

Aug. 18, 1942.

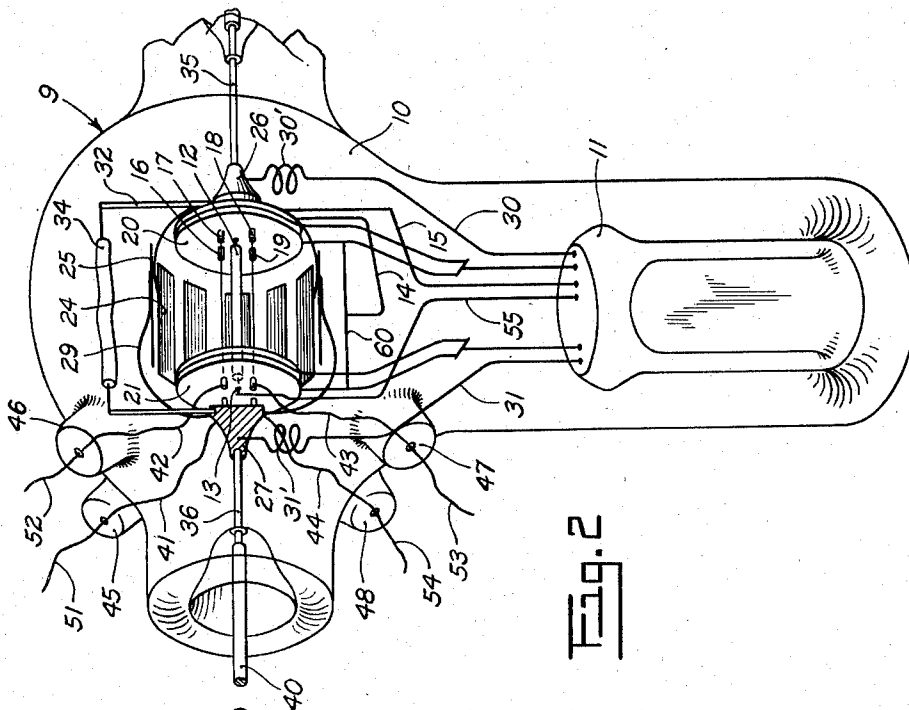
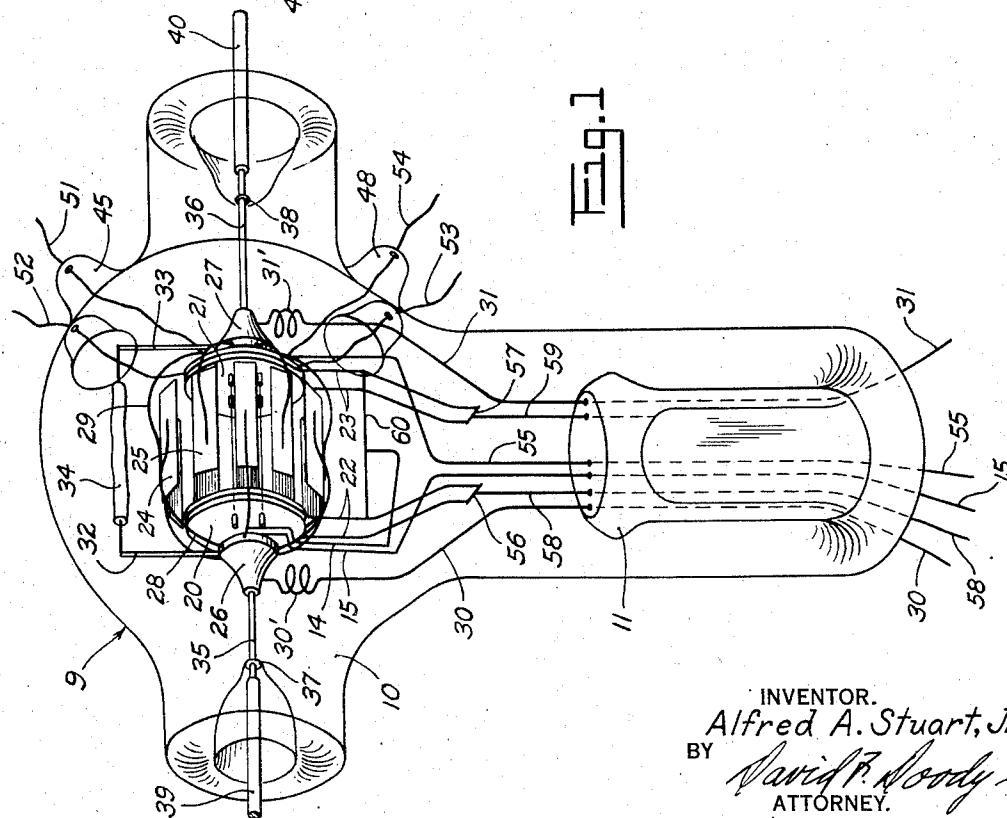
A. A. STUART, JR

2,293,368

SYSTEM OF FREQUENCY CONVERSION

Filed June 20, 1940

2 Sheets-Sheet 1



Aug. 18, 1942.

A. A. STUART, JR

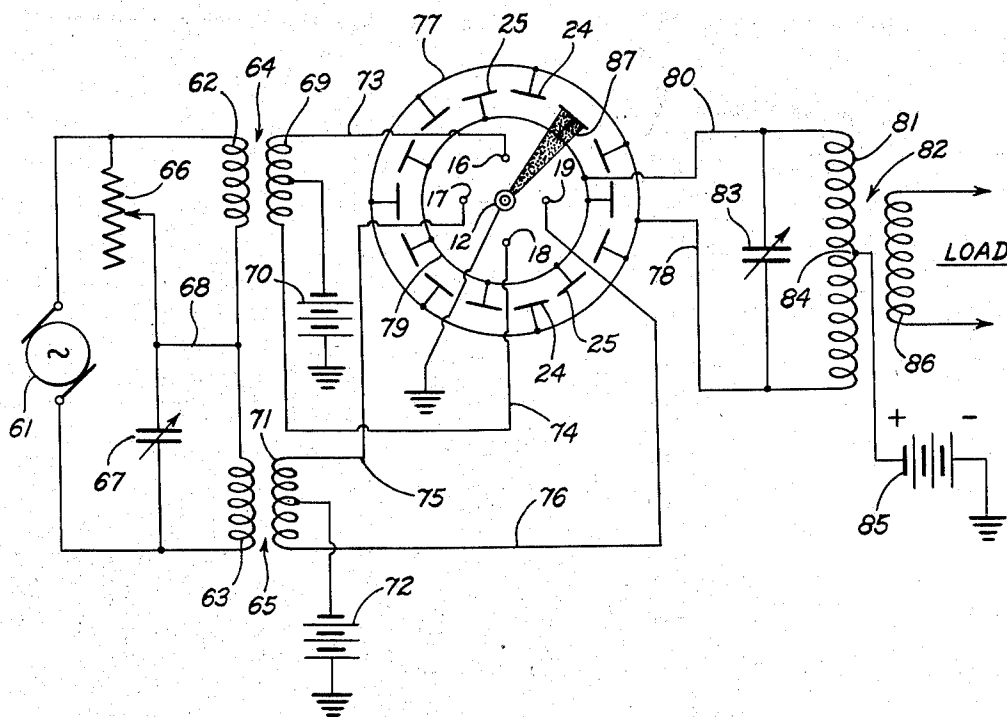
2,293,368

SYSTEM OF FREQUENCY CONVERSION

Filed June 20, 1940

2 Sheets-Sheet 2

Fig. 3



INVENTOR.
Alfred A. Stuart, Jr.
BY *David P. Woody*
ATTORNEY.

UNITED STATES PATENT OFFICE

2,293,368

SYSTEM OF FREQUENCY CONVERSION

Alfred A. Stuart, Jr., Closter, N. J., assignor to
Bendix Aviation Corporation, South Bend, Ind.,
a corporation of Delaware

Application June 20, 1940, Serial No. 341,564

9 Claims. (Cl. 250—36)

This invention relates to thermionic tubes and tube circuits, and more particularly to means for the conversion of alternating current frequencies from one value to another.

Many systems for the multiplication of frequencies, particularly radio frequencies, have been devised in the past, but the best of these systems are limited by their complexity, by the amount of power which can be handled in a single stage of frequency multiplication, or by low factors of frequency multiplication.

By means of the present invention, a simple system is provided by which frequencies may be multiplied without the objections existing in the prior art systems.

One of the objects of the present invention is the provision of a thermionic tube which, by novel construction and by a particular electrical and spatial relation of electrodes, will effect a predetermined frequency multiplication of a fundamental source.

Other objects include the provision of a new system for the obtaining of variable frequencies and for the multiplication or division of frequencies of an alternating current source in a system having high factors of multiplication or division.

These and other objects of the present invention will become readily understood upon a study of the following specification when made in conjunction with the attached drawings, throughout which like parts are designated by like reference characters.

Fig. 1 is a perspective view of the thermionic tube of the present invention;

Fig. 2 is another perspective view of the new tube; and

Fig. 3 is a schematic diagram of a novel circuit embodying the tube of the present invention.

In accordance with the present invention, a source of oscillations of polyphase alternating current is used to dynamically bias grid elements in a new type of vacuum tube in such a manner as to create a rotating beam of electrons, which in rotation, will impinge upon segmental anodes and set up, in an output circuit, a frequency of a predetermined multiple value of the frequency of excitation and of single or polyphase character, as desired.

Having particular reference to Figs. 1 and 2, there is shown at 9 a thermionic tube having a sealed envelope 10 of glass, metal, or other suitable material, having a press member 11 for supporting the electrodes of the tube. These electrodes include a cathode member 12 which may

be an elongated cylinder of any suitable electron emitting material which is indirectly heated by a filament 13 having leads 14 and 15. Four grid members 16, 17, 18 and 19 are symmetrically arranged about cathode 12, and closely adjacent thereto. These grid members are supported at one end by a disk 20 of insulating material, such as glass, and by a similar disk 21 at the other end. Disks 20 and 21 are maintained in spaced relation to each other and are rigidly supported within envelope 10 by means of wires 22 and 23 which engage disks 20 and 21 in pre-formed peripheral grooves.

Symmetrically arranged about cathode 12, and relatively distantly spaced from cathode 12 and grids 16, 17, 18 and 19 are two series of anode members 24 and 25 which are supported upon hub connectors 26 and 27 by a plurality of wires 28 and 29, respectively. Hub members 26 and 27 are, in turn, held rigidly in space within envelope 10 by means of wire leads 30 and 31 which also are brought out of the sealed press 11 to form connections to a direct current source (not shown) of anode voltage. Radio frequency choke coils 30' and 31' are formed in leads 30 and 31, respectively, close to hub connectors 26 and 27. Further support to the series of anodes 24 and 25 is given by means of vertical supporting wires 32 and 33 which are bent horizontally at their upper ends and sealed into a glass rod member 34. Output connections in the form of rod members 35 and 36, are connected at their inner ends to hub members 26 and 27, and at their outer ends 37 and 38, respectively, are sealed to envelope 10. Arm-like members 39 and 40 extend outside the sealed portion of tube 9. Flexible connectors 41, 42, 43 and 44 are attached at their inner ends to grid members 16, 17, 18 and 19, respectively, and are sealed at their outer ends to projections 45, 46, 47 and 48 upon the surface of envelope 10. The terminal connector members, such as extension rods 39 and 40, and leads 51, 52, 53 and 54 of grid connectors 45, 46, 47 and 48 are provided for connection of the tube to an external circuit which will be described later. A lead 55 for external connection of cathode 12 is brought out of press member 11 along with filament lead 15 and anode leads 30 and 31. Each of wires 22 and 23 are joined together at their ends as indicated at 56 and 57 and are supported by upright wire members 58 and 59 which extend into press member 11. Wire member 58 carries current from lead 14 of filament 13 through the wire spreader 60 which acts as a spacing member for disks 20 and 21.

A novel frequency multiplying circuit employing the tube just described, is shown in Fig. 3, wherein 61 is a source of alternating current, the frequency of which is to be multiplied, having its output connected to the primaries 62 and 63 of transformers 64 and 65, respectively. Shunted across alternator 61 is an adjustable resistor 66 and a variable condenser 67 joined together by center tap 68, which is also connected to one end of each of transformers 64 and 65. With resistor 66 and condenser 67 adjusted to have particular values, the voltage in primary 62 will be 90 degrees out of phase with the voltage in primary 63. As this is a common form of phase splitting system, it will be readily understood without further explanation. Secondary 69 of transformer 64 has its center portion connected to a biasing battery 70, while secondary 71 of transformer 65 likewise has its center portion connected to a biasing battery 72. Leads 73 and 74 are connected to grid members 16 and 18, while leads 75 and 76 are connected to grid members 17 and 19, respectively. Anode or segmental plate members 24 are joined together through conductor 77 and to output lead 78, while anode members 25 are connected together through conductor 79, which is connected to output lead 80. Leads 78 and 80 are connected to opposite ends of primary 81 of transformer 82 which is tuned by means of a variable condenser 83 in shunt therewith, to the frequency to which it is desired to multiply the frequency of source 61. Primary 81 has a center tap 84, by means of which suitable anode potential from a source, such as battery 85, may be connected to anodes 24 and 25. The secondary 86 of transformer 82 is connected to any suitable load, such as, for example, an antenna, a resistance or another amplifier, or another frequency multiplier.

By connecting the split phases of source 61, as shown, a rotating electrical field is set up in the tube, as the polyphase voltages are impressed upon grids 16, 17, 18 and 19. Grids 16 and 17 are electrically out of phase with grids 18 and 19 by 90 degrees, and by suitable biasing imposed through batteries 70 and 72, the electrons emitted from cathode 12 are restricted to a narrow beam or sheet, such as indicated by 87. This beam or sheet, extending between cathode 12 and anodes 24 and 25, is rotated at a speed depending on the frequency of source 61 through the medium of the rotating electrical field caused by phase splitting.

By virtue of the connection of battery 85 to anodes 24 and 25, a high potential exists in the anode and cathode circuit in the absence of a beam of electrons 87. As the beam impinges upon any one of the segmental plates 24 or 25, such as that one of plates 25 shown in Fig. 3, current flows from battery 85 to the particular segmental plate 25 upon which beam 87 impinges, and to the cathode through ground, back to the battery 85. When current flows, a magnetic field is, of course, set up in the primary of transformer 81, which induces an alternating current in secondary coil 86. In one complete cycle of alternation of source 61, beam 87 will have swept through a complete circle and will have impinged upon each of the segmental plates that make up anodes 24 and 25. Therefore, if N = the number of segmental plates in tube 10, N impulses will have been set up in primary 81 and will have induced an alternating current, $N/2$ times in secondary 86. The output frequency available across the terminals of secondary 86 is,

determined by the speed of rotation (cycles per second) of beam 87 and the number of pairs of plates that make up anodes 24 and 25.

It will be seen, therefore, that a frequency appears across terminals of secondary 86, the stability of which is a measure of the stability of source 61. Since cathode 12 is made of appreciable extent, beam 87 exists throughout the length of cathode 12 and thus, the current that flows through the anode-cathode circuit can be of appreciable value, giving a frequency, not only in a fixed multiple, either odd or even, of an exciting source, but which is also of substantial power.

Since a real multiplied frequency appears in the output of the tube, the tuned circuit made up of coil 81 and condenser 83 is not essential to the obtaining of the multiplied frequency, and it is provided merely to afford a circuit of low impedance and good wave form to the multiplied frequency.

If the out-of-phase relation between the currents in transformers 64 and 65 is varied from 90 degrees, then a varying frequency appears in the output of the tube. The actual variation in frequency per degree of displacement of the 90 degree phase relation can be demonstrated mathematically, but for present purposes it suffices that variation of the 90 degree relationship varies the speed of the beam 87 for different portions of a complete cycle of rotation, and the output frequency apparent in leads 78 and 80 will vary through a predetermined number of cycles per second.

The circuit shown in Fig. 3 can be used for the obtaining of either audio or radio frequencies. It is particularly well adapted to the obtaining and radiation of radio frequencies having wavelengths of less than a meter, and arm-like extensions 39 and 40 may be adjusted axially of their length forming a tuned antenna system, so that the output of the vacuum tube may be radiated directly into space.

If desired, screen grid elements suitably biased by battery 85 may be interposed adjacent segmental plates 24 and 25 in order to prevent defocusing of beam 87, which defocusing may occur upon large anode voltage changes, which may result from certain types of loads that may be connected to the output of the circuit shown. Further, space charge grids may be placed in the space between cathode 12 and grid elements 16 to 19, in order to minimize the effect of a space charge in this region and, if desired, suppressor grids in the region of anodes 24 and 25 may be electrically connected to cathode, or near cathode, potential in order to eliminate undesired charge conditions in the neighborhood of anodes 24 and 25.

Source of alternating current 61 is shown as being a single-phase alternator, with its output split into two phases, 90 degrees apart. It will be readily understood that a polyphase alternator may be substituted for the split-phase arrangement shown, and the circuit will be equally operative. Two-phase or split-phase excitation is shown principally because it seems to be the simplest to describe, but it is obvious that a different number of grids connected to three or more phases of excitation will result in a similar beam 87 sweeping anodes 24 and 25 at constant speed. Also, slight phase variations will cause the beam to move at a non-uniform rate, resulting in the obtaining of frequency modulation or a varying frequency in the output of the tube,

as has been described above. Also, for simplicity, the output of the multiplied frequency has been shown as single-phase, but it is obvious that a polyphase output may be obtained, if desired. Secondary of transformer 86 may be connected to any source of utilization of the multiplied frequency, such as an amplifier of audio or radio frequencies, or another stage of frequency multiplication similar to that shown in Fig. 3. By means of the system of the present invention, frequencies may be multiplied at appreciable power levels due to the formation of beam 87 along the entire length of cathode 12.

While only one embodiment of the present invention has been shown, it is to be understood that the invention is not limited to this example, but by the scope of the appended claims.

What is claimed is:

1. A frequency multiplying circuit including a source of polyphase current, the frequency of which is to be multiplied, an electronic tube having a cathode capable of emitting electrons, a plurality of anode members, a plurality of grid members interposed between said cathode and anodes, adjacent grids being equally spaced from one another and occupying separate angular positions, said grids being so connected to said source of polyphase current as to produce a revolving electrostatic field and restrict the electrons emitted into a narrow beam, a source of high potential, alternate anodes being connected together and to said source of high potential to form an output circuit, whereby, upon said beam rotating in sequence upon said anodes, an alternating current of the frequency desired may be set up in said output circuit.

2. A circuit for multiplying the frequency of an alternating current including an electronic tube having a cathode, a plurality of angularly spaced grids symmetrically disposed about said cathode and a plurality of anodes circularly spaced about said cathode, alternate anodes being connected together and to a source of anode potential, an input circuit including a source of polyphase current of the frequency to be multiplied, said source being connected in polyphase relation to said grids, so as to set up a rotating electric field in said tube, an electron emissive surface on said cathode, and an output circuit connected to said anodes and to said source of anode potential, whereby an alternating current of the desired multiple frequency will be set up in said output circuit through the rotation of electrons from said cathode by said electric field.

3. In a system of frequency multiplication, a source of alternating current, an electronic tube having a cathode, angularly spaced grids and anodes, said grids being symmetrically disposed about said cathode and connected to said source of alternating current in polyphase relation so as to set up a rotating field, alternate ones of said anodes being connected together and to opposite sides of an output circuit containing a source of anode potential, whereby electrons emitted by said cathode will be rotated in a beam by said rotating field, impinging on each of said anodes in series, and setting up in said output circuit an alternating current of the frequency to which said source of alternating current is multiplied.

4. In a frequency conversion system, an input including a source of alternating current of fixed frequency, means for splitting the phase of said source by 90 degrees, an electron tube having an electron emitting cathode, a plurality of grids, and a plurality of anodes, an output circuit con-

nected to said anodes, said grids being connected in pairs out of phase electrically by 90 degrees to thereby set up a rotating field carrying electrons about said cathode at a constant angular rate and set up a constant frequency in said output circuit, and means for varying the 90 degree phase split whereby a variable frequency, of value depending on the variation in phase split, will be set up in said output circuit.

5. In a system of frequency multiplication, a source of alternating current having polyphase leads, an electronic tube including a cathode, a plurality of angularly spaced grids and a plurality of anodes, said grids being symmetrically disposed about said cathode and connected in polyphase relation to said polyphase leads to set up a rotating field, a source of anode potential connected to said anodes, an output circuit including said source of anode potential, and means for biasing said grids to restrict electronic flow between cathode and anodes into a beam which revolves with said rotating field and creates the desired multiplied frequency in said output circuit.

6. A circuit for obtaining a variable frequency from a relatively fixed frequency source which comprises a source of alternating current of the relatively fixed frequency, a thermionic device including an electron emitting cathode, grids and a plurality of anodes equally spaced from said cathode, means including a source of anode potential for instituting flow of electrons from said cathode to said anodes, polyphase connections between said fixed frequency source and said grids for setting up a rotating field, biasing means associated with said grids to restrict said electrons to a beam rotating in synchronism with said rotating field, means for varying the polyphase relations of said polyphase connections, and an output circuit connected to said anodes for receiving a frequency which varies with phase variation of said polyphase connections.

7. A circuit for the multiplication of frequencies which includes a source of alternating current to be multiplied, an electronic tube having an electron-emissive cathode, a plurality of grids angularly and symmetrically spaced about said cathode, a plurality of pairs of anodes equidistantly spaced from said cathode and beyond said grids, the anodes of each of said pair being electrically connected together and leads from each pair being connected to an output circuit, said grids being connected in polyphase relation to said source of alternating current, whereby a rotating electric field is created between said cathode and anodes, which restricts electrons emitted from said cathode to rotate in a beam, sweeping said anodes in sequence at the frequency of said alternating current, and setting up in said output circuit a frequency which is the product of the frequency of said source of alternating current and the number of pairs of anodes in said tube.

8. A thermionic tube comprising an evacuated envelope, cathode, grid, and anode electrodes therein, said cathode electrode extending along an axis of symmetry, said grid electrodes being closely adjacent said cathode electrode, electrically insulated from said cathode and from each other and symmetrically disposed about said cathode electrode, said anode electrodes being segmental plates equidistantly spaced from said cathode electrode and spaced angularly from each other and symmetrically disposed cylindrically about said cathode electrode, two connections for said anodes, means connecting adjacent

anode plates to different ones of said connections, an output connection for each of said connections and terminals for the external connection of said cathode grids and anodes in a circuit.

9. A thermionic tube having a sealed envelope, 5 a cathode, grids and anodes therein, said cathode being linear along a central axis, said grids being angularly spaced and electrically insulated from each other, equidistantly spaced from said

cathode and symmetrical about said central axis, said anodes comprising plates symmetrically disposed about said central axis, two conductors for connection to a source of anode potential, adjacent plates being connected to different ones of said conductors, and output connections for said anodes.

ALFRED A. STUART, JR.