

Feb. 4, 1941.

M. ARTZT

2,230,822

SYNCHRONIZING APPARATUS

Filed June 21, 1939

4 Sheets-Sheet 1

*Fig. 1*

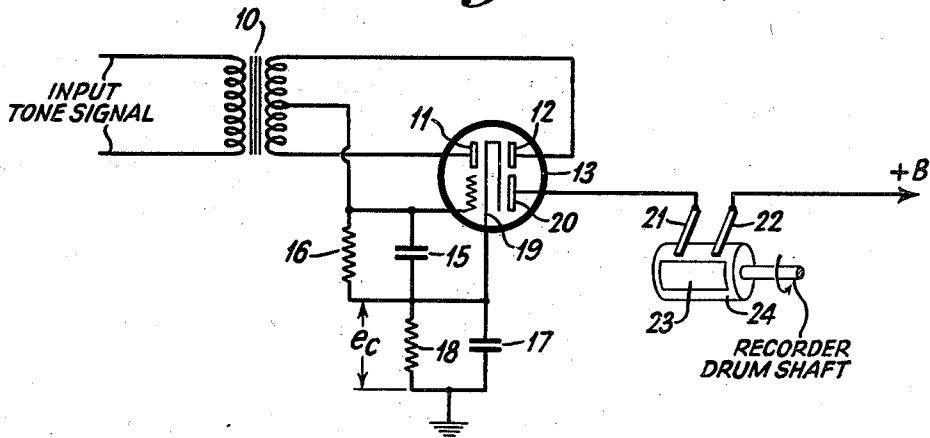
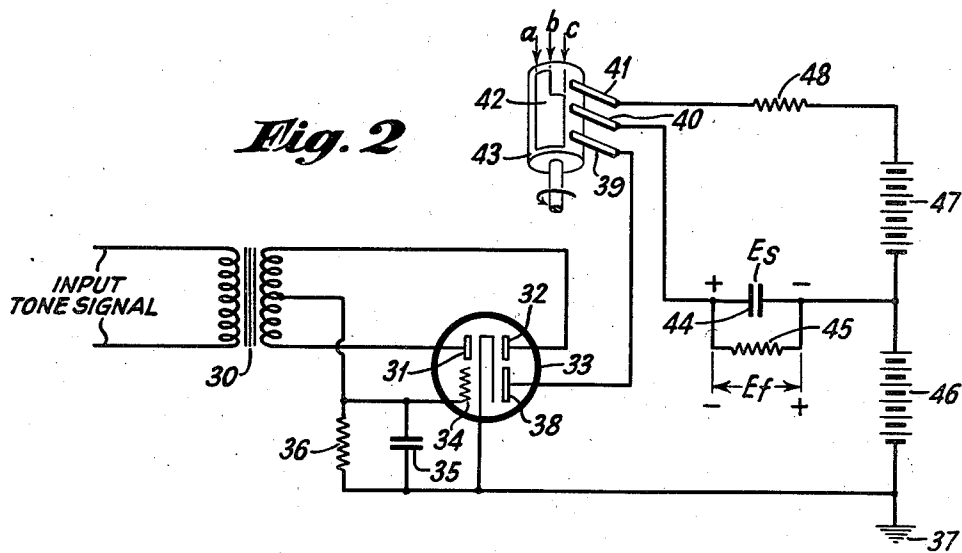


*Fig. 2*



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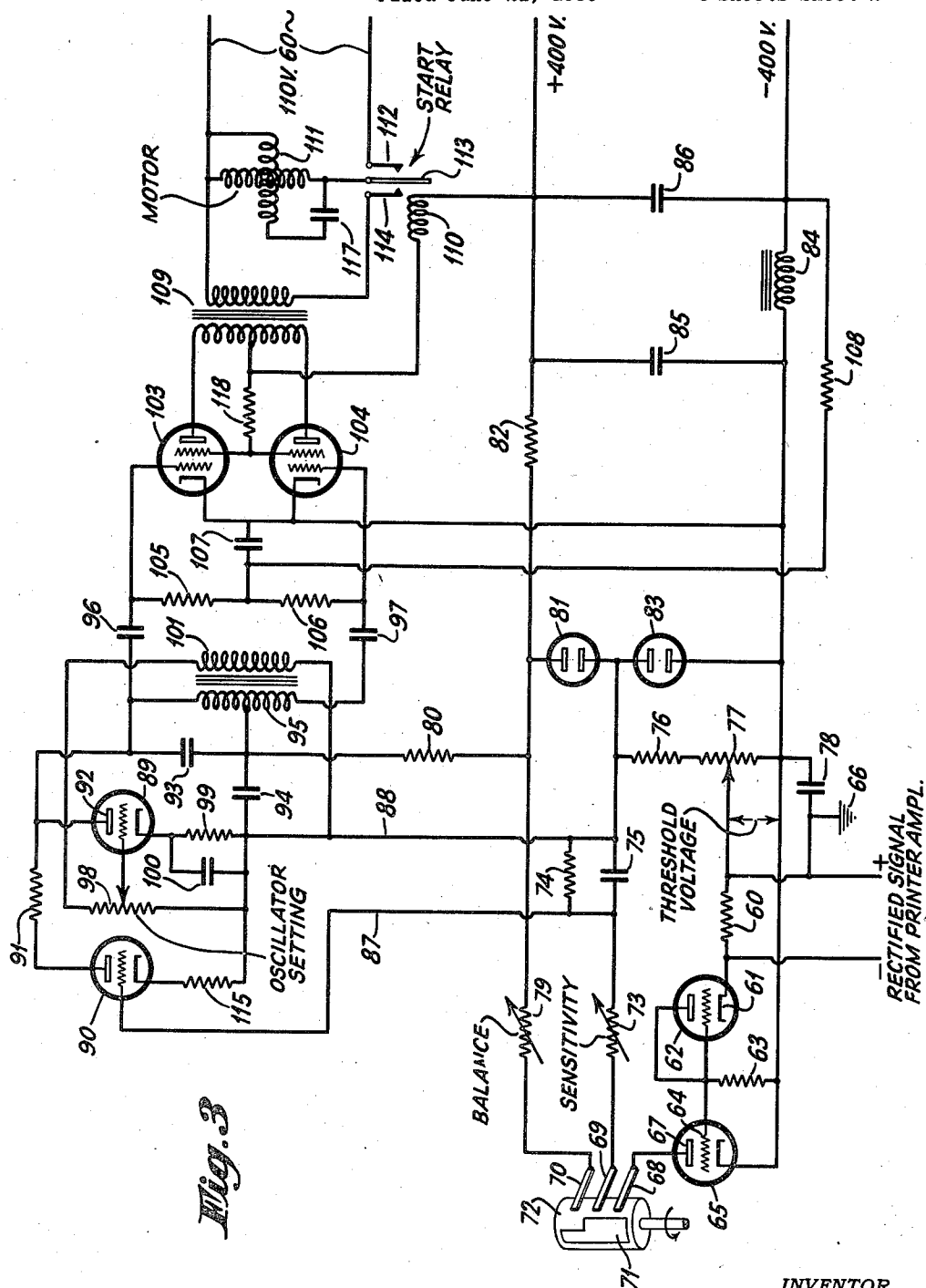
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## SYNCHRONIZING APPARATUS

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4 Sheets-Sheet 2



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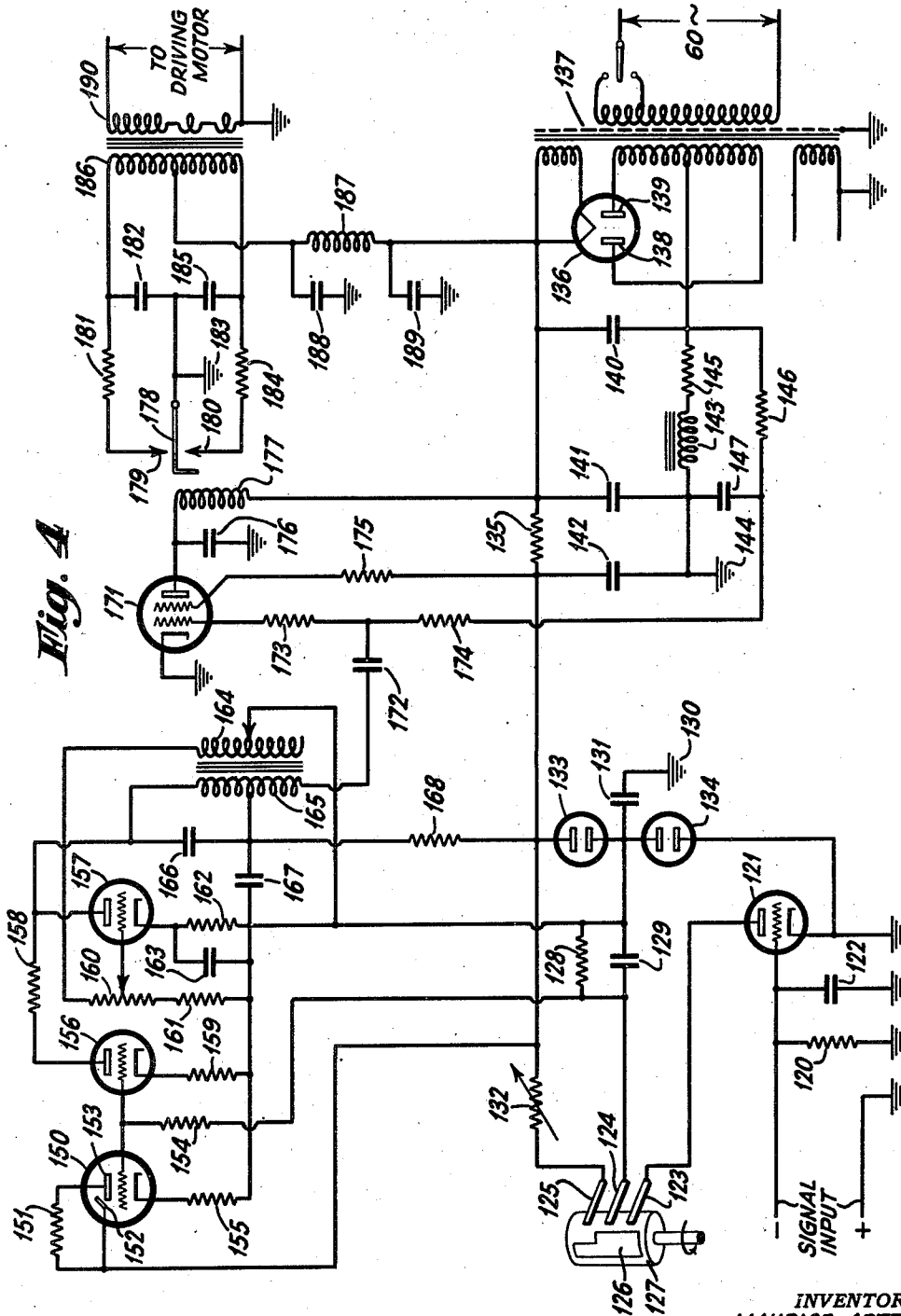
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SYNCHRONIZING APPARATUS

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4 Sheets-Sheet 3

Fig. 4



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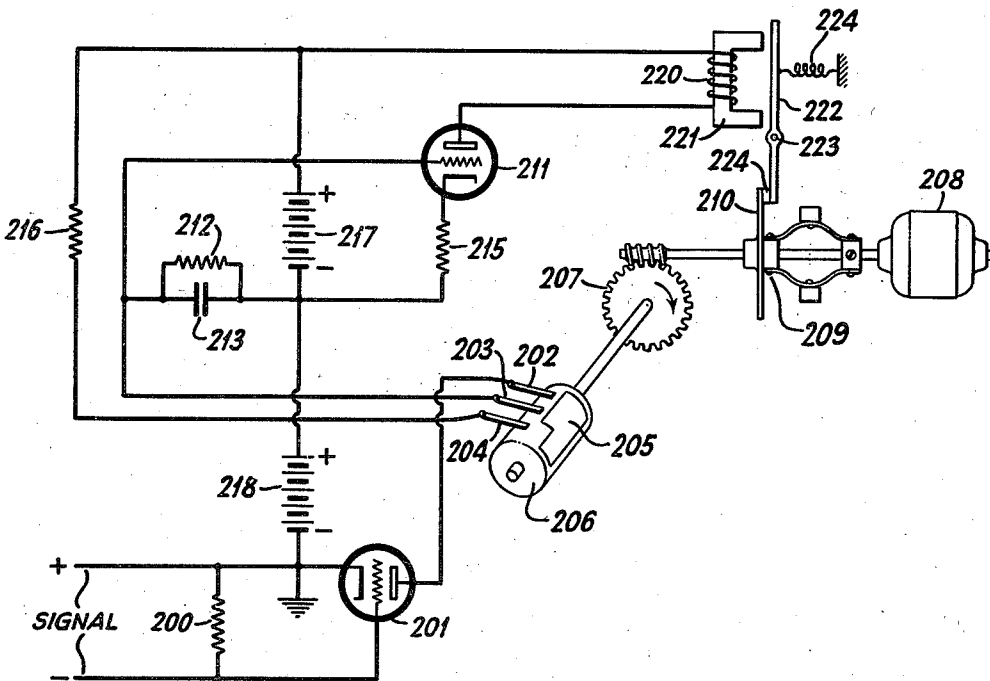
**2,230,822**

## SYNCHRONIZING APPARATUS

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4 Sheets-Sheet 4

*Fig. 5*



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## UNITED STATES PATENT OFFICE

2,230,822

## SYNCHRONIZING APPARATUS

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Application June 21, 1939, Serial No. 280,304

12 Claims. (Cl. 178—69.5)

My invention relates in general to apparatus for synchronizing the movement of two prime movers, and more particularly to such apparatus as applied to the operation of two or more electric motors.

In a number of fields of activity, it is necessary to operate prime movers in synchronism. This is particularly true where such prime movers comprise electric motors. In a number of devices, the electric motors must be operated at the same speed, and in others the devices must be operated not only at the same speed but co-phasally. Accordingly, it is one of the objects of my invention to provide an apparatus which will accurately synchronize both as to speed and phase the movement of two prime movers.

One of the fields in which mechanical apparatus must move not only synchronously with respect to speed but also in a co-phasal relationship in the facsimile field, or the field in which images are transmitted and recorded. In general, such apparatus comprise a transmitter which linearly scans the image to be transmitted and a receiver which is adapted to be actuated by the signals developed from the transmitter to reproduce elemental optical areas in a linear fashion which follows the movement of the transmitter scanning arrangement. It will be appreciated that in order that a true and undistorted optical image is reproduced, the movement of the recorder must not only be the same in speed as that of the scanning apparatus but must be operated co-phasally with respect thereto. Accordingly, it is another of the objects of my invention to provide a synchronizing apparatus and arrangement which will be particularly adaptable for use in the facsimile field.

One of the methods suggested for synchronizing facsimile apparatus is to utilize the same power line which is supplying the motor at the transmitter to supply also the driving motor of the receiver and thus maintain a phase relationship between the two driving motors. One of the disadvantages of such a system is the fact that it definitely limits the area in which receivers can be operated, and in large cities where this might ordinarily be feasible, it is not uncommon to have two or more power supplies which are entirely independent and do not maintain a definite phase relationship each with the other. Accordingly, it is another of the objects of my invention to provide a device which will not be dependent upon the use of a common power supply to synchronize two driving motors which must

be operated in synchronism both as to speed and phase.

Some commercial facsimile systems at the present time are maintained in synchronism by the use of tuning forks which are accurately adjusted and which are maintained in a related set of conditions with respect to temperature, humidity and the like. This often involves the use of complex and highly critical temperature control apparatus and, hence, is not adapted for use on a large scale such as in the ordinary home where facsimile receivers are now finding ready use. Accordingly, it is another of the objects of my invention to provide a synchronizing apparatus which will be relatively simple, accurate, and will avoid the use of complex apparatus.

Also, it is for some purposes such, for instance, as the transmission of secret telephony and telegraphy desirable to accurately control the rate of oscillation of an oscillating circuit. Again, it is desirable from a standpoint of remote control to be able to definitely affect the period of oscillation of such an oscillator. Accordingly, it is another of the objects of my invention to provide a device for the easy control of oscillators by signals transmitted from an external source.

In summary, the objects of my invention are as follows:

1. To provide an apparatus which will accurately synchronize, both as to speed and phase, the movement of two prime movers.

2. To provide a synchronizing apparatus and arrangement which will be particularly adaptable for use in the facsimile field.

3. To provide a device which will not be dependent upon the use of a common power supply to synchronize two driving motors which must be operated in synchronism both as to speed and phase.

4. To provide a synchronizing apparatus which will be relatively simple, accurate, and will avoid the use of complex apparatus.

5. To provide a device for the easy control of oscillators by signals transmitted from an external source.

The operation of my device in general is as follows: For purposes of clarity, the motor such as is used at a facsimile transmitter may be called the first motor, and the motor at the receiver and which must be synchronized therewith as to speed and phase may be termed the second motor. Expressed differently, the second motor comprises a prime mover whose speed and phase must be substantially identical with a first motor with whose operation it is desired to be synchronized.

A signal is developed and transmitted, which represents a definite position of the first motor, and this signal is sent at recurrent intervals. A signal is developed at the second motor which is representative of the position of the second motor at a particular time; and these two signals are compared as to time in such a fashion that an electrical quantity is stored whose amplitude and polarity indicate both the direction and amount of deviation in the operation as to speed and phase of the second motor with respect to the first. This stored signal is used to operate corrective apparatus, the latter being adapted to change the speed, and hence the phase of the second motor with respect to the first motor when non-synchronous operation occurs.

My invention will best be understood by reference to the figures in which

Fig. 1 is a schematic representation of a comparing circuit,

Fig. 2 is another embodiment of such a comparing circuit,

Fig. 3 is an embodiment of my invention, and

Fig. 4 is a second embodiment of my invention,

Fig. 5 is a further embodiment of my invention.

Referring to Fig. 1, there is shown one embodiment of a circuit for comparing the received signal which has been generated in accordance with the position of a first prime mover with the position of a second prime mover. This type of arrangement has been especially adapted for use for so-called facsimile apparatus. The motor which drives the scanner, drives the elements thereof so that once for every scanned line, there is developed a signal which identifies the position of the motor armature. It has been found convenient to generate this signal by merely taking the steady amplitude signal which results when clamping members which hold the picture to be transmitted on the drum pass by the scanning means. Since the position of these clamps is fixed, it will be appreciated that this clearly defines the position of the driving motor armature during at least a portion of its cycle of operation.

In general, the comparison is made between the received signal and a signal developed at the receiver, the latter being dependent upon the position of the driving motor armature at the receiver. A bridge arrangement is used in general. However, the showing of Fig. 1 does not include such a bridge. If the motors are operated synchronously, that is to say, with the proper speed and phase, the bridge remains balanced. If the motors are not operating synchronously, the comparison is caused to develop an energy whose value is dependent upon the degree of divergence between the operation of the two motors.

In Fig. 1, the receiver signal is impressed on the primary of a transformer 10, the secondary thereof having its terminals connected to the plates 11 and 12 of a duo-diode-triode tube 13. The center tap from the secondary is connected to the control grid 14 of the tube 13 and is connected to two time constant circuits, the first comprising condenser 15 and resistor 16, and the second comprising condenser 17 and resistor 18. These two time constant circuits are connected serially and the cathode 19 of a duo-diode-triode is connected to the terminal where the two time constant circuits are joined to each other. The anode 20 of the triode section of the tube 13 is connected to a brush member 21 which is

positioned adjacent a second brush member 22, the two brushes being adapted to co-act with a commutator which is shown in this figure and has a conducting section 23 and an insulating section 24. Brush 22 is connected to the positive side of the plate supply potential and, as indicated here by the symbol +B, the negative side of the plate supply being grounded. The commutator is rotated through appropriate driving means by the driving motor which is desired to be synchronized with the motor which causes the development of the recurring signal.

The conducting section 23 closes the plate circuit of the triode section of the tube 13 once per scanning line of the device for a length of time slightly less than the length of the framing line signal. If the two motors are in phase, the commutator of the conducting section will be at the center when the transmitted signal arrives and biases the tube to cut-off. This will leave a definite charge on condenser 17, and the value of the voltage across the time constant circuit 17, 18 will be at its natural position of half value. If the motor tends to speed up, the conducting section of the commutator closes the contacts 21 and 22 earlier during the next revolution and the condenser 17 is charged for a longer period of time before the arrival of the signal biases the tube 13 to cut-off. Thus,  $e_c$  will rise in average value. Likewise, a slowing down of the motor will lower the average charge time of condenser 17 and lower  $e_c$ . The changing voltage  $e_c$  is then passed on to control the motor speed through one of the systems which will be described more fully hereinafter. The chief advantage of this circuit is simplicity. In this particular circuit, the resistor 18 must be set to bleed the condenser 17 to a voltage lower than the next control pulse so that correction can be made for slowing down or speeding up.

A refinement of this circuit can be made by fixing the zero value of the control voltage at some predetermined point and not depend on an averaging effect of the system.

Referring to Fig. 2, there is shown a true bridge arrangement for comparing the received signal with the position of the driving motor at the receiver. In this figure, the received signal is impressed on the primary of a transformer 30, the secondary of which is connected at its terminals to the plate members 31 and 32 comprising the diode sections of a duo-diode-triode 33. The center tap from the secondary is connected to the control grid 34 of the triode section of the tube 33 and also at the same terminal is connected to a resistance-condenser combination comprising condenser 35 and resistance 36. The other terminal of the resistance-condenser combination is connected to the cathode of the tube which in turn is grounded at the point 37. The anode 38 of the triode section of the tube 33 is connected to a brush member 39 which is one of three brushes, the other two brushes being brushes 40 and 41, all three of the brushes being adapted to coact with a commutator having an L-shaped conducting section 42 and an insulating section 43. This commutator is driven by the receiver driving motor. The brush 40 is connected to a resistance-condenser parallel combination comprising condenser 44 and resistance 45. The other terminal of this combination is connected to the common terminal of two sources of potential 46 and 47 which, in this case, may be batteries. The negative terminal of the battery 46 is grounded at 37. The positive terminal of battery 47

is connected to a resistance 48 which, in turn, is connected with brush 41. Accordingly, it will be seen that the potential supplies 46 and 47 and the resistance 48 and the internal resistance of the triode section of the tube 33 when the tube is conducting can have their values so chosen as to form a balanced bridge. The three-brush arrangement allows a setting of the brushes so that any brush wear will not cause the arrangement to close the circuits in an incorrect timing relationship.

The action of the device is as follows: In effect, brushes 39, 40, and 41 contact the conducting section 42 of the commutator at the same time closing the circuit comprising anode 38, brushes 39, 40 and 41, the resistance-condenser combination 44 and 45, and the potential supplies 46 and 47, and accordingly the conducting segment 42 will be at the same potential as the connection between batteries 46 and 47, and the condenser 44 receives no charge. At a later time the signal arrives and biases the tube to cut-off, opening the lower side of the bridge system. If the recorder is in exact frame, in other words, if the driving motor at the receiver is in proper phase relationship with the driving motor at the transmitter, the insulating section of the commutator will open the brush 41 and the upper side of the bridge at this same time, and the condenser 44 will not receive an additional charge, in view of the fact that both sides of the bridge are opened together. If the recorder were fast, the brush 41 would be opened before the received signal biases the triode section of the tube 33 to cut-off and the condenser 44 would receive a negative charge through the tube and brushes 39 and 40. If the recorder were slow, the triode section of the tube 33 would be cut-off first, and the condenser 44 would receive a positive charge through the brushes 40 and 41. If the resistance 48 is equal to the plate resistance of the triode section of the tube 33, the same error whether fast or slow will leave the condenser 44 with the same charge voltage but of a polarity determined by whether the time error was fast or slow. The circuit constants are so arranged that the condenser 44 is charged essentially at a constant current and, therefore, the control voltage E will be directly proportional to the time error. The resistor 45 is high in value compared to the resistor 48 and the tube resistance, and gradually discharges the condenser 44 to a zero value during the picture portion of the scanning line. In this way, when this apparatus is applied to the facsimile field, the correction applied at the start of each scanning line is directly proportional to the time error of a scanning line just received.

Referring to Fig. 3, there is shown one embodiment of my invention. In this embodiment, the rectified signal from the printer amplifier is impressed onto a resistor 60, this resistor being connected to the cathode 61 of a threshold rectifier 62, the plate of the rectifier being connected to one terminal of a resistor 63 and to the control grid 64 of tube 65. The other terminal of the resistor is grounded at 66. The anode 67 of the tube 65 is connected to a brush member 68 which comprises one of the three brushes 68, 69 and 70, the latter being so positioned as to remain in contact with the commutating member having a conducting portion 71 and an insulating portion 72. The brush 69 is connected to one terminal of a variable resistor 73 by means of which the sensitivity is controlled, and the other terminal of

the resistor 73 is connected to one terminal of a resistance-condenser combination comprising resistance 74 and condenser 75, this combination acting to store the corrective impulse when the device is out of synchronous operation. The other terminal of the resistance-condenser combination 74 and 75 is connected to one terminal of a resistance 76, and the latter is connected serially with a potentiometer 77, the terminal remote from that connected to resistor 76 being grounded through a condenser 78. The sliding contact of the resistor 77 is connected to ground. The third brush member 70 is connected serially with a resistor 79, the other terminal of the resistor 79 being connected to one terminal of a resistor 80 and to one electrode of a glow tube 81, and to a further resistor 82, the resistors 79, 80, 82 and the glow tube 81 having one terminal in common. The other electrode of the glow tube 81 is connected to an electrode of the glow tube 83, and the common connection is connected to one terminal of the resistor 76 and one terminal of the resistance-condenser combination 74-75, as illustrated. The other electrode of the glow tube 83 not connected with the glow tube 81 is in turn connected to one terminal of the resistor 77. In addition, this latter electrode is also connected to one terminal of a filter inductance 84 and filter condensers 85 and 86, the terminal of the inductive member 84 remote from this connection with the glow tube 83 being connected to the negative side of the source of energy.

The terminal of the resistance 82, which is remote from the terminal connected to the glow tube 81, is connected in turn to filter condenser 85 and 86 and to the positive side of the supply voltage. Shunted across the resistance-condenser combination 74 and 75 are a pair of leads 87 and 88, one of these leads being connected to the common cathode terminal of the oscillator tube 89 and the load tube 90. The lead 87 is connected to the control grid of the load tube 90. The anode of the tube 90 is connected through a resistance 91 to the anode 92 of the oscillator tube 89. The oscillating tube 89 has its plate connected back to its cathode serially through two condensers 93 and 94. Connected in parallel with the condenser 93 is a tapped section of an inductive member 95, variations in the inductive member being fed to the grids of two tubes connected in push-pull through condensers 96 and 97. The control grid of the tube 89 is connected to the sliding contact of a potentiometer 98 which has one terminal thereof connected to the cathode of tube 89 through a resistance 99, the latter having a condenser 100 shunted in parallel thereto.

The terminal of the potentiometer 98, remote from that connected to the resistance 99, is joined to one terminal of an inductive member 101 which is interposed in inductive relationship with the inductive member 95, the other terminal of the inductive member 101 being connected to the terminal of the resistance 99 remote from the cathode connection. A pair of push-pull amplifying tubes 103 and 104 have the control grids thereof connected to one side of the condensers 96 and 97 respectively, and to one terminal of serially connected resistors 105 and 106, the common terminal of the latter being connected to the cathodes of the tubes 103 and 104 through a condenser 107. The terminal of the condenser 107 remote from that connected to the cathodes of the tubes 103 and 104 is connected to the negative side of the voltage supply through

a resistance 108. The anodes of the tubes 103 and 104 are connected in push-pull to the terminal of transformer 109, the center tap of this terminal being connected through the actuating coil 110 of a relay to the positive side of the voltage supply.

The secondary of the transformer is connected so as to drive a motor 111, and one side of a power supply system is connected to one terminal of the motor 111, and the other is connected to one contact 112 which is adapted to be closed or opened by the armature 113 of the relay whose activating coil is 110. This armature also closes the contact 114 which is connected to one terminal of the secondary of transformer 109.

In the arrangement illustrated in Fig. 3, the signal used as a source of control is the voltage supplied to the grid of the "white" printer tube in the printer amplifier, and reference should be had here to my copending application Serial No. 133,135 filed March 26, 1937. This varies from zero on white to about twenty volts negative on black. The framing line is fully black and, therefore, twenty volts is delivered to the resistor 60 during the framing line. The threshold rectifier 62 is introduced to prevent noise of any value less than about 60% of this twenty volts from affecting the control tube 64. The threshold setting is determined by the setting of the moving contact on resistor 77. The tube 65 and commutator circuit of the brushes 68 and 69 form one-half of the bridge, the other half being furnished by the circuit of the brushes 69 and 70, and the resistor 79. The resistor 79 is set in value to equal the plate resistance of the tube 65 with no signal, and thus to balance the bridge. The two halves of the bridge are held balanced by the glow tube regulators 81 and 83. The output voltage of the bridge is obtained from the resistance-capacity combination 74 and 75, and the resistance 73 is used to set the over-all amplification of the system. The oscillator 89 uses a conventionally tuned plate circuit and is self-biased by the resistance-condenser combination 99 and 100. The potentiometer 98 adjusts the grid drive and controls the frequency over a fairly wide range. By varying the value of resistor 80 and resistor 99, and by readjusting the frequency of the oscillator to a desired number of cycles which in practice has been 60, the change of rate of drift of frequency of the oscillator with line voltage can be brought to a minimum. This adjustment must be made with the load tube 90 drawing its normal load from the oscillator through a resistor 115 which has one terminal thereof connected to the cathode of tube 90 and the other terminal thereof connected to one terminal of the resistor 99. This is not critical.

As well as regulating the bridge voltages, the two glow tubes 81 and 83 regulate the oscillator plate supply and the load tube.

The output stage, which in practice has comprised two 6-L-6-G tubes connected in push-pull is excited directly from the oscillator and is biased by the voltage drop in the filter reactor 84. The output transformer has been especially designed to deliver a full 110 volts to the standard motor used when the motor is properly tuned by its capacitor 117. In practice, the total load on the 400 volt supply is 215 milliamperes of which the output stage draws 160 milliamperes plate current and twenty milliamperes screen current. Total plate and screen load of this stage has been 72 watts, and the output realized is 25 watts in the motor, 3 watts in the output transformer and 2

watts in the screen resistor 118. Thus, the plate dissipation of the tube is 21 watts, which is within the tube rating. The motor when stalled offers too low an impedance to the transformer 109 which so reduces the voltage that the system is not self-starting. To overcome this, a relay is provided which starts the motor on the non-synchronous 110 volt 60 cycle supply illustrated, and when the tubes 103 and 104 have warmed up, the coil 110 actuates the armature 113 which normally is in contact with the contactor 112 and thus switches the supply to the motor to the transformer.

It will be appreciated that the bridge circuit which develops the corrective voltage operates similarly to the bridge as illustrated in Fig. 2 to develop a corrective signal by storing energy in the condenser 75, whose polarity is determined by whether the motor is operating too fast or too slow. If the motor runs slow, the direction of the signal is such that the control grid of tube 90 is rendered more positive and thus draws more current from the oscillator tube, and in effect lessens the inductance of the tank circuit of the oscillator and hence the frequency of oscillation is raised, which tends to speed the motor up. The reverse is true if the motor is running fast, the charge on condenser 75 is stored in such a direction as to bias the grid of tube 90 more negatively, hence the load tube draws less current from the oscillator, and the effect is that the inductance of the tank circuit is increased, and hence its frequency of oscillation is decreased, and the motor is slowed down.

If the machine is completely out of frame so that no signals come in during the time when a conducting portion of the commutator is in contact with one of the brush members, the oscillator or other control device is set for the extreme slow position by a maximum charge being impressed on the storage capacitor in the slow direction. This will cause the recorder motor to run slowly enough to come to a position gradually where the commutator overlaps the received signal, and from this position it will come into exact frame by the slow or fast action of the corrections then applied. Thus the recorder seeks the frame position, and then synchronizes on this exactly.

Referring to Fig. 4, there is shown another embodiment of my invention. The corrective signal developing circuit in this figure is somewhat similar to that disclosed in Fig. 2. The batteries 46 and 47 of Fig. 2 have been supplanted by glow tubes, and a triode arrangement is used rather than a duo-diode-triode, and the signal is impressed onto a time constant circuit in the control grid-cathode circuit of the triode.

In the figure, the input signal is impressed on a resistor 120 which has one terminal thereof connected to the control grid of a triode 121, and the other terminal thereof connected to ground. Connected in parallel with the resistor is a condenser 122. The anode of tube 121 is connected serially to a brush member 123, the brush member being one of three brushes 123, 124 and 125, which are adapted to co-act with a commutator having at least one L-shaped conductor 126 and an insulating section 127. The brush member 124 is connected serially to a resistor-condenser combination 128 and 129 respectively, the condenser being adapted to store the corrective charge. The terminal of the resistance-condenser combination 128 and 129, which is remote to that connected to the brush 124, is connected to ground at 130 through a

condenser 131. The brush member 125 is connected serially with the variable resistor 132, the latter having the terminal thereof remote from that connected to the brush member 125 connected to one electrode of a glow discharge tube 133. The other electrode of the glow discharge tube is connected to the terminal of the resistance-condenser combination 128 and 129 which is remote from the terminal connected to the brush member 124. Also connected to this terminal is one electrode of a second glow tube 134 and the other electrode thereof is grounded. The electrode of glow tube 133, which is connected to one terminal of variable resistor 132 is connected through a resistance 135 to the cathode of a full wave rectifying tube 136.

The tube 136 has the normal apparatus associated therewith for rectifying an alternating current supply wave, the cathode thereof being heated from one secondary of a transformer 137, the other secondary thereof having its terminals connected to two anode members 138 and 139. Shunted across the rectified output are three condensers 140, 141 and 142 which are filter condensers, and a filter choke 143 is connected serially with one side of the line which is grounded at 144. Also serially connected with the filter choke is a biasing resistor 145 having the terminal thereof remote from the terminal connected to the filter choke 143 connected to a bias resistor 146, the latter being grounded through the filter condenser 147. The elements 135 through 146 comprise the power supply for the apparatus.

The terminal of resistor 132, which is remote from the terminal thereof connected to brush 125, is connected to the anode of a thermionic tube 150 having a resistance 151 connected serially with the two anodic sections 152 and 153. The control grid of this tube is connected through a resistor 154 to one terminal of the resistance-condenser combination 128 and 129. The cathode of the tube has a resistor 155 serially connected therewith. This tube comprises the so-called "magic eye" type of tube, and its function will be explained more in detail hereinafter. The control grid of the tube 150 is also connected to the control grid of the load tube 156, and hence is connected through resistor 154 to one terminal of the resistance-condenser combination 128 and 129. The load tube has the anode thereof connected to the anode of oscillator tube 157 through a resistance member 158. The cathode of the load tube 156 is connected through resistor 159 to one terminal of the resistor 155. The control grid of the oscillator tube 157 is connected to the sliding arm of a potentiometer 160, the potentiometer having one of its terminals connected through resistor 161 and resistor 162 to the cathode of tube 157. The common terminal of resistors 161 and 162 is connected to the common terminal of resistors 155 and 159. The resistance 162 has a condenser 163 shunted in parallel therewith, and this resistance-condenser combination acts as a self-biasing arrangement. The terminal of potentiometer 160, remote from the terminal thereof connected to the resistance 161, is connected to one terminal of an inductive member 164 having a tap associated therewith, the tap member being connected back to cathode of the tube 157 through the resistance 162. The anode of tube 157 is connected to one terminal of an inductance 165 which is inductively associated with the inductance 164. This inductance has a tapped section,

and the tapping terminal is connected to one terminal of a condenser 166 which has its other terminal connected to the anode, and also the tapping section is connected to one terminal of a condenser 167, the other terminal thereof being connected to the common terminal of resistors 161 and 162. The common terminal of resistance 161 and 162 is connected to the terminal of the resistance-condenser combination 128 and 129 remote from the terminal thereof which is connected to the grid of the load tube 156. The anodes of tubes 156 and 157 are energized by electrically connecting the anodes to the positive side of the power supply through resistor 168. The output of the oscillator is fed to the control grid of an amplifying tube 171 which, in this case, is illustrated as a screen grid tube. The plate circuit inductance 165 of tube 157 has one terminal thereof connected to the control grid of tube 171 through condenser 172 and resistor 173. The common terminal of condenser 172 and 173 is connected through resistor 174 to the common terminal of resistor 146 and condenser 147. The cathode of tube 171 is grounded. The screen grid of tube 171 is energized from the positive side of the supply through a resistor 175. The anode of tube 171 is grounded through a condenser 176 and is also connected to the positive side of the supply line through a coil member 177. The coil member controls the vibration of an armature 178 which is associated with two contacts 179 and 180. The contact 179 is connected to the armature through a resistor 181 and a condenser 182. The armature and one terminal of the condenser is grounded at 183. The contactor 180 is connected or is grounded at the point 183 through a resistor 184 and a condenser 185, the condenser 185 and the condenser 182 having a common terminal. Shunted in parallel with the series combination of condensers 182 and 185 is the primary 186 of a transformer, and the center tap of the primary is connected to the cathode of tube 136 through an inductive member 187, the inductance being grounded at each terminal thereof through condensers 188 and 189 respectively. The output from the transformer whose secondary is 190 is used to drive the motor synchronously. The resistors 181, 184 and condensers 182, 185 are used as spark suppressors for the vibrator; and the inductance 187, and the condensers 188 and 189 form a filter.

The operation of the device is as follows: With synchronous operation, the top of the L-shaped conducting segment 126 should just open the circuit of the brush 125 simultaneously with the beginning of the synchronizing signal, and the signal should last for a time until the brushes 123 and 124 are opened by the insulating section of the commutator, that is to say, they have just passed the edge of the L-shaped conductor. If the machine is in synchronism, the effect of the opening of the circuit of the brush 125 which normally would unbalance the bridge is offset by the effect of the synchronizing signal in driving the tube 121 to cut-off. Consequently, the bridge remains balanced and no charge is stored in the condenser 129.

On the other hand, if the machine is operating too fast, the circuit of the brush 125 is opened while brushes 123 and 124 remain closed. This means that the anode circuit of tube 121 is closed while the tube is conducting, and as a consequence the bridge comprising the internal resistance of tube 121, resistance 132, glow lamps

133 and 134 is unbalanced, and there is impressed across condenser 129 a voltage which charges the condenser to a degree depending upon the length of time that tube 121 is conducting. If the machine is only slightly fast, a synchronizing signal will come in while tube 121 is conducting for only a short period of time, and as a consequence the charge accumulated on the condenser 129 will be small. This charge is in such a direction as to bias the grid of tube 156 negatively, and the tube 156 being a load tube draws less current from the plate of tube 157 which effectively changes the inductance of the tank circuit of the oscillator tube 157 so as to decrease the natural period of oscillation of the oscillator, thus slowing down the vibrator armature 178 and thus slowing down the driving motor. On the other hand, if the device is operating slowly, the synchronizing signal will come in and drive the tube 121 to cut-off while brushes 124 and 125 are still in contact with the conducting section 126 of the commutator, and the result will be that the bridge is unbalanced and that a charge will be stored in the direction opposite to that which is stored when the brush 125 is open and the tube 121 is conducting. This charge is in such a direction as to bias the grid of the tube 156 positively, and hence this tube draws more current from the oscillator tube 157 and effectively changes the inductance of the tank circuit so that the oscillator period of oscillation is increased. Consequently, the armature 178 is vibrated more rapidly, and thus passes to the driving motor a higher frequency than when the device is operating synchronously.

Tube 150 is the so-called "magic eye" type of tube which gives a light and shadow portion which is proportional to the potential impressed on the grid of the tube. The parameters of resistance 155 are chosen so that the eye is open half way of its total swing. It will be observed from the drawing that the corrective pulses go not only to the grid of tube 156 but also to the grid of this tube 150. The "eye" will then close or open to an extent depending upon the direction of the charge on the terminal of the condenser 129 to which the grid of tube 150 is connected. Hence, a visual indication is given of the direction of the correction needed, that is to say, as to whether the device is operating slowly or too speedily.

It will be appreciated that there are a number of modifications that well fall within the spirit and scope of the invention. For instance, the commutator might be entirely conducting with the exception of a small insulating section having the width of the upper section of the L-shaped conductor illustrated in Fig. 4, and a lower insulating section which would contact with brush 123 and which would be of the width of the presently shown conducting sections. The tube 121 might be biased to cut off and could be rendered conducting by the synchronizing signal instead of the presently illustrated system wherein the tube is driven to cut-off.

Again, the corrective voltage need not change the frequency of an oscillator as is done here, but might very well be used to vary the voltage supplied to a motor. It will be appreciated that all such arrangements will fall fairly within the spirit and scope of my invention.

Due to the high capacity of condenser 129, the correction being applied once per cycle of the movement of the commutator is illustrated here,

the condenser tends to effect the corrective effect over the entire cycle.

Referring to Fig. 5, there is shown a still further embodiment of my invention. In this figure, the recurrent synchronizing signal is impressed across a resistor 200 connected in the control grid-cathode circuit of a vacuum tube 201. The anode of the tube is connected to a brush 202 which is one of three brushes 202, 203 and 204 mounted adjacent to each other and in such position as to be co-operatively associated with the commutator member having an L-shaped conducting segment 205 and an insulating segment 206. The commutating member is driven through appropriate gearing means 207 by the recorder motor 208 which has on the shaft thereof a flyball governor 209 to which is fastened a disc member 210.

The brush member 203 is connected to the control grid of a thermionic tube 211 and is also connected to the cathode thereof through a resistance-condenser combination comprising a resistance 212 and a condenser 213. The terminal of the resistance-condenser combination remote from the terminal which joins the brush member 203 being connected to the cathode of tube 211 through a resistor 215. The brush member 204 is connected through a resistor 216 to the positive terminal of a source of potential 217 whose negative terminal is connected to the terminal of the resistance-condenser combination 212 and 213 remote from the terminal thereof connected to the brush member 203. The common terminal of the potential supply 217 and the resistance-condenser combination is also connected to the positive terminal of a second source of potential supply 218 whose negative terminal is grounded. The common terminal of the resistor 216 and the source of potential supply 217 is connected to the anode of tube 211 through the magnetic winding 220 which is wound about a magnetic core member 221, and the latter being adapted to be energized by currents flowing through the winding 220. Positioned immediately adjacent the core member 221 is a magnetic arm member 222 which is pivoted at the point 223 and is held under restraint by a spring member 224 so that the end thereof which is remote from the core member 221 is pressed into engagement with the disc member 210, the latter being connected to the flyball governor 209. The end of the arm which is normally pressed against the rotating disc 210 has joined thereto a friction pad 224 which bears against the surface of the disc 210.

The operation of the device is as follows: The two sources of potential 217 and 218, the resistor 216, the tube 201 and the resistance-condenser combination 212, 213 form an equivalent bridge system connected to the commutator as illustrated in Fig. 2. Thus the condenser 213 will have developed thereacross voltages varying in direction and amplitude according to the phase of the commutator with respect to the transmitted signal. This corrective voltage is applied directly to the grid of tube 211, the tube being biased by the resistor 215 so as to give a center governor setting. The plate current of the tube 211 then controls the motor speed in either direction by varying the position of the governor control lever 222 electromagnetically by the element 221 against the force of the spring 224. The charge on the condenser 213 thus will vary the friction pad pressure of the governor in such a direction as to correct any speed change that

might take place, and thus frame and synchronize the governor motor.

What I claim is:

1. A synchronizing apparatus comprising means for receiving synchronizing signals from an external source, means for developing a signal within said apparatus, means for comparing said received signal and said developed signal to develop a corrective signal of a value and polarity proportional to the deviation from synchronous position of the device to be synchronized, and means responsive to said corrective signal for controlling the rate of operation of the device to be synchronized.

2. Apparatus in accordance with claim 1 wherein said received signal and said signal developed within said apparatus are impressed on a Wheatstone bridge for comparison purposes.

3. A synchronizing apparatus comprising means for receiving synchronizing signals from a source external from said apparatus, means for rectifying said received signal, a signal generator within said apparatus, means for controlling the signal generator within said apparatus for a predeterminable period of time by said rectified signal, means for comparing said signal from an external source and said signal generated within said apparatus, means for storing energy in accordance with the value of and of a polarity dependent upon the comparison of the compared signals, said stored energy serving as a corrective signal, and means responsive to said stored energy for controlling the speed of operation of the device to be synchronized.

4. Apparatus in accordance with claim 1 wherein the device to which the corrective signal is applied to control the rate of operation comprises an oscillator.

5. Apparatus in accordance with claim 3 wherein the corrective signal affects the period of oscillation of an oscillator.

6. A synchronizing apparatus comprising means for receiving synchronizing signals from a source external to said apparatus, means for developing a signal within said apparatus at predeterminable intervals, means for comparing said received signals with said signal developed within said apparatus comprising a Wheatstone bridge, storage means electrically connected to two non-adjacent junction points of said bridge whereby energy is stored in said storage means in a direction and of a quantity dependent upon the comparison of said energizing signals and said signals developed within said apparatus, and means responsive to said stored energy to control the rate of operation of said device to be synchronized.

7. Apparatus in accordance with claim 6 wherein the device whose rate of operation is controlled by the stored energy comprises an oscillator.

8. Apparatus in accordance with claim 3 wherein the device whose rate of operation is controlled by the stored energy comprises an oscillator.

9. Apparatus in accordance with claim 6 wherein the device to which the corrective signal is applied comprises a prime mover governor.

10. Apparatus in accordance with claim 3 wherein the device to which the corrective signal is applied comprises a prime mover governor.

11. Apparatus in accordance with claim 6 wherein the device which is controlled by said stored energy comprises a mechanical vibrating element.

12. Apparatus in accordance with claim 3 wherein the device which is controlled by said stored energy comprises a mechanical vibrating element.

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