March 7, 1939. D. A. BELL 2,149,721

THERMIONIC OSCILLATION GENERATOR

Filed Aug. 14, 1936

Fig. 1

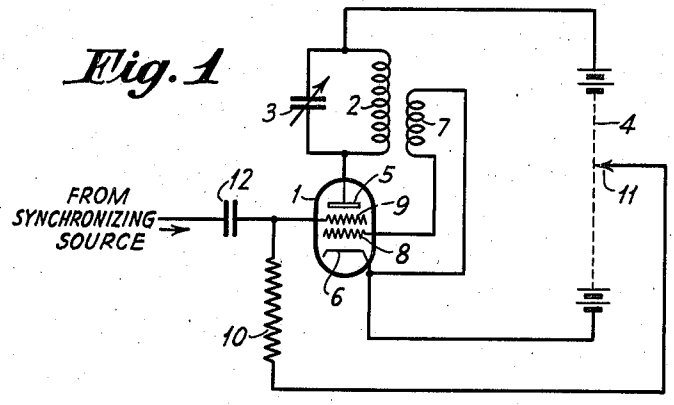


Fig. 2

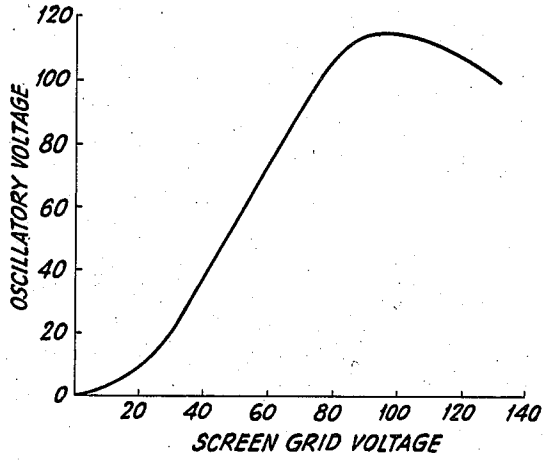


Fig. 3

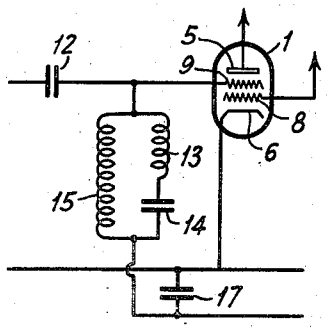
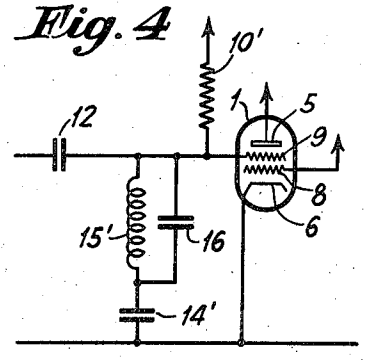


Fig. 4



INVENTOR
DAVID ARTHUR BELL
BY H. S. Grover
ATTORNEY

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THERMIONIC OSCILLATION GENERATOR

David Arthur Bell, Chelmsford, England, assignor to Radio Corporation of America, a corporation of Delaware

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4 Claims. (Cl. 250—36)

This invention relates to thermionic oscillation generators and more particularly to thermionic oscillation generators adapted to be synchronized by memans of an external source of oscillating potential.

It is frequently desired to control an oscillation generator so that the frequency of the oscillations generated is the same or an exact multiple or sub-multiple of the frequency of some external alternating voltage source. Various methods have been proposed for "locking" an oscillation generator into step with a controlling source of potential, one of the most usual methods being to employ as the oscillator a valve having at least two control grids and to employ the cathode, the second grid and the anode as the oscillator electrodes, applying the synchronizing or controlling voltage to the remaining grid. This type of arrangement involves the use of a valve having at least two grids and the simplest form of such valve is the tetrode, the screened grid valve being the type of tetrode most usually available. Now with this type of valve the mutual conductance between screening (second grid) and anode is usually quite small; a mutual conductance of the order of 0.24 mA/volt between second grid and anode as against a mutual conductance of from 1 to about 4 mA/volt between first (control) grid and anode is quite usual. This known method wherein the first grid is the synchronizing input grid and the cathode, second grid and anode are used as the oscillator electrodes is, therefore, not always satisfactory, for the mutual conductance between second grid and anode may be too low to sustain oscillation under all required conditions. The principal object of this invention is to avoid this defect.

According to the present invention, a thermionic oscillation generator adapted to be synchronized or locked into step with an external source of voltage and of the kind wherein there is employed a valve having at least two grids between the cathode and anode thereof, the cathode, anode and one grid cooperating to act as an oscillation generator, is characterized in that the synchronizing or locking signals are applied to a grid which is between the oscillator grid and the anode.

The invention is illustrated in, and further explained in connection with the accompanying drawing, wherein Fig. 1 shows an example of my device and Figs. 3 and 4 show preferred modifications thereof, while Fig. 2 shows a curve which is used to explain an adjustment of my device.

Referring to Fig. 1, which shows diagrammatically one simple arrangement in accordance with the invention, a screen grid valve 1 has a parallel tuned circuit 2, 3, in series with a source 4 of anode potential connected between its anode 5 and its cathode 6, and a coil 7 coupled to the coil 2 in said tuned circuit is connected between the control or first grid 8 and the cathode 6. The screen or second grid 9 is maintained at a suitable mean or direct current potential by connecting it through a suitable resistance 10 to a tapping 11 on the source 4. Synchronizing potentials from a source (not shown) are applied to the second grid 9 through a suitable condenser 12. The tuned circuit 2, 3, is tuned to the desired oscillating frequency ($f2$), and the synchronizing frequency ($f1$) applied to grid 9 may be the same as $f2$ or a multiple or a submultiple thereof.

It is, of course, not necessary to employ the inductively back-coupled oscillator circuit shown, for any other suitable oscillator circuit, e. g., a so-called Hartley or Colpitts circuit could be used. Again, the synchronizing pulses need not be applied by resistance-capacity coupling, as illustrated, for a transformer, or a tuned input circuit could be employed therefor.

If, in the arrangement of Fig. 1, a source of variable direct current voltage (instead of the synchronizing alternating current voltage source) be applied to the screen grid, the static characteristic of the system may be obtained and such a characteristic is exemplified in the accompanying Fig. 2 in which oscillatory voltage (ordinates) is plotted against screen grid voltage (abscissae). From Fig. 2 it will be seen that variation of screen grid voltage has little effect upon output in the neighborhood of zero screen grid volts, while at a point where the screen grid voltage is somewhat higher than that normally applied in a screen grid valve, the output amplitude passes through a maximum.

In practice, the mean screen grid voltage upon which the synchronizing voltage is superimposed is preferably such that there is obtained a large rate of change of oscillation amplitude with screen grid voltage variation about said mean voltage; e. g., for the case of an arrangement with a characteristic as plotted in Fig. 2, a mean screen grid voltage of from about 30 to 70 volts would be satisfactory.

There is a tendency for the output frequency ($f2$) to appear on the grid 9 and be conveyed back to the synchronizing source. This appearance can take place from three causes (1) by reason of mutual conductance between grids 8 and 9 (2) by reason of reflex mutual conductance between anode 5 and grid 9, rise in anode current tending to cause a fall in second grid current, and (3) by reason of capacitative coupling (which may be appreciable at high frequencies) between grid 9 and some other electrode or electrodes. Of these three causes, the first may be reduced or eliminated by employing a valve having more than two grids and utilizing as the synchronizing input grid a grid which does

not collect any appreciable current, e. g., the third grid in a pentode. Of course, where a pentode is used, the screen grid may be employed as the synchronizing grid, although the use of the suppressor grid for this purpose is preferred. The second cause may, in the case of a tetrode, be reduced or eliminated by operating with the anode voltage well above the screen grid voltage, since then neither the anode nor the screen grid current is much affected by changes in anode potential. As regards the third cause, the capacity coupling may, to some extent, be balanced, since the grid and anode voltages of an oscillator are in phase opposition, and by suitably adjusting the oscillator grid and anode voltage amplitudes, their net effect upon the synchronizing grid may be made to approximate to zero.

If, in any case, it is impracticable to adopt the above precautions to the full extent, feed-back of output voltage to the source of synchronizing voltage may be minimized by so designing the synchronizing input coupling circuit that the impedance from synchronizing electrode to cathode (or other point of zero potential) is very low at the output frequency ($f2$) but adequately high at the synchronizing frequency ($f1$). Such an arrangement is illustrated in the accompanying Fig. 3 where the synchronizing input coupling circuit includes a circuit 13, 14, 15 which is in parallel resonance for the synchronizing frequency ($f1$), the series elements 13, 14 forming, however, an acceptor circuit for the output frequency ($f2$). The circuit of Fig. 3 (only part is shown) is suitable for the case where $f2$ is a multiple of $f1$. Where $f2$ is a sub-multiple of $f1$, a circuit as shown in Fig. 4 could be employed. Here the elements 15', 16 constitute a parallel tuned circuit for the frequency $f1$, while the whole coupling circuit 15', 14', 16 is in series resonance for the frequency $f2$. Of course, Figs. 3 and 4 are merely examples of the many frequency discriminating networks which might be employed. The synchronizing electrode may (and usually will) be required to receive some constant potential upon which the synchronizing potential wave is superimposed. Accordingly, in Fig. 3, a condenser 17 of negligible impedance at the synchronizing and output frequencies is shown connecting the lower end of the circuit 13, 14, 15 to the cathode (earth), this condenser acting as a blocking condenser to permit the application of a direct current potential to grid 9. In Fig. 4 the circuit for applying direct current potential to the grid 9 includes the resistance 10'.

Where there is employed a long chain of oscillators locked one to another, difficulties due to feed-back along the chain may be reduced or eliminated by interposing "buffer" amplifiers in the chain instead of, or as well as, by adopting one or other of the anti-feed-back expedients already mentioned.

The principal application of this invention is to frequency multiplication and division, and arrangements in accordance with the invention have proved to be stable when used to provide a frequency division ratio of 3:1 or 4:1 and more (per stage) provided the tuning is accurate. When employed for frequency multiplication, it has been found that good results are readily obtainable with multiplication ratios as high as 6:1.

What is claimed is:

1. In a synchronizing system, an electron discharge device oscillation generator having a cathode, first and second grids and an anode, in the order named, circuits interconnecting said anode, cathode and first grid in such manner as to cause said device to produce oscillations, a source of synchronizing energy of substantially constant frequency coupled to said second grid, an output circuit coupled to said anode and tuned to a different frequency having a predetermined relationship to said synchronizing frequency, and a circuit including a series arrangement of capacitance and inductance between said second grid and cathode, said last circuit being so arranged and constructed as to form a path of low impedance to energy of the frequency in said output circuit and high impedance to energy of the frequency of said synchronizing source, said series arrangement being tuned to the frequency in said output circuit.

2. In a synchronizing system, an electron discharge device oscillation generator having a cathode, first and second grids and an anode, in the order named, a source of synchronizing energy of constant frequency coupled to said second grid, a tuned output circuit coupled between said anode and cathode, a feed-back path connected between said first grid and cathode and coupled to said output circuit, said output circuit being tuned to a harmonic of said synchronizing frequency, and a series tuned path of low impedance to said harmonic between said second grid and cathode.

3. In a synchronizing system, an electron discharge device oscillation generator having a cathode, first and second grids and an anode, in the order named, circuits interconnecting said anode, cathode and first grid in such manner as to cause said device to produce oscillations, a source of synchronizing energy of substantially constant frequency coupled to said second grid, an output circuit coupled to said anode and tuned to a frequency which is a sub-harmonic of the frequency of said source of synchronizing energy, and a series tuned path of low impedance to said sub-harmonic between said second grid and cathode.

4. In a synchronizing system, an electron discharge device oscillation generator having a cathode, first and second grids and an anode, means for applying a relatively high positive potential to said anode and a less positive potential to said second grid relative to said cathode, circuits interconnecting said anode, cathode and first grid in such manner as to cause said device to produce oscillations, a single source of synchronizing energy of substantially constant frequency coupled to said second grid, and an output circuit coupled to said anode and tuned to a different frequency having a predetermined relationship to said synchronizing frequency, and a circuit including a series arrangement of capacitance and inductance between said second grid and cathode, said last circuit being so arranged and constructed as to form a path of low impedance to energy of the frequency in said output circuit and high impedance to energy of the frequency of said synchronizing source, said series arrangement being tuned to the frequency in said output circuit, the mean potential applied to said second grid being so chosen that said device operates over a linear portion of the output oscillatory amplitude-second grid voltage characteristic curve, whereby there is obtained a large rate of change of oscillation amplitude with screen grid voltage variation about said mean potential.

DAVID ARTHUR BELL.