

May 18, 1954

J. L. WHEELER

2,679,014

MULTIFREQUENCY VOLTAGE GENERATOR

Filed April 15, 1953

6 Sheets-Sheet 1

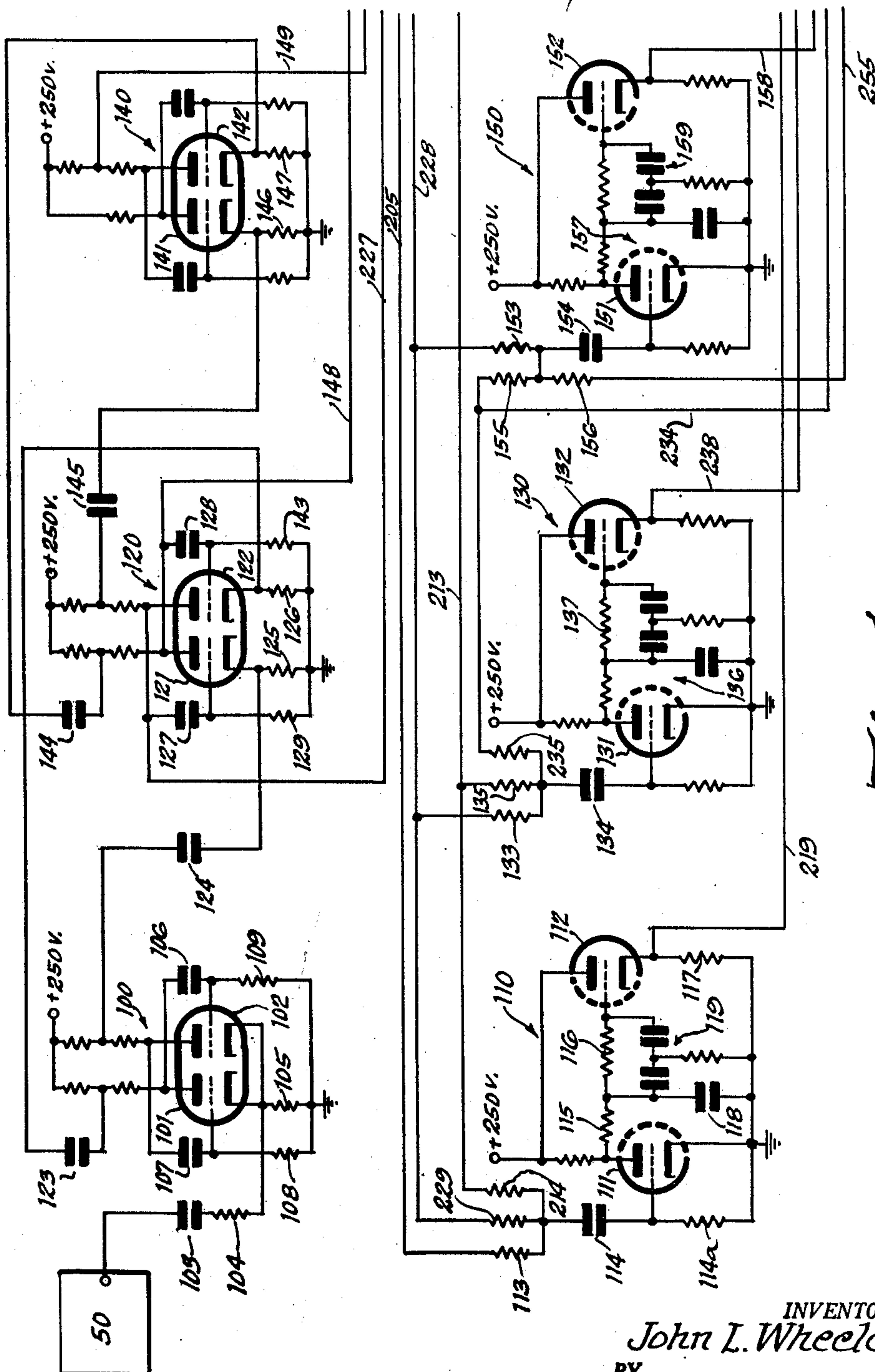


Fig. 1

INVENTOR.
John L. Wheeler
BY
J. L. Bowes
Att'y

May 18, 1954

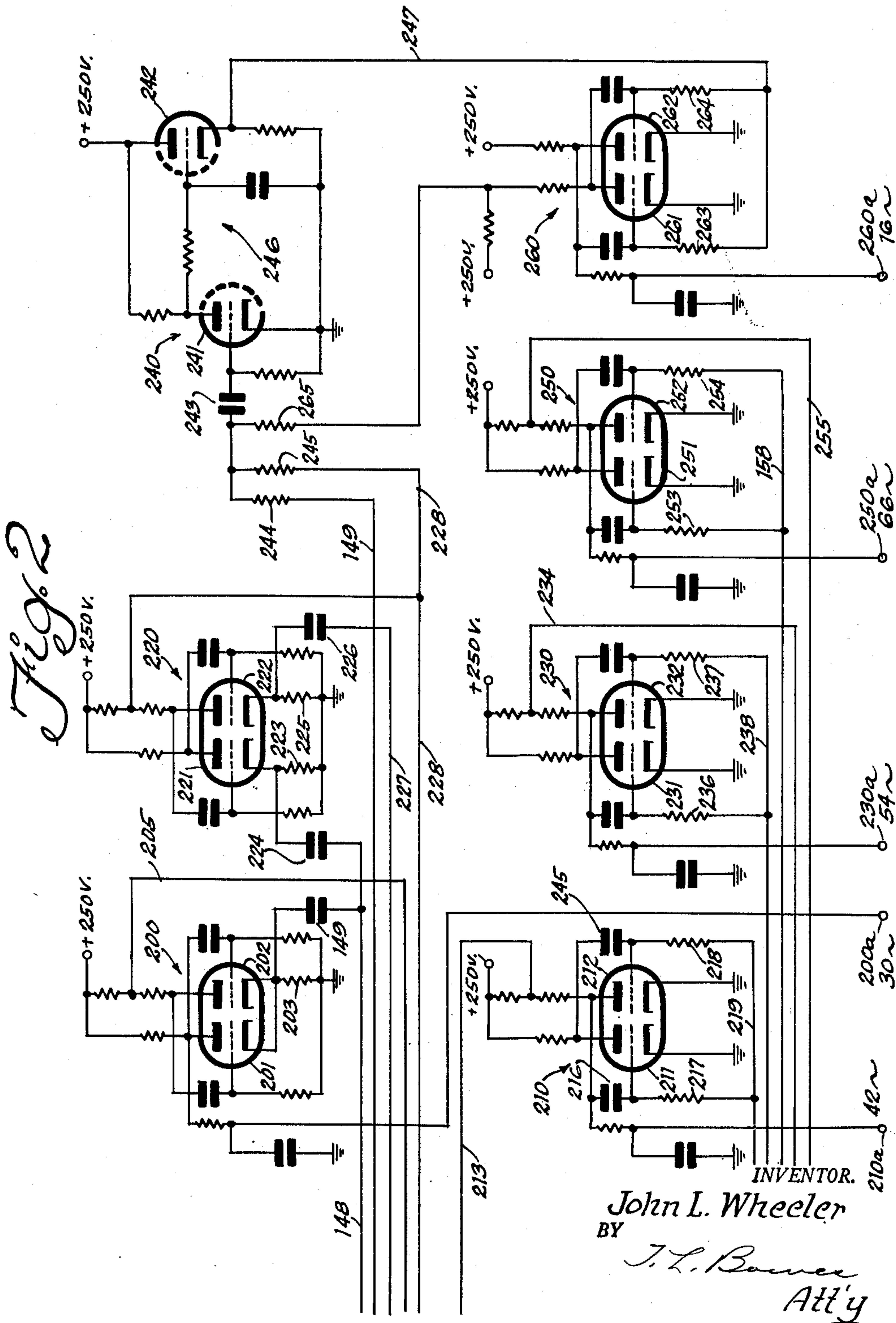
J. L. WHEELER

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J. L. WHEELER

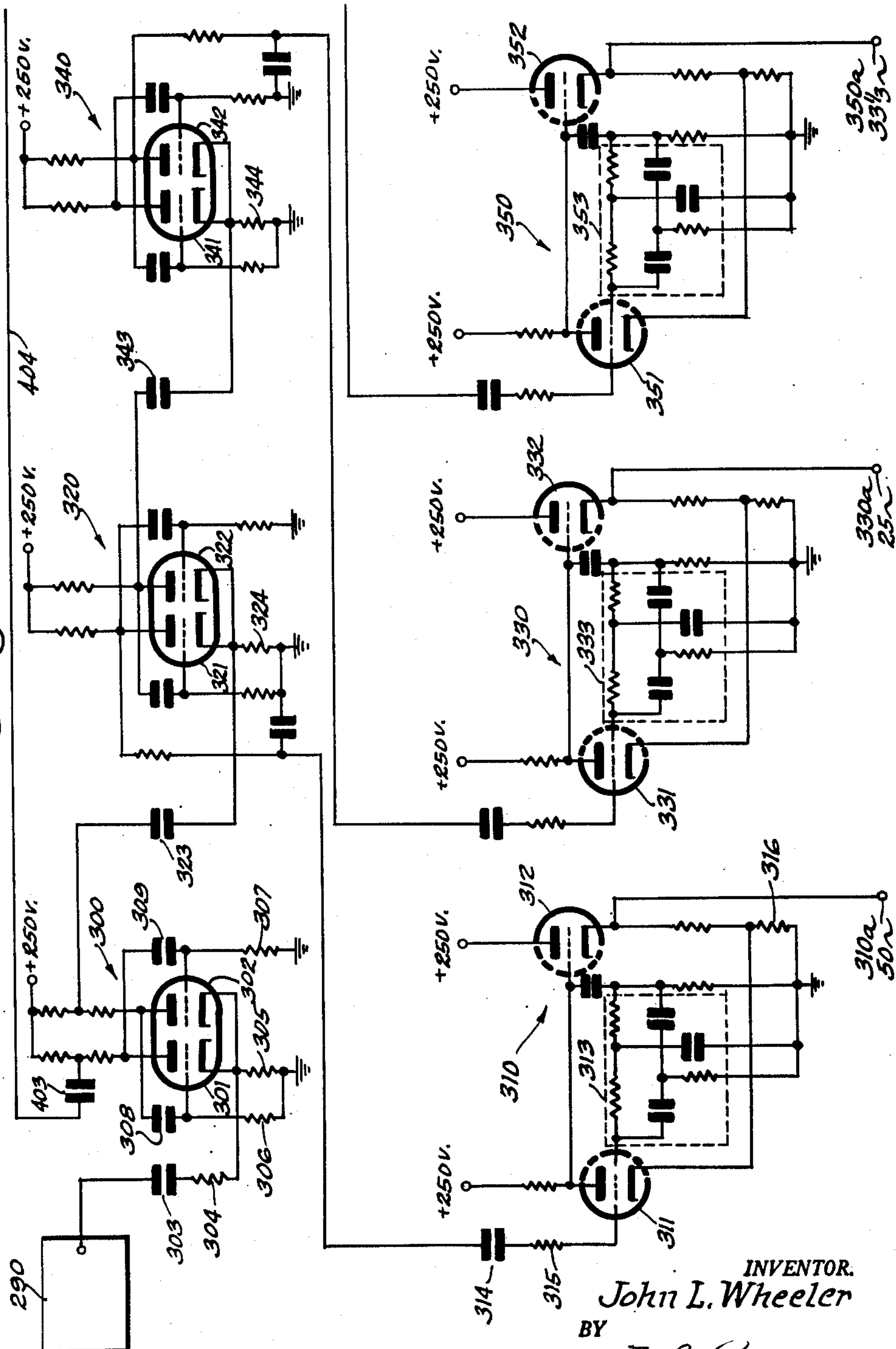
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MULTIFREQUENCY VOLTAGE GENERATOR

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6 Sheets-Sheet 3

Fig. 3



INVENTOR.
John L. Wheeler
BY
J. L. Barner
Att'y

May 18, 1954

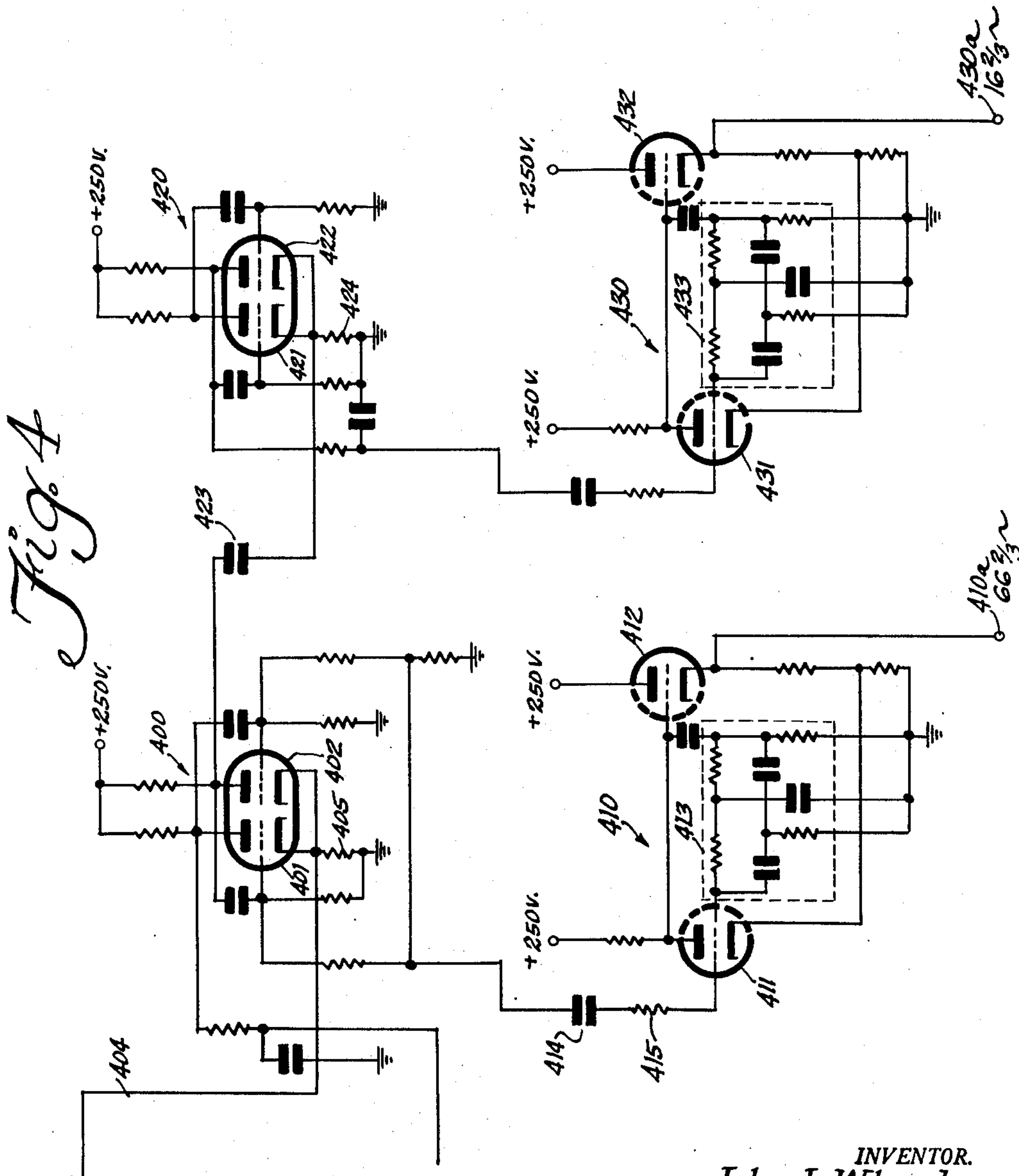
J. L. WHEELER

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MULTIFREQUENCY VOLTAGE GENERATOR

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6 Sheets-Sheet 4



INVENTOR.
John L. Wheeler
BY
J. L. Bowes
Att'y

May 18, 1954

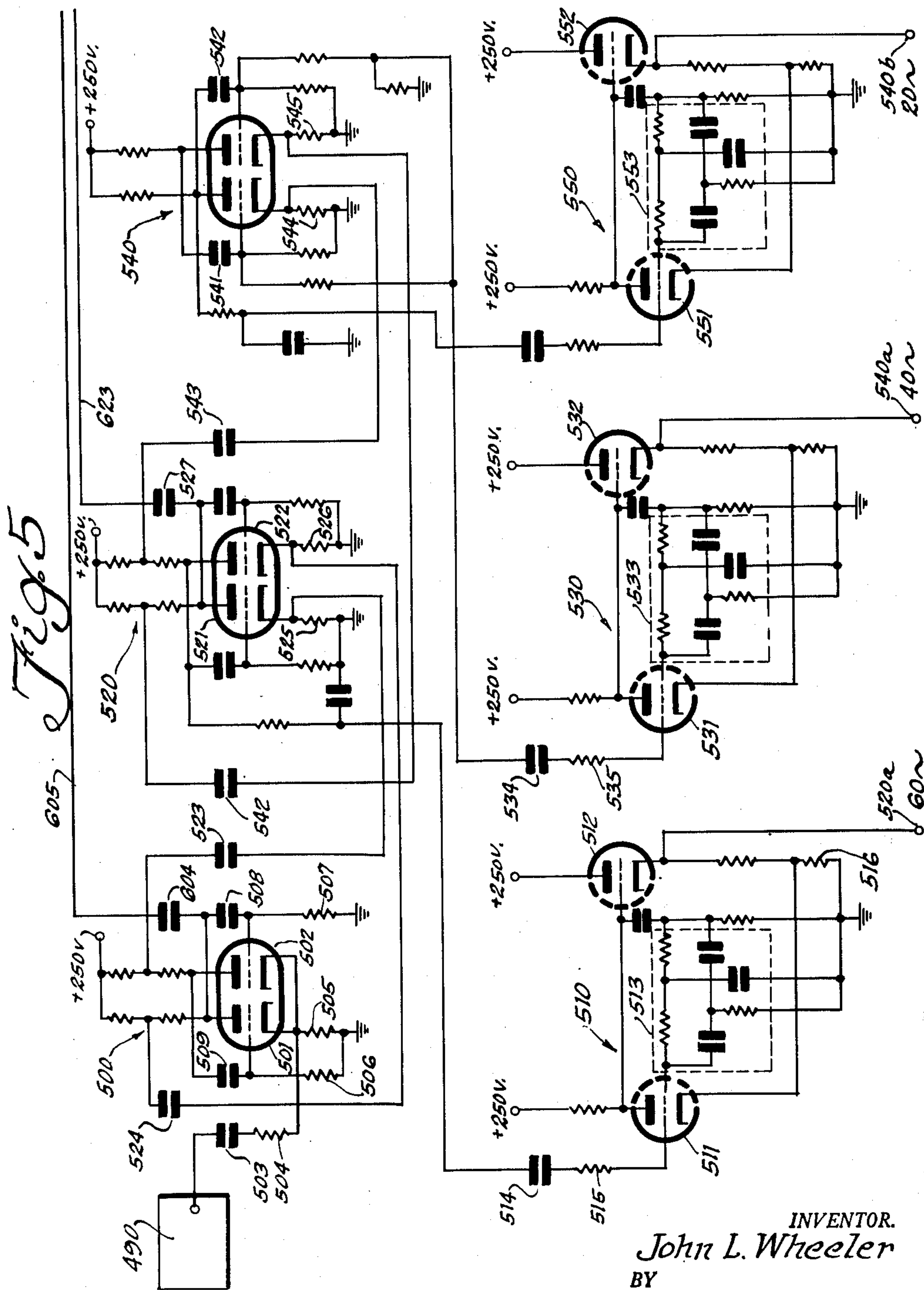
J. L. WHEELER

2,679,014

MULTIFREQUENCY VOLTAGE GENERATOR

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6 Sheets-Sheet 5



INVENTOR.
John L. Wheeler
BY

J. L. Bowes
Att'y

May 18, 1954

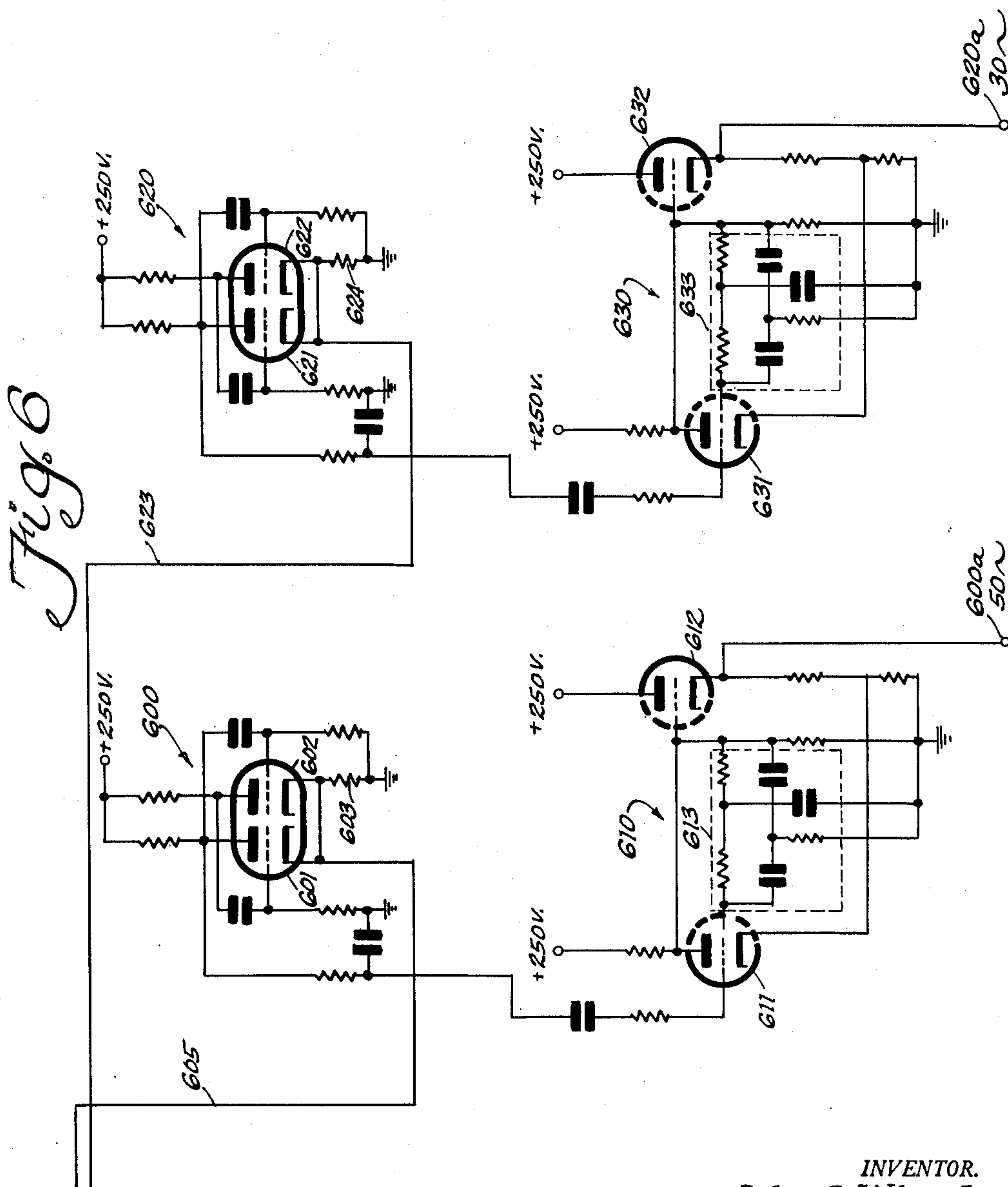
J. L. WHEELER

2,679,014

MULTIFREQUENCY VOLTAGE GENERATOR

Filed April 15, 1953

6 Sheets-Sheet 6



INVENTOR.
John L. Wheeler
BY
J. L. Bowes
Att'y

UNITED STATES PATENT OFFICE

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MULTIFREQUENCY VOLTAGE GENERATOR

John L. Wheeler, Rochester, N. Y., assignor to
Stromberg-Carlson Company, a corporation of
New York

Application April 15, 1953, Serial No. 348,907

15 Claims. (Cl. 307—151)

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This invention relates to a voltage generator and, more particularly, to such a generator for producing a plurality of voltages having different frequencies.

Because of the large demand for service on existing telephone facilities, a large number of multi-party subscriber lines are now being utilized. These party lines are common to a plurality of subscriber stations which are selectively rung by ringing voltages of different frequencies. In the past, the voltage generators utilized to produce the plurality of different ringing frequencies were either mechanical or electromechanical in nature, with the consequent disadvantages of lacking stability in operation and requiring a large amount of space for installation. Although some electronic ringing machines are now being utilized, these prior generators of ringing frequency voltages normally utilize narrowly tuned output filters for the purpose of providing the exact frequency necessary in order to selectively energize a particular one of a plurality of subscriber stations on a single subscriber line.

Also, the development of electronic telephone switching equipment has necessitated the design of all electronic ringing circuits which are adapted to selectively provide any one of a number of ringing frequencies. These circuits, which are intended for use in electronic systems, must be very stable in their operating characteristics, should occupy small amounts of physical space, and should be compatible for use with existing electromechanical systems.

Accordingly, one object of this invention is to provide a new and improved voltage generator for producing a plurality of different frequencies for use in signaling systems.

Another object is to provide a new and improved electronic multi-frequency voltage generator wherein each of the frequencies produced is not harmonically related to a single frequency source from which the plurality of different frequencies are derived.

Another object is to provide a multi-frequency voltage generator in which each of the plurality of different frequency voltages produced is related to each other in the ratio of integral multiples of ten.

Another object of this invention is to provide a multi-frequency voltage generator in which the plurality of different frequency voltages produced are not related harmonically to the basic frequency source from which they are derived, and in which this plurality of different frequency voltages are not related to each other by any given integral factor of multiplication.

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A still further object is the provision of an electronic frequency voltage generator having an accurate and stable output which is controlled by a single standard frequency source.

Another object is to provide a multi-frequency voltage generator in which a plurality of different frequency voltages are produced by adding and subtracting a plurality of standard frequency voltages to produce frequencies which are not harmonically related to any of the plurality of standard frequencies.

Another object is to provide a voltage generator for producing a plurality of different frequencies by utilizing a plurality of independent oscillators which are controlled in accordance with an error voltage derived from the comparison of the output of these independent oscillators with a combination of standard frequency voltages.

Another object of this invention is to provide an electronic multi-frequency voltage generator in which the output from a standard frequency source is divided into a plurality of different harmonically related frequencies which are subsequently added to or subtracted from each other and then filtered in a frequency selective network to prevent the production at the output of the generator of frequencies other than those produced by the arithmetical operations on the standard frequency voltages.

A still further object is the provision of a frequency doubling means of stable operating characteristics in which the output of both halves of a multivibrator circuit are added to produce a double frequency output.

In accordance with these and many other objects, one embodiment of the invention comprises a multi-frequency voltage generator energized by a standard frequency source of oscillatory voltage in which a plurality of cathode connected multivibrator circuits energized by the standard source divide the frequency of the standard source by certain integral factors to produce a plurality of different frequency voltages. Another group of multivibrator circuits, having a natural frequency of oscillation near that of the summation or difference of certain of the different frequency voltages derived from the standard source, produce voltages which are combined at the grid of a non-linear detector with certain combinations of the voltages produced by division of the frequency of the standard source. The mixing of the standard frequency voltages and the output voltage of the independent multivibrator in the non-linear detector produces a control voltage which is integrated over several

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cycles and returned to the independent multivibrator to control the frequency thereof in accordance with the differences between the output frequency of the independent multivibrator and the addition or difference frequencies of the combined standard frequencies. The non-linear detectors are also provided with a filtering network for the purpose of preventing any tendency of the circuits to oscillate and for removing all of the undesirable frequency components of the control voltage.

A second embodiment of the invention comprises a harmonic frequency voltage generator in which the output voltage of a standard frequency source is divided into a plurality of voltages having different frequencies lower than that of the standard source by frequency division in a plurality of cathode coupled multivibrators. These different frequencies are individually filtered in a band pass circuit utilizing a pair of amplifier tubes which are so coupled as to prevent the production of signals having any frequencies other than that produced by the frequency division of the standard source of frequency.

A third embodiment of the invention comprises a decimonic frequency voltage generator in which a source of oscillatory voltage of a standard frequency energizes a plurality of cathode coupled multivibrators for the purpose of dividing this standard frequency by different integral factors to produce a plurality of different standard frequencies which are related in being integral multiples of ten. Each of these standard decimal frequency voltages is filtered in a band pass filter including a pair of selectively coupled amplifier tubes for the purpose of providing an output voltage free from frequencies other than that produced by the multivibrator division of the standard frequency source. This decimonic frequency voltage generator includes a frequency doubler circuit wherein the output of both plates of a multivibrator are combined for the purpose of providing an output voltage having a frequency twice that of the multivibrator producing it.

Many other objects and advantages of this invention will become apparent from a consideration of the following specification when taken in conjunction with the drawings in which:

Figs. 1 and 2 are a circuit diagram of a synchronomic voltage generator of the present invention;

Figs. 3 and 4 are a circuit diagram of a harmonic voltage generator embodying the invention; and

Figs. 5 and 6 are a circuit diagram of a decimonic voltage generator.

Referring now to Figs. 1 and 2 of the drawings, there is shown a synchronomic voltage generator comprising a standard frequency source 50, the frequency of the output voltage of which is divided into a plurality of different standard frequencies by a plurality of multivibrator frequency dividing circuits 100, 120, 140, 200 and 220. The output frequencies of selected ones of the frequency dividing multivibrators 100, 120, 140 and 200 and 220 are combined in one of a plurality of phase detecting circuits 110, 130, 150 and 240, each of which is also selectively energized by one of a plurality of independent sources of oscillation or multivibrators 210, 230, 250 and 260. The natural frequency of oscillation of each of these independent sources is approximately the same as the summation or difference of the frequencies of the selected ones of the standard voltages produced by the multivibrators

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100, 120 and 140, 200 and 220 which are applied to each of the phase detecting circuits. It is not necessary for the natural frequencies of oscillation of the multivibrators 210, 230, 250 or 260 to be substantially equal to the sum or difference frequencies since they may be either an integral multiple or submultiple of the combined frequencies.

In response to this simultaneous energization by one of the independent multivibrators 210, 230, 250 and 260 and by a selected group of the frequency dividing multivibrators 100, 120, 140, 200 or 220, each of the phase detectors provides a control voltage proportional to the difference in phase between the combined standard frequency voltages and the output of the independent sources of oscillation. This control or error voltage is subsequently returned to the associated independent multivibrator for the purpose of varying the frequency thereof to reduce the phase differential between these voltages. Therefore, the output voltage which is derived from each of the multivibrators 210, 230, 250 and 260 is controlled in accordance with the combined standard frequency voltages and is accurate and stable.

The standard frequency source 50 which energizes the plurality of frequency dividing multivibrators 100, 120, 140, 200, and 220 may be of any of the well known types in the art, and, more specifically, may be a 1200 C. P. S. harmonic ringing oscillator controlled by a tuning fork as disclosed in the copending application of Robert B. Trousdale, Serial No. 348,861, filed April 15, 1953 entitled, Multi-Frequency Voltage Generation and assigned to the same assignee as the present application. Although the output frequency of the harmonic ringing oscillator 50 is set at 1200 C. P. S., it should be understood that any output frequency which contains the proper integrally related frequencies may be utilized.

The output voltage from the standard frequency source 50 is coupled to the first frequency dividing multivibrator 100 through a coupling condenser 103 and a resistor 104 and, more specifically, is applied to a resistor 105 common to the cathodes of a pair of tubes 101 and 102 forming the multivibrator 100. The multivibrator 100, including the tubes 101 and 102, is of a conventional design wherein the grids of the tubes 101 and 102 are cross coupled by a pair of condensers 106 and 107 which, together with a pair of grid resistors 108 and 109, determine the natural frequency of operation of the multivibrator 100.

The values of the condensers 106 and 107 and of the resistors 108 and 109 are so designed that the natural frequency of oscillation of the multivibrator 100 is slightly less than 300 C. P. S. or one quarter of the output frequency of the standard source 50. Since the driving or synchronizing voltage coupled to the multivibrator 100 from the standard frequency source 50 is applied to the common cathode resistor 105, this injected voltage tends to stabilize operation of the multivibrator 100 at this even integral submultiple of the frequency of the injected voltage. This is true because the injected synchronizing voltage from the standard source 50 is applied to both of the tubes 101 and 102 in the same phase. Accordingly, the multivibrator 100 tends to operate at a frequency of 300 C. P. S. and is held at this frequency by the injected voltage from the standard frequency source 50.

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The output voltage derived from the multivibrator 100 is coupled to the multivibrator 120 through a pair of coupling condensers 123 and 124, and, more specifically, the output voltage from the multivibrator 100 is applied to a pair of cathode resistors 125 and 126 of a pair of tubes 121 and 122 forming the multivibrator 120 so that this multivibrator tends to operate at a frequency which is an odd integral submultiple of the frequency of the injected voltage from the multivibrator 100. The multivibrator 120 tends to operate at the odd integral submultiple of the 300 C. P. S. voltage coupled thereto from the multivibrator 100 since the voltages applied to the tubes 120 and 122 are 180 degrees out of phase.

The magnitudes of a pair of grid coupling condensers 127 and 128 and a pair of grid resistors 129 and 143 are chosen so that the natural frequency of oscillation of the multivibrator 120 is slightly less than 60 C. P. S., which frequency is one-fifth of the output frequency of the multivibrator 100.

The output of the multivibrator 120 is coupled to the frequency dividing multivibrator 140 through a pair of coupling condensers 144 and 145, and is applied 180 degrees out of phase to a pair of cathode resistors 146 and 147 of a pair of tubes 141 and 142 so that the frequency of the multivibrator 140 tends to be an odd integral submultiple of the frequency of the multivibrator 120. The grid coupling condensers and the grid resistors of the multivibrator 140 are so chosen in value that the natural frequency of oscillation thereof is slightly less than 20 C. P. S. or one-third of the frequency of the multivibrator 120.

The 60 C. P. S. output of the multivibrator 120 is coupled to the frequency dividing multivibrator 200 (Fig. 2) through a conductor 148 (Figs. 1 and 2) and a condenser 149. This voltage is applied to a cathode resistor 203 which is common to the cathodes of a pair of tubes 201 and 202 forming the multivibrator 200 so that this multivibrator tends to operate at a frequency which is an even integral submultiple of the output frequency of the multivibrator 120. The grid coupling condensers and the grid resistors of the multivibrator 200 are of such a magnitude that the multivibrator 200 tends to oscillate at a frequency of 30 C. P. S. or one-half of the frequency of operation of the multivibrator 120.

The output from the multivibrator 120 is also applied to a cathode resistor 223 of a tube 221 in the multivibrator 220 through a coupling condenser 224. A cathode resistor 225 of a tube 222 forming the other half of the multivibrator 220 is supplied with voltage, 180 degrees out of phase with that supplied to the cathode resistor 222, through a coupling condenser 226 and a conductor 227 (Figs. 1 and 2) which is connected to the plate of the tube 122 in the multivibrator 120. Accordingly, the multivibrator 220 tends to operate at a frequency which is an odd integral submultiple of the 60 C. P. S. output of the multivibrator 120. The coupling condensers and grid resistors of the tubes 221 and 222 are so chosen in value that the natural frequency of oscillation of the multivibrator 220 is slightly less than 12 C. P. S. or one-fifth of the output frequency of the multivibrator 120.

Therefore, the plurality of multivibrators 100, 120, 140, 200 and 220 provide a series of different frequency voltages which are stable in frequency and integral submultiples of the 1200 C. P. S. voltage provided by the standard source 50. For gen-

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eral convenience, the 60 C. P. S., 20 C. P. S., 30 C. P. S. and 12 C. P. S. voltages provided by these multivibrators are designated standard frequencies inasmuch as they are produced under the direct control of the standard frequency source 50.

The 30 C. P. S. voltage output of the multivibrator 200 is coupled to the phase detector 110 (Fig. 1) through a conductor 205 (Figs. 1 and 2), a mixing resistor 113 and a grid condenser 114. The 12 C. P. S. voltage output of the multivibrator 220 is also coupled to the phase detector 110 through a conductor 228, a mixing resistor 229 and the condenser 114. These two voltages are mixed at the grid of a grounded cathode amplifier tube 111 which functions, by virtue of its grounded cathode, as a non-linear triode detector. The grid of the non-linear detector tube 111 is also provided with voltage from the independent multivibrator 210 (Fig. 2) through a conductor 213, a mixing resistor 214 and the condenser 114.

The multivibrator 210 includes a pair of triodes 211 and 212, the grids of which are cross connected by a pair of condensers 215 and 216. The magnitudes of the condensers 215 and 216 and a pair of grid resistors 217 and 218 are so chosen that the natural frequency of oscillation of the multivibrator 210 is approximately 42 C. P. S. The frequency of 42 C. P. S. is also the summation frequency produced by the addition of the 30 C. P. S. and 12 C. P. S. voltages coupled to the phase detector 110 from the multivibrators 200 and 220.

Therefore, when the plurality of voltages provided by the multivibrators 200, 210 and 220 are mixed by the resistors 113, 214 and 229 at the grid of the zero-bias triode 111, a direct current error voltage is produced at the output thereof which is proportional to the phase difference between the output of the multivibrator 210 and the combined frequency outputs of the multivibrators 200 and 220. The instantaneous value of this error voltage is directly proportional to the phase difference between the above mentioned voltages. On the positive portion of the voltage applied to the grid of the tube 111, a grid current is drawn so that the condenser 114 becomes charged. This charge leaks off the condenser 114 through a grid resistor 114a during the negative portions of the applied voltage so that the resistor 114a establishes a negative grid bias to prevent the tube 111 from conducting except during a selected positive portion of the applied voltage.

This output voltage from the tube 111 is coupled to a cathode follower tube 112 forming a part of the phase detector network 110 through a pair of serially connected resistors 115 and 116. The cathode follower tube 112 couples the error or control voltage applied to the grid thereof to the grid resistors 217 and 218 of the multivibrator 210 through a conductor 219 (Figs. 1 and 2). This control voltage applied to the grid resistors 217 and 218 varies the frequency of oscillations of the multivibrator 210 or the phase thereof so as to maintain the output frequency of the oscillator 210 equal to that provided by the addition of the 30 and 12 C. P. S. voltages produced by the multivibrators 200 and 220.

Inherent in the intermodulation of the voltages applied to the grid of the tube 111 are a number of low frequency intermodulation products. It is desirable to prevent these low frequency intermodulation products from being applied through the cathode follower tube 112 to the in-

dependent multivibrator 210, and, therefore, an integration network comprising the resistor 115 and a condenser 118 is provided at the output of the tube 111. The time constant of these two elements is long enough to remove a six C. P. S. signal, and is short enough that the phase detector 110 is capable of responding to variations in phase in the output of the multivibrator 210.

The presence of the integrating network provided by the resistors 115 and 118 tends to reduce the overall gain of the system so that, in order to obtain an adequate magnitude of control voltage on the conductor 219, it is often necessary to raise the driving voltage coupled to the grid of the tube 111. This increased driving voltage may cause the feedback network including the multivibrator 210 and the phase detection circuit 110 to exhibit a lack of stability, or, in some instances, to exhibit a tendency to oscillate at relatively low frequencies. This tendency to break into oscillation is prevented by the insertion of a bridged T-filter network 119. The magnitude of the components of the filter network 119, including the resistor 116, is so chosen that the real component of the product of the fraction of feedback voltage and the amplification of the circuit in the absence of feedback, i. e. the feedback factor, is considerably less than unity at the point at which the phase shift of the system is 180 degrees. By this choice of the magnitude of the components forming the filter network 119, the feedback network provided by the phase detector 110 and the multivibrator 210 exhibits a large degree of stability in operation.

Therefore, the phase detector network 110 provides a control voltage proportional to the difference in phase between the output voltage of the multivibrator 210 and the composite voltage produced by the addition of the output voltages of the multivibrators 200 and 220, and this control voltage is utilized to control the frequency of oscillation of the multivibrator 210 to reduce the phase difference therebetween to a minimum. The output voltage from the multivibrator 210 which is coupled to an output terminal 210a is both extremely accurate and positively synchronized with the standard source of frequency 50.

The 12 C. P. S. voltage output of the multivibrator 220 is also applied to the control grid of a zero-bias triode 131 in the phase detection network 130 through the conductor 228, a frequency mixing resistor 131 and a grid condenser 134. The grid of the tube 131 is also supplied with the 42 C. P. S. voltage from the multivibrator 210 through the conductor 213, a mixing resistor 135, and the condenser 134.

The multivibrator 230 (Fig. 2) which includes a pair of tubes 231 and 232 is provided with grid coupling condensers and grid resistors of such a magnitude that the natural frequency of oscillation of the multivibrator 230 is approximately 54 C. P. S. or the sum of the frequencies applied to the grid of the triode 131 from the multivibrators 210 and 220. The output voltage of the multivibrator 230 is coupled to the grid of the non-linear detector 131 through a conductor 234 (Figs. 1 and 2), a mixing resistor 225 and the condenser 134.

The phase detection network 130 including an integrating network 136 and a filter network 137 operates in the same manner as the phase detection network 110 to produce an error or control voltage which is coupled through a cathode fol-

lower tube 132 and is connected to a pair of grid resistors 236 and 237 through a conductor 238. This control voltage varies the bias on the grids of the tubes 231 and 232 so as to force the multivibrator 230 to operate at a frequency of 54 C. P. S., i. e. to maintain a minimum phase difference between the output of the multivibrator 230 and the additive component of the 42 C. P. S. and 12 C. P. S. voltages coupled to the grid of the nonlinear detector 131. Therefore, the output frequency of the multivibrator 230, which is coupled to an output terminal 230a, is equal to the sum of the frequencies of the voltages produced by the multivibrators 210 and 220.

The phase detection network 130 also includes a cathode follower tube 132 similar to the tube 112, an integrating network indicated generally as 136, and a band rejection bridged T-filter network indicated generally as 137.

The phase detection network 150 includes a zero-bias triode 151, the grid of which is provided with 12 C. P. S. voltage from the multivibrator 220 through the conductor 226, a mixing resistor 153 and a grid condenser 154, and also with 54 C. P. S. voltage from the multivibrator 230 through the conductor 234, a mixing resistor 155 and the condenser 154. These voltages are added at the grid of the triode 151 to produce an additive component of 66 C. P. S.

The multivibrator 250 associated with the phase detector 150 includes a pair of tubes 251 and 252 which are cross coupled by a pair of coupling condensers and are provided with a pair of grid resistors 253 and 254 of such magnitude that the natural frequency of oscillation of this multivibrator is approximately the 66 C. P. S. produced by the addition of the output frequencies of the multivibrators 230 and 220. This output frequency is coupled to the grid of the tube 151 in the phase detection network 150 through a conductor 255 (Figs. 1 and 2) and a mixing resistor 156.

The voltage from the multivibrator 250 and those provided by the multivibrators 220 and 230 are combined at the grid on the non-linear detector tube 151 in the manner described in conjunction with the phase detection networks 110 and 130 to produce a control voltage proportional to the phase difference between these voltages. This control voltage is integrated in a network 157 and coupled back to the grid resistors 253 and 254 through a filter network 159, a cathode follower tube 152, and a conductor 158. This control voltage functions in the same manner described above to control the frequency of oscillation of the multivibrator 250, and thereby to hold the output frequency of this multivibrator at 66 C. P. S. The output voltage of the multivibrator 250 is coupled to an output terminal 250a.

The multivibrator 260 provides a 16 C. P. S. output voltage at a terminal 260a in accordance with the selected values of a pair of grid coupling condensers and a pair of grid resistors 263 and 264. The output of the multivibrator 260 is also applied to the grid of a zero-bias triode 241 in the phase detector circuit 240 through a mixing resistor 265 and a grid condenser 243.

The grid of the detector tube 241 is also provided with 20 C. P. S. voltage from the multivibrator 140 through a conductor 149 (Figs. 1 and 2), a mixing resistor 244 and the condenser 243. The 12 C. P. S. voltage generated by the multivibrator 220 is applied to the grid of the tube 241 through the conductor 228, a frequency mixing resistor 245, and the coupling condenser 243.

The third harmonic of the 12 C. P. S. signal and the fundamental of the 20 C. P. S. voltage are added to provide a subtractive component of 16 C. P. S., the phase of which is compared with the 16 C. P. S. signal from the multivibrator 260 to produce a control voltage having an instantaneous value proportional to the amount of phase displacement. This control voltage is integrated in a network 246 and coupled to a cathode follower tube 242 which is connected to the grid resistors 263 and 264 through a conductor 247 in order to control the frequency of operation of the multivibrator 260.

The phase detection network 240 does not include a filter of the bridged-T type disclosed in conjunction with the phase detection networks 110, 130 and 150, although such a filtering network could obviously be added to the circuit if it is necessary to prevent oscillations or hunting in the feedback network including the phase detection network 240 and the multivibrator 260.

Accordingly, the synchronomic voltage generator, disclosed in Figs. 1 and 2 of the drawings, comprises a means for producing a plurality of different standard frequency voltages which are subsequently combined to control the operation of a plurality of independent sources of oscillation. These independent sources of oscillation produce output frequencies which are equal to the sum or the difference of the standard frequency voltages or an integral multiple or submultiple thereof, under the control of the standard frequency source 50, and, accordingly, provide stable and accurate frequency sources. If extraneous frequencies are present in the output provided at plurality of output terminals 200a, 210a, 230a, 250a and 260a, these output terminals may be connected to the input of individual band pass filters similar to those described hereinafter in conjunction with the voltage generators shown in Figs. 2 to 6, inclusive, of the drawings. These filters convert the generated square wave into sine waves and insure that the plurality of outputs contain only the desired synchronomically related frequencies.

Referring now to Figs. 3 and 4 of the drawings, there is disclosed a harmonic voltage generator including a plurality of frequency dividing multivibrators 300, 320, 340, 400 and 420 which are energized in cascade from a single standard frequency source 290. The plurality of voltage dividing multivibrators produce output frequencies which are controlled in accordance with the standard frequency source 290 and, therefore, are held in synchronism at the desired harmonic frequencies. The plurality of multivibrators 300, 320, 340, 400 and 420 energize a plurality of band pass filters 310, 330, 350, 410 and 430, respectively, so that the output frequencies at a plurality of output terminals 310a, 330a, 350a, 410a, and 430a include only the selected harmonic submultiple frequencies produced under the control of the standard frequency source 290.

In order to provide a first subdivision of the 1200 C. P. S. standard frequency provided by the source 290, the multivibrator 300 is connected to the source 290 through a coupling condenser 303 and a resistor 304 so that the voltage from the source 290 is applied to a cathode resistor 305 which is common to both of the pair of tubes 301 and 302 comprising the multivibrator 300. A pair of grid resistors 306 and 307 together with a pair of grid coupling condensers 308 and 309 are so chosen in magnitude that the natural frequency of oscillation of the multivibrator 300

is slightly less than 200 C. P. S. Since the synchronizing voltage injected from the standard frequency source 290 is applied to both of the tubes 301 and 302 in the same phase, the multivibrator 300 tends to operate at a frequency which is an even integral submultiple of the frequency of the source 290 and the multivibrator 300 is thereby synchronized at an operating frequency of 200 C. P. S.

This 200 C. P. S. voltage output of the multivibrator 300 is coupled to the multivibrator 320 through a coupling condenser 323 and applied to a cathode resistor 324 which is common to a pair of tubes 321 and 322 forming the multivibrator 320. The grid resistors and grid coupling condensers for the tubes 321 and 322 are so chosen in value that the natural frequency of oscillation of the multivibrator 320 is slightly less than 50 C. P. S. so that the injected voltage, which is applied in like phase to both of the tubes 321 and 322, tends to operate the multivibrator 320 at a frequency which is an even integral submultiple of the injected 200 C. P. S. voltage of the multivibrator 300, i. e. 50 C. P. S.

To provide a third subdivided frequency harmonically related to the frequency of the standard source 290, the output voltage of the multivibrator 320 is applied to the multivibrator 340 through a coupling condenser 343 to a cathode resistor 344 which is common to both of a pair of tubes 341 and 342 comprising the multivibrator 340. The grid resistors and condensers of the tubes 341 and 342 are selected in magnitude so that the multivibrator 340 tends to operate at a frequency of 25 C. P. S., and, since the injected synchronizing voltage provided by the multivibrator 320 is applied in like phase to both of the tubes 341 and 342, the multivibrator 340 operates at a frequency of 25 C. P. S. or an even submultiple of the operating frequency of the multivibrator 320.

To provide a fourth frequency harmonically related to the frequency of the standard source 290, the multivibrator 400 (Fig. 4) is coupled to the output of the 200 C. P. S. multivibrator 300 through a coupling condenser 403 and a conductor 404 (Figs. 3 and 4). The voltage provided by the multivibrator 300 is applied to a resistor 405 common to the cathodes of both of a pair of tubes 401 and 402 forming the multivibrator 400. The grid resistors and coupling grid capacitors for the tubes 401 and 402 are so chosen in value that the natural frequency of oscillation of the multivibrator 400 is slightly less than $33\frac{1}{3}$ C. P. S., and, since the synchronizing voltage is applied to both of the tubes 401 and 402 in like phase, the multivibrator 400 tends to operate at a frequency which is an even integral submultiple of the synchronizing 200 C. P. S. voltage provided by the multivibrator 300.

To provide a fifth standard frequency harmonically related to the frequency of the standard source 290, the multivibrator 420 is coupled to the output of the $33\frac{1}{3}$ C. P. S. multivibrator 400 through a coupling condenser 423 so that synchronizing voltage is applied to a resistor 424 common to the cathodes of a pair of tubes 421 and 422. The grid resistors and grid coupling condensers of the tubes 421 and 422 are of such magnitude that the natural frequency of oscillation of the multivibrator 420 is approximately $16\frac{2}{3}$ C. P. S., and, since the injected synchronizing voltage provided by the multivibrator 400 is applied in like phase to both of these tubes, the multivibrator 420 tends to operate at a fre-

quency which is an even integral submultiple of the $33\frac{1}{3}$ C. P. S. output of the multivibrator 400, i. e. $16\frac{2}{3}$ C. P. S.

The output of the 50 C. P. S. multivibrator 320 is coupled to the band pass filter network 310 through a coupling condenser 314 and a resistor 315. This voltage is applied to the grid of an amplifier tube 311, the output of which is applied to a second amplifier tube 312 in the band pass filter network 310. The tube 312 forms a portion of a cathode follower circuit in order to provide a means for matching the high impedance of the multivibrator 320 and the filter 310 with the low impedance of external apparatus, i. e. lines and ringers (not shown), energized by the 50 C. P. S. voltage connected to the output terminal 310a.

In order to prevent the appearance of undesired frequencies at the output terminal 310a, the plate of the tube 311 is returned to the grid thereof through a parallel-T filter network 313 which is tuned to reject only the desired output frequency or, in this case, an output voltage having a frequency of 50 C. P. S. The filter network 313 provides a degenerative feedback network so that when voltages of a frequency other than that desired appear at the grid of the cathode follower tube 312, these voltages are returned to the grid of the tube 311 180 degrees out of phase with the voltages applied thereto to cancel these off-frequency voltages. Therefore, the insertion of the degenerative feedback network including the filter network 313 insures that only an output voltage of the desired frequency will be coupled to the output terminal 310a. In effect, the square waves generated by the multivibrator 320 are converted into sine waves by the output filter 310 since all of the odd harmonics are cancelled out of the square waves to leave only a residual 50 C. P. S. fundamental.

In order to compensate for the inherent loss of gain because of the insertion of the degenerative or negative feed-back network including the filter 313, the cathode of the tube 311 is connected to a cathode resistor 316 which is common to the cathode circuits of both of the tubes 311 and 312. This provides a positive feedback network for increasing the amplitude of the voltage wave forms produced by the tube 311 and, accordingly, compensates for the loss of gain introduced by the degenerative network.

The 25 C. P. S., $33\frac{1}{3}$ C. P. S. and $16\frac{2}{3}$ C. P. S. voltage outputs of the multivibrators 340, 400 and 420 are coupled to the output terminals 330a, 350a, and 430a through the band pass filter networks 330, 350, and 430, respectively, to provide sine wave voltages having a frequency of only the desired value. To accomplish this result, a parallel-T filter network 333 degeneratively interconnects a pair of tubes 331 and 332 in the band pass filter network 330 and is tuned to reject only voltages having a frequency of 25 C. P. S., a parallel-T filter network 353 degeneratively interconnects a pair of tubes 351 and 352 in the band pass filter network 350 and is tuned to reject only voltages having a frequency of $33\frac{1}{3}$ C. P. S., and a parallel T-filter 433 tuned to reject $16\frac{2}{3}$ C. P. S. degeneratively interconnects a pair of tubes 431 and 432.

In order to provide a $66\frac{2}{3}$ C. P. S. output signal at the terminal 410a, the band pass filter 410 is interconnected with both plates of the multivibrator 400 through a coupling condenser 414 and a coupling resistor 415. Since the grid of an amplifier tube 411 in the filter 410 is energized from

the outputs of both of the tubes 401 and 402 in the multivibrator 400, the $33\frac{1}{3}$ C. P. S. output signal of each of these tubes is combined on the grid of the tube 411 to provide a $66\frac{2}{3}$ C. P. S. signal which is coupled to the grid of the tube 412. A portion of this voltage is returned to the grid of the amplifier tube 411 through a parallel T-filter network 413 which is tuned to reject only $66\frac{2}{3}$ C. P. S. so that the degenerative feedback path provided by the filter 413 prevents the coupling of voltages having a frequency other than $66\frac{2}{3}$ C. P. S. to the cathode follower tube 412 and, consequently, to the output terminal 410a.

Therefore, the harmonic voltage generator, disclosed in Figs. 3 and 4 of the drawings, provides a plurality of output voltages which are controlled and synchronized by the standard frequency source 290 so as to be quite stable in frequency. Any undesired frequencies are removed from these output voltages by the use of the degenerative band pass filters 310, 330, 350, 410 and 430 through which each of these output voltages is transmitted.

Referring now to Figs. 5 and 6 of the drawings, there is disclosed a decimonic voltage generator in which a standard source of frequency 490, similar to the source 50 (Fig. 1), energizes a plurality of frequency dividing multivibrators 500, 520, 540, 560 and 520 to produce a plurality of standard frequencies which are related in being integral multiples of a decimal basic frequency such as 10 C. P. S. In the embodiment disclosed, output frequencies of 20, 30, 40, 50 and 60 C. P. S. are provided by the plurality of multivibrators 500, 520, 540, 560 and 520. The standard frequency signals produced by this plurality of multivibrators are coupled to a plurality of output terminals 520a, 540a, 540b, 560a and 520a through a plurality of band pass filters 510, 530, 550, 610 and 630, respectively. These filters function to remove any frequency components from the output voltages which are not the desired decimally related frequencies.

To produce a first frequency division of the 1200 C. P. S. voltage provided by the standard source 490, the output voltage therefrom is coupled through a condenser 503 and a resistor 504 and is applied to a resistor 505 which is common to the cathodes of a pair of tubes 501 and 502. A pair of grid resistors 506 and 507 and a pair of grid coupling condensers 508 and 509 are so chosen in value that the natural frequency of operation of the multivibrator 500 is approximately 300 C. P. S. The multivibrator 500 is synchronized at this operating frequency which is an even submultiple of the standard frequency since the injected voltage from the standard frequency source 490 is applied in like phase to both of the tubes 501 and 502.

To provide a second multiple frequency controlled by the standard source 490, the output of the multivibrator 500 is coupled to the multivibrator 520 through a pair of coupling condensers 523 and 524. This voltage is applied to a pair of cathode resistors 525 and 526 for a pair of tubes 521 and 522 forming the multivibrator 520. A pair of grid resistors and a pair of grid coupling condensers are so chosen in value that the natural frequency of oscillation of the multivibrator 520 is approximately 60 C. P. S. and, since the synchronizing voltage of the multi-vibrator 500 is applied 180 degrees out of phase to the tubes 521 and 522, this multivibrator tends to operate at a frequency which is an odd integral submultiple of the 300 C. P. S. synchronizing signal.

To provide a third subdivided frequency controlled by the standard source of oscillation 490, the output of the multivibrator 520 is coupled to the multivibrator 540 through a pair of coupling condensers 542 and 543. This voltage is applied to a pair of cathode resistors 544 and 545 of a pair of tubes 541 and 542. The grid resistors and grid coupling condensers for the tubes 541 and 542 are so chosen in value that the natural frequency of oscillation of the multivibrator 540 is approximately 20 C. P. S. The multivibrator 540 is synchronized at this frequency of operation by the voltage injected from the multivibrator 520 since the application of synchronizing voltages in opposite phase to the pair of tubes 541 and 542 tends to force the multivibrator 540 to operate at a submultiple frequency which bears an odd integral relationship to the injected voltage.

The 300 C. P. S. output of the multivibrator 500 is also applied to a cathode resistor 603 (Fig. 6) common to the cathodes of a pair of tubes 601 and 602 through a coupling condenser 604 and a conductor 605 (Figs. 5 and 6). The grid resistors and the grid coupling condensers for the tubes 601 and 602 are of such magnitude that the natural frequency of oscillation of the multivibrator 600 is approximately 50 C. P. S. and this multivibrator is stabilized at this operating frequency, which is an even integral submultiple of the injected synchronizing frequency provided by the multivibrator 500, since the injected voltage is applied to both of the tubes 601 and 602 in like phase.

To produce a fifth frequency division of the standard frequency provided by the standard source 490, the multivibrator 620 is coupled to the output of the multivibrator 520 through a coupling condenser 527 and a conductor 623 (Figs. 5 and 6) to apply a voltage to a cathode resistor 624 which is common to the cathodes of a pair of tubes 621 and 622. The coupling condensers and grid leak resistors of the tubes 621 and 622 are of such a magnitude that the natural frequency of oscillation of the multivibrator 620 is approximately 30 C. P. S., and the operation of the multivibrator 620 at this frequency is stabilized by the application of the synchronizing voltage from the multivibrator 520 to both of the tubes 621 and 622 in the same phase.

To insure the application of only 60 C. P. S. voltage to the output terminal 520a from the multivibrator 520, the voltage produced by this multivibrator is coupled to an input amplifier tube 511 of the band pass filter network 510 through a coupling condenser 514 and a resistor 515. This voltage is amplified in the tube 511 and is applied to the grid of a cathode follower tube 512 which provides a means for matching the high impedance of the multivibrator 520 and filter network 510 with the relatively low impedance of the external apparatus (not shown) to which the output terminal 520a is connected. The filter network 510 also includes a band rejection parallel T-filter 513 which degeneratively interconnects the plate and the grid of the tube 511 to prevent amplification in the tube 511 of any signals having a frequency other than the desired 60 C. P. S. voltage. The filter network 510 also includes a cathode resistor common to both of the tubes 511 and 512 to provide positive feedback to the tube 511 to increase the gain thereof as a means for compensating for the loss in gain produced by the parallel T-filter 513.

To provide a 40 C. P. S. output at the output terminal 540a, the filter network 530 is energized

through a coupling condenser 534 and a resistor 535 from the grids of both of the tubes 541 and 542 in the 20 C. P. S. multivibrator 540. Since an input amplifier tube 531 in the band pass filter 530 is energized with voltage from both of the grids of the multivibrator 540, these individual grid outputs are combined to produce a 40 C. P. S. signal which is coupled to the output terminal 540 through an impedance matching cathode follower tube 532. A filter network 533 degeneratively interconnecting the plate and the grid of the tube 531 prevents the amplification of extraneous frequencies.

The 20 C. P. S. output of the multivibrator 540, the 50 C. P. S. output of the multivibrator 600 (Fig. 2), and the 30 C. P. S. output of the multivibrator 620 are connected to the output terminals 540b, 600a, and 620a through the band pass filter networks 550, 610 and 630 which function in the same manner as that described in conjunction with the filter networks 510 and 530 to produce output voltages substantially free from undesired frequencies.

While this invention has been described with particular reference to three embodiments thereof, it will be understood that various modifications may be made therein which are within the true spirit and scope of the appended claims.

What is claimed as new and is desired to be secured by Letters Patent of the United States is:

1. A multi-frequency generator comprising a source of oscillations of a fixed frequency, means for dividing the fixed frequency oscillation into a plurality of different lower frequency signals, a plurality of first amplifying means each energized by one of the lower frequency signals, and frequency responsive means degeneratively interconnecting the input and output of each of the amplifying means, said frequency responsive means transmitting only frequencies different than the lower frequency energizing the amplifying means to which it is connected whereby each amplifying means produces an output signal of only the energizing lower frequency.

2. A multi-frequency generator comprising means for producing a signal voltage of a fixed frequency, means energized by said fixed frequency voltage for producing a plurality of different frequency voltages lower in frequency than said fixed frequency, electron valve means having input and output means, means for energizing the input means of each tube with a one of said lower frequency voltages, a plurality of frequency responsive means interconnecting the input and output means of the amplifying means, each of said responsive means degeneratively returning signal voltages of a frequency different than the lower frequency voltage energizing the amplifying means, and voltage coupling means connected to the output means for providing a plurality of different frequencies.

3. A multi-frequency generator comprising a source of signal voltage of a fixed frequency, means energized by said voltage for producing a plurality of different frequency voltages, a plurality of vacuum tube amplifiers having at least a grid and a plate, each of said grids being energized by one of the different frequency voltages, a plurality of filter networks interconnecting the plates with the grids, each of said filters rejecting voltages of the frequency energizing the grid of the tube associated therewith, and a plurality of cathode follower tubes having grids thereof connected to the plates of the amplifier

tubes for providing low impedance output means for each of the different voltages.

4. The generator defined by claim 3 in which the amplifier tube and the cathode follower tube are provided with a common cathode resistor to produce positive feedback from the follower tube to the amplifier tube.

5. The generator defined by claim 3 in which the different voltages are harmonically related to the fixed frequency.

6. The generator defined by claim 3 in which the frequencies of the different frequency voltages are integral multiples of ten and lower than the fixed frequency.

7. A synchromonic frequency voltage generator comprising a source of voltage of a fixed frequency, means for converting the fixed frequency voltage to a plurality of voltages of different frequencies, means for combining certain of the different frequencies to produce additive frequency voltages, and means for producing voltages of said additive frequencies under the control of the difference in phase between the outputs of the combining means and the producing means.

8. A voltage generator comprising a source of voltage of a first fixed frequency, a source of voltage of a second fixed frequency, means for combining the first and second frequency voltages to provide a voltage of a third frequency, means for producing a voltage of a fourth frequency, and means for controlling the voltage producing means in accordance with the phase difference between the third and fourth frequencies.

9. A voltage generator comprising a first frequency voltage source, a second frequency voltage source, means for combining the voltage of the first and second frequencies to produce a voltage of a third frequency, means for producing a fourth frequency voltage, detecting means for combining the third and fourth frequency voltages to produce an error voltage, and means for controlling the fourth frequency in accordance with the error voltage.

10. A voltage generator for producing a fixed frequency voltage from a plurality of standard frequency voltages comprising a source of voltage of a variable frequency, means for combining the variable frequency voltage with the standard frequency voltages to produce a control voltage having a magnitude proportional to the phase difference between the sum of the standard frequencies and the variable frequency, and means for controlling the source of voltage of variable frequency in accordance with the control voltage to produce voltage having an output frequency equal to the sum of the frequencies of the standard voltages.

11. A voltage generator for producing a fixed frequency voltage from a plurality of standard frequency voltages comprising a controllable source of voltage of said fixed frequency, means for combining the standard frequency voltages with the fixed frequency voltage, means for detecting a phase difference between a voltage produced by an arithmetical operation on the standard frequency voltages and the fixed frequency voltage, and means for controlling the source of the fixed frequency voltage in accordance with the detected phase difference.

12. A voltage generator for producing a predetermined frequency voltage from a plurality of standard frequency voltages comprising a controllable source of voltage of said predetermined frequency, means for combining the predetermined frequency voltage with the standard frequency voltages, means for detecting a phase difference between the sum or difference of the standard frequency voltages and the predetermined frequency voltages, means energized by the detecting means to produce a control voltage of varying magnitude in accordance with said phase difference for controlling the frequency of the voltage produced by the source of predetermined frequency voltage, and phase shifting means interposed between the detecting means and the controllable source for preventing oscillation of a circuit including said source and said detecting means.

13. A generator for producing a plurality of voltages from a plurality of standard voltages of harmonically related frequencies comprising means for producing a first voltage of a frequency not harmonically related to the standard voltages under the control of a number of said standard frequency voltages, and means controlled by said first voltage and another one of said standard frequency voltages for producing a second voltage not harmonically related to the standard frequency voltages.

14. A generator for producing voltages not related harmonically from a plurality of harmonically related voltages derived from a single standard frequency voltage source, comprising a first oscillation generator controlled by the combination of a first group of said harmonically related voltages to produce a first voltage not related harmonically to said combining voltages, means for varying the frequency of oscillation of said first generator in accordance with the difference in phase between the combined voltages and the first voltage, second generating means controlled by said first voltage and another of the harmonically related voltages for producing a second voltage not related harmonically in frequency to the harmonically related voltages, and means for varying the frequency of oscillation of said second generator in accordance with the difference in phase between the first voltage and the harmonically related voltage controlling the production of the second voltage.

15. A ringing machine comprising a source of standard frequency voltages, a controllable source of voltage having a first frequency, a zero-bias triode, means for applying said first frequency voltage and a voltage representing the result of an arithmetic operation on a selected group of said standard frequency voltages to the input of said triode, said triode including output means provided with a control voltage related to the difference in phase between said first frequency voltage and said representing voltage, a cathode follower tube, a filtering network interposed between the output means and the cathode follower tube, and means interconnecting the cathode follower tube with the controllable source to vary the operation thereof in accordance with said control voltage.

No references cited.