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CIRCUIT FOR OSCILLOGRAPHS OR THE LIKE

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FIG. 1

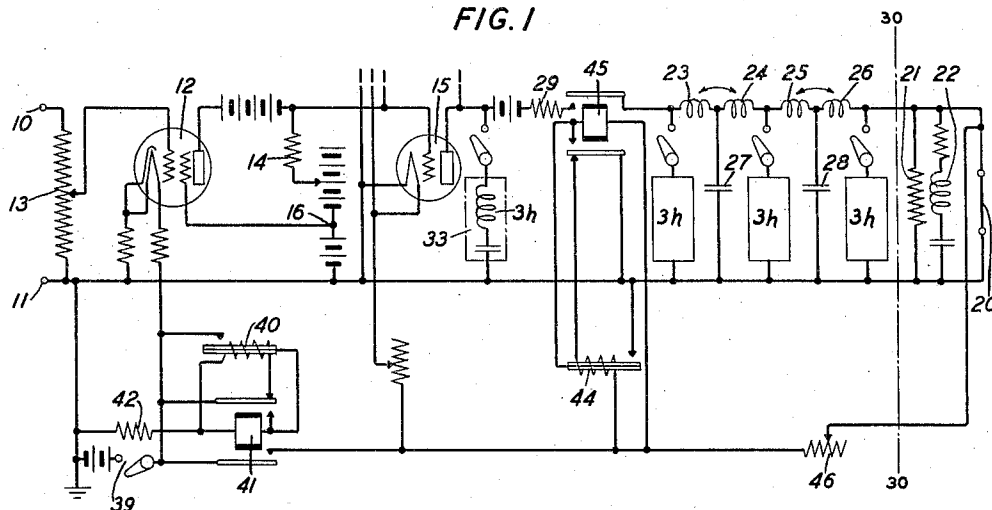
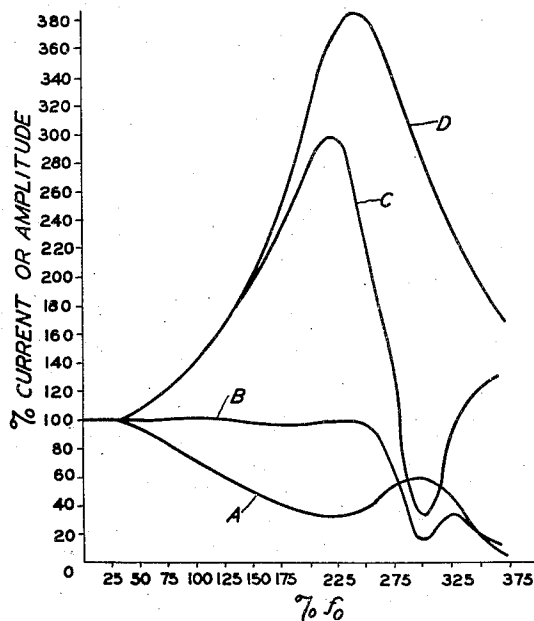


FIG. 2



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## UNITED STATES PATENT OFFICE

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CIRCUIT FOR OSCILLOGRAPHS  
OR THE LIKE

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5 Claims. (Cl. 171—95)

The present invention relates to the electrical transmission of currents of a broad band of frequencies from a source to a utilization device to secure uniform effects in such device for all impressed frequencies.

The invention will be illustrated and described with particular reference to the problem of the electrical oscillograph, although it is not to be taken as limited in its application to this problem, this being given by way of example. In the case of the oscillograph to be described, a wire or "string", as it is usually called, is placed under suitable tension in a magnetic field and is made to deflect or vibrate in response to electrical current sent through the string. This type of instrument is well known in the art and is exhibited, for example, in A. M. Curtis Patent 1,907,745, of May 9, 1933. The amplitude of deflection of the string is a measure of the current through the string, other things being equal. Such instruments are widely used for making measurements of relatively low frequency, it being a relatively simple matter to secure reliable results at low frequencies.

It becomes an increasingly difficult problem to operate such an oscillograph for "rapid" work involving frequencies up to, say, 10,000 cycles a second. There are two main difficulties. First, the resonant effects when currents are used at or near the resonant frequency of the string, and, second, the non-uniform response of the string to currents of frequencies covering a wide band. In other words, at some frequencies, the response is disproportionately large, and at other frequencies, it is disproportionately small. Attempts at equalizing these effects by prior art methods have been unsuccessful or unsatisfactory because of difficulties more or less inherent in the methods and apparatus used.

An object of the present invention is a circuit combination whereby currents of a broad band of frequencies are correctly and faithfully registered by a device of widely varying characteristic, such as a string oscillograph.

The invention involves a number of circuit features and subsidiary objects which will appear as the description proceeds. The nature of the invention and its mode of operation in practice will now be made clear from the following detailed description taken in connection with the attached drawing.

In the drawing, Fig. 1 is a schematic diagram of an oscillograph circuit embodying the invention in one specific form, and

Fig. 2 shows curves to be referred to in de-

scribing the operation and design of the circuit of Fig. 1.

In the circuit of Fig. 1 the circuit whose current or voltage components are to be determined is connected to the input terminals 10, 11, the proportion of the voltage applied to the first stage 12 of the two-stage amplifier being determined by the setting of the potentiometer 13. Stage 12 is shown as a screen-grid tube stage, resistance coupled to stage 15 which in practice may comprise one tube or two or more tubes in parallel. In a typical circuit used by applicants, two tubes in parallel were used in the second stage. There is nothing critical in the design of the amplifier, the main requirements being adequate gain and power output and a flat characteristic over the range of frequencies embraced by the waves being studied.

In a specific embodiment used by applicants, a Western Electric 259—A tube was used at 12 and two Western Electric 275—A tubes in parallel were used at 15, with 180 volts plate supply to both stages. The coupling resistor 14 was 24,000 ohms. Output series resistor 29 was of 750 ohms.

The string of the oscillograph is shown at 20, the field and other elements being omitted for simplicity. In one case, the string was  $1\frac{1}{4}$  inches long and .0008 inch diameter, and had a resistance of 6.8 ohms, with fundamental resonance at 4,000 cycles. Shunt 21, comprising 100 ohms, and the tuned shunt 22 resonant at 4,000 cycles together with the string gave a load impedance at 30—30 of 6.5 ohms.

The response curve of the string when shunted by 22 to entirely compensate for the resonant peak at 4,000 cycles, is shown by curve A of Fig. 2. The abscissae for this curve are in per cent of the fundamental frequency which, as stated, was 4,000 cycles. The ordinates are in per cent of the deflection for a standard applied direct current input which gave 0.25 inch image deflection. Curve A exhibits a resonance at the third harmonic frequency, in this case 12,000 cycles. Curve B is a substantially flat response curve, actually obtained by applicants in practice, the flat portion extending from zero frequency (direct current) to and including 10,000 cycles. Curve C shows the factor by which the response curve A must be multiplied to give the resultant characteristic B. It is seen from inspection, that this factor varies from unity to about three at the maximum. Curve D is of interest as showing the manner in which the current must vary (in per cent of direct

current) to produce in the string the desired resultant response according to curve B. It is seen that nearly four times as much current is required at the maximum as at the very low frequencies.

In order to transform the current between the flat output delivered by the amplifier and the widely varying current required by the string at different frequencies, as disclosed above in connection with the curves of Fig. 2, a network comprising a plurality of sections of series and mutual inductances 23, 24, 25 and 26 and shunt condensers 27 and 28 is inserted between the amplifier output and the point 30—30, which may be considered the input to the string compensated by the two shunts 21 and 22.

This network may take various forms and is preferably of the configuration disclosed in U. S. patent to W. R. Bennett, 1,953,459, April 3, 1934 but modified and designed to work from a high impedance into a low impedance. Any of the forms disclosed by Bennett could be used, that illustrated corresponding to Bennett's Fig. 4 network.

As used by applicants, this network had constants as follows: Inductances 23, 24, 25 and 26 were respectively 0.443 millihenry, 0.603 millihenry, 0.0610 millihenry and 0.0635 millihenry. The mutual between windings 23 and 24 was 0.517 millihenry and that between windings 25 and 26 was 0.622 millihenry. Capacity 27 was 0.318 microfarad; capacity 28 was 2.65 microfarads. Windings 23 and 24 were wound on the same ring-core of pressed comminuted nickel-iron alloy. Windings 25 and 26 were also wound on a similar core.

The network so designed and used acted somewhat as a variable ratio transformer giving large output current at those higher frequencies where it was required and smaller current at the lower frequencies according to the relations set forth in Fig. 2. It was necessary in order to realize the curve B to employ a shunt at some suitable point in the circuit tuned to the third harmonic of the string. A suitable location for this was found to be at 33, in the output of tube 15 separated from the equalizer network by the series resistance 29. Other possible locations are as shown by the rectangles labeled "3h" in the drawing, or as shown in the Curtis patent, above cited, although these latter locations might require a modification of the design of the equalizer network from that given above.

The results obtained with this type of connecting network contrast strongly with those obtainable with a variable attenuation type which would require a large number of tubes similar to 15 in parallel to deliver the requisite current, most of which would then be dissipated by the attenuating network at low frequencies. In typical cases observed by applicants, as many as thirty or forty such tubes, like tube 15, would have been required in parallel whereas according to this invention two such tubes in parallel proved adequate. One factor which makes the oscillograph problem especially difficult at high frequencies is the small mass and low mechanical resistance of the vibrating system as contrasted, for example, with a sound reproducing diaphragm operating over a similar frequency range. In the latter case, no such sharp resonances are involved and the air load represents useful damping of such broad resonances as are present. Absence of such factors accounts, in

part, for the difficult response curve of the oscillograph.

As an auxiliary circuit feature, not a part of the present invention but the invention of A. M. Curtis, there are employed in the circuit of Fig. 1, protective relays for preventing accidental damage to the string during the process of starting up the circuit. With the cathodes cold, battery 16 puts 90 volts positive on the grid of tube 15. If the cathode of this tube were heated under this condition, violent transient or more or less sustained oscillations might develop which would damage the string if not actually burn it out. In order to prevent this, thermal relays 40 and 44 and electromagnetic relays 41 and 45 act successively to introduce delays first in the closure of the heating circuit of tube 15 until the cathode of tube 12 is hot and then in the closure of the circuit to the string until the cathode of tube 15 is heated.

This action is as follows: Closure of switch 39 starts the heating of the heater of tube 12, and the heating of thermal relay 40 through left-hand armature and rest contact of relay 41. After adequate delay, as measured by thermal relay 40, that relay closes its circuit and energizes relay 41 which, at its left armature, disconnects the thermal relay and locks itself up, and by its right armature projects heating current to the cathode of tube 15. Thermal relay 44 then begins heating and, by eventual closure of its contact, energizes relay 45 which locks up and closes the upper conductor from the amplifier plate to the string.

Variable resistance 46 enables compensation in the string of the effect of normal space current flow with zero input at 10, 11, or may be used occasionally to compensate for changes in direct current input.

It is to be understood that the various quantities, numerical relations and other details that have been given are for illustrative purposes and to facilitate practice of the invention and that the invention is not limited to them or to the specific disclosure but its scope is defined in the claims.

What is claimed is:

1. In combination, a low impedance current-responsive element requiring for uniform response widely different values of current at different frequencies above resonant frequency, a high impedance circuit carrying current of amplitude substantially independent of frequency throughout a wide range, and a current transforming device of tapered characteristic connected to receive currents of said range of frequencies from said circuit and to deliver to said element the variable current required for substantially uniform response of said element for frequencies in said range above resonant frequency.
2. The combination with a response element having a resonant frequency and a resonant shunt therefor for damping response of said device at the resonant frequency, said element having a falling response characteristic for frequencies above resonance, of a source of current of a broad range of frequencies from and including direct current up to a frequency above the resonant response frequency of said element and a current transforming equalizer between said source and said element for compensating said falling characteristic and providing substantially uniform response throughout said range of frequencies.
3. A string oscillograph for recording currents

of frequencies extending from very low frequencies to well above the resonant frequency of the string, comprising an amplifier of flat characteristic over the range of frequencies embraced in the currents to be indicated, and an impedance transforming network connected between said amplifier output and the string, said network giving an insertion gain for currents of frequencies above the resonant frequency in amounts to produce uniform response of the oscillograph at all frequencies in said range.

4. A string oscillograph, in combination with a circuit for operating the oscillograph throughout a frequency range extending from zero or near zero up to frequency several times the fundamental resonant frequency of the string, said string exhibiting a response characteristic

falling with frequency over a part of said range above resonant frequency, said circuit comprising an amplifier of substantially flat characteristic throughout said range and an equalizing network for converting the output current of said amplifier into the current of varying magnitude at different frequencies to compensate for the falling response characteristics of said string at the frequencies above resonant frequency.

5. A combination according to claim 4 in which said network gives an insertion gain at those frequencies at which the response characteristic is less than that at resonant frequency.

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