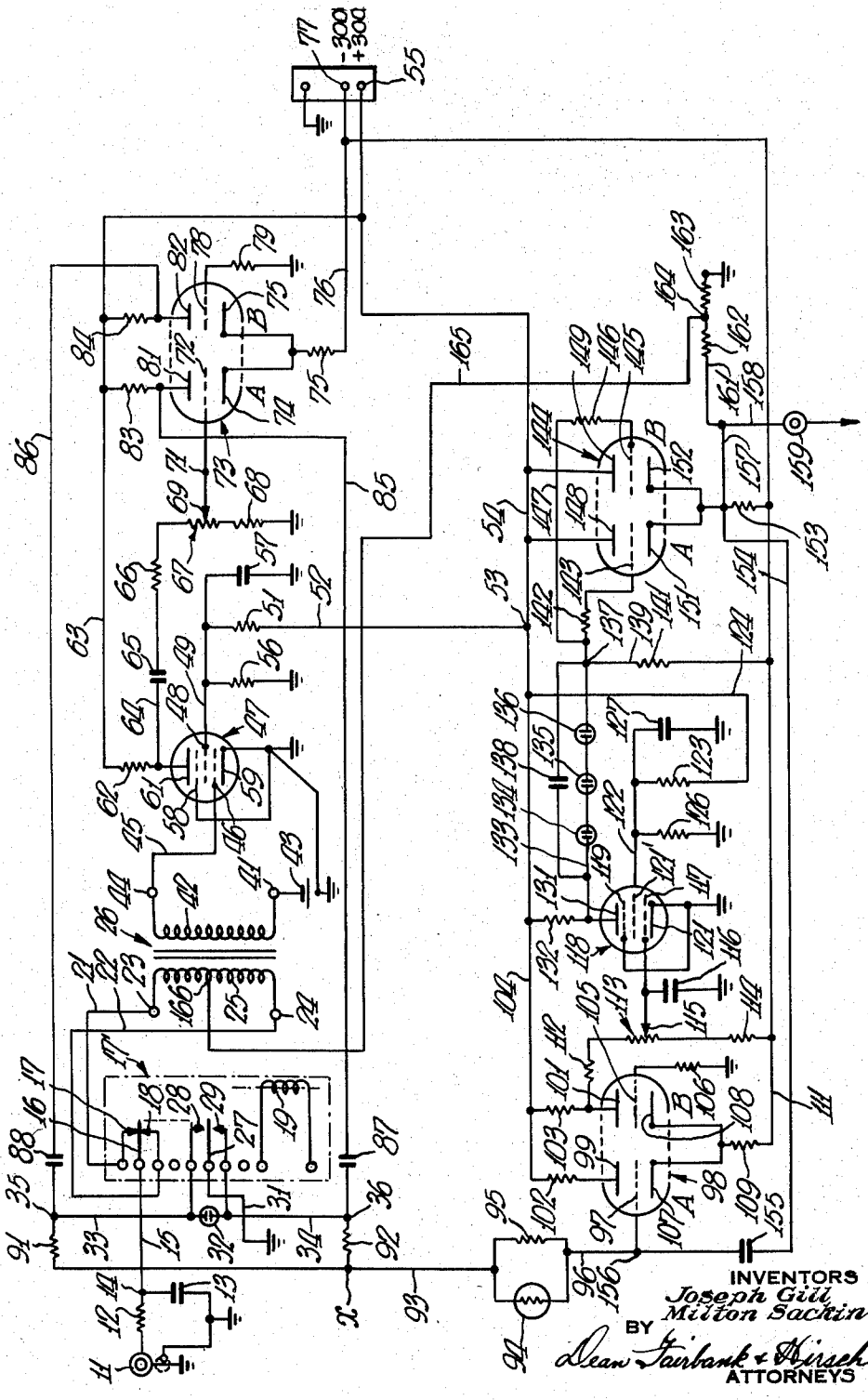
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DIRECT CURRENT AMPLIFIER

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DIRECT CURRENT AMPLIFIER

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It is among the objects of the invention to provide a direct current amplifier that is relatively simple in construction, dependable in operation and may be made at relatively low cost, that will provide a D. C. output proportional by a given amount to a D. C. input, that has a low drift and low noise level and a rapid response and that is free of alternating current components including those caused by the chopper used in the equipment.

According to the invention, these objects are accomplished by the arrangement and combination of elements hereinafter described and particularly recited in the claims.

In the accompanying drawings in which is shown one of various possible embodiments of the several features of the invention, the single figure is a circuit diagram of the amplifier.

Referring now to the drawing, the input terminal 11 is connected through resistor 12 and capacitor 13 to ground, said resistor capacitor combination defining an A. C. filter. The junction 14 between resistor 12 and capacitor 13 is connected by lead 15 to the movable contact arm 16 of a chopper rectifier unit 17'. The contact arm 16 is normally engaged by two fixed contacts 17 and 18 when in neutral position. The contacts 16, 17 and 18 are so designed that when the contact arm 16 is vibrated by the action of the coil 19 of the unit 17', when the contact arm 16 moves in one direction, i. e., upwardly, in the illustrative example, it will move away from fixed contact 18 and remain in engagement with fixed contact 17 and when the contact arm 16 moves downwardly past neutral position it will move away from fixed contact 17 and remain in engagement with fixed contact 18.

The fixed contacts 17 and 18 are connected respectively by leads 21 and 22 to the terminals 23, 24 at the respective ends of the primary winding 25 of a transformer 26. The unit 17' has an additional movable contact arm 27, normally spaced from fixed contacts 28 and 29 and also vibrated by the coil 19 of the unit. Contact arm 27 is connected by lead 31 to ground. Fixed contacts 28 and 29 are connected to the respective sides of a neon lamp 32 which serves to protect the contacts by limiting the maximum signal that can be developed across such contacts and also are connected respectively by leads 33 and 34 to junctions 35 and 36 respectively.

One end 41 of the secondary winding 42 of transformer 26 is connected to one side of a source of potential, illustratively a battery 43 having a value of 1.5 volts and the other side of said battery is connected to ground. The other end 44 of transformer secondary 42 is connected by lead 45 to the control grid 46 of an amplifier tube 47, the battery 43 providing bias for this tube. The screen grid 48 of vacuum tube 47 is connected by lead 49 through resistor 51 and lead 52 to junction 53 and thence by lead 54 to terminal 55 which is connected illustratively to a plus 300 volt source.

Screen grid 48 is also connected through resistor 56 and capacitor 57 in parallel to ground. The suppressor grid 58 and cathode 59 of tube 47 are connected to ground and the plate 61 of said tube is connected through

resistor 62 and lead 63 to terminal 55, the positive 300 volt source. The plate 61 is also connected by lead 64 through capacitor 65 and resistor 66 connected in series to one side of a gain adjust potentiometer 67, the other side of which is connected through resistor 68 to ground.

The contact arm 69 of potentiometer 67 is connected by lead 71 to the control grid 72 of the first section A of a phase splitter tube 73 which comprises two vacuum tubes in one envelope. The cathodes 74, 75 of sections A and B of tube 73 are tied together and connected to a common cathode resistor 75 and lead 76 to terminal 77 to which a negative 300 volt supply may be connected. The control grid 78 of section B of tube 73 is connected through resistor 79 to ground. The plates 81 and 82 of tube 73 are connected through associated plate load resistors 83 and 84 to terminal 55, the positive 300 volt source.

In addition, plates 81 and 82 are connected by leads 85 and 86 respectively through capacitors 87 and 88 to junctions 36 and 35.

The junctions 35 and 36 are connected through resistors 91 and 92 to lead 93 which is connected to one side of a parallel connected unit comprising a voltage sensitive resistor 94 and a resistor 95. The voltage sensitive resistor has characteristics such that when the voltage applied thereto rises above a certain amount, say one-half volt, its resistance drops to a relatively small value, i. e., from say 5 megohms at one-half volt to 2,000 ohms at 5 volts. This voltage sensitive resistor may be of conventional type such as that put out by General Electric Company and known as a "Thyrite." The resistor 95 illustratively is of relatively high value in the order of 1.5 megohms. The other side of the parallel combination comprising "Thyrite" 94 and resistor 95 is connected by lead 96 to the control grid 97 of an amplifier tube 98 comprising two sections A and B. The plates 99 and 101 of sections A and B of tube 98 are connected through associated plate load resistors 102 and 103 to lead 104 which in turn is connected to terminal 55, the positive 300 volt source. The control grid 105 of section B is connected through resistor 106 to ground. The cathodes 107 and 108 are connected together and then through common cathode resistor 109 are connected by lead 111 to terminal 77 for connection thereto of the negative 300 volt source.

The plate 101 of section B of tube 98 is connected through resistor 112 to one side of the D. C. zero adjust potentiometer 113, the other side of which is connected through resistor 114 to lead 111 connected to the negative 300 volt source. The contact arm 115 of potentiometer 113 is connected through capacitor 116 to ground and also to the control grid 117 of a vacuum tube 118. The supressor grid 119 and cathode 121 of tube 118 are connected to ground. The screen grid 121' of tube 118 is connected by lead 122 through resistor 123 and lead 124 to terminal 55, the positive 300 volt source. Screen grid 121 is also connected through parallel resistor 126 and capacitor 127 to ground. The plate 131 of tube 118 is connected through plate load resistor 132 to lead 104 which is connected to terminal 55, the positive 300 volt source. The plate 131 is also connected by lead 133 through series connected neon lamps 134, 135 and 136 to junction 137, said three neon lamps being bypassed by a capacitor 138. The junction 137 is connected by lead 139 through resistor 141 to lead 111 connected to the negative 300 volt source.

Junction 137 is also connected through resistor 142 to the control grid 143 of section A of an amplifier tube 144, the latter having two sections A and B contained in the same envelope, the series connected neon lamps 134, 135 and 136 permitting the total change in voltage on plate 131 of tube 118 to appear on grids 143 and 145

of tube 144. The control grid 145 of section B of tube 144 is connected through resistor 146 and lead 147 to junction 137. The plates 148 and 149 of tube 144 are connected directly to the terminal 55 for application of the positive 300 volt source. The cathodes 151 and 152 of tube 144 are tied together and thence are connected through common cathode resistor 153 to lead 111 which is connected to the negative 300 volt supply. The cathodes 151 and 152 are also connected by lead 154 through capacitor 155 to junction 156 between the parallel connected elements 94, 95 and the control grid 97 of tube 98. The cathodes 151 and 152 are also connected by leads 157 and 158 to output terminal 159 and by lead 161 to one side of the series connected resistors 162 and 163, the other side of said series connected resistors being connected to ground.

The resistors 162, 163 are designed to provide an output which is proportional to the input and in the illustrative example shown the resistor 162 has a value of 99,000 ohms and the resistor 163 has a value of 1,000 ohms. The junction 164 between resistors 162 and 163 is connected by lead 165 to the center tap 166 of the primary winding 25 of transformer 26.

In the operation of the amplifier, assuming that a D. C. signal is applied to terminal 11, the corresponding signal will be also applied to the movable contact arm 16 of unit 17', any A. C. components which may be picked up being bypassed through capacitor 13 to ground, the capacitor 13 and resistor 12 serving as a filter for such A. C. components. As the contact arm 16 is vibrating due to the energization of coil 19, it will successively engage fixed contacts 17 and 18. As the result, the D. C. potential will be alternately applied to each end 23, 24 of the primary winding 25 of transformer 26 and a voltage will be developed between the respective ends 23, 24 and the center tap 166 of such winding. As the result of the transformer action, a voltage will appear across the secondary winding 42 of transformer 26, such voltage being in the form of square waves. As such voltage is applied to the control grid 46 of amplifier tube 47, it will be amplified and so appear at the plate 61 of such tube in opposite phase to its application to the control grid 46 thereof.

Such square waves, each of amplitude proportional to the applied signal to terminal 11, will appear across potentiometer 67 and will be applied to the control grid 72 of phase splitting tube 73.

Consequently, the signal applied to grid 72 will appear on plate 81 in amplified but reversed phase and on plate 82 in amplified, but in the same phase. Thus, the phase splitting tube provides two signals of equal amplitude but opposite in phase. The signals from plates 81, 82 will be applied respectively through leads 85, 86 and capacitors 87, 88 to junctions 36, 35 and thence to the fixed contacts 29, 28 of unit 17'. As the contact arm 27 of unit 17' is vibrating in synchronism with the contact arm 16 of such unit, it is apparent that as the contact arm 27 is grounded by lead 31, half of each cycle will be grounded so that successive signals in one direction only will appear at junction X, such signals being of amplitude proportional to the input signal to terminal 11. Thus the contact arm 27 and fixed contacts 28 and 29 together with the phase splitter tube 73 provide rectification of the signal developed by the chopper contacts 16, 17 and 18.

The amplified D. C. voltage at junction X will be applied through the parallel combination 94, 95 to the control grid 97 of amplifier unit 98 and the amplified voltage will be tapped from potentiometer 113 and applied to the control grid 117 of the third amplifier 118. The voltage amplified by tube 118 will be applied through neon lamps 134, 135 and 136 to the control grids 143, 145 of tube 144. This tube is connected as a cathode follower and hence such voltage will appear across resistor 153 in the cathode circuit of such tube 144. In addition, the voltage will also appear across resistors 162, 163 connected in series.

As resistor 163 has a value equal to $\frac{1}{100}$ of the combined values of resistors 162, 163, it is apparent that a signal equal to $\frac{1}{100}$ of the output signal will appear at junction 164 and through lead 165, be fed back to the center tap winding 166 of the primary winding 25 of transformer 26.

As the signal at center tap 166 opposes the signal applied to the ends 23, 24 of the tranfsormer, it is apparent that if the center tap signal at 166 were equal to the signal at ends 23, 24 of transformer 26, the output of the transformer would be zero and there would be no output voltage and hence no feedback voltage applied to center tap 166. However, this condition never occurs for so long as the equipment is operating, the feedback signal is always less than that applied to either end 23 or 24 of transformer 26 and approaching such input signal in value. Since such feedback voltage is $\frac{1}{100}$ of the voltage across resistors 162, 163, the voltage from cathodes 151, 152 will be retained at substantially 100 times the value of the input voltage and this voltage will appear at output terminal 159.

The purpose of the amplifier is to provide a D. C. output proportional to the input and which is filtered so that there are no fluctations in the output which would introduce an error in the equipment fed by the amplifier. If sufficient filtering is introduced to provide pure D. C., the response time of the system might be too slow to follow rapid variations in the input signal, i. e., such response time might be in the order of 30 seconds.

With the "Thyrite" 94 in parallel with resistor 95, which together with capacitor 155 forms the filter, as soon as the input signal fluctuations, there would be a large error signal, i. e., the difference between the input voltage to ends 23, 24 of transformer 26 and the feedback voltage to center tap 166. Consequently, the resistance of the "Thyrite" due to the relatively large voltage would be low so that the high resistance 95 would be bypassed to reduce the time constant of the filter 95, 155 to substantially eliminate filtering action. As soon as the error signal is reduced, due to the feedback previously described, the "Thyrite" resistance would increase so that filtering would again occur.

Thus, the circuit provides rapid response to variations in the input signal with dependable filtering action.

As many changes could be made in the above equipment, and many apparently widely different embodiments of this invention could be made without departing from the scope of the claims, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

Having thus described our invention, what we claim as new and desire to secure by Letters Patent of the United States is:

1. A D. C. amplifier comprising a transformer having a center tapped primary and a secondary, means alternately to apply a D. C. signal to the respective ends of said primary, a phase splitting device electrically connected to the secondary of said transformer to provide two signals 180 degrees out of phase and each of amplitude proportional to the input signal to said primary, means in synchronization with the means alternately to apply the D. C. signal to the primary, to rectify said two out of phase signals to provide a continuous D. C. signal of amplitude proportional to the input signal, an output, a filter between said rectifying means and said output, said filter comprising a resistor having a relatively high ohmic value and a capacitor, a voltage responsive resistor connected in parallel with said filter resistor, the resistance of said voltage responsive resistor being inversely proportional to the voltage applied thereto, means to feed a signal proportional to said rectified D. C. to said output, a voltage divider connected to said output

and across which an output signal is developed, said voltage divider having means to provide a signal of amplitude a given fraction of said output signal and means to feed back said fractional signal to the center tap of said primary to oppose the input signal applied thereto.

2. A D. C. amplifier comprising a transformer having a center tapped primary and a secondary, means alternately to apply a D. C. signal to the respective ends of said primary, a phase splitting device comprising a pair of vacuum tubes each having a plate, a control grid, a cathode and a common cathode resistor, a load resistor in each of the plate circuits of said tubes, means to feed the output from the secondary of said transformer to the control grid of one of said tubes whereby voltages 180 degrees out of phase will be developed across said plate load resistors, means in synchronization with the means alternately to apply the D. C. signal to the primary, to rectify said two out of phase signals to provide a continuous D. C. signal of amplitude proportional to the input signal, an output resistor, means to feed a signal proportional to said rectified D. C. to said output resistor, said means including a filter having a resistor of relatively high ohmic value, and a capacitor, a voltage responsive resistor in parallel with said filter resistor, the resistance of said voltage responsive resistor being inversely proportional to the voltage applied thereto, a voltage divider comprising a resistor network connected to said output resistor and across which the output voltage will be developed and means to feed back a given fraction of the voltage across said network to the center tap of said primary to oppose the input signal applied thereto.

3. The combination set forth in claim 2 in which an amplifier stage is electrically connected between said secondary and the control grid of said phase splitting tube.

4. The combination set forth in claim 2 in which a vacuum tube unit is provided having a plate, a control grid and a cathode, said output resistor having one end connected to said cathode, to an output terminal and to one end of said voltage divider network, a second vacuum tube unit is provided having a plate electrically connected to the control grid of said first tube and a control grid electrically connected to one end of said filter resistor and to one side of said filter capacitor, the other side of said capacitor being connected to said output terminal.

5. The combination set forth in claim 2 in which a vacuum tube unit is provided having a plate, a control grid and a cathode, said output resistor having one end connected to said cathode, to an output terminal and to one end of said voltage divider network, a second vacuum tube unit is provided having a plate and a control grid electrically connected to one end of said filter resistor and to one side of said filter capacitor, the other side of said capacitor being connected to said output terminal, a vacuum tube amplifier unit having a control grid electrically connected to the plate of said second vacuum tube unit, and a plate electrically connected to the control grid of said first vacuum tube unit, a neon lamp being connected in series between said plate and control grid.

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