

Nov. 3, 1942.

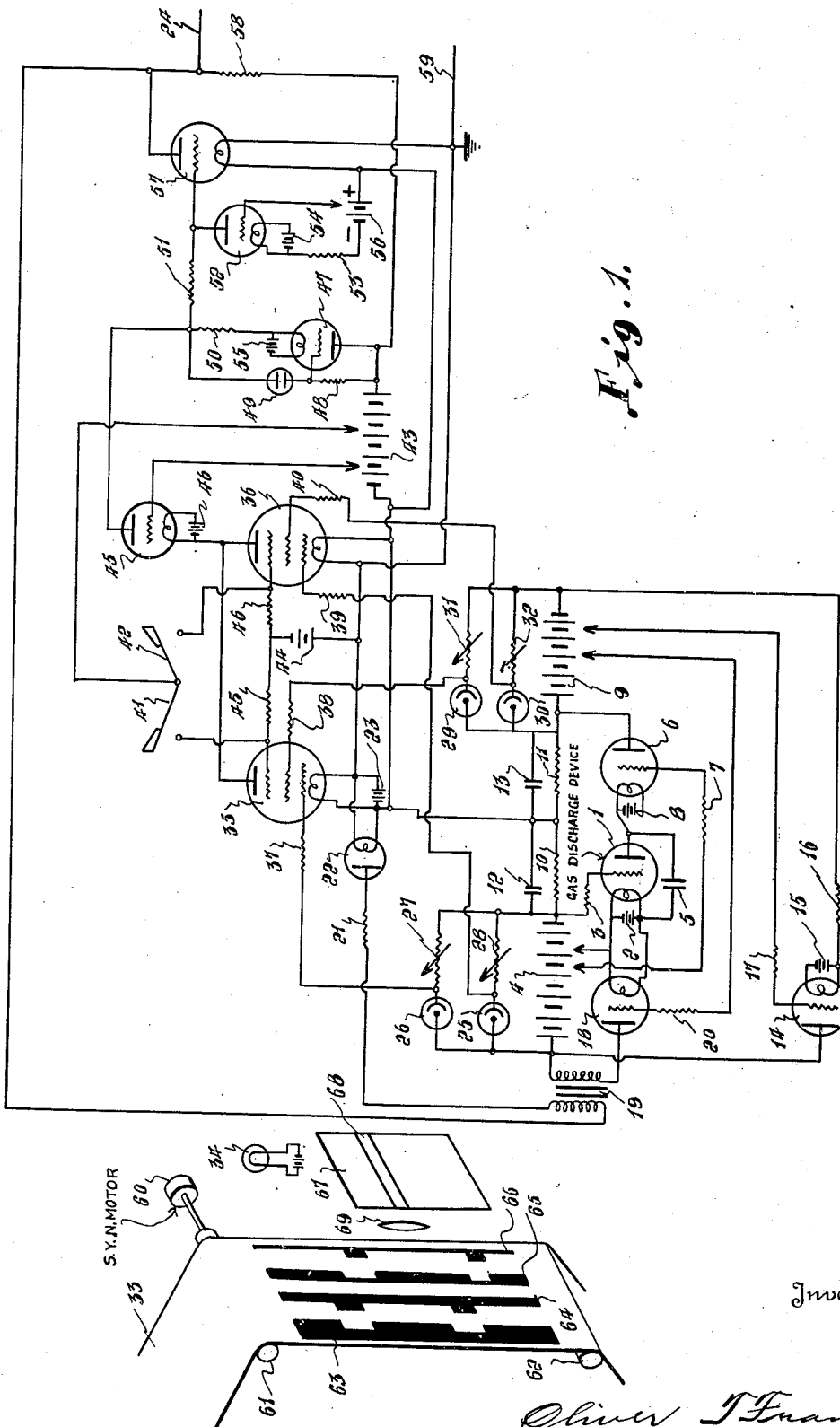
O. T. FRANCIS

2,300,664

MULTIPLEX SYSTEM

Filed April 25, 1940

3 Sheets-Sheet 1



Nov. 3, 1942.

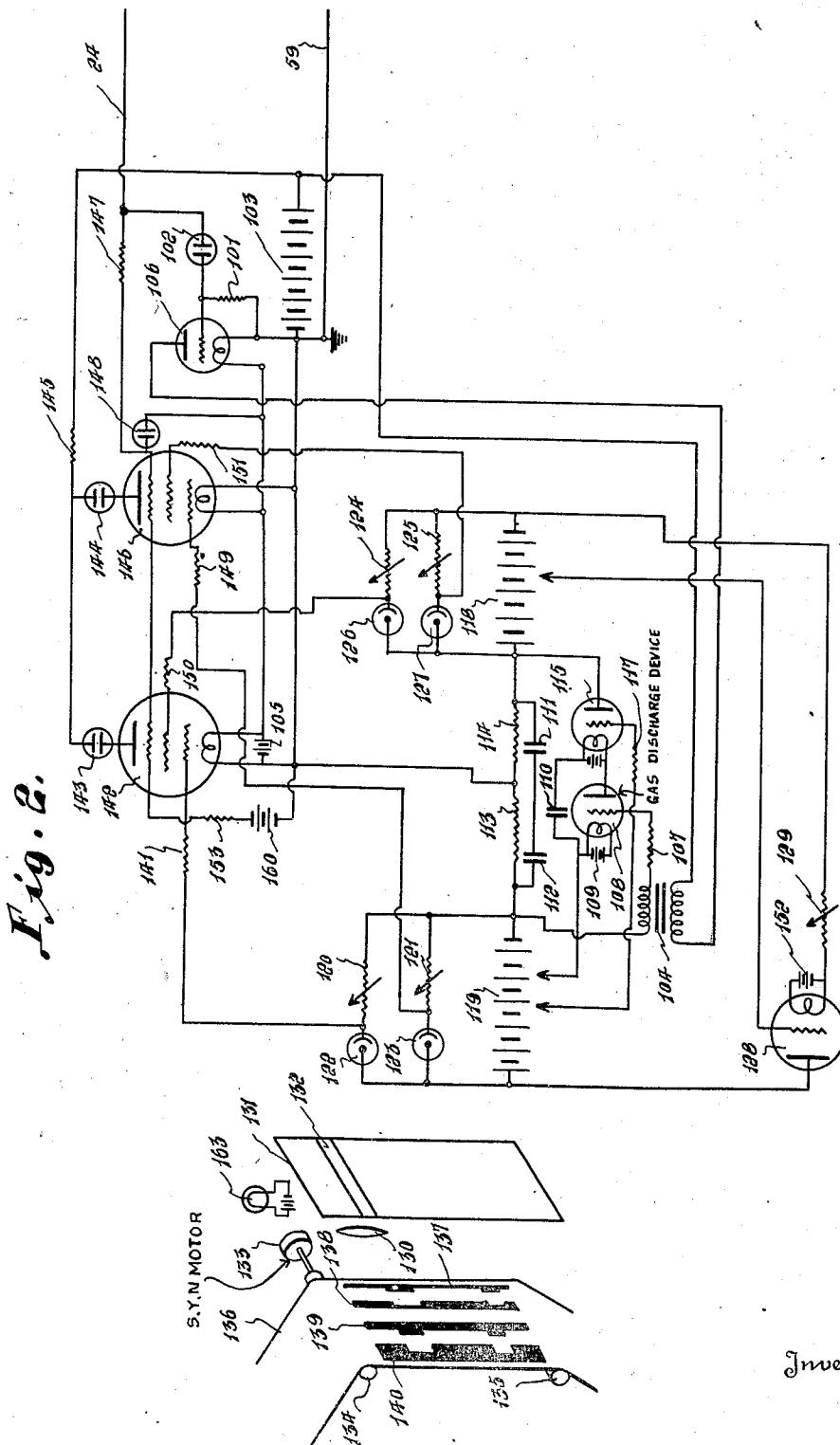
O. T. FRANCIS

2,300,664

MULTIPLEX SYSTEM

Filed April 25, 1940

3 Sheets-Sheet 2



Inventor

Oliver J. Francis.

Nov. 3, 1942.

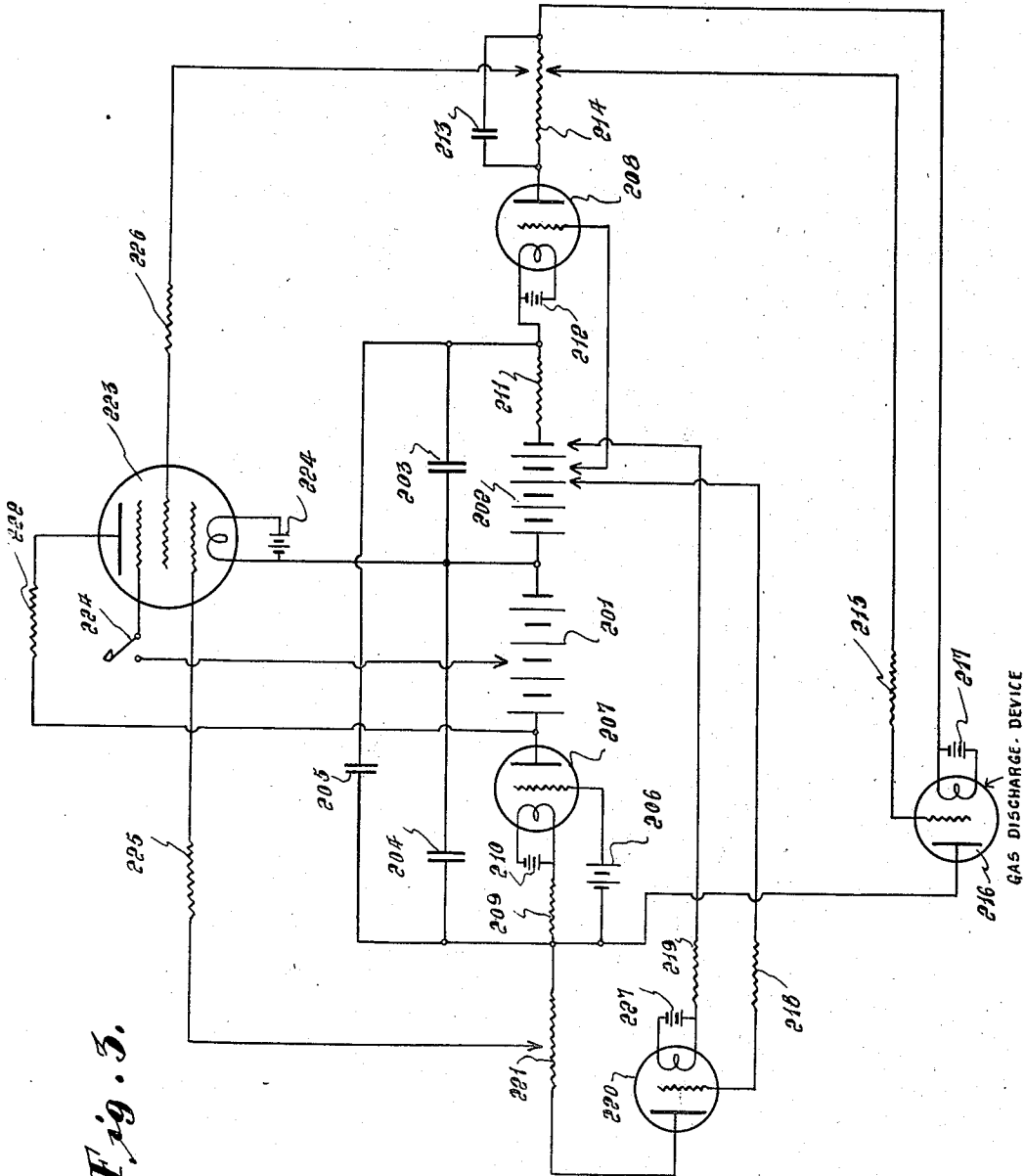
O. T. FRANCIS

2,300,664

MULTIPLEX SYSTEM

Filed April 25, 1940

3 Sheets-Sheet 3



UNITED STATES PATENT OFFICE

2,300,664

MULTIPLEX SYSTEM

Oliver T. Francis, Renville, Minn.

Application April 25, 1940, Serial No. 331,644

19 Claims. (Cl. 178—22)

This invention relates to multiplex systems on the time division basis, and more particularly to electronic commutators used at the transmitting and receiving stations, to means for shifting multiplex channels from one to another and to means for synchronizing said commutators.

This invention is a continuation in part of my copending application Ser. No. 281,965 filed June 29, 1939 entitled "Electronic commutator."

In the above application a synchronizing station separate from, and operating on a different frequency from the signal transmitting station was illustrated. It is an object of this invention to illustrate means whereby the synchronizing pulses may be sent out over the same channel as the signals are sent over.

In multiplex signal amplification comprising the amplification of a series of pulsations of the same polarity, difficulty is experienced in amplifying the "square wave" forms without undue distortion. Especially is this the case where the number of channels involved is large. The "tails" left on the signals by transformer, impedance, or even resistance condenser coupling are well known to those experimenting in these fields. Combinations of resistance and impedance coupling have given somewhat better results, but even here electrical "inertia" once introduced into a circuit is difficult to compensate against. In U. S. Patent No. 1,886,386 issued to me November 8, 1932, I illustrated a method of amplification whereby weak signals may be built up to any desired strength in a single stage of amplification without the use of capacitive or inductive reactances. It is an object of this invention to illustrate how the system of amplification therein illustrated may be adapted to distortionless amplification of the "square wave" forms of multiplex systems and similar systems.

In multiplex systems the scanner voltages usually obtained from three electrode gas discharge devices, is limited to 100 or 200 volts if any degree of linearity is to be preserved. The power obtainable from such circuits where the number of commutator units involved is large is limited. It is an object of this invention to illustrate how the magnitude of this "sweep voltage" may be increased to any desired degree by placing said gas discharge device in the input and output circuit of a thermionic tube, and placing a vacuum tube choke as the load of said thermionic tube.

Multiplex signal communication is not a secret method of communication, since it may be picked up by anyone having similar apparatus. It is an

object of this invention to illustrate a multiplex system which is rendered secret by means of a random method of shifting said channels at frequent intervals.

With these and other objects in view the invention may be more readily understood by reference to the following description and drawings wherein:

Fig. 1 is a multiplex signal transmitter.

Fig. 2 is a multiplex signal receiver.

Fig. 3 is a modification of Fig. 1.

Referring to Fig. 1, 1 is a grid controlled gas discharge device, the cathode of which is heated by an A battery 2, the grid of which is connected through a resistance 3 to a negative source of voltage 4, the cathode of gas device 1 being connected to 4 at a more positive potential to thereby place the desired negative potential on the grid of 1. In parallel with 1 is a condenser 5. Device 1 is connected in the input and output circuit of thermionic grid controlled tube 6. The grid of 6 is connected through a resistance 7 to a point on battery 4 more positive than the cathode of 1 to reduce the IR drop across tube 6. The cathode of tube 6 is heated by an A battery 8. The anode of 6 is connected to source of voltage 9. In parallel with tubes 1 and 6, are connected resistances 10 and 11, which in turn are in parallel with small condensers 12 and 13, which act to bypass high frequency transients.

In the output circuit of 1 and 6 is connected vacuum tube choke 14, the anode of which is connected to the positive terminal of battery 4, the cathode being heated by battery 15, and connected through resistance 16 to the negative terminal of battery 9. The grid of 14 is connected through resistance 17 to a point on 9 more positive than its cathode to render the direct current voltage drop across 14 small.

Grid controlled thermionic tube 18, with its cathode heated by battery 2, and its anode connected through primary of transformer 19 to the positive terminal of battery 4, and its grid connected through resistance 20 to a negative point on battery 9 comprises a means for impressing synchronizing pulses on secondary of 19. One terminal of secondary 19 is connected through a resistance 21, and rectifier tube 22, the filament of which is heated by battery 23, to ground. The other terminal of the secondary is connected to the other side of line 24.

Across battery 4 is a plurality of potentiometers comprising photo-electric cells 25, 26 and variable resistances 27, 28. Across battery 9 is a plurality of potentiometers comprising photo-

electric cells 29, 30 and variable resistances 31, 32. Tape 33, which is illuminated by a source of light 34, controls the impedance of photo-electric cells 25, 26, 29, 30 in the following manner.

Light from source 34 illuminates tape 33. On this tape are darkened strips 63, 64, 65, 66. Light from strip 63 is focused by lens system 69 through linear opening 68 in shield 67 onto photo-electric cell 25. Light from strip 64 is focused onto 26. Light from strip 65 is focused onto cell 29 and light from strip 66 is focused onto cell 30. Tape 33 is drawn over roller 62 in front of opening 68 by roller 61 which in turn is drawn by synchronous motor 60.

Two commutator tubes 35, 36 are shown in Fig. 1, and operate on the differential grid action described in my above referred to copending application. Tube 35 has two scanner grids one of which is connected through high resistance 37 to the connection between photo-electric cell 26 and variable resistance 27. The other scanner grid of tube 35 is connected through high resistance 38 to the connection between photo-electric cell 29 and variable resistance 31. Similarly the scanner grids of tube 36 are connected through high resistance 39 to the connection between the photo-electric cell 25 and variable resistance 28, and through resistance 40 to a point between photo-electric cell 30 and resistance 32. Once these variable resistances have been set at a desired value it will be evident that the potential on the scanner grids of tubes 35, 36 will be controlled by the impedance of photo-electric cells 25, 26, 29, 30 which in turn is controlled by light reflected from various parts of film 33 onto these cells in a manner described above. It is therefore evident that the sequence of scanning tubes 35, 36 operability is controlled in accordance with secret tape 33.

The means for impressing signals on tubes 35, 36 comprises keys 41, 42 connected to battery 43, to impress a positive potential on the third grids of 35, 36 to counteract the effect of the normal negative bias impressed on these grids by C battery 44 through resistances 45, 46. The cathodes of 35, 36 are heated by battery 23.

The anodes of tubes 35, 36 are connected to the cathode of tube 45 in such a manner as to render their plate impedances common to the input and output circuits of amplifier three electrode tube 45, the cathode of 45 being heated by a battery 46. In the output circuit of tube 45 is connected vacuum tube choke 47 having its cathode heated by battery 55. Resistance 50 is common to the input and output circuits of 47. A high resistance 48 impresses a positive potential on grid of 47 through gas tube 49, which counteracts the effect of the normally high negative potential impressed on the grid of 47 by the IR drop through resistance 50, and thereby renders the direct current impedance of tube 47 small. Reference is made to my U. S. Patent No. 1,886,386 issued November 8, 1932, for further description of amplification produced by tubes such as 45, and 47.

The grid and cathode of amplifier 57 are connected across vacuum tube choke 47 in a novel manner comprising a high resistance 51 and a vacuum tube grid leak 52. The plate of tube 45 is maintained at a much higher D. C. potential than required by grid of amplifier 57. The resistance 51 has a high impedance to D. C. currents while tube 52 has a low D. C. impedance depending on the point where its grid is con-

nected to battery 56. Tube 52 on the other hand has an extremely high impedance to the flow of alternating current, this A. C. impedance being equal to the value of resistance 53 plus the product of the ohmic resistance of 53 and the μ of tube 52. It is therefore evident that the grid of 57 is maintained at its proper operating voltage by reason of the direct current IR drop through resistance 51, whereas substantially all of the A. C. generated across tube 47 is impressed on grid of 57. The resistance 53 is common to the anode and grid circuit of tube 52 and is connected through a proper biasing battery 56 to the cathode of tube 57, which cathode is in turn heated by battery 23. In the output circuit of tube 57 is load resistance 58, and voltage variations thereacross are passed on to a receiving station by means of lines 24, 59.

Fig. 2 illustrates a multiplex receiving station for receiving the signals sent out by transmitting station shown in Fig. 1. Synchronizing pulses received from transmitting station over lines 24, 59 are in the present instance of opposite polarity to and greater in magnitude than the signal pulses so as to render a current to flow from 59 through resistance 101, gas tube 102 back to line 24. The breakdown voltage of 102 is of much higher value than the signal pulses so that the signal pulses will not effect the bias of thermionic three electrode tube 106. A negative bias is placed on tube 106 by the synchronizing pulses, thereby causing a decrease in its plate current flowing from battery 103 through primary of transformer 104 to plate of the tube 106. The secondary of 104 is so poled that a positive surge of voltage is impressed on grid controlled gas discharge device 108, through resistance 107, thereby overcoming the effect of the high negative bias impressed on 108 by battery 119. Gas device 108 then discharges condenser 110. The cathode of 108 is heated by battery 109 and is connected to a point on battery 119 more positive than its control grid.

One plate of condenser 110 is connected to the cathode of three electrode thermionic tube 115. The other plate of condenser 110 is connected to the cathode of gas discharge device 108. The grid of tube 115 is connected to battery 119 through resistance 117 to a point more positive than the cathode of 108, to render the voltage drop across 115 small when condenser 110 is discharged through gas device 108. Since the condenser 110 is in the grid cathode circuit of tube 115, as the voltage builds up across this condenser a negative potential is impressed on grid of tube 115.

In the common output circuit of tube 115, and gas device 108 is connected a vacuum tube choke 128, of the three electrode high vacuum type. The anode of 128 is connected to the positive terminal of battery 119. Its cathode is heated by battery 152, and connected through variable resistance 129 to the negative terminal of battery 118. The grid of tube 128 is connected to battery 118 at a point more positive than its cathode, thereby rendering the plate impedance of tube 128 small when a small anode voltage is impressed thereon through tubes 108, 115.

Across battery 119 are potentiometers comprising photo-electric cells 122, 123, variable resistances 120, 121. Across battery 118 are potentiometers comprising photo-electric cells 126, 127 and variable resistances 124, 125. The impedance of these photo-electric cells is controlled by light reflected from tape 136 which is illumi-

nated by a source of light 163. The movement of tape 136 is synchronized with the movement of tape 33 at the transmitting station by synchronous motor 133 driving rollers 134 and pulling tape 136 over roller 135. Light from the darkened portion 137 is focused through lens system 130 through linear opening 132 in shutter 131 onto photo-electric cell 122. Similarly the darkened portion 138 is focused on cell 123, and darkened portion 139, 140 are respectively focused on cells 126, 127, thereby rendering scanner tubes 142, 146 operable at different values of voltage existing across resistances 113, 114, which resistances are connected across the plate impedances of tubes 115, 108. Condensers 111, 112 are shunted across these resistances to by-pass high frequency transients existing in the circuit.

The cathodes of scanner tubes 142, 146 are heated by battery 105 and connected to the center point of resistance 113, 114. One of the scanner grids of tubes 142 is connected through high resistance 141 to the cathode of photo-electric cells 122. The other scanner grid is connected through high resistance 150 to the cathode of photo-electric cell 126. Similarly one of the scanner grids of tube 146 is connected through resistance 149 to the cathode of cell 123, while the other scanner grid is connected through resistance 151 to cathode of cell 127.

The control grids of tubes 142, 146 are connected in parallel to line 24, through resistance 147, a gas regulator tube 148 in parallel with resistance 153 and battery 160, regulating the magnitude of this voltage to a predetermined limit.

In the output circuit of tubes 142, 146 is battery 103, resistance 145 and their respective loads 143, 144, here shown in the form of neon lamps.

In operation when the key controlling one of the commutator tubes is closed at the transmitting station a signal is sent out during a portion of the time interval between synchronizing pulses, which portion is variable in accordance with the record on tape 33. This signal appears at the receiving station in its corresponding receiving unit, which unit is operative during the same portion of said time interval as its corresponding commutator tube at the transmitting station and variable in accordance with secret tape 136 in synchronism with variations in said transmitting station.

The means for maintaining synchronism are shown as synchronous motors. Where alternating current from the same source is available such method of maintaining synchronism between the movement of tape 33 and 136 is ideal. Where currents from a single source are not available at the transmitting and receiving stations other known methods may be resorted to, such as the synchronously driven magnets, which have been used in driving the mechanical commutators of multiplex telegraphy for many years, or synchronized clock mechanisms may be used. It is therefore not desired to limit the synchronous tape driving mechanism of the transmitting and receiving stations to the synchronous motors described.

The circuits shown in Figs. 1 and 2 each require three sources of high voltage supply. This adds weight to the equipment. As two of these sources are not at ground potential, but vary from ground potential as the voltage across the gas discharge device varies, undesirable transients are introduced into the circuit. Fig. 3

shows how these sources of high voltage may be obtained from a single supply at ground potential and thereby make possible simplification of circuit arrangement.

Referring to Fig. 3, batteries 201, 202, constitute a single source of voltage supply. The scanner voltage generating circuit may be traced as follows: positive terminal of battery 201, vacuum tube choke 207, gas discharge device 216, biasing resistor 214, vacuum tube choke 208, battery 202. Vacuum tube choke 207 is a high vacuum three electrode tube having its filament heated by battery 210, a resistance 209 common to its plate and grid circuits, and C-battery 206 poled to place a positive potential on its grid to render its impedance low to D. C. currents.

Vacuum tube choke 208 similarly is a three electrode high vacuum tube having its filament heated by battery 212, resistance 211 being common to its plate and grid circuits, and its grid connected to battery 202 at a point more positive than its filament to render its D. C. impedance small.

Tube 216 is a grid controlled gas discharge device, its filament being heated by battery 217 and connected to the positive terminal of biasing resistance 214. Its grid is connected through resistance 215 to a point on biasing resistance 214 more negative than its filament. Condenser 205 in parallel with transient by-pass condensers 203, 204 is connected in parallel with device 216.

One scanner tube 223, with its filament heated by battery 224, is shown. Its anode current is supplied through load resistance 222, the signal is impressed thereon by placing a positive voltage on its signal grid from battery 201. One of the scanner grids of tube 223 is connected through high resistance 225 across vacuum tube choke 207 through a source of biasing voltage consisting of resistance 221 in series with vacuum tube choke 220. The other scanner grid of tube 223 is connected through resistance 226 to biasing resistance 214, which is in parallel with filter condenser 213 of high capacity.

Vacuum tube choke 220 is a three electrode vacuum tube with cathode heated by battery 227 and connected through resistance 219 to the negative terminal of battery 202. The control electrode of tube 220 is connected through resistance 218 to a point on battery 202 more positive than its filament to render the D. C. impedance of tube 220 small.

While I have illustrated one method of synchronized channel shifting arrangement in accordance with a secret record at a transmitting and receiving station, various other means may be used with a variety of electronic commutators without departing from the scope of my invention. My invention is to be limited in scope only by prior art and as described in the following claims.

What is claimed is:

1. In a multiplex time division signal communication system, a transmitting station, a plurality of sources of signals at said transmitting station, means for producing synchronizing pulses at a predetermined time interval, means for transmitting said signals from one of said sources during one portion of said time interval, means for shifting the portion of said time interval during which said signals from said one source are transmitted to other portions of said time interval, in accordance with a random record, a receiving station, a plurality of

signal receiving devices at said receiving station, means for impressing said signals from said one of said transmitting means on a corresponding one of said receiving devices during said one portion of said time interval, and means for shifting the portion of said time interval during which said receiving device receives signals in synchronism with said shifting of said one of said transmitting means, said last mentioned means comprising a second record similar to said first record at said receiving station, and means for synchronizing the movements of said records at said transmitting and receiving stations.

2. In a signalling system, a transmitting station, a vacuum tube having an input and an output circuit at said station, cyclically operable signal generating elements connected in parallel in said input and said output circuit, a load in said output circuit, a receiving station, cyclically operable signal receiving elements at said receiving station, means for synchronizing said signal generating elements with said signal receiving elements and means for applying voltages across said load produced by one of said signal generating elements to a corresponding one of said signal receiving elements.

3. In a signalling system, a transmitting station, a vacuum tube amplifier having an anode, a cathode, and a control electrode at said station, cyclically operable signal generating elements connected in parallel in the circuit of said control electrode, a load connected in the circuit of said anode, a second vacuum tube amplifier, having a plate, grid, and filament, a load connected in the circuit of said plate, said grid being connected to said anode through a voltage dropping resistance, a vacuum tube grid leak having an anode, a cathode and a control electrode, said grid being connected to said anode of said grid leak tube, said cathode of said grid leak tube being connected to said filament through a resistance common to the anode and control electrode circuit of said grid leak tube, a receiving station, cyclically operable signal receiving elements at said receiving station, means for synchronizing said signal generating elements with said signal receiving elements, and means for applying voltage variations across said load in said circuit of said plate of said second amplifier, produced by one of said signal generating elements, to a corresponding one of said signal receiving elements.

4. In a signalling system, a transmitting station, a plurality of signal generating elements at said station, a scanner voltage source, comprising a vacuum tube having an input and an output circuit, a generator of a variable voltage connected in said input and said output circuit, a load connected in said output circuit, means for rendering said signal generating elements sequentially operable as said voltage across said load varies, a receiving station, cyclically operable receiving elements at said receiving station, means for synchronizing said signal generating elements with said signal receiving elements, and means for applying signal produced by said generating elements to corresponding ones of said receiving elements.

5. In a signalling system, a transmitting station, cyclically operable signal generating elements at said station, a receiving station, cyclically operable signal receiving elements at said receiving station, means for synchronizing said generating elements with said receiving elements, means for synchronously generating

sequence controlling voltages at each of said stations, and means for synchronously changing the sequence of operability of said generating elements and said receiving elements to a new sequence with said sequence controlling voltages, said voltage generating means comprising similar photoelectric records at each of said stations, and means for synchronously varying the magnitude of said voltages generated at each of said stations in accordance with light variations synchronously produced at each of said stations by successive corresponding elemental areas of said records.

6. In a signalling system, cyclically operable transmitting elements, cyclically operable receiving elements, means for synchronizing said transmitting elements with said receiving elements, a photoelectric record, means for controlling the sequence of operability of one of said transmitting elements with light variations produced by successive elemental areas of said record, and a second photoelectric record for controlling the sequence of operability of one of said receiving elements in synchronism with said one of said transmitting elements, by light variations produced by corresponding successive elemental areas of said second record.

7. In a time division multiplex signaling system, an electronic commutator comprising a plurality of commutator unit vacuum tubes, a generator of a variable current, said generator comprising a vacuum tube having an input and output circuit, means for applying impulses to said input circuit, said last means comprising a condenser in parallel with a gas discharge device, having an anode, a cathode and a control electrode, said anode and said cathode being connected in said input and said output circuit, a load connected in said output circuit, means for rendering said unit vacuum tubes cyclically operable in accordance with said variable current, means for impressing a different signal on each of said unit vacuum tubes, a receiving station and means at said receiving station for receiving said signal.

8. In a multiplex signaling system, with a plurality of channels, a generator of variable current, said generator comprising a vacuum tube having an input and output circuit, means for supplying a voltage to said input circuit, said means comprising a gas discharge device and condenser in parallel, said device having an anode, a cathode, and a control electrode, said anode and said cathode being connected in said input and said output circuit, a vacuum tube choke connected in said output circuit, means for generating a synchronizing voltage, means for controlling the potential of said control electrode with said synchronizing voltage, means for rendering each of said channels operable at different portions of the cycle of said variable current, and means for controlling each of said channels with a different signal.

9. In a multiplex signaling system, with a plurality of channels, cyclically operable transmitting means, for each of said channels, cyclically operable receiving means for each of said channels, pulse generating means, said pulse generating means comprising a vacuum tube having an input and an output circuit, a gas discharge device in parallel with a condenser in series with a source of current and an impedance in said input circuit, a source of voltage and the primary of a transformer in said output circuit, an unidirectional current conductor in series with the

secondary of said transformer, means for storing energy in the core of said transformer during the interval said gas discharge device is non-conductive, and means for releasing said energy in the form of a high voltage pulse when said gas discharge device becomes conductive, and means for synchronizing said receiving means with said transmitting means with said high voltage pulse.

10. In a multiplex signaling system with a plurality of channels, cyclically operable transmitting means for each of said channels, said means comprising a vacuum tube having an anode, a cathode, and a control electrode, cyclically operable receiving means for each of said channels, means for synchronizing said transmitting and receiving means, means for impressing different signals on each of said transmitting means, means for amplifying said signals, said last means comprising a vacuum tube amplifier having an input and output circuit, a plate, filament and grid, said anode and said cathode of said first mentioned vacuum tube of each of said channels being connected in parallel in said input and output circuits, a load in said output circuit, a second vacuum tube amplifier having a plate, filament and grid, a voltage dropping resistance connecting the grid of said second amplifier to the plate of said first amplifier, a vacuum tube grid leak connecting said grid and filament of said second amplifier, said vacuum tube grid leak comprising a vacuum tube having a plate, grid and filament, the plate of said vacuum tube grid leak being connected to said grid of said second amplifier, the filament of said grid leak tube being connected to said filament of said second amplifier through a resistance, said last resistance being common to the plate and grid circuits of said grid leak, and means for controlling said receiving means with said amplified signal.

11. In a multiplex signaling system, a transmitting station, a receiving station, an electronic commutator at each of said stations, each of said commutators comprising a plurality of commutator unit vacuum tubes, each of said vacuum tubes having an anode, a cathode, and a control electrode, means for impressing a different signal on the control electrode of each of said vacuum tubes, means for amplifying said signals, said last means comprising an amplifier vacuum tube having an input and an output circuit, a load connected in said output circuit, means for applying said signals to said input circuit, said last means comprising the parallel connection of said anode and said cathode of each of said unit vacuum tubes in said input and said output circuits, means for synchronizing said commutators, and means at said receiving station for translating said voltages across said load into signals.

12. In a signaling system, means for producing a plurality of pulses of the same polarity, a first vacuum tube amplifier having an anode, a cathode, and a control electrode, a load connected in said anode circuit, means for impressing said pulses on said control electrode, a second vacuum tube amplifier having a plate, grid, and filament, a load in the plate circuit of said second amplifier, said grid being connected to said anode through a voltage dropping resistance, a grid leak comprising a vacuum tube having an anode, a cathode and a control electrode, said anode of said grid leak tube being connected to said grid, said cathode of said grid leak tube being connected to said filament through a resistance common to said anode and control electrode circuits

of said grid leak tube, a receiving station, and means at said receiving station for translating voltage variations across said last mentioned load into signals.

13. In a multiplex signaling system, cyclically operable units at a transmitting station, cyclically operable units at a receiving station, means for synchronizing said units at said transmitting and receiving stations, means for simultaneously changing the sequence of operability of said units at both of said stations to a different sequence, said last means comprising a tape at each of said stations and means for synchronizing the movements of said tape at each of said stations.

14. In a signaling system, a transmitting station, a receiving station, cyclically operable units at each of said stations, means for synchronizing said units at said transmitting and receiving stations, means for varying the sequence of operability of said units at both of said stations to a new sequence, said last means comprising similar tapes at each of said stations, means for synchronizing the movements of said tapes, and means for varying said sequence in accordance with a record on said tapes.

15. In a multiplex signaling system, a transmitting station, a receiving station, an electronic commutator at each of said stations, said commutators comprising commutator unit vacuum tubes, each of said vacuum tubes having a plurality of grids, means for synchronizing said commutators at said transmitting and receiving stations, said synchronizing means comprising means for generating a voltage at each of said stations, means for applying said voltage to said grids of each of said vacuum tubes to tend to produce a positive potential on one of said grids of each tube, and a negative potential on another of said grids of each of said tubes, means for biasing said grids of corresponding vacuum tubes of said commutators to render said corresponding units operable simultaneously, means for changing the sequence of operability of said vacuum tubes to a new sequence, said last means comprising a plurality of sources of voltage, a plurality of potentiometers across each of said sources of voltage for biasing said grids in different magnitudes, each of said potentiometers comprising a photo-electric cell and a resistance, a photo-electric record at each of said stations, means for synchronizing the movements of said records, and means for changing the bias on each of said grids in accordance with said records.

16. In a signaling system, a transmitting station, a receiving station, an electronic commutator at each of said stations, each of said commutators comprising a plurality of commutator unit vacuum tubes, means for synchronizing said commutators, to render corresponding vacuum tubes operable simultaneously, means for changing the sequence of operation of said unit vacuum tubes to a new sequence, said last means comprising a plurality of photo-electric cells, each of said cells controlling the instant of operability of a different one of said tubes, a photo-electric record at each of said stations, means for synchronizing the movements of said records, and means for controlling the impedance of said photo-electric cells in accordance with light received from said records.

17. In a multiplex signaling system, a transmitting station, a receiving station, an electronic commutator at each of said stations, said electronic commutator comprising unit vacuum tubes, each of said vacuum tubes having a plu-

rality of grids, means for synchronizing said commutators, means for generating a variable voltage, said means comprising a gas discharge device in parallel with a condenser, in series with a source of voltage and a load, said load comprising a plurality of vacuum tube chokes, each of said chokes comprising a high vacuum tube with an anode, a cathode, and a control electrode, a resistance common to the circuit of said anode and the circuit of said control electrode, means for impressing a voltage across one of said chokes on one of said grids, to tend to produce a positive potential on a first of said grids, means for impressing the voltage across the other of said chokes on the other of said grids, to tend to produce a negative potential on another of said grids, and means for biasing said grids to render each of said vacuum tubes conductive to different magnitudes of said variable voltage.

18. In a multiplex signaling system, a transmitting station, a receiving station, an electronic commutator at each of said stations, each of said commutators comprising a plurality of unit vacuum tubes, each having a plurality of grids, means for generating a variable voltage, said means comprising a gas discharge device in parallel with a condenser, in series with a source of voltage and a plurality of load resistances, means for applying the voltage across one of said resistances to one of said grids, thereby causing said one grid to tend to assume a positive poten-

tial, means for applying the voltage across the other of said resistances to the other of said grids, thereby causing said other grid to tend to assume a negative potential, means for biasing said grids to render each of said vacuum tubes conductive at different values of said variable voltage, one of said biasing means comprising a resistance in series with said source of voltage, one of said load resistances, and a vacuum tube choke, said choke having an anode, a cathode, and a control electrode, a resistance common to said anode and control electrode circuits of said choke, said other biasing means comprising a resistance in parallel with a condenser, said last resistance being in series with said gas discharge device.

19. An apparatus for producing pulses for synchronizing a receiver with a transmitter comprising: a vacuum tube having an input and an output circuit, a gas discharge device in parallel with a condenser in said input circuit, a source of voltage and the primary of a transformer in said output circuit, means for storing energy in the core of said transformer during the interval said gas discharge device is nonconductive, means for releasing said energy in the form of a high voltage pulse when said gas discharge device becomes conductive, and means for synchronizing said receiver with said transmitter with said pulse.

OLIVER T. FRANCIS.