

Sept. 23, 1941.

M. ARTZT

2,256,512

DUAL CHANNEL AMPLIFIER

Filed Oct. 22, 1937

2 Sheets-Sheet 1

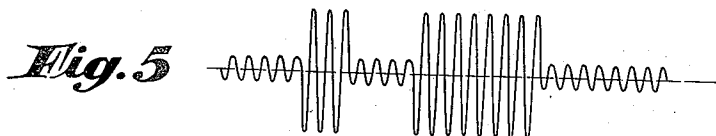
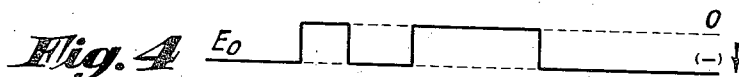
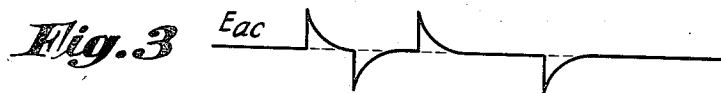
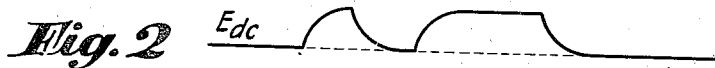
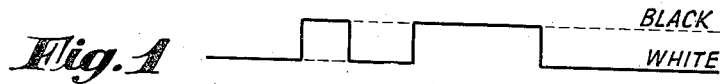
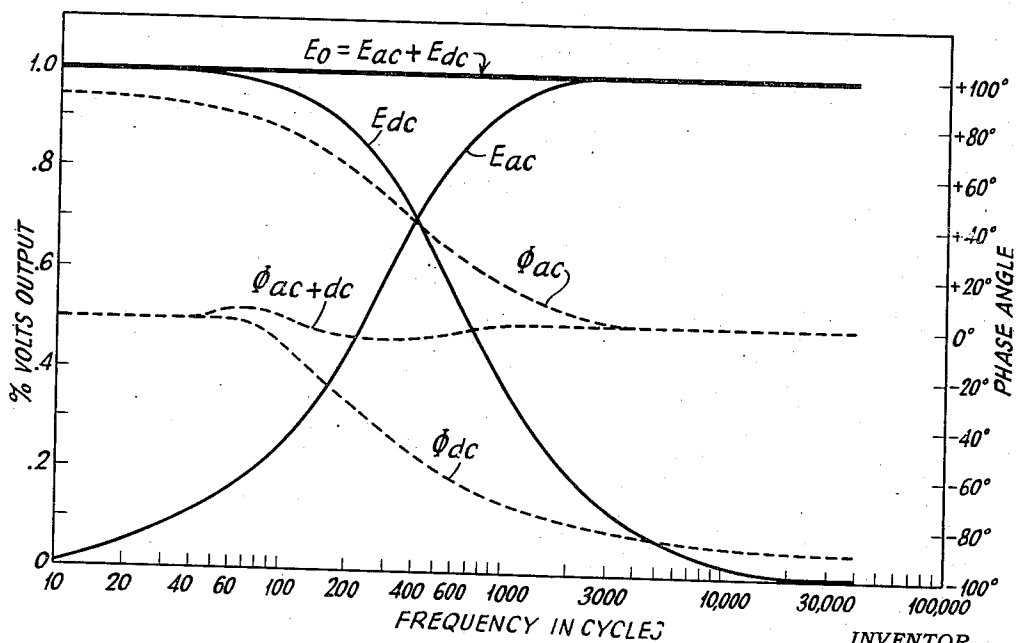


Fig. 6



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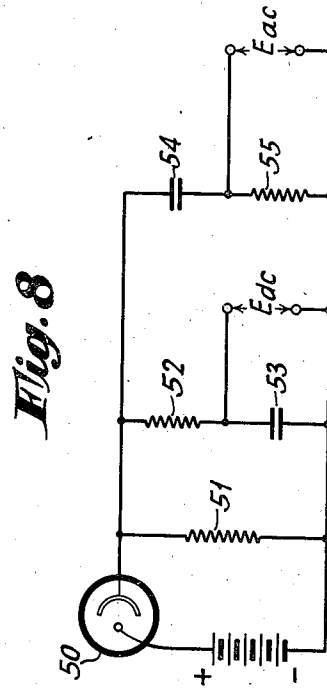
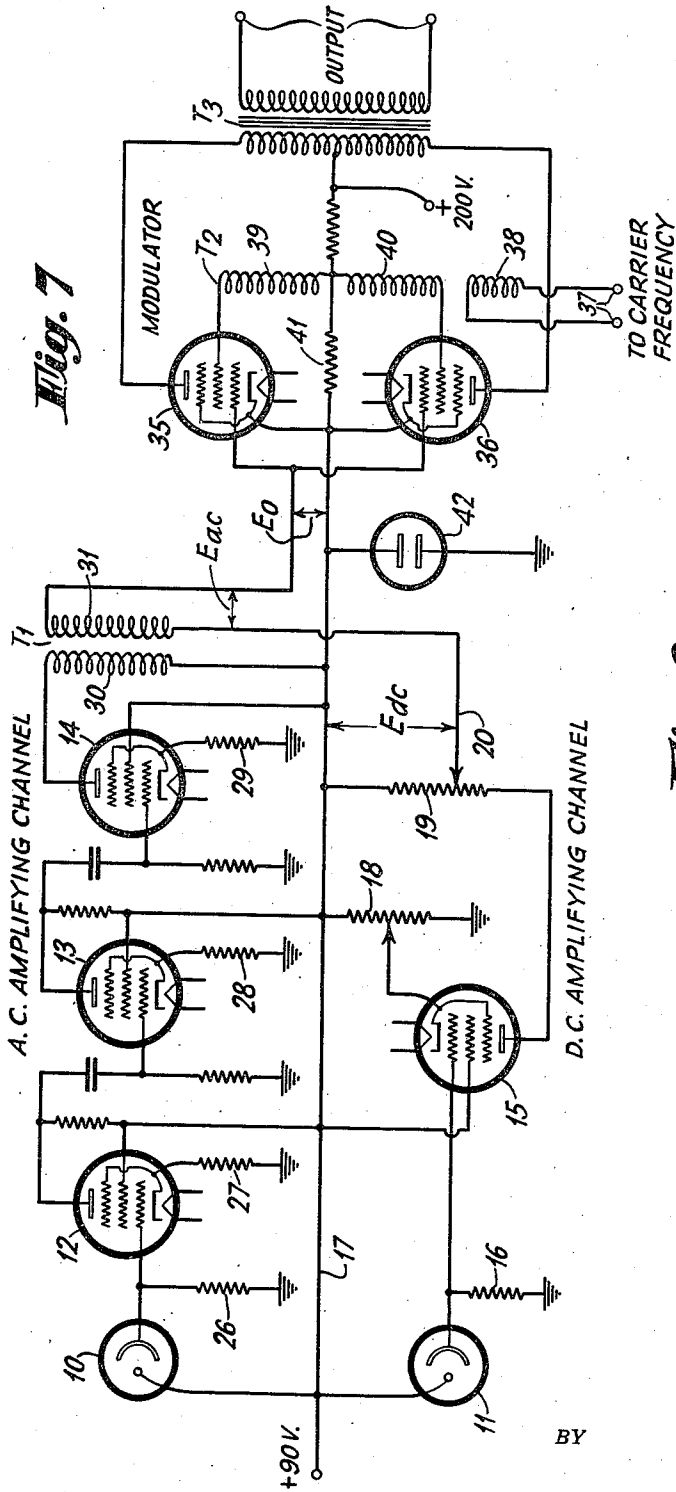
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2 Sheets-Sheet 2



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DUAL CHANNEL AMPLIFIER

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4 Claims. (Cl. 179—171)

This invention relates to a dual channel amplifier system and more particularly to an amplifier to be used in connection with facsimile transmitting and receiving apparatuses.

In facsimile transmitting devices, the beam of light which is used to scan the character or indicia bearing surface is generally reflected from the surface and is then directed upon a photoelectric cell or some other light responsive element for translating light values into electrical variations and these electrical signals or potential variations are amplified and are then transmitted to the various remotely located facsimile receiving apparatuses. In such systems the electrical signals as derived from the photoelectric cell or light responsive member include both alternating and direct current components. In order to properly reproduce the particular subject matter being transmitted, both the direct and the alternating current portions of the signal train must be amplified and transmitted.

In facsimile transmitting systems such as have heretofore being used and at the speed at which such facsimile transmitters have been operated, the amplifying systems which have been used therein are suitable and sufficient, since they will amplify the signals derived from the photoelectric cell from zero frequency, i. e. the direct current component, to some several hundred or a thousand cycles A. C. in a substantially linear manner.

Since it is desired to materially increase the speed of operation of facsimile transmitters, new amplifying systems must be provided inasmuch as the known and previously used amplifying systems are not adequate and will not satisfactorily maintain a linear amplification over the entire frequency range of the transmitting device, in other words, uniform amplification over the entire frequency range, which may, for instance, vary from zero frequency or direct current to frequencies of the order of 12,000 cycles per second, or greater.

In virtually all photoelectric cell circuits an output resistor must be connected to the photoelectric cell and to this resistor is connected the amplifying system. In known amplifying systems for facsimile transmitting apparatuses this resistor has been made relatively large in order that the voltage variations for varying light values be large, and therefore a stable amplifier system which includes direct current in its response becomes relatively simple and free from drift in adjustment. The use of a high resistance output for the photoelectric cell is not, how-

ever, desirable where high frequency alternations are present, since linear amplification cannot be readily derived from a circuit connected to a resistance of a considerable magnitude due to the shunting effect of circuit and photo-cell capacitances. If the value of the output resistance is reduced the high frequencies are more faithfully amplified but at the same time the direct current component of the signal train, as well as the low frequency portion become so small in amplitude that it becomes difficult to maintain the system in adjustment and consequently the direct current component and low frequencies are not linearly amplified and distortion results.

In the present invention, separate amplifying channels are used, one of which is for the purpose of amplifying the direct current component as well as certain low alternating current frequencies whereas the other channel is for the purpose of amplifying all alternating current frequencies above a certain value. The cut-off points of the two channels are not sharp and well defined, and, as a matter of fact, overlap, but this overlapping and the amplification of each individual channel is so arranged that, when the amplified signals from the separate channels are combined, a straight line over-all amplification of all frequencies from zero to 12,000 or more cycles per second will result.

It is therefore one purpose of the present invention to provide an amplifying system, particularly for facsimile use, in which straight line or linear amplification of all frequencies from zero to many thousands will result.

A further purpose of the present invention is to provide an amplifying system wherein separate amplifying channels are provided for individually amplifying selected frequencies from the output of a photoelectric cell, together with means for later combining the separately amplified signals.

A still further purpose of the present invention is to provide an amplifying system for the output of a photoelectric cell wherein linear amplification over a wide range of frequencies will result, and wherein these frequencies may be properly modulated in order that they may be in condition for transmission either by wire or by radio.

Another purpose of the present invention resides in the provision of separate light responsive elements for each amplifying circuit in order that the original of the signals for each amplifying circuit will be separate.

Another purpose of the present invention is the provision of means whereby a plurality of separate amplifying channels may be used for selectively amplifying predetermined ranges of frequencies and wherein the signals supplied to the separate amplifying channels are derived from a common light responsive element.

Another purpose of the present invention resides in the proper choice of the input impedance of each channel whereby maximum response for the frequency spectrum amplified by that channel is attained and means whereby variations in amplitude due to these different impedances may be adjusted by changes in the amplification provided for each channel.

Still another purpose of the present invention resides in the use of a plurality of amplifying channels whereby linear amplification over a wide range of frequencies may be accomplished, and wherein the phase shift of the amplified signals will be substantially zero over the entire range of the composite amplifying circuit.

Other advantages and purposes of the present invention will become more apparent to those skilled in the art from a reading of the following specification and claims, particularly when considered in connection with the drawings, wherein:

Figure 1 shows by way of example a curve of the amount of light which is permitted to strike a light responsive element.

Figure 2 shows a curve indicating the direct current component of the output of a direct current amplifier of limited high frequency response connected to a photoelectric cell or other light responsive cell, when subjected to light in accordance with the values shown by the curve in Figure 1.

Figure 3 shows the alternating current component of the output of an alternating current amplifier of limited low frequency response when connected to a light responsive cell that is subjected to light in accordance with the values shown by the curve in Figure 1.

Figure 4 shows a curve in which the alternating and direct current components of the output of the amplifying channels are combined when the cell connected thereto is subjected to light in accordance with the values shown by the curve in Figure 1.

Figure 5 shows a carrier frequency which has been modulated in accordance with the examples shown in the curve of Figures 1 through 4.

Figure 6 shows curves indicating the separate amplified components of the output of a light sensitive cell as amplified by the multi-channel amplifier system with the input circuit of Figure 8 in accordance with the present invention, together with the sum of these components. The figure also shows the separate phase shifts in the separate components as well as the over-all phase shift after the separate components have been combined. The two components are, of course, added vectorially to produce the final sum.

Figure 7 shows a schematic diagram of a dual channel amplifying system which is constructed in accordance with the present invention, and

Figure 8 shows an alternate form of the present invention whereby dual amplification channels may be supplied with signal current from a common light responsive element.

Referring to the drawings, and particularly to Figure 7 wherein one example of a dual amplifying channel is shown, it will be seen that two

separate light responsive elements 10 and 11 are provided. Connected to the output of light responsive element 10 are a plurality of thermionic amplifying devices 12, 13 and 14, which are for the purpose of amplifying all alternating current frequencies above a predetermined amount. For the sake of clarity, this portion of the system will be called the alternating current amplifying channel. Connected to the output of light responsive element 11, is a thermionic amplifying device 15 which is for the purpose of amplifying the direct current component of the output of the photoelectric cell as well as certain low alternating frequencies. For the purpose of clarity this portion of the system will be referred to as a direct current amplifying channel.

To the output of the light responsive element 11 is connected an output resistance 16 which is rather high in value and which, for example, may be of the order of 10 to 30 megohms. The thermionic amplifying tube 15 as shown in the drawings is a triple grid amplifier and which may have characteristics similar to those of the standard 6C6 vacuum tube. The light responsive element or photoelectric cell 11 is connected to the first intermediate electrode or the control grid of the tube 15. In the specific schematic diagram shown, the second intermediate electrode is connected to a source of positive potential and the suppressor grid or third intermediate electrode is connected to the electron emitter, these two tube elements being in turn connected to a potentiometer 18 in order that an appropriate potential may be maintained on these elements. The anode of tube 15 is connected to a source of positive potential by way of a resistance 19. The value of the resistance 16 is such that the direct current component of the output of the cell 11 as well as certain low alternating current frequencies are amplified by the tube 15, the amplification being linear over a certain range and decreasing in accordance with a particular function as the frequency increases. The output voltage of the direct current amplifying channel is therefore present across conductors 17 and 20 and this voltage, for the purpose of explanation, will be designated as E_{dc} .

The output of the photoelectric cell 10 is connected to an output resistance 26 and to the first intermediate electrode or control grid of the tube 12. This resistance is relatively low as compared to the value of the resistance 16, and is of a low value in order that high frequencies may be properly supplied to the alternating current amplifying channel of the system. The tubes 12, 13 and 14 may, for example, be triple grid amplifiers and may have the same general characteristics as that of the tube 15 which is used in connection with the direct current amplifying channel. In each of the tubes 12, 13 and 14 the suppressor grid or third intermediate electrode is connected to the emitter element and these elements are in turn connected to ground by way of resistances 27, 28 and 29 for the purpose of maintaining proper biasing potentials on these elements. The tubes 12, 13 and 14 are connected in tandem and operate as successive stages of amplification in the alternating current amplifying channel of the system. The tubes are connected by capacity coupling as indicated by the drawings, in a manner which is well known in the art.

The output of tube 14 is connected to the primary winding 30 of transformer T1, and the out-

put or amplified alternating current component accordingly appears across the terminals of the secondary 31 of the transformer. This amplified output will be referred to as E_{ac} in the further explanation of the operation of the system.

The addition or combining of the outputs of the two separate amplifying channels is accomplished by connecting the output (E_{ac}) of the secondary 31 of transformer T1 to the potentials (E_{dc}) which appear across the conductors 17 and 20. It will be noticed that the conductor 20 is connected to an adjustable point along the resistance 19 in order that the amplification ratio of the two channels may be varied so that an absolutely overall linear amplification may result. After the amplified outputs of the two amplifying channels have been combined, the combined voltages, which will be referred to as E_0 , are impressed upon the control grid or first auxiliary electrode of tubes 35 and 36 which are connected for push-pull operation. These tubes may be similar to the tubes used in the alternating and direct current amplifying channels and are for the purpose of further amplifying the combined outputs of the amplifying channels as well as modulating a carrier frequency by the outputs of the amplifier channels. The carrier frequency, which may be derived from any appropriate oscillator, is applied to terminals 37 which are connected to winding 33 of transformer T2, the windings 39 and 40 of this transformer being in turn connected to the cathode and second intermediate electrode of tubes 35 and 36 respectively. The second intermediate electrodes of tubes 35 and 36 are maintained at proper operating potential by reason of the resistance 41 which is inserted in the connection between the common terminals of the windings 39 and 40 and the cathodes of the tubes. The anodes of tubes 35 and 36 are connected to the primary winding of transformer T3, the mid-point of which is connected to a source of positive potential.

It may be seen from the above, therefore, that separate channels are provided for amplifying separate portions of the output of the light sensitive cells 10 and 11. The operating range of the direct current amplifying channel is indicated in Figure 6 by the curve E_{dc} which, as shown by the curve, produces linear amplification of direct current as well as low alternating current frequencies. At about 50 cycles per second, the curve or amplification factor begins to decrease and continues to do so until substantially zero amplification results in the higher frequency brackets. The curve E_{ac} shows the range of the alternating current amplifying channel which, of course, is zero for direct current and increases according to a certain function to a frequency of the order of 2000 cycles per second at which frequency linear amplification of a constant value begins and is maintained to a frequency of the order of 30,000 or more cycles per second. It will be noticed that the curves E_{dc} and E_{ac} intersect at a frequency of about 400 cycles per second, and by adding the amplification factors of the curves representing the alternating current amplification channel and the direct current amplification channel, a curve E_0 will result which, as will be seen by reference to Figure 6, is in the form of a straight line and which represents the amplification factor of the combined dual channel amplifying system. When the voltage represented by the curve E_0 is applied to the modulating and amplifying tubes 35 and 36 a modulated high frequency carrier current will appear across the secondary

winding of the transformer T3 and this modulated current is suitable for transmission by any appropriate means to outlying facsimile receiving apparatuses.

The two photoelectric cells 10 and 11 are provided in order that each amplifying channel will have a separate source of signals. These cells are each actuated by light which is reflected from the facsimile tape as a result of one light beam being projected thereon. By means of appropriate optical systems the reflected light from the facsimile tape is gathered and directed upon the two individual cells.

As stated above, Figure 1 shows, by way of example, a curve of the amount of light which may, at a particular instant, be projected upon the photoelectric cells as a result of the scanning operation and the reflective qualities of the surface of the tape as determined by the indicia thereon. When this light strikes the cells a certain direct current component is present together with a certain alternating current component as explained above. Figure 2 shows a curve of the output of the D. C. amplifier channel when light of a form indicated by the curve shown in Figure 1 is projected upon cell 11. It may be seen from the curve in Figure 2 that a predetermined maximum output is maintained so long as the cell is activated by light and it may further be seen that the transition from zero to this maximum or from the maximum to zero is in accordance with a predetermined function as determined by the parameters of the circuits. In Figure 3 is shown a curve representing the output of the alternating current amplifying channel when the cell 10 is subjected to light having a wave form as shown by Figure 1. In this curve it may be seen that there is an output from the amplifier channel only during those instances when the value of the light projected upon the cell 10 is changed. The amount of current from the alternating current amplifying channel therefore increases substantially instantaneously to a value determined by the intensity of the light and decreases according to a predetermined function in accordance with the particular circuit used. Because of the variables and particular characteristics of the separate amplifying channels the rate of change of current from zero to a maximum in the direct current amplifying channel is substantially the same as the rate of change of current from maximum to zero in the alternating current amplifying channel. When the envelopes of the curves shown in Figures 2 and 3 are added a curve such as shown in Figure 4 will result. This curve corresponds to the curve E_0 in Figure 6 and it is this potential curve which is impressed upon the control electrodes of the modulator tubes 35 and 36 as explained above in connection with Figure 7, to produce a curve of a modulated carrier frequency such as shown in Figure 5.

Figure 6 also shows the phase displacement which is present in each of the separate amplifying channels, the curves ϕ_{ac} and ϕ_{dc} representing the phase displacement of the alternating and direct current amplifying channels respectively. The curve ϕ_{ac+dc} represents the over-all phase displacement of the system as determined by the amplification factors of the two separate amplifying channels for a particular frequency. It may be seen from the curve that substantially no phase displacement takes place over the entire range of the composite amplifying system

with the result that the amplification is not only linear in nature, but also is of high fidelity.

Figure 8 shows an alternate form of the present invention wherein a single photoelectric cell or other light responsive element 50 is used. Connected to the photoelectric cell is a source of potential and a resistance 51 which are connected in series, the resistance forming an output resistance for the photoelectric cell. Connected in parallel with the resistance 51 are two current paths each of which includes a resistance and a condenser. The resistance 52 and the condenser 53 of one of the current paths are connected as shown in the drawing and across the condenser 53 are provided a pair of terminals to which the direct current amplifying channel shown in Figure 7 may be connected. The condenser 54 and the resistance 55 which forms the other current path are connected as shown in the drawing and a pair of terminals are provided whereby the potential variations which appear across the resistance 55 may be impressed upon the alternating current amplifying circuit of Figure 7. In actual practice it has been found that the resistances 52 and 55 should be of substantially the same magnitude as is also the case in connection with the condensers 53 and 54. The resistances 52 and 55 are, however, low in value as compared to the value of the resistance 51. The circuit shown in Figure 8 may be readily connected to the amplifying system shown in Figure 7 for use therewith and in this case the total reflected light from the facsimile tape may be directed upon the single photoelectric cell 50. The system shown in Figure 8 performs the function of segregating the direct current component as well as certain low frequency variations of the output of the photocell from the remaining higher frequency variations in order that each may be separately and individually amplified by the two amplifying channels of the amplifying system shown in Figure 7.

From the above description of the present invention it may, therefore, be seen that an amplifying system has been provided wherein signal variations from zero frequency to 12,000 or more cycles per second may be amplified linearly and with great fidelity. By the use of such a system, it is possible to materially increase the rate at which facsimile transmitters may be operated without producing distortion of the reproduced subject matter.

In the system shown in Figure 7 the output signals from the direct and alternating current amplifying channels are combined by using a transformer T1. It is not necessary that such means be used since the signals may be combined by other means. For example, a pentode or multigrid tube may be used in the direct current amplifying channel for combining the signals and for amplifying the direct current and low frequency signals. When this is done the signal variations from the light responsive device are applied to the first control grid while the amplified output signals from the high frequency or alternating current amplifying channel are applied to the second control grid. The anode electrode or output of the tube would then be connected to the control grids of the modulating tubes. Such a system would be advantageous to use inasmuch as no phase shift would be introduced since no inductive elements would be present in the system.

It is to be understood, however, that, although the system is shown and explained as particularly

useful in connection with facsimile systems, the system is, of course, readily adaptable to other purposes wherein an amplification of a wide range of frequencies is desired. An example of another use to which the system might be put is in connection with television systems since a wide range of frequency variations is present in such systems.

In view of the fact that the present amplifying system may be used in various respects, it is also to be understood that the signal variations may be derived from any source and that they may represent letters, pictures, news reports, drawings, sketches or in fact any subject matter which may, by appropriate means, be translated into electrical potential variations. It is also conceivable that it is not necessary that the signals be derived from light responsive elements since signal variations of a wide frequency range from any source could as well be supplied to the amplifying system and would be amplified with the same fidelity and linearity.

It is also to be understood that, although rather specific electron discharge tubes are shown in the amplifying system, other types of tubes which will perform the same or similar functions could as well be used. When other tubes are substituted for those specifically shown in the figures, the appropriate and obvious minor circuit connections would also be made to accommodate such a change.

Furthermore, it is not essential that the specific voltages or potentials indicated in Figure 7 be applied to the system since the use of other electron discharge tubes might necessitate the use of different potentials. In the system shown a positive 200 volt potential is applied to the center tap of the primary of transformer T3 while a positive 90 volt potential is applied to the common anode conductor 17 of the various discharge tubes. The 90 volt potential is maintained constant through the use of a glow discharge tube 42 which may be, for example, the standard 874 glow discharge device. Such a tube is of particular advantage inasmuch as the presence of such a tube maintains the potential of the conductor 17 absolutely constant, small changes in potential being compensated for by the current passed by the tube 42. If the sources of potential are sufficiently constant, however, the use of the glow discharge tube is of course superfluous.

Other modifications and alterations in the present system may be made without departing from the spirit and scope thereof and it is to be understood that any and all such modifications be considered within the purview of the present invention except as limited by the art and the hereinafter appended claims.

I claim as my invention:

1. An amplifier system for use in a facsimile transmitter comprising a direct coupled and an impedance coupled amplifying channel, a separate light responsive element for each amplifying channel, means connected to one of said light responsive elements whereby the direct current and the low frequency portions of the output of said one element will predominate and means for applying said portions to said direct coupled amplifying channel, means connected to the other of said light responsive elements whereby the high frequency portion of the output of said other element will predominate, means for applying said portion to said impedance coupled amplifying channel, a transformer having a primary winding and an inductively coupled sec-

ondary winding, means for applying the output of the impedance coupled amplifying channel to the primary winding of the transformer, and means for connecting the secondary of the transformer in series with the output from the direct coupled amplifying channel whereby the amplified signals from both amplifying channels will be present in the secondary of said transformer.

2. An amplifying system for use in a facsimile transmitter comprising a first and a second light responsive element, a direct coupled amplifying channel particularly adapted to amplifying direct and low frequency current variations, an impedance coupled amplifying channel particularly adapted to amplify high frequency current variations, means for connecting the output of said first element to said direct coupled amplifying channel whereby the direct current and the low frequency portion of the output will be amplified, means for connecting the output of said second elements to said impedance coupled amplifying channel whereby the higher frequency portions of the output will be amplified, a transformer having a primary winding and an inductively coupled secondary winding, means for applying the output from the impedance coupled amplifying channel across the primary winding of the transformer, means for applying the output from the direct coupled amplifying channel across a resistance element, and means for directly connecting one end of the secondary of the transformer to a point along said resistance whereby amplified potential variations may be present between the other end of the secondary transformer and one end of the resistance.

3. An amplifying system for use in a facsimile transmitter comprising a light responsive element, a plurality of amplifying channels, means connected to said element for separating the signal output thereof into separate frequency bands, means for individually applying each frequency band to one of said plurality of amplifying

channels, each amplifying channel being adapted to maintain a substantially constant amplification factor over the applied frequency band, one of said channels including a direct coupled amplifier to amplify direct current components, and means including a transformer for combining the outputs of the amplifying channels, said transformer including a primary winding and an inductively coupled secondary winding, the secondary of said transformer being directly connected in series with the output of the direct coupled amplifier and the primary of said transformer being connected to the output of the remaining amplifying channels whereby amplified energy from all of the channels will be present in said secondary winding and whereby a constant amplification factor is maintained over the entire range of frequencies derived from said light responsive element.

4. An amplifier system comprising a light responsive element, circuit means connected to said element to provide a series of signals in which direct current and low frequency potential variations predominate, additional circuit means connected to said element to provide a series of signals in which higher frequency potential variations predominate, means including a direct coupled and impedance coupled amplifier for separately amplifying each series of signals, each amplifying means being adapted to maintain substantially linear amplification over the applied frequency range of the series of signals, a transformer including two inductively coupled windings, one of said windings being connected to the output of the impedance coupled amplifier, the other of the windings being connected to the output of the direct coupled amplifier whereby said other winding will have applied thereto the amplified direct current and low frequency series of signals and will have induced therein the amplified higher frequency series of signals.

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