

Dec. 6, 1949

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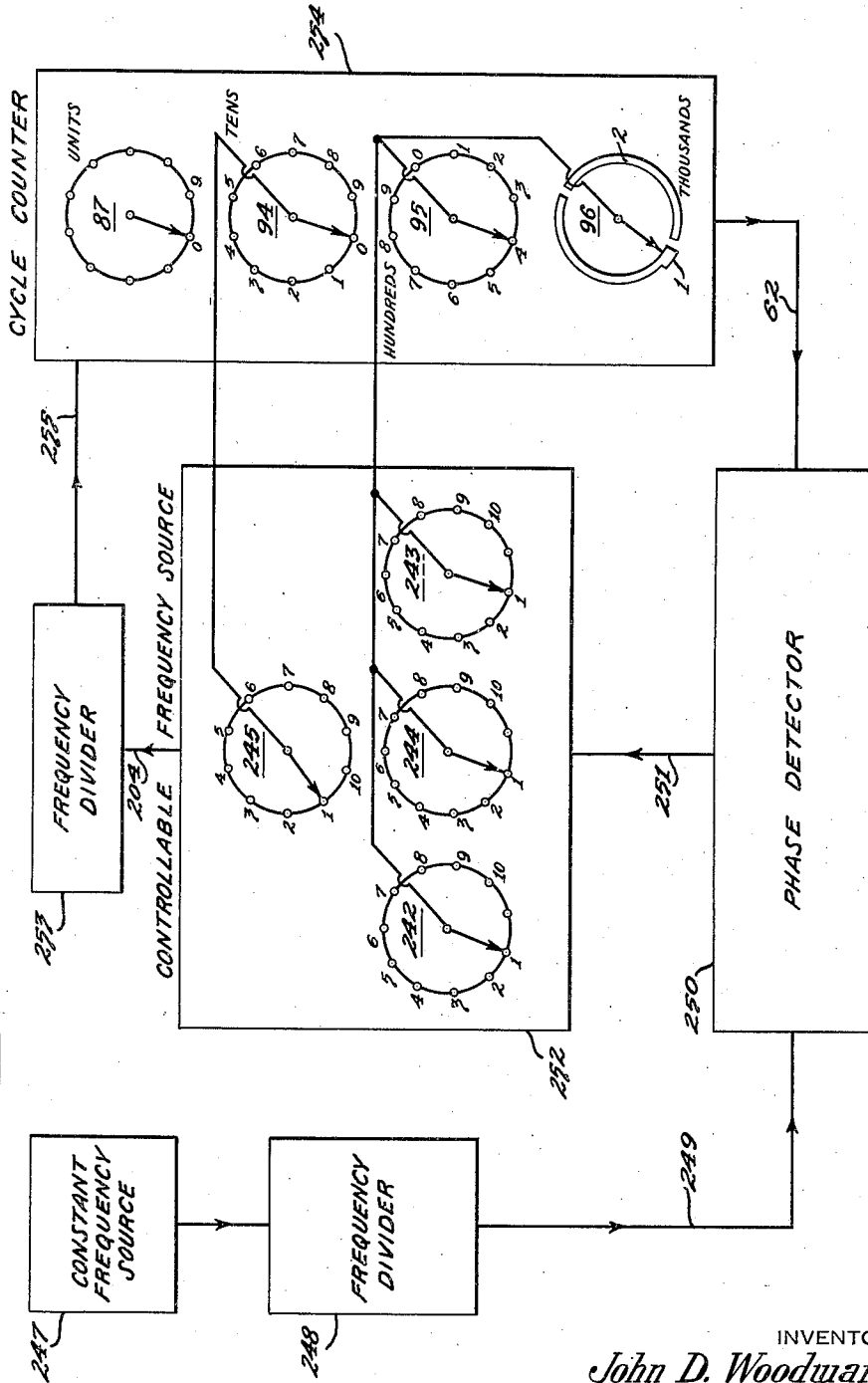
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VARIABLE FREQUENCY OSCILLATION GENERATOR

Filed April 23, 1947

4 Sheets-Sheet 1

Fig. 1



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4 Sheets-Sheet 2

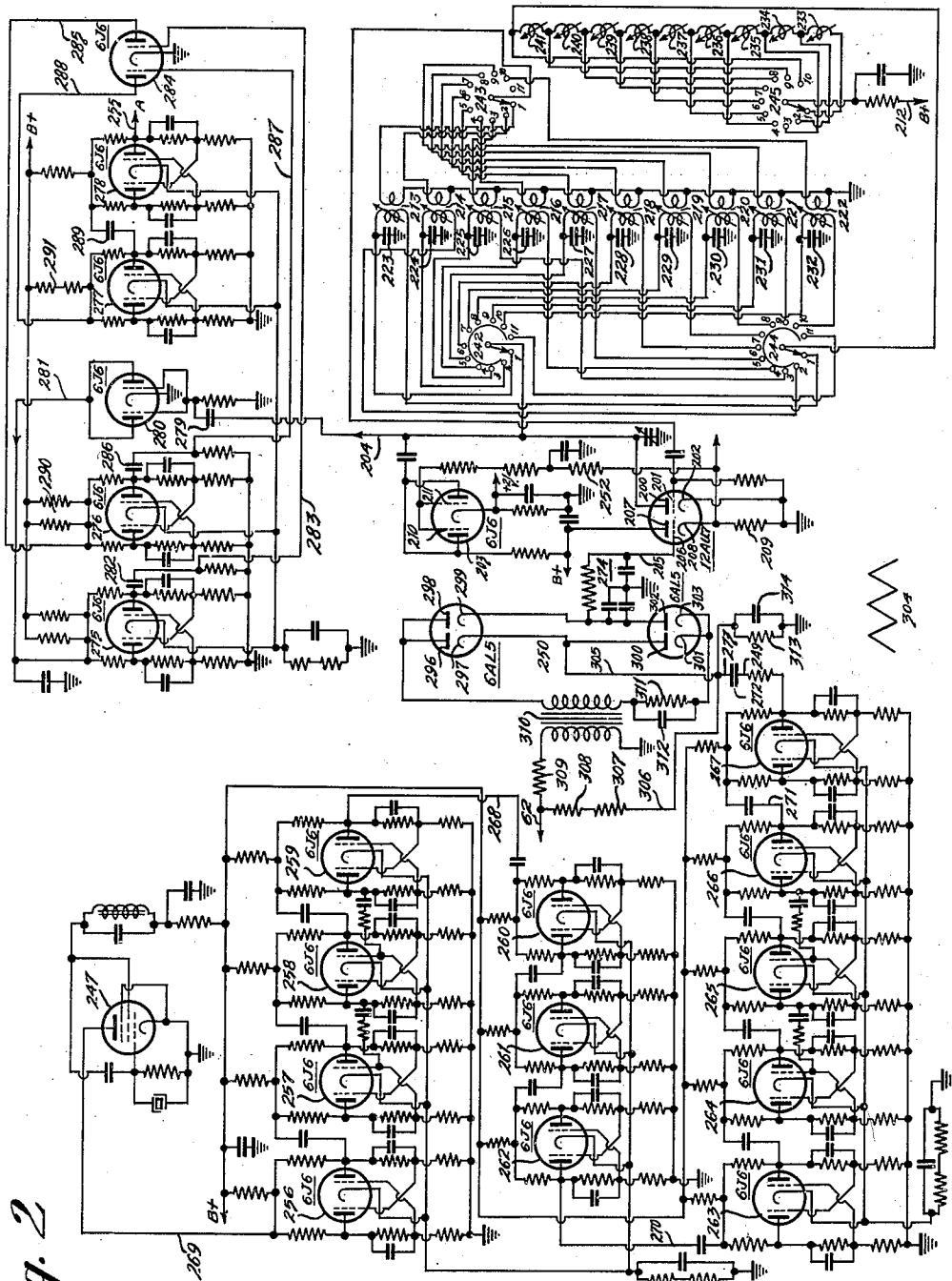


Fig. 2

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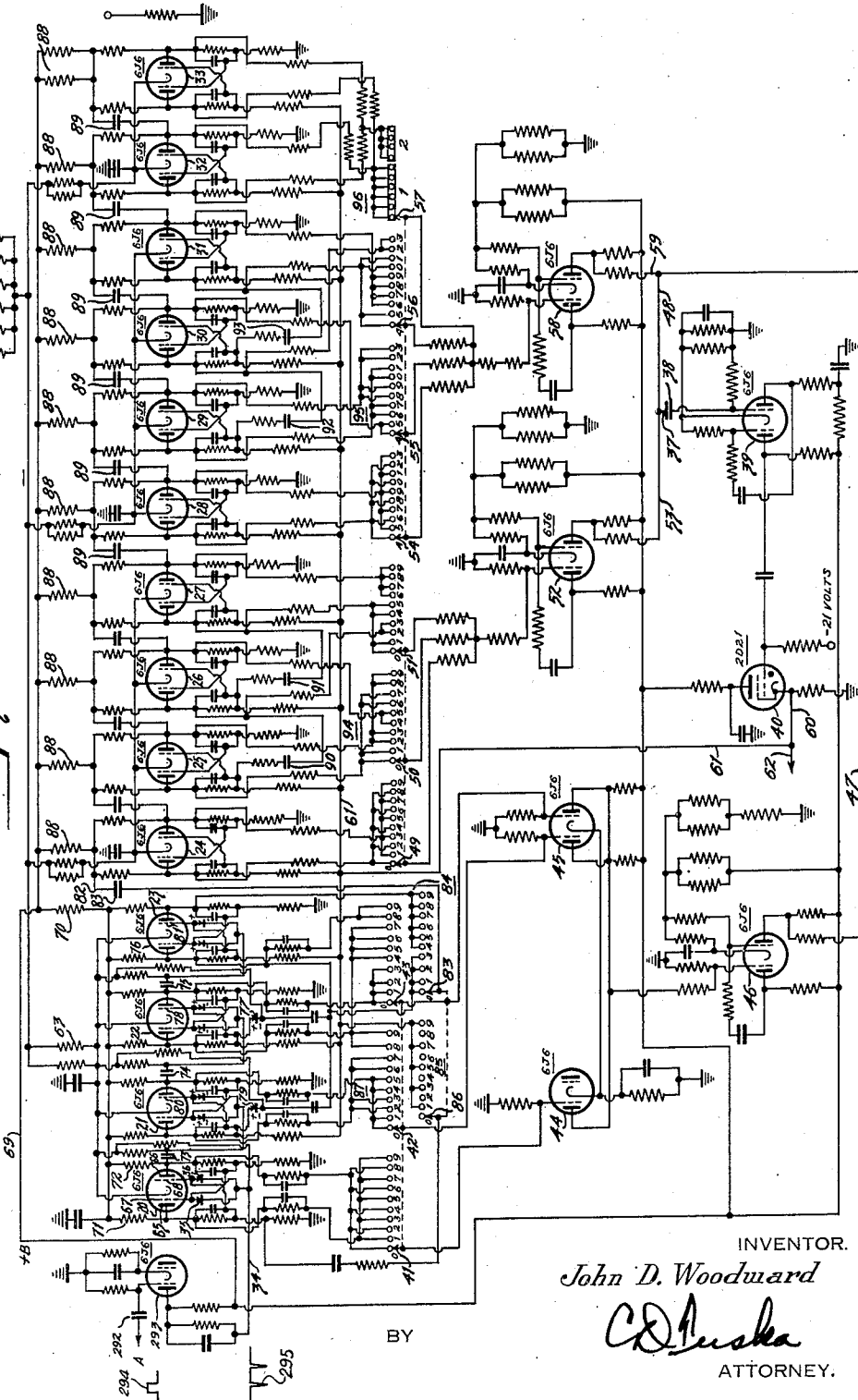
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VARIABLE FREQUENCY OSCILLATION GENERATOR

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Fig. 3



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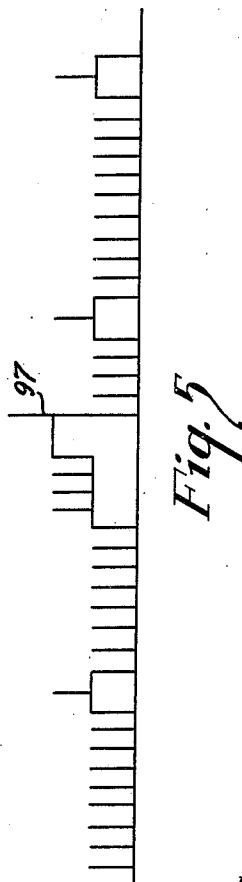
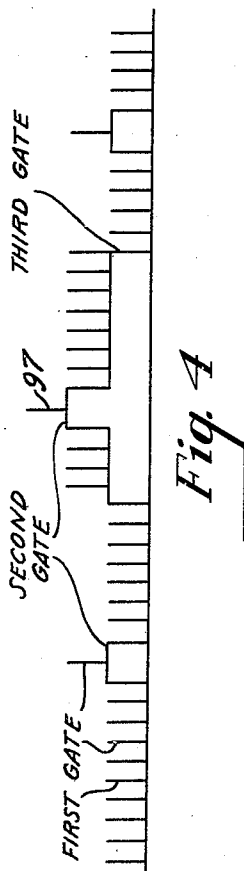
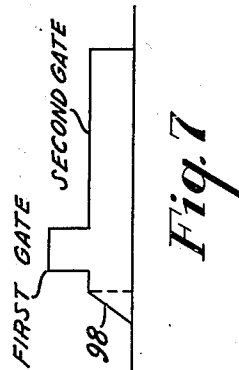
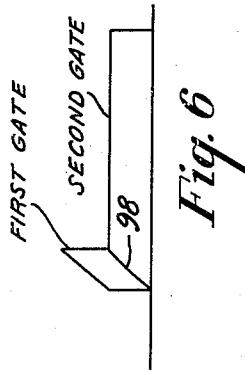
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VARIABLE FREQUENCY OSCILLATION GENERATOR

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4 Sheets-Sheet 4



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VARIABLE FREQUENCY OSCILLATION GENERATOR

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Application April 23, 1947, Serial No. 743,234

8 Claims. (Cl. 250—36)

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This invention relates to variable frequency oscillation generators and has for its principal object the provision of an improved apparatus and method of operation whereby the output frequency of such a generator may be varied over a considerable range by equal steps and may be stabilized with crystal accuracy at each of these steps.

For accomplishing this result, there is provided an oscillation generator having control means whereby its output frequency may be varied by substantially equal steps over the desired frequency range. The output of this generator is supplied to a counter or frequency divider which is so controlled in conjunction with the generator as to produce a substantially constant low frequency. This substantially constant low frequency is applied to a phase detector. Also applied to this phase detector is a constant frequency derived from a crystal controlled generator through a counter or frequency divider having a fixed division ratio, or derived from some other standard frequency source such as a tuning fork. The output of the phase detector is utilized to control the reactance of a reactance tube by which the frequency of the variable frequency generator is held to crystal accuracy at each step of its adjustment.

So long as the substantially constant low frequency derived from the adjustable counter is at its proper value, the phase relation between this frequency and that derived from the constant frequency source is constant and the effect of the reactance tube on the frequency of the variable frequency generator is constant. When the frequency derived from the adjustable counter tends to change, however, there is applied from the phase detector to the reactance tube a control potential by which the output frequency of the variable frequency generator is restored to its proper value. This of course restores the proper phase relation between the two low frequencies applied to the phase detector so that, at any one of its selected output frequencies, the variable frequency generator operates with crystal-controlled accuracy.

Considered from another viewpoint, the ganged controls of the variable frequency generator and the adjustable cycle counter function as a coarse frequency regulating means and the constant frequency source together with its fixed division ratio counter function as a fine frequency regulating or stabilizing means.

Important objects of the invention are the provision of an improved variable frequency genera-

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tor which is adapted to have its output frequency adjusted by equal steps and accurately stabilized at each of these steps; and the provision of a variable frequency generator which is free running over a predetermined frequency range to produce, with crystal controlled accuracy, frequencies separated in value by predetermined submultiples of such range.

The invention will be better understood from the following description considered in connection with the accompanying drawings and its scope is indicated by the appended claims.

Referring to the drawings:

Fig. 1 is a block diagram indicating the relation between the various parts of the apparatus.

Fig. 2 is a wiring diagram showing the connections of the constant frequency generator, the fixed division ratio counter, the phase detector, the reactance tube, the variable frequency generator and a frequency divider which connects the variable frequency generator to the adjustable cycle counter.

Fig. 3 is a wiring diagram of the adjustable cycle counter, and

Figs. 4 to 7 are explanatory diagrams relating to the operation of the adjustable cycle counter.

Fig. 1 shows a constant frequency source 247 from which oscillations are supplied through a frequency divider 248 and a lead 249 to a phase detector 250. Oscillations of substantially constant frequency are also supplied to the phase detector 250 from an adjustable cycle counter 254 through a lead 62. The output of the phase detector 250 is supplied to a controllable or variable frequency generator 252 through a lead 251. The output of the generator 252 is supplied through a lead 204 to a fixed division ratio counter or frequency divider 253 which is connected through a lead 255 to the adjustable cycle counter 254. The counter 254 is provided with a "units" control switch 87, a "tens" control switch 94, a "hundreds" control switch 95 and a "thousands" control switch 96. By manipulation of these control switches, output pulses, of substantially constant frequency may be produced at the lead 62 in response to variable frequency pulses delivered through the lead 255. As hereinafter explained in connection with Fig. 3, the switches 95 and 96 may be ganged together so that the frequency division ratio of the counter is variable over a range of 1400 to 2399 input pulses and a single output pulse is applied to the lead 62 in response to any number of input pulses within this range.

The variable frequency generator is provided

with four control switches. Three of these switches, 242, 243 and 244 function to connect different tuning coils into the tank circuit of the generator for producing equal and relatively large steps in the generator output frequency. The fourth switch 245 functions to connect to the selected tuning coil a plurality of inductance units which are varied in value to produce an equal number of relatively small steps over the range of each of the relatively large steps. In this way, the output frequency of the generator 252 is varied by equal and relatively small steps over a predetermined range.

For purpose of illustration it is assumed that (1) the constant frequency generator 247 delivers a frequency of 100 k. c. which is reduced by the frequency divider 248 to a frequency of 62.5 cycles so that this frequency is applied through the lead 249 to the phase detector 250, (2) the control switch 242, 243 and 244 are so connected that the output frequency of the generator 252 is 700 k. c. when they are in their number 1 positions and is increased by 50 k. c. steps as these switches are moved clockwise into engagement with the successive fixed contacts, and (3) the movement of the switch 245 into engagement with its successive fixed contacts divides each 50 k. c. step into ten 5 k. c. steps. This means that the output frequency of the generator 252 is varied over a range of 700 k. c. to 1195 k. c. by equal steps of 5 k. c. Thus the cycle of operation is movement of the switches 242, 243 and 244 from one fixed contact to another, movement of the switch 245 over all its fixed contacts and subsequent repetition of these two operations.

As hereinafter explained in connection with Fig. 2, the division ratio of the frequency divider 253 is 16 so that the input frequency of the cycle counter 254 varies over a range of 74,687.5 to 43,750 cycles. If the substantially constant output frequency at the lead 62 is to be 31.25 cycles, this means that the division ratio of the counter 254 must be variable over a range of 2399 to 1400. Thus for the 700 k. c. output of the generator 252, the various control switches of Fig. 1 are set to their illustrated positions as a result of which the 700 k. c. tuning coil is connected in the generator tank circuit in series with the maximum number of inductance units and the counter 254 is set for a division ratio of 1400. Under these conditions, pulses are delivered at the output lead 62 at a frequency of 31.25 cycles per second.

From this 700 k. c. value, the generator output frequency is increased to 745 k. c. by 5 k. c. steps in response to movement of the switch 245 and at the same time the switch 94 is rotated to increase the division ratio of the counter 254 by steps of ten. From 745 k. c., the generator output frequency is increased to 750 k. c. by moving the switches 242, 243 and 244 to their 2 positions and the switch 95 to its 5 position. From its 750 k. c. value, the generator output frequency is increased by 5 k. c. steps to 795 k. c. by operation of the switch 245 and at the same time the division ratio is increased by steps of 10 as described above. Further increases in the generator frequency are effected by following the same procedure with the other tuning coils of the generator.

The constant frequency generator 247 is illustrated in Fig. 2 as of a conventional crystal controlled type. The frequency divider 248 is shown as including a plurality of stages 256 to 267. The four high speed stages 256 to 259 are interconnected in a well known manner to form

a decade counter which delivers, at the lead 268, one output pulse for every ten pulses applied to the input lead 269 from the generator 247. The intermediate speed stages 260 to 262 are connected in tandem so that they deliver one output pulse at the lead 270 for every eight pulses applied to the input lead 269. The next four stages 263 to 266 are connected to function as a decade counter so that they deliver one pulse at their output lead 271 for each eight hundred pulses applied to the input lead 269. The last stage 267 divides the frequency at the lead 271 by two so that one pulse is produced at the lead 249 for every 1600 pulses applied to the lead 269 and the 100 k. c. output of the generator 247 is reduced to 62.5 cycles per second.

This 62.5 cycle frequency is applied through a capacitor 272 and a lead 273 to the phase detector 250.

The variable frequency generator 252 includes an oscillator triode 200—201—202 which is interconnected with a reactance tube 203 in a conventional manner to deliver at an output terminal 204 oscillations of a frequency dependent on (1) the reactance of the tube 203, (2) the selected tuning coil connected to the anode 200, and (3) the number of inductance units connected in series with this selected coil.

The output frequency of the generator is established at the desired reference frequency by means of a potential applied through a lead 205 to the grid 206 of a cathode follower 206—207—208 which is provided with a cathode load resistor 209. As is well known, the reactance across the oscillator tank circuit is thus established at a value dependent on the potential applied from the resistor 209 to the grids 210—211 of the reactance tube. This reactance is connected to the oscillator tank circuit in parallel with the selected tuning coil so that, if it is adjusted to a fixed value, the variation in the generator output frequency is produced by change in the tuning coil and in the inductance connected to a +B lead 240 in series with it.

The various oscillator coils beginning with the lowest frequency coil are indicated by the reference numerals 213 to 222. Connected in parallel with these oscillator coils are capacitors 223 to 232 respectively. The various inductance units are indicated by the reference numerals 233 to 241.

Selection of the various oscillator coils and inductance units is effected by four switches 242, 243, 244 and 245. Switch 243 selectively connects the oscillator coils to the grid 201 of the triode 200—201—202. Switch 242 selectively connects the low voltage terminal of these coils to the anode 200 of the triode. Switch 244 selectively connects the high voltage terminal of the coils to a lead 246 of the inductance unit 241. Switch 245 selectively connects the inductance units 233 to 241 to the +B terminal 212.

It will be noted that switches 242 and 244 are each provided with 11 fixed contact numbered from 1 to 11. Contacts 1 to 10 are used to connect the various tank coils into the circuit, while contacts 11, which are connected together, short the unused coils through the shorting rings. This is a customary procedure to eliminate undesirable effects from the unused coils. To obtain a frequency of 1195 k. c. switches 242, 243, and 244 would be on contact 10 and switch 245 would also be on contact 10.

To reduce this output frequency by 5 k. c. steps,

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the movable contact of the switch 245 is moved to engage the fixed contacts 9 to 1 successively until the output frequency is reduced to 1150. When the movable contacts of the switches 242, 243 and 244 are moved to their number 9 positions and the movable contact of switch 245 is moved to the number 10 position the +B lead 212 is connected directly to the high voltage terminal of the 1145 k. c. oscillator coil 222 and this coil is connected through the switches 242 and 243 respectively to the anode 200 and the grid 201. This output frequency of 1145 k. c. is reduced by 5 k. c. steps by operation of the switch 245 as explained in connection with the 1195 k. c. oscillator coil 222. The same procedure is repeated with each of the oscillator coils 220 to 213. The switches 242, 243 and 244 may be ganged together for simultaneous operation.

It will be noted that the lead 205 is connected through a capacitor bank 274 to the output of the phase detector 250.

Output pulses of a frequency from 700 k. c. to 1195 k. c. are applied through the lead 204 to a frequency divider which includes stages 275 to 278. Thus such pulses are applied through a capacitor 279, a coupling tube 280 and a lead 281 to the common anode terminal of the stage 275. Pulses of one half the input frequency are delivered from the right anode of the stage 275 through a capacitor 282, a lead 283, a coupling tube 284 and a lead 285 to the common anode terminal of the stage 276. Pulses of one fourth the input frequency are delivered from the right anode of the stage 276 through a capacitor 286, a lead 287, the coupling tube 284 and a lead 288 to the common anode terminal of the stage 277. Pulses of one-eighth the input frequency are delivered from the right hand anode of the stage 277 through a capacitor 289 to the common anode terminal of the stage 278. Pulses of one-sixteenth of the input frequency are applied from the right hand anode of the stage 278 to the lead 255.

As indicated by Fig. 3, the lead 255 is connected to the adjustable cycle counter 254 through a capacitor 292 and a duotriode 293 which is so connected as to differentiate the pulses 294 of the lead 255 for applying to the adjustable cycle counter 254 pulses of the form indicated by the reference numeral 295.

The adjustable cycle counter of Fig. 3 includes a high speed decade comprising the duotriodes 20 to 23, an intermediate speed decade comprising the duotriodes 24 to 27, a low speed decade comprising the duotriodes 28 to 31 and two additional duotriodes 32 and 33. Input pulses 295 of negative polarity are applied from a lead 34 through the crystal diodes 35 and 36 to the grids of the duotriode 20. Output pulses are applied from an output lead 37 through a capacitor 38 to a reset circuit which includes a duotriode 39 and a tetrode 40. The number of input pulses required to produce one output pulse is determined by the setting of the selector switches of the different decades. If the output frequency is to be maintained constant, it is necessary that the setting of the selector switches be changed at each change in output frequency.

These selector switches 87, 94, 95 and 96 which are shown immediately below the decades which they control, have their movable contacts connected through gates of the duotriode type to the output terminal 37. Thus the three movable contacts 41, 42 and 43 of the selector switch of the decade 20-23 are connected through the

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duotriodes 44, 45 and 46 and the leads 47 and 48 to the output lead 37 so that the lead 37 is made more positive when the count of the decade 20-23 corresponds to the setting of the movable contacts 41-42-43 of the selector switch of this decade. Likewise the three movable contacts 49, 50 and 51 are connected through a duotriode 52 and a lead 53 to the output lead 37 so that this lead is made more positive when the count of the decade 24-27 corresponds to the setting of the contacts 49, 50 and 51. Similarly the three movable contacts 54, 55 and 56 of the selector switch of the decade 28-31 and the single movable contact 57 of the selector switch of the counter units 32 and 33 are connected through a duotriode 58, a lead 59 and the lead 48 to the output lead 37 so that this lead is made more positive when the count corresponds to the setting of the contacts 54 to 57.

During the counting operation, the more positive potentials mentioned above must be simultaneously applied to the output lead 37 in order to activate the reset circuit. Thus a more positive potential is established at the lead 59 when the count to decade 28-31 and stages 32 and 33 corresponds to the setting of the contacts 54 to 57, at the lead 53 each time the count of decade 24-27 corresponds to the setting of contacts 49, 50 and 51, and at the lead 47 each time the count of the decade 20-23 corresponds to the setting of the contacts 41, 42 and 43. When these three potentials are all at their most positive value, the reset tube 39 is biased on and one output pulse is produced at a lead 60 which is connected to a counter reset lead 61 and the output lead 62.

The character of the pulses produced at the leads 37 and 60 are to be discussed hereinafter in considerable detail for the reason that they relate to important features of the invention. As already indicated, these pulses are dependent on the potentials produced at the fixed terminals of the various selector switches by the trigger circuits of which the counter is constructed. It is therefore necessary to consider the circuit connections of the trigger circuits, their interconnections with one another, their connections to the fixed contacts of the selector switches, and the arrangement of these fixed contacts with respect to one another.

All the trigger circuits of the counter are of a type wherein two triodes each has its anode cross-connected to the grid of the other through a resistor shunted by a capacitor so that current conduction is in either one or the other of the triodes.

Thus the first trigger circuit of the decade 20-23 has its anode 65 cross-connected to its grid 68 and its anode 66 cross-connected to its grid 67. The cathode of this trigger circuit is grounded through resistors 63 and 64 and operating potential is applied to the anodes 65 and 66 from a +B lead 69 through a resistor 70 which functions to maintain all the anodes of the decade at the potential level required for proper operation of the counter with these connections, the application of a negative pulse from the lead 34 through the diode crystals 35 and 36 to the grids 67 and 68 functions in a well known manner to transfer current conduction from the conducting to the non-conducting triode of the trigger circuit.

The other three trigger circuits of the decade 20-23 are similar to the first. All of them are connected in tandem through the coupling

capacitors 73, 74 and 75. An important feature of the decade 20-23 is the connection of the anode of tube 76 of the last stage through a crystal diode 77 to the right hand grid 78 of the third stage and through a diode crystal 79 to the right hand grid 80 of the second stage. With these connections, the operation of the decade 20-23 is as indicated by the following tabulation wherein the number of pulses applied to the input lead 34 are shown in the first column and the current conducting condition of the various stages are indicated by R (right-hand triode) and L (left-hand triode).

Tabulation No. 1

Pulse No.	Trigger circuit number			
	20	21	22	23
0	R	R	R	R
1	L	R	R	R
2	R	L	R	R
3	L	L	R	R
4	R	R	L	R
5	L	R	L	R
6	R	L	L	R
7	L	L	L	R
8	R	L	L	L
9	L	L	L	L
10	R	R	R	R

It is apparent from the above tabulation that a negative pulse is produced at the anode of tube 76 of the last stage in response to right input pulses and at the anode 81 of this stage in response to ten input pulses.

Such negative pulse at the anode of tube 76 functions to transfer current conduction from the right-hand triodes to the left-hand triodes of the second and third stages so that the operating cycle of the decade 20-23 is completed in response to ten input pulses. This type of feed-back is disclosed in a copending application of I. E. Grosdoff, Ser. No. 580,446, filed March 1, 1945.

Output pulses of negative polarity are fed to the input terminal 82 of the decade 24-27 through a capacitor 83 from one or the other of the anodes 76 and 81 depending on the setting of the movable contact 83 which cooperates with fixed contacts 0, 1, 2 and 3 (connected to the anode of tube 76) and fixed contacts 4 to 9 (connected to the anode 81). This switch as a whole is indicated by the reference numeral 84. Its purpose is hereinafter explained in connection with the form of pulse which is effective to operate the reset circuit previously mentioned.

Associated with the decade 20-23 is a switch 85 which includes a movable contact 86 and fixed contacts 0 to 9. The function of this switch is to connect the right-hand grid 68 of the first stage to the reset lead 61 only when the stage is not in its zero count condition. The purpose of this is to avoid interference between the input pulses which may be applied continuously and the reset pulse which might otherwise operate the stage to produce inaccuracy of the count.

The three point switch which controls the application of the anode potentials of the decade 20-23 to the gates 44, 45 and 46 is indicated by a general reference numeral 87 for convenience of reference. It includes the movable contacts 41, 42 and 43 and three corresponding groups of fixed contacts. Each group of fixed contacts is numbered 0 to 9 like the fixed contacts of the switches 84 and 85. As indicated by broken lines, the movable contacts of the switches 84, 85 and 87 may be all ganged together so that each movable contact

engages the same numbered fixed contact in all the switch positions.

By assuming any desired position of the switches 84, 85 and 87 and referring to the above "Tabulation No. 1," it is easy to see that the movable contacts 41, 42 and 43 of the switch 87 are all least positive only when the number of input pulses corresponds to the particular switch setting. Thus if the switch 87 is set at the number 5 more negative potentials only when five input pulses have been applied to the lead 34. The same is true for all the other settings of the switch 87.

As hereinafter explained in greater detail, these more negative pulses of the movable contacts 41, 42 and 43 are combined and reversed by the triodes 44 and 45, then passed through the gate 46 to give a single reversed pulse, which is again reversed and amplified by the second half of the duotriode 46 so that a more positive pulse is applied to the lead 47.

The remaining stages of the counter differ from the stages of decade 20-23 in that (1) anode potential is applied from the lead 69 through a common resistor 88 to the individual anode resistors, (2) input pulses are applied between the different stages through capacitors 89 to a terminal at the junction of the common and individual resistors, (3) the feed-back connections of the decades 24-27 and 28-31 are made through capacitors 90 to 93 instead of crystal diodes and (4) the feed-back in each decade is from the last to the third and from the third to the second instead of from the last to the second and third stages.

The use of crystal diodes in the grid circuits of the first decade 20 to 23 has the advantage that it facilitates more rapid operation of this stage. The second and third decades operate at speeds which permit the use of capacitors through the circuit. It is, of course, apparent that the decade 24-27 counts tens, the decade 28-31 counts hundreds and the stages 32 and 33 count thousands. The operation of the decade 24-27 is apparent from the following tabulation wherein the input pulses are each indicated as a group of 10.

Tabulation No. 2

Input Pulse No.	Trigger circuit number			
	24	25	26	27
0	R	R	R	R
10	L	R	R	R
20	R	L	R	R
30	L	L	R	R
40	R	R	L	R
50	L	L	L	R
60	R	R	R	L
70	L	R	L	L
80	R	L	L	L
90	L	L	L	L
100	R	R	R	R

The operation of the decade 28-31 is similar to that of the decade 24-27 with the exception that each impulse applied to it represents 100 pulses applied to the lead 34. Similarly each input pulse to the stages 32 and 33 represents 1000 input pulses applied to the lead 34.

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Three point switches 94 and 95 similar to the three point switch 87 are provided for applying the anode potentials of the decade 24-27 and the decade 28-31 respectively to the gate 52 and the gate 58. Ganged with the switch 95, as indicated by a broken line, is a switch 96 by which the counts of the stages 32 and 33 are combined with the counts of the decade 28-31 to produce a result to be explained in greater detail.

Assuming the switch 94 to be set for a count of 70, as indicated by the numeral 7 adjacent its corresponding fixed contact, it is seen that the movable contact 49 is connected to the right-hand anode of the stage 24, the movable contact 50 is connected to the left-hand anode of the stage 25, and the movable contact 51 is connected to the right-hand anode of the stage 27. Referring to "Tabulation No. 2," it is seen that all the anodes to which these movable contacts are connected are not conducting current in response to the 70th input pulse and are therefore at their more positive potentials. These more positive potentials are combined and amplified in the gate 52 and function to produce a more positive pulse at the lead 53. In the same manner, each setting of the switch results in a more positive potential at the lead 53 when the number of input pulses correspond to the selected setting of the switch 94.

While the decade 28-31 is similar to the decade 24-27, its three point switch 95 has somewhat different arrangement of its fixed contacts as indicated by the reference numerals which are adjacent the fixed contacts and have the same significance as in the cases of the switches 87 and 94.

Assuming the switches 95 and 96 to be set in their illustrated positions, it will be noted that the contact 54 is connected to the left-hand anode of the stage 28, the contact 55 is connected to the right-hand anode of the stage 30, and the contact 56 is connected to the left-hand anode of the stage 31. Since all these anodes are not conducting current at a count of four hundred input pulses and are therefore at their more positive potentials, a more positive potential tends to be applied to the gate 58. This potential is not sufficient to open the gate because of the negative potential applied to it from the right-hand anode of the stage 32. When the number of input pulses reaches 1400, however, the gate 58 is opened and the lead 59 is made more positive.

As the movable contacts 54, 55, 56 and 57 are moved to the right, the gate 58 is opened successively in response to input pulses numbering 1500, 1600, 1700, 1800, 1900, 2000, 2100, 2200 and 2300. This particular arrangement is provided to facilitate the maintenance of a constant frequency of 31.25 cycles at the output terminal 62 while the input frequency at the lead 34 is changed by equal steps from 43,750 to 74,687.5 cycles.

With the switch settings previously assumed, one output pulse is produced in response to 1475 input pulses. Such a single output pulse may be produced by input pulses numbered from 1400 to 2399 with the switches 95 and 96 ganged together as illustrated. Thus if the input frequency is 43,750 cycles and the output frequency is to be kept at 31.25 cycles, the selector switches are set at 1400. Similarly the selector switches are set at 1410 for an input frequency of

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$$\frac{705000}{16} \text{ cycles}$$

at 1420 for an input frequency of

$$\frac{710000}{16} \text{ cycles}$$

at 1430 for an input frequency of

$$\frac{715000}{16} \text{ cycles}$$

at 1440 for an input frequency of

$$\frac{720000}{16} \text{ cycles}$$

at 1450 for an input frequency of

$$\frac{725000}{16} \text{ cycles}$$

etc.

As indicated above but not explained in detail, the anode voltages of the various stages of the counter are applied through the three point selector switches 87, 94 and 95 and the one point switch 96 to the isolating tubes 44 and 45 and to the gate tubes 46, 52 and 58 for producing a reset or output pulse in response to a number of input pulses corresponding to the setting of the selector switches.

These tubes are illustrated as of the duotriode type, only one of the triodes being utilized in the case of 44. The more negative potentials of the switch 87 are applied respectively to the grid of the tube 44 and to the grids of the tube 45. As a result, the tubes 44 and 45 draw less current through their anode resistors and a more positive potential is applied to the left-hand grid of the gate 46. When all three of the triodes of 46 and 47 are conducting, sufficient voltage is applied to the grid to override the bias and cause 46 to conduct, thus increasing the current of its left-hand triode and applying a more negative potential to its right-hand grid so that the current of its right-hand triode is reduced and a more positive potential is applied to the lead 47.

In previously known means of combining the anode voltages of a decade counter, it has been customary to insert large isolating resistors in the fixed contact leads of the selector switch and to connect the selected ones of these resistors through the movable switch contacts to a common terminal which is connected to the grid of the gate tube. The disadvantage of such a combining system is that the large isolating resistors in series with the input capacity of the gate tube produces a slope on the leading edge of the pulse applied to the grid of the gate tube so that the gate tube is operated a fraction of a cycle late.

By using the three isolating triodes 44 and 45 as explained above, the gate tube control voltage wave is made to have about the same steepness as those of the anode voltage waves. At the same time there is maintained such complete isolation between the anodes of the decade as is required to prevent interference with the operation of the decade by variation in the selector switch settings.

It should be noted that the cathodes of the isolating tubes 44 and 45 are all connected together and are so biased as to conduct only when a more positive voltage is applied from the selected anodes of the decade.

The operation of the gate tubes 52 and 58 is readily understood without detailed explanation. When a more positive pulse is applied from the selected anodes to their left-hand grids, more

current is drawn by their left-hand triodes, the potentials of their right-hand grids is made more negative, the current of their right hand triodes is reduced and more positive potentials are applied to the leads 53 and 59.

The more positive potential which is applied to the lead 37 in response to the selected number of pulses applied to the input lead 34 is now to be considered in connection with Figs. 4 to 7. Fig. 4 is a diagrammatic indication of the composition of the potential applied to the lead 37. The potentials applied through gate 46 are indicated by straight lines, the potentials applied through the gate 52 are represented by square waves of short width, and the potentials applied through the gate 58 are indicated as square waves of larger width.

It will be noted that these gated potentials are super-imposed on one another, as indicated by the reference numeral 97, when the number of pulses applied to the input lead 34 corresponds to the setting of the selector switches 87, 94, 95 and 96. This pulse 97 makes the right-hand grid of the peak detector 39 more positive, more current is drawn through the right-hand anode resistor, the potential of the left-hand grid is made more negative, less current is drawn through the left-hand anode resistor and a positive pulse potential is applied to the grid of the tube 40. As a result, the tube 40 triggers, drawing a large pulse of current through its cathode resistor and a positive pulse potential is applied to the lead 60. This potential is applied (1) to the output lead 62 and (2) to the reset lead 61 which is connected to the right-hand grids of the various stages of the counter. When this more positive potential is so applied to these right-hand grids, all the stages of the counter are reset to their zero count or standing condition with current in their right-hand anodes. The effect of this on the potentials at 37 is shown in Fig. 5.

In connection with Fig. 4, it has been assumed that all the voltages change instantaneously. Actually, the step from the potential of the second gate to that of the first gate may have a curvature on its front edge as indicated at 98 in Figs. 6 and 7 wherein the anode potentials of the first and second decade are shown much wider than in Fig. 1. Assuming the pulses of the first gate to have straight sides, this curvature results in a control and reset pulse occurring a fraction of a second later than it should.

Such inaccuracy is minimized or obviated by the provision of the switch 84 connected between the first and second decade. This switch functions to advance the time (but not the rate) at which pulses are fed to the second decade when its movable contact 83 is in engagement with the fixed contacts 0 to 3. The resulting effect, as indicated by Fig. 7, is to advance the beginning of the "second gate" potential so that the "first gate" potential is not superimposed on the curved portion 98 of the "second gate" potential. In this manner, correct timing of the reset and output pulses is assured. This feature is of course useful in many other cases where superimposed voltages are derived through a plurality of gates from sources of potentials which are of a wave form subject to curvature.

In resetting a variable frequency counter, such as that of the present invention, the most critical point is the first stage of the high frequency decade. For all odd numbered settings of the selector switch, this first stage must be reset and ready to operate in less than one cycle so that

no counts are missed. For all even numbered settings of the selector switch, the first stage must not be reset and must not hold over for an extra cycle. These conflicting requirements are met by applying the reset potential to the right-hand grid of the first stage of the high frequency decade only on the odd counts. This is accomplished by the switch 85 which has its odd numbered fixed contacts connected to the reset lead 61 and has its movable contact 86 connected through a relatively high resistance to the right-hand grid of the first stage so that the reset pulse applied to this grid is of an amplitude reduced to the optimum value for the condition under which this stage is operated.

The substantially constant frequency of about 31.25 cycles per second is fed from the adjustable cycle counter 254 through the output lead 62 to the phase detector 250, the circuit connections of which are shown in Fig. 2. This phase detector includes four diodes 296—297, 298—299, 300—301 and 302—303. Potential of a wave form indicated at 304 and a frequency of 62.5 cycles per second is applied through the lead 273 to the leads 305 and 306. It will be noted that the lead 305 is connected to the cathode 297 and to the anode 300, that the lead 306 is connected through resistors 307 and 308 to the lead 62 through which the 31.25 cycle pulses are applied from the adjustable cycle counter 254, and that the lead 62 is connected through a resistor 309 to the primary circuit of a transformer 310. The secondary circuit of this transformer is connected to the anodes 296 and 298 and to the cathodes 301 and 303 through a resistor 311 which is shunted by a capacitor 312. The cathode 297 and anode 300 are connected to ground through a resistor 313 which is shunted by a capacitor 314 and the cathode 299 and anode 302 are connected to ground through the capacitor bank 274 from which potential is applied to the grid of the cathode follower 206—207—208 for regulating the reactance of the tube 203.

Assuming that various circuit components of the phase detector to have the values indicated by the legends placed adjacent to them, the potential applied to the grid 206 of the cathode follower is determined in a well known manner by the phase relation between the 62.5 cycle and 31.25 cycle pulses applied to it respectively through the leads 249 and 62. Thus if the frequency of the pulses at the lead 62 tends to increase, a more positive potential is applied to the grid 206 so that the potential across the resistor 209 is increased, the reactance of the tube 203 is decreased and the frequency of the variable frequency generator is reduced. When the frequency of the pulses at the lead 62 tends to decrease, the opposite effect is produced. Thus the variable frequency generator delivers at its various selected frequencies an output frequency which is maintained with crystal controlled accuracy.

What the invention provides is a variable or adjustable frequency generator which is readily controlled to operate at different frequencies which are separated by equal ranges and are each regulated with crystal controlled accuracy.

I claim as my invention:

1. The combination of a controllable frequency generator, a phase responsive device, a constant frequency generator, a frequency divider connected between said constant frequency generator and said phase responsive device, means including a frequency divider of adjustable division ratio con-

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ected between said controllable frequency generator and said phase responsive device, and means interconnecting said phase responsive device and said controllable frequency generator for regulating the output frequency of said controllable frequency generator in response to change in the phase relation between the output pulses of said generators.

2. The combination of a constant frequency source, a controllable frequency generator, an adjustable division ratio frequency divider connected to the output of said generator, means for simultaneously controlling the frequency of said generator and the division ratio of said divider so that the output frequency of said divider is maintained at a substantially constant value, and means responsive to the phase relation between the outputs of said source and said divider for stabilizing the frequency of said generator.

3. The combination of a controllable frequency generator, an adjustable division ratio frequency divider connected to the output of said generator, and unitary means for changing said frequency and said division ratio so that the output frequency of said divider is maintained substantially constant.

4. The combination of a controllable frequency generator, an adjustable division ratio frequency divider connected to the output of said generator, and unitary means for changing said frequency and said division ratio so that the output frequency of said divider is maintained substantially constant and means responsive to each output pulse of said divider for resetting said divider to its standby condition.

5. The combination of a constant frequency source, a controllable frequency generator, an adjustable division ratio frequency divider connected to the output of said generator, means for simultaneously controlling the frequency of said generator and the division ratio of said divider so that the output frequency of said divider is maintained at a substantially constant value, a phase detector connected to said source and to the output of said divider, and means including a

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cathode follower connected between said detector and said generator for stabilizing the output frequency of said generator.

6. The combination of a constant frequency source, a controllable frequency generator, an adjustable division ratio frequency divider connected to the output of said generator, means for simultaneously controlling the frequency of said generator and the division ratio of said divider so that the output frequency of said divider is maintained at a substantially constant value, phase responsive means connected to said source and to the output of said divider, a reactance tube connected to said generator, and a cathode follower connected between said phase responsive means and said reactance tube for stabilizing the frequency of said generator.

7. The combination of a constant frequency source, a controllable frequency generator, means for changing the frequency of said generator by discrete steps, a frequency divider responsive to the output frequency of said generator, means for controlling the division ratio of said divider in accordance with said steps and maintaining the output frequency of said divider at a substantially constant value, and phase responsive means responsive to the outputs of said source and said divider for stabilizing the output frequency of said generator at each of said steps.

8. The combination of a constant frequency source, a controllable frequency generator, means for changing the frequency of said generator by discrete steps, a frequency divider responsive to the output frequency of said generator, means for controlling the division ratio of said divider in accordance with said steps and maintaining the output frequency of said divider at a substantially constant value, and means responsive to the outputs of said source and said divider for stabilizing the output frequency of said generator at each of said steps.

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No references cited.