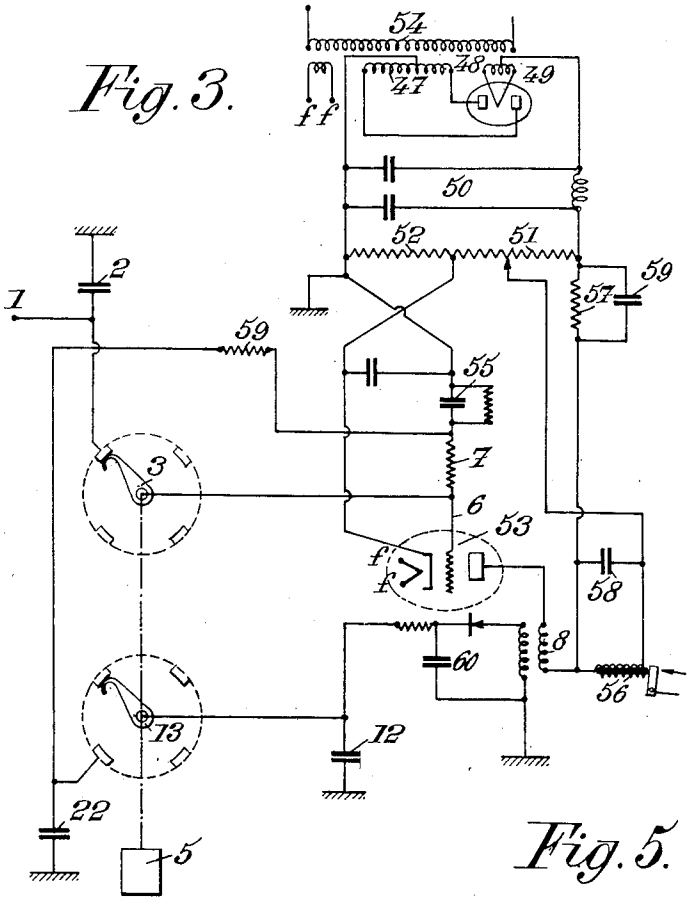


Fig. 5.

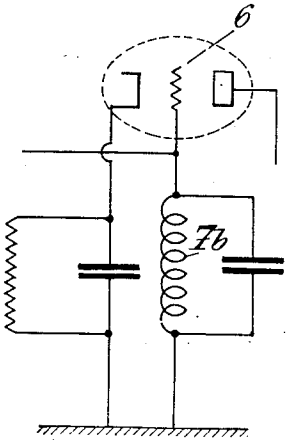
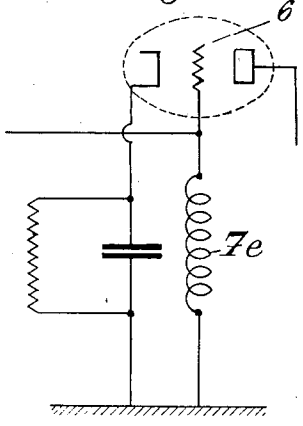


Fig. 4.



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SINGLE-STAGE HIGH-GAIN AMPLIFIER

Pierre Marie Gabriel Toulon, Neuilly-sur-Seine, France

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Patent expires August 16, 1964

8 Claims. (Cl. 179—171)

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The present invention relates to methods and apparatus for amplifying very small differences of direct potential without requiring a great number of amplifying tubes.

My invention is particularly adapted for use in the control of electric relays, intended for instance to ensure an automatic supervision or adjustment, or it may be applied to electric measurement systems.

As it is known, the use of amplifying tubes (triodes, pentodes, hexodes, etc.), which gives excellent results for amplification of high or low frequency alternating currents, is hardly satisfactory for amplification of low differences of direct potential. This is due to the fact that the conventional method for amplifying a low voltage consists in applying this voltage between the grid and cathode of the tube and in detecting or utilizing the concomitant plate current (or voltage drop produced in a resistance mounted in series.)

If a cascade arrangement is used for amplifying a small difference of direct potential, its sensitivity is generally poor because the gain per stage of amplification is relatively low. Furthermore, such an arrangement is unstable because the anode feed voltage and the heating current are difficult to stabilize. It follows that electronic emission is subjected to incessant fluctuations, either instantaneous (blast noise and small-shot effect) or slow (gradial drifting due to variation of the temperature or of the cathode emissive power in the course of time). If several amplifying tubes, resistance coupled in the anode circuits, are connected together in cascade fashion, high sensitiveness can be obtained, but the system is unstable and practically useless.

The object of my invention is to obviate this drawback and to permit of obtaining, by means of an amplifier including either a single tube or a very small number of tubes, as high an amplification as may be desired.

To this effect, in order to obtain stable operation, I provide means for producing short impulses, which are periodically fed to the amplifier. My invention consists essentially in charging a condenser with the small difference of potential that is to be amplified and then discharging it into a resistance to which is connected the input grid of an amplifier. This discharge supplies the

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grid with a sudden voltage variation (impulse) the duration of which depends upon the value of the resistance and that of the condenser.

The amplifier passes and amplifies but a very narrow frequency band chosen as it will be hereinafter indicated.

Instead of discharging the condenser into a resistance I may advantageously substitute thereto a high inductance coil.

The condenser discharge may be either a damped discharge or an oscillating discharge. The function which represents the variation of voltage as a function of time during the transitory period (impulse) may be decomposed into a Fourier series. I choose the characteristics of the amplifier, or I associate therewith an electric filter, so as to pass and to amplify but frequencies close to the fundamental term of the series. The amplifier output current is rectified and then preferably passed through a low-pass filter constituted by condensers and inductances or resistances. The voltage obtained at the output is a function of the direct voltage that was to be amplified. I thus obtain an output voltage substantially proportional to the input voltage but considerably amplified with respect thereto.

It will be readily understood that, in a device working as above stated, the amplifier is used only for very short periods of time, corresponding to the passage of impulses, and that it remains inactive for the long intervals that elapse between the passage of two consecutive impulses.

According to a preferred embodiment of my invention, the output voltage is again amplified and for this purpose it is applied to the input terminals of the amplifier. The time intervals between the initial impulses are utilized for obtaining one or several further amplifications. For this purpose, at the output of the low-pass filter, I charge a second condenser, which is temporarily connected, for instance by means of a second switch, when the impulse passes. A short time thereafter, this second condenser is discharged into the amplifier which is thus utilized a second time. At the same time, the output of the low-pass filter is connected with a third condenser. This third condenser may in turn be discharged into the amplifier and so on. Finally, I collect and utilize the voltage obtained in the last condenser for operating the desired relay. I may

also utilize this voltage for modifying the mean potential of the input grid and operate a relay by means of the mean plate current.

Owing to these successive amplifications obtained by means of the same amplifier (which may include but a small number of tubes or even one single tube), I obtain an extremely high gain of power, by means of a very simple and economical apparatus. The various switching means are preferably constituted by insulated flexible strips actuated by cams driven by a small motor synchronized with the electrical distribution network, whereby the rhythm of the modulation remains very stable.

Preferred embodiments of my invention will be hereinafter described with reference to the accompanying drawings, given merely by way of example and in which:

Fig. 1 illustrates the principle of my invention;

Fig. 2 discloses a cam arrangement for actuating the switches;

Fig. 3 shows how the impulse amplifying tube can be used for simultaneously operating a relay;

Figs. 4 and 5 are partial views showing modifications of the arrangement of Fig. 1.

As shown by Fig. 1, the very small direct voltage 1 which is to be amplified is caused to charge a highly insulated condenser 2 of small size (some centimeters for instance). This small condenser is connected with a fixed contact 3 adapted to cooperate with a rotating brush 4 driven at constant speed by a small electric clock motor 5 synchronized with respect to the distribution network, of a frequency of, say, 50 periods per second. Brush 4 is connected with the grid 6 of an amplifier tube between this grid discharges and a discharge resistance 7 of a value sufficiently high (for instance 10 meghoms), but however relatively small as compared with the insulating resistance, whereby the "mean" potential of the grid cannot change.

According to my invention, the amplifier is adapted selectively to amplify the low frequency impulses, the period of which corresponds to the discharge time constant of condenser 2 into resistance 7.

The output circuit of the amplifier is connected to a transformer 8. The current impulse which is produced in the secondary is rectified by valve 9 and serves to charge condenser 10. After passing through a low-pass filter (constituted by a resistance 11 and a capacitor 12), the voltage thus obtained is supplied to brush 13, driven by motor 5 in synchronism with brush 4. When brush 4 reaches contact 3, brush 13 is already engaged on contact 14. This contact is connected with a highly insulated condenser 15. The flow of the rectified impulse has for its effect to charge this condenser. I thus obtain in condenser 15 an amplified voltage substantially proportional to that of condenser 2.

According to my invention, the amplifier may be utilized a second time, a little later. For this purpose, motor 5, in the course of its rotation, brings brush 13 onto contact 17 and, immediately thereafter, brush 4 onto contact 16. Contact 16 is connected with condenser 15. The charge accumulated in this condenser (which is proportional to the charge of 2, i.e. to the voltage at 1) flows suddenly into resistance 7 and causes a voltage impulse to be applied to grid 6; this impulse is amplified and rectified as already explained above. Contact 17 is connected with condenser 18. I thus obtain in condenser 18 a voltage proportional to that of condenser 15, but amplified. The voltage of condenser 18 is therefore proportional to that of condenser 2 (that is to say to the voltage to be measured), but amplified to a considerable degree.

In turn, condenser 18 is connected with a contact 20. When further rotating under the action of motor 5, brushes 4 and 13 ensure a third amplification (and more if so desired). Brush 13 comes onto contact 21 a very short time before brush 4 comes onto contact 20. The charge stored up in condenser 18 applies to grid 6 a voltage impulse which, amplified and rectified, supplies brush 13 and contact 21 with a voltage which charges condenser 22, connected with this contact. The mean voltage received on this condenser is finally measured, for instance by means of a voltmeter 23, connected with a high resistance 24 so that the time constant of the circuit is great with respect to the period of motor 5.

Contacts 19, intermediate between working contacts 14, 17, 21, are intended to discharge the condensers 10, 12 of the low-pass filter so as to avoid any interference between the respective impulses that are successively amplified by the same amplifier.

Resistance 7 may be replaced by a suitable reactance coil, as shown at 7*a* in Fig. 4, or by an oscillatory circuit, as shown at 7*b* in Fig. 5.

Instead of making use of a rotary switch, it is advantageous, especially for the first stage (contact of brush 4 with contact 3), to have recourse to elastic contacts controlled by cams. I thus avoid heating of the contacting pieces, wear and tear thereof and modification of their texture. Heating of the pieces is particularly objectionable especially when the voltages to be measured are very small (for instance some microvolts), because parasitic thermo-electric forces might be unduly generated.

Fig. 2 shows the principle of an elastic contact and cam device according to my invention, for successively ensuring the desired connections without involving the drawbacks above pointed out.

Synchronous motor 5 drives two wheels mounted on the same axis. The first is provided with a small projection 25 of short circumferential length, whereas the second is provided with a longer projection 26 followed by a hollow 73.

Projection 25 comes to bear successively upon insulating pieces 31, 34, 37 and 70 respectively carried by spring holders 29, 33, 35 and 71, made of a conductor material. Spring holders 29, 33 and 35 are connected together and to the input grid 6 of the amplifier and spring 71 is earthed. These spring holders, which are carefully insulated by means of an insulator 30 of high electrostatic quality, are provided with respective contacts. Opposite these contacts are provided contact springs 27, 32, 36 and 72, respectively. Springs 27 and 72 are very carefully insulated (amber or the like) and connected with condenser 2. Spring 32 is connected with condenser 15 and spring 36 with condenser 18.

In a likewise manner, projection 26 comes to bear successively upon insulating pieces 38, 41, 44 fixed to spring holders 39, 42, 45, which are connected together and to the terminals 12 of the low-pass filter coupled with the output of the amplifier. Above these spring holders are provided earthed contact springs 74 intended to discharge the low-pass filter, during the intervals between the passage of the various impulses, when the "recess" 73 of the wheel comes opposite pieces 38, 41 and 44.

Opposite the other face of holders 39, 42, 45, are provided other contact springs 75, 76, 77 respectively connected with condensers 15, 18 and 22.

Instead of making use of a measurement apparatus 23 or of a relay having a high resistance and therefore rather sensitive and delicate, I may also, according to a feature of my invention, make use of the amplifying tube itself (which has already served to amplify the successive impulses) for further ensuring a "direct current" amplification of the impulse.

For this purpose, the voltage supplied by output condenser 22 is applied in series to the input grid 6 of the amplifier, in such manner as to modify its mean potential, efficient filtering means being interposed between condenser 22 and the return point of resistance 7 (Fig. 1), so that only the value of the mean voltage passes, but all the low and high frequency components are eliminated. Such an arrangement is shown by Fig. 3.

In this figure, I have shown some of the essential elements of the system already illustrated in the preceding figures the same numerals designating the same elements.

It has been supposed that the amplifier is reduced to a single tube 53 and is supplied from an alternating current distributing network 54 (110 volts, 50 periods per second for instance).

Secondary windings 47 and 48 are connected in the conventional manner to a double diode 49. A filter circuit 50 permits of supplying the potentiometer 51 from which is collected the fixed voltage of cathode 52.

The plate output is applied to transformer 8, and thence to a fixed resistance 57. Relay 56 is placed between a point of the connection between 8 and 57 and a point suitably chosen on potentiometer 51. A condenser 58 disposed in shunt with relay 56 and another condenser 59 in shunt with resistance 52 pass the high frequency components. The output condenser 22 supplies, through discoupling resistance 59, a condenser 55 associated with a high resistance, which has for its effect to modify the "mean" potential of grid 6.

This grid thus simultaneously receives voltage 52 corresponding to a fixed bias, voltage 55 corresponding to the amplified and detected impulse and the instantaneous voltage corresponding to the discharge of condenser 2 into resistance 7.

The tube thus permits of independently and simultaneously amplifying:

1. The extremely short impulse resulting from the discharge of condenser 2 into resistance 7. This impulse has for its effect to supply in transformer 8 a stiff front wave which, after rectification at 60, is supplied to the successive condensers 15, 18, and then, finally, to the output condenser 22. This amplification takes place whatever be the mean value of the grid voltage 6, and in particularly whatever be the voltage of condenser 55;

2. The very slow and gradual variation of the grid mean potential due to the charge accumulated on condenser 55. This slow variation has for its effect to change the mean value of the place current and therefore creates a current in relay 56 which is connected in "bridge-like" fashion owing to potentiometer 51. Thus a single tube 53 suffices to ensure distinct results.

In a general manner, while I have, in the above description, disclosed what I deem to be practical and efficient embodiments of my invention, it should be well understood that I do not

wish to be limited thereto as there might be changes made in the arrangement, disposition and form of the parts without departing from the principle of the present invention as comprehended within the scope of the accompanying claims.

What I claim is:

1. A device for amplifying a small difference of direct potential which comprises, in combination, a low frequency amplifier adapted to pass only a narrow frequency band, at least two condensers each adapted to supply, by discharge thereof, a voltage impulse having its fundamental oscillation inside said frequency band, one of said condensers being mounted to be charged by said difference of direct potential, means for periodically discharging said condenser to produce successive voltage impulses, means for applying said impulses to the input of said amplifier, a rectifier having its input connected to the output of said amplifier, means for periodically charging the other condenser from the output of said rectifier, means for periodically discharging said second mentioned condenser to produce successive voltage impulses during the intervals between discharges of the first mentioned condenser, and means for applying said second mentioned impulses to the input of said amplifier.

2. A device for amplifying a small difference of direct potential which comprises, in combination, a low frequency amplifier adapted to pass only a narrow frequency band, at least two condensers each adapted to supply, by discharge thereof, a voltage impulse having its fundamental oscillation inside said frequency band, said condensers being mounted to be charged by said difference of direct potential, switch means for periodically discharging said condenser to produce successive voltage impulses, means for applying said impulses to the input of said amplifier, a rectifier having its input connected to the output of said amplifier, switch means operatively connected with said first mentioned switch means for periodically charging the other condenser from the output of said rectifier, means for periodically discharging said second mentioned condenser to produce successive voltage impulses during the intervals between discharges of the first mentioned condenser, and means for applying said second mentioned impulses to the input of said amplifier.

3. A device for amplifying a small difference of direct potential which comprises, in combination, a low frequency amplifier adapted to pass only a narrow frequency band, at least two condensers each adapted to supply, by discharge thereof, a voltage impulse having its fundamental oscillation inside said frequency band, one of said condensers being mounted to be charged by said difference of direct potential, contact means for periodically discharging said condenser to produce successive voltage impulses, means for applying said impulses to the input of said amplifier, a rectifier having its input connected to the output of said amplifier, contact means for periodically charging the other condenser from the output of said rectifier, contact means for periodically discharging said second mentioned condenser to produce successive voltage impulses, interconnected cam means for operating said respective contact means to produce the second mentioned voltage impulses during the intervals between discharges of the first mentioned condenser, and means for applying said second mentioned impulses to the input of said amplifier.

4. A device for amplifying a small difference of direct potential which comprises, in combination, a low frequency tube amplifier adapted to pass only a narrow frequency band, at least two condensers each adapted to supply, by discharge thereof, a voltage impulse having its fundamental oscillation inside said frequency band, one of said condensers being mounted to be charged by said difference of direct potential, means for periodically discharging said condenser to produce successive voltage impulses, means for applying said impulses to the input of said amplifier, a rectifier having its input connected to the output of said amplifier, means for periodically charging the other condenser from the output of said rectifier, means for applying the mean voltage of said second mentioned condenser, exclusively of high and low frequency components, to the input grid of said amplifier, and an apparatus for collecting the final amplified voltage inserted in the output plate circuit of said amplifier in bridge-like fashion.

5. A device for amplifying a small difference of direct potential which comprises, in combination, a low frequency amplifier adapted to pass only a narrow frequency band, at least two storing means each adapted to deliver a voltage impulse having its fundamental oscillation inside said frequency band, one of said storing means being arranged to be supplied with said difference of direct potential, means for periodically connecting the output of said last mentioned storing means with the input of said amplifier to impress successive voltage impulses on said input, a rectifier having its input connected with the output of said amplifier, means for periodically connecting the input of the other storing means with the output of said rectifier, means for periodically connecting the output of said second mentioned storing means with the input of said amplifier during the intervals between the time periods for which the output of the first mentioned storing means is connected with the input of said amplifier.

6. A device for amplifying a small difference of direct potential which comprises, in combination, a low frequency tube amplifier adapted to pass only a narrow frequency band, at least two storing means each adapted to deliver a voltage impulse having its fundamental oscillation inside said frequency band, one of said storing means being arranged to be supplied with said difference of direct potential, a resistance connected with the input grid of said amplifier, means for periodically connecting the output of said last mentioned storing means with said resistance to impress successive voltage impulses across said resistance, a rectifier having its input connected with the output of said amplifier, means for periodically connecting the input of the other storing means with the output of said rectifier, means for periodically connecting the output of said second mentioned storing means with said resistance during the intervals between the time periods for which the output of the first mentioned storing means is connected with the said resistance.

7. A device for amplifying a small difference of direct potential which comprises, in combination, a low frequency tube amplifier adapted to pass only a narrow frequency band, at least two storing means each adapted to deliver a voltage impulse having its fundamental oscillation inside said frequency band, one of said storing means being arranged to be supplied with said difference of direct potential, a reactance coil connected with the input grid of said amplifier, means for periodically connecting the output of said last mentioned storing means with said reactance coil to impress successive voltage impulses across said reactance coil, a rectifier having its input connected with the output of said amplifier, means for periodically connecting the input of the other storing means with the output of said rectifier, means for periodically connecting the output of said second mentioned storing means with said reactance coil during the intervals between the time periods for which the output of the first mentioned storing means is connected with the said reactance coil.

8. A device for amplifying a small difference of direct potential which comprises, in combination, a low frequency tube amplifier adapted to pass only a narrow frequency band, at least two storing means each adapted to deliver a voltage impulse having its fundamental oscillation inside said frequency band, one of said storing means being arranged to be supplied with said difference of direct potential, an oscillatory circuit connected with the input grid of said amplifier, means for periodically connecting the output of said last mentioned storing means with said oscillatory circuit to impress successive voltage impulses across said oscillatory circuit, a rectifier having its input connected with the output of said amplifier, means for periodically connecting the input of the other storing means with the output of said rectifier, means for periodically connecting the output of said second mentioned storing means with said oscillatory circuit during the intervals between the time periods for which the output of the first mentioned storing means is connected with the said oscillatory circuit.

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