May 29, 1951 E. M. JONES 2,555,038

INTERLOCKED GENERATOR CIRCUIT

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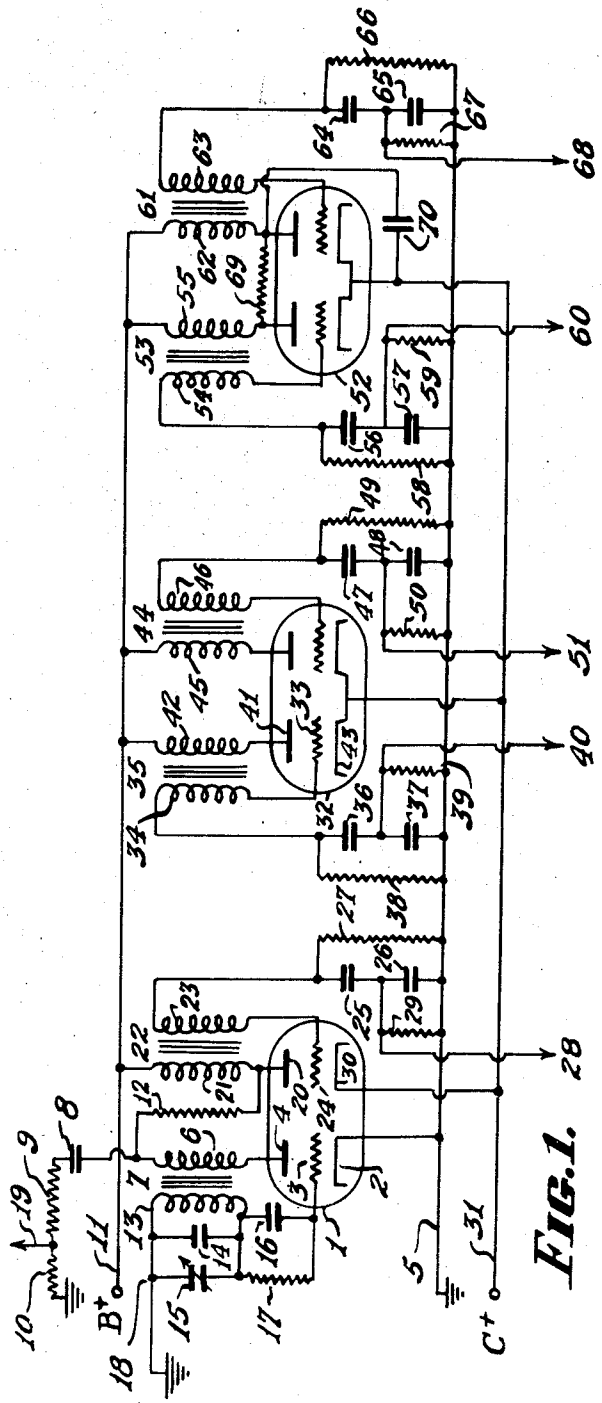


FIG. 1.

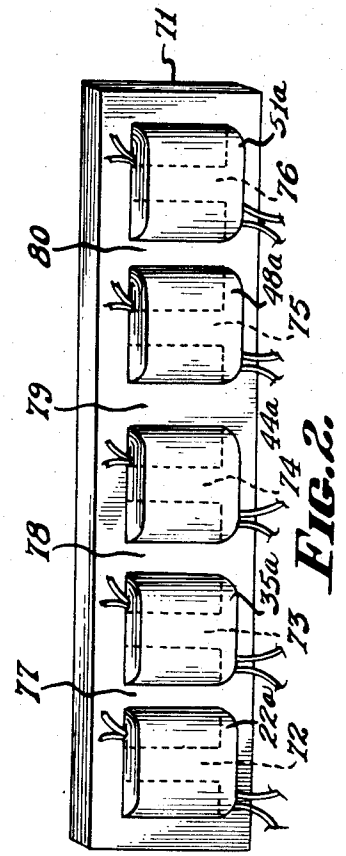


FIG. 2.

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INTERLOCKED GENERATOR CIRCUIT

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17 Claims. (Cl. 250—36)

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My invention relates to generator circuits in which a master oscillator controls the operation of a second generator which in turn controls the operation of a third, and so on throughout a desired series, the generators all operating at harmonically related frequencies. While such systems have other uses, they are especially valuable in electrical musical instruments. Reference may be made to Patents 2,230,429 in the names of Kock and Jordan, and 2,233,948 in the name of Kock, which patents deal with musical instruments employing systems of interlocked generators.

In such instruments it is usual to arrange the generators for all notes of the same nomenclature in a system in which there is a master oscillator for the note in a high register, and a plurality of controlled, interlocked generators for notes octavely related to the first. Since there are twelve semi-tones in the equitempered scale, twelve of these systems are provided in the instrument. There are means for deriving signals or oscillations from each oscillator or generator in the system, and these signals are transmitted through switches connected with playing keys to appropriate headers. The oscillations produced are of complex wave form, and the desired variety of voices is obtained by filtering and other means.

In some suggested systems the pulsations from a controlling generator were caused to stabilize and fix the frequency of oscillation of a controlled generator at a harmonically related value. It has hitherto been suggested also, that if instead, the controlled generators are made to be non-self oscillating and are arranged to be triggered into discharge by alternate pulsations of the controlling generators, a number of advantages are obtained. Should any controlling generator fail, the controlled generator and all generators following it in the system will become and remain inoperative, but will not generate incorrect and uncontrolled frequencies.

Accordingly, systems have been provided in which the master generator is a regenerative self-oscillator, alternate pulsations of which trigger a discharge in the circuit of a controlled generator which is incapable of self-oscillation. Alternate pulsations from the controlled generator in turn trigger a discharge in the circuit of the next controlled generator, and so on. A system of this type is taught in the first of the patents referred to above.

A principal object of this invention is the provision of improvements in systems of this general type.

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It is an object of this invention to provide a system in which greater stability is obtained.

It is an object of the invention to provide a new and advantageous way of coupling the first controlled generator to the master oscillator.

It is an object of the invention to provide a new and advantageous way of coupling interstage beyond the master oscillator, and in particular a mode of inductive coupling.

It is an object of the invention to provide a new and highly advantageous means for interstage coupling.

In the attainment of these objects I secure, as further objects of the invention, a substantial simplification of circuits and elimination of parts, together with markedly increased ease and simplicity of assembly.

These and other objects of the invention which will be set forth hereinafter or will be apparent to one skilled in the art from the following teachings, I attain by that construction and arrangement of parts and in that mode of operation of which I shall now describe an exemplary embodiment. Reference is made to the accompanying drawings wherein:

Figure 1 is a circuit diagram of an exemplary generating system embodying my invention.

Figure 2 is a perspective view of an inductive coupling means.

Figure 1 is illustrative of a system comprising a master oscillator and five controlled generator stages. More or fewer may be employed; but the illustrated system is typical of those used in an electrical organ of conventional range. The tubes indicated are electronic discharge tubes of double construction, i. e., two sets of elements in one envelope; but other types of tubes may be employed.

The master oscillator uses the first section of tube 1, comprising a thermionic cathode 2, grid 3 and plate 4. The cathode 2 is connected as shown to a grounded lead 5. Generally throughout this description I shall use ground as a common return for circuits, and as a second terminal for sources of electric potential. The plate 4 has in series with it a winding 6 of an iron-cored transformer 7. A source of positive or B+ potential is connected to a header 11, and the plate circuit derives its B+ voltage from this header through a lead containing a resistance 12, as will be more fully described hereinafter.

The other winding 13 of the transformer 7 forms a resonant circuit with a fixed capacity

14 and a variable capacity 15 which is used for tuning the master oscillator to the desired frequency. The resonant circuit is connected to the grid 3 through a capacity 16 and shunt resistance 17.

The circuit thus far described will be seen to be a regenerative oscillator circuit. The terminal 18 on the resonant circuit is shown as connected to ground. However, I may insert in this connection another oscillator which, operating at subaudio frequency, supplies a variable voltage modifying the frequency of the master oscillator and giving thus a frequency tremolo not alone to the oscillations produced by the master oscillator but also to the oscillations produced by the controlled generators in the system. For deriving a signal at the frequency of the master oscillator a connection is provided between the B+ end of the transformer winding 6 and ground, containing therein in series the capacity 8, the resistance 9 and the resistance 10, with the signal lead 19 connected to the junction point of the resistances.

The second stage generator in my system uses the second half of tube 1. Its plate 20 is connected to the B+ header 11 through one coil 21 of an iron-cored transformer 22. The other coil 23 of this transformer is in series with the grid 24 and with capacities 25 and 26 which are in series with each other, and the latter of which is connected to the ground lead 5. A resistance 27 is in shunt to these capacities.

A lead 28 connected intermediate the capacities 25 and 26, and bypassed to ground by a resistance 29, serves as a take-off for the signal from the second stage generator.

The capacity 26 is large in value and serves to provide a low impedance output for the signal circuit while delivering thereto a preferred sawtooth waveform of signal. (The resistance 29 provides a drainage path for any direct current component which might appear as the result of leakage in the capacity 25.) Moreover the much smaller capacity 25 is thus able to control the conditions permitting discharge in the second half of the tube without being influenced by output circuits.

It will be noted that the cathode 30 is not grounded but instead is connected to a lead 31 which, by reason of a source of control voltage C+ is maintained at a positive potential above ground. This biases the cathode 30 positively and renders the second stage generator circuit non-self-oscillatory.

The connection to the plate 4 of the master oscillator (which connection includes the resistor 12) is not made directly to the B+ header 11, but rather, as shown, is made through the winding 21 of the transformer 22. Consequently plate circuit pulsations of the master oscillator produce pulsations in winding 21, and corresponding pulsations are produced inductively in the described circuit of grid 24 of the second stage generator.

A discharge will occur in the second half of the tube 1 when the grid potential becomes sufficient to permit a discharge in spite of the bias of the cathode 30. Thus, if capacity 25 and resistance 27 are chosen to have a discharging time (to bring the grid to the desired potential) somewhat greater than a cycle of the frequency of the master oscillator, the grid 24 will be brought to the potential which permits discharge only upon the occurence of alternate pulses received from the master oscillator. Hence, the frequency of pulsations produced by the second stage generator will be half the frequency of the oscillations produced by the master oscillator.

The third stage generator utilizes the first half of tube 32, and is generally similar in circuit to the second stage generator. The grid 33 is connected through the winding 34 of an iron-cored transformer 35 to a network comprising capacities 36 and 37 and resistances 38 and 39, with provision for a signal take-off at 40. The plate 41 is connected through the other winding 42 of the transformer to the B+ header 11. The cathode 43 is connected to the lead 31 and is therefore biased, so that the circuit is non-self-oscillatory.

The remaining stages are similar to the third. In Figure 1, the second half of the tube 32 is used for a fourth stage generator. The transformer for this stage is indicated at 44, with windings 45 and 46. The stage has a network of capacity and resistance including capacities 47 and 48, resistances 49 and 50, with a signal take off at 51.

The first half of the tube 52 is used for a fifth stage generator having a transformer 53 with windings 54 and 55, a network comprising capacities 56 and 57, resistances 58 and 59 and a signal take off 60.

The second half of the tube 52 is used for a sixth stage generator having a transformer 61 with windings 62 and 63, a network comprising capacities 64 and 65, resistors 66 and 67, with a signal take off at 68.

It will be understood that the cathodes of the several tubes are heated by filaments powered from a suitable source of current (not shown). Twelve generating systems of the type described will take care of a range of six octaves in a musical instrument. In some instruments it is desired to have one or more additional notes. Thus in a current instrument I provide a low C coupled to the last or sixth stage of a C-generator system of the kind illustrated. In this event it is advantageous to interconnect the plate windings 55 and 62 of transformers 53 and 61 by a resistance 69. Coupling between the sixth stage of the illustrated generator system and a suboctave generator may be effected through a lead to the point of connection of this resistance with winding 62. Such a connection tends to drain away voltage and diminish the strength of pulses received by the sixth stage from the fifth stage generator. The resistance 69 tends to compensate for this by providing electrical in addition to magnetic transfer between the fifth and sixth stage. In a generator system in which the sixth generator is not required to control a suboctave generator the resistance 69 is omitted.

I have also shown a connection between the plate and cathode of the last half of tube 52, which connection includes a capacity 70. Difficulty is sometimes encountered due to the migration of electrons from one set of tube elements to another when employing double tubes as shown. The capacity 70, connected as shown, prevents incorrect discharge in the second half of the tube. I have not, however, found it necessary to provide any such capacitative connection for any of the stages of my generator systems excepting the last.

The coupling between the second and following stages in the illustrated system is effected inductively, i. e. there is inductive coupling between transformers 22 and 35, and between the latter and transformer 44, and so on throughout the system. This inductive coupling between stages I find provides greater stability of operation as compared with other systems of the type where-

in interstage energy transfers are effected electrically through capacities and/or resistances. The several transformers **22**, **35**, **44**, **53** and **61** may be made up as windings on single-leg cores, and may be so mounted on a panel or the like that the transformers are located close to each other in a series in which the core legs are parallel. In this event the magnetic flux from a transformer, passing through the air, will affect the core of an adjacent transformer.

I prefer, however, to locate the windings for transformers **22**, **35**, **44**, **53** and **61** on a single core as shown in Figure 2. Here the core **71** is so constructed as to provide a closed magnetic circuit about all windings. Each of the winding assemblies **22***a*, **35***a*, **44***a*, **48***a* and **51***a* is located upon its own core leg **72**, **73**, **74**, **75**, and **76** forming part of the general core, and between the several winding assemblies I provide other core legs **77**, **78**, **79**, and **80**.

A much closer magnetic coupling is obtained in this way, and one which is not affected by external conditions. The legs **77**—**80** between windings are in effect magnetic by-passes, and offer a means of controlling the degree of magnetic coupling with great accuracy. This is advantageous because the pulses received by a controlled generator from a controlling generator should be strong, and are of fairly critical voltage value. Control may easily be effected by apportioning the size of the by-pass core legs.

The structure shown in Figure 2 has other advantages. It is a less expensive structure when the several windings are placed on the same core rather than on separate cores. The structure provides a single unit which may be mounted in any convenient place in a generator system. The location of individual transformers on a panel or the like, and adjustment of their respective positions to secure proper magnetic or inductive coupling is not involved.

The inductive coupling which I have described results in the transference of pulses from a controlling generator to a controlled generator as will now be understood. The third stage generator receives pulses from the second stage generator through its transformer **35**. These pulses momentarily reduce the negative potential of the grid **33**, and a discharge will occur in the first half of the tube **32** if the capacity **36** has discharged through the resistance **38** enough to permit the grid **33** to come to a sufficiently small negative potential with respect to the cathode **43**, positively biased as previously described. The capacity **36** recharges upon the occurrence of discharge in the tube, terminating the discharge and bringing the grid to a sufficiently negative potential such that a pulse from the second stage generator will not again cause a discharge in the third stage until the capacity **36** has again discharged sufficiently through resistance **38**. A similar action occurs in the fourth stage generator, the coupling being between transformers 35 and **44**, and so on throughout the series.

The tuning throughout the several controlled generators in a system will vary; but this can largely be accomplished by variations in the sizes of the parts indicated. Furthermore, a structure like that shown in Figure 2 may be made as a standard item, and used for all of the generator systems in an electrical musical instrument, with appropriate changes in the values of the other circuit elements. This further makes for simplicity and economy.

The values of the circuit elements in a generator system may be chosen by the skilled worker in the art in the light of these teachings to give him a system which will produce the desired harmonically related frequencies. By way of example, I give the following as constants and parts in an exemplary system or series, this being the one for the production of the octavely related A notes of a musical instrument:

Signal frequencies

At **19**, 1760 cycles per second
At **28**, 880 cycles per second
At **40**, 440 cycles per second
At **51**, 220 cycles per second
At **60**, 110 cycles per second
At **68**, 55 cycles per second

Resistances

9, 47,000 ohms	**49**, 85,000 ohms
10, 1,800 ohms	**50**, 4,700 ohms
17, 270,000 ohms	**58**, 85,000 ohms
27, 85,000 ohms	**59**, 4,700 ohms
29, 4,700 ohms	**66**, 80,000 ohms
38, 55,000 ohms	**67**, 4,700 ohms
39, 2,200 ohms	**69**, 700,000 ohms

Capacities

8, .02 microfarad	**37**, .2 microfarad
14, .0011 microfarad	**47**, .025 microfarad
15, .0003–.0006 microfarad	**48**, .25 microfarad
16, .002 microfarad	**56**, .05 microfarad
25, .006 microfarad	**57**, .5 microfarad
26, .06 microfarad	**64**, .1 microfarad
36, .02 microfarad	**65**, 1.0 microfarad
	70, .0003 microfarad

Tubes

Type 6SN7

Potentials

At **11**, 165 volts
At **31**, 15 volts

Master oscillator transformer

Winding **13**, 5 henries
Winding **6**, approx. .14 henry
(Turns ratio 6:1)

Interstage coupling

Winding **21**	480 turns	core leg **72**	$\frac{3}{8}$'' width
Winding **23**	240 turns	core leg **77**	$\frac{5}{32}$'' width
Winding **34**	240 turns	core leg **73**	$\frac{3}{8}$'' width
Winding **42**	480 turns	core leg **78**	$\frac{1}{4}$'' width
Winding **45**	680 turns	core leg **74**	$\frac{3}{8}$'' width
Winding **46**	340 turns	core leg **79**	$\frac{9}{32}$'' width
Winding **54**	480 turns	core leg **75**	$\frac{3}{8}$'' width
Winding **55**	960 turns	core leg **80**	$\frac{3}{16}$'' width
Winding **62**	960 turns	core leg **76**	$\frac{3}{8}$'' width
Winding **63**	480 turns		

Window areas for windings: each $\frac{11}{16}$'' x $\frac{1}{4}$''; core material and thickness: 32 laminations, interleaved E's and I's, .014'', Allegheny Ludlum Steel Corporation Audio A.

Modifications may be made in my invention without departing from the spirit of it. Having thus described my invention in an exemplary embodiment, what I claim as new and desire to secure by Letters Patent is:

1. In a generator system, a generator comprising a thermionic tube having a plate, a grid and a cathode, a transformer having a pair of windings, one of said windings being connected between said plate and a source of positive potential, the other of said windings being in series with said grid in a grid-to-cathode circuit containing a capacity and a gradual discharge shunt,

said cathode being connected to a source of positive potential so as to bias said cathode to prevent said generator from producing self-oscillations without external excitation, and magnetic means in juxtaposition to one of said windings for impressing upon said winding magnetic pulses from an outside source to create corresponding electrical pulses in said winding for biasing the said grid sufficiently to overcome the bias of said cathode upon sufficient discharge of said capacity, to permit discharges to occur in said tube.

2. The structure claimed in claim 1 wherein said magnetic means impresses pulses on said winding of a desired frequency, and wherein the value of said capacity is such as to have a period of discharge to bring said grid to operative potential, which period of discharge is greater than a cycle of said frequency whereby discharges are caused to occur in said tube at a frequency harmonically related to said first mentioned frequency and not greater than one-half thereof.

3. The structure claimed in claim 1 wherein said magnetic means impresses pulses on said winding of a desired frequency, and wherein the value of said capacity is such as to have a period of discharge to bring said grid to operative potential which period of discharge is greater than a cycle of said frequency, whereby discharges are caused to occur in said tube at a frequency harmonically related to said first mentioned frequency and not greater than one-half thereof, and in which the said circuit from the grid to cathode includes means to derive a signal therefrom at the second mentioned frequency.

4. In a generator system, a generator comprising a thermionic tube having a plate, a grid and a cathode, a transformer having a pair of windings, one of said windings being connected between said plate and a source of positive potential, the other of said windings being in series with said grid in a grid-to-cathode circuit containing a capacity and a gradual discharge shunt, said cathode being connected to a source of positive potential so as to bias said cathode to prevent said generator from producing self-oscillations without external excitation, and means for impressing upon said generator pulses from an outside source to bias the said grid sufficiently to overcome the bias of said cathode upon sufficient discharge of said capacity, to permit a discharge to occur in said tube, in combination with a second generator comprising a plate, a grid and a cathode, a transformer having a pair of windings, one of said windings being connected between said plate and a source of positive potential, the other of said windings being in series with the grid of said second generator in a grid-to-cathode circuit containing a capacity and a gradual discharge shunt, said cathode of said second generator being connected to a source of positive potential so as to bias said last mentioned cathode to prevent said second generator from producing self-oscillations without external excitation, the transformers of the two generators being so related to each other that an inductive coupling occurs between them whereby a discharge occurring in the first mentioned generator will produce a pulse in the circuits of the second generator tending to bring the grid of said second generator toward a potential permitting discharge between the cathode and plate thereof.

5. The structure claimed in claim 4 in which the first generator produces successive pulses of a desired frequency, and in which the capacity in the grid-to-cathode circuit of the second generator has a period of discharge to bring the grid thereof to a potential for discharge greater than a cycle of the frequency of the first generator, so that discharges occur in the second generator at an harmonically related frequency not greater than one-half the frequency of the first generator.

6. In a generator system, a master oscillator comprising a thermionic tube having a plate, a grid and a cathode, said elements having circuits related for self-oscillation at a desired frequency, a second generator comprising a plate, a grid and a cathode, a transformer having windings, one of said windings being in a circuit between said plate and a source of positive potential, the other of said windings being in series with said grid in a grid-to-cathode circuit, the plate of said master oscillator being connected to a source of positive potential through the plate winding of the transformer of the said second generator, whereby oscillations produced by said master oscillator produce pulsations in the circuits of said second generator, and means for biasing said second generator to prevent self-oscillation so that a discharge between the cathode and plate of said second generator can occur only upon the occurrence of a pulse from said master oscillator.

7. In a generator system, a master oscillator comprising a thermionic tube having a plate, a grid and a cathode, said elements having circuits related for self-oscillation at a desired frequency, a second generator comprising a plate, a grid and a cathode, a transformer having windings, one of said windings being in a circuit between said plate and source of positive potential, the other of said windings being in series with said grid in a grid-to-cathode circuit, the plate of said master oscillator being connected to a source of positive potential through the plate winding of the transformer of the second mentioned generator, whereby oscillations produced by said master oscillator produce pulsations in the circuits of said second generator, and means for biasing said second generator to prevent self-oscillation so that a discharge between the cathode and plate of said second generator can occur only upon the occurrence of a pulse from said master oscillator, the means for biasing said second generator comprising means for maintaining the cathode thereof at a positive potential, the said grid circuit of said second generator containing a capacity with discharging means and having a period of discharge to bias the grid thereof to permit a discharge between the corresponding cathode and plate at a period more than the period of a cycle of the frequency of the master oscillator, so that a discharge occurs in the second generator at an harmonically related frequency not greater than one-half the frequency of the master oscillator.

8. In a generating system, a source of oscillations and a series of controlled generators, each of said controlled generators comprising a thermionic tube having a plate, a grid and a cathode, a transformer having windings, a plate-to-cathode circuit containing one of said windings in series and connecting said plate to a source of positive potential, a grid-to-cathode circuit containing the other of said windings in series therewith, means for transferring pulses from said source to the first of said generators to

produce discharges in the generator bearing an harmonic relation to said pulses, the transformers of the several controlled generators being inductively coupled one to another in a series whereby pulses occurring upon discharge in the first generator are transmitted to the circuits of the second generator and so on, said controlled generators having their respective cathodes biased to a positive potential preventing self-oscillation, the respective grid-to-cathode circuits of the controlled generators containing capacities which become charged upon discharge of the tube, and which upon discharge permit the respective grids of said generators to be brought toward potentials permitting discharge under the influence of incoming pulses.

9. The structure claimed in claim 8 wherein each such capacity has a discharging period to bring its grid to the potential for discharge, which period is greater than a cycle of the frequency of pulsations impressed upon it by a preceding source or generator so that discharges occur in a controlled generator at a frequency harmonically related to but not greater than one-half the frequency of the pulses impressed thereon.

10. The structure claimed in claim 8 wherein each such capacity has a discharging period to bring its grid to the potential for discharge, which period is greater than a cycle of the frequency of pulsations impressed upon it by a preceding source or generator so that discharges occur in a controlled generator at a frequency harmonically related to but not greater than one-half the frequency of the pulses impressed thereon, and in which each controlled generator has means for deriving a signal therefrom.

11. In a series of serially controlled generators, each generator having a thermionic tube with a plate, a grid and a cathode and each controlled generator having a transformer with windings located respectively in plate and grid circuits thereof, a structure comprising a common magnetic core, the windings of the transformers of a plurality of the controlled generators being located on said core, said core providing a closed magnetic path about all windings, a separate leg for each transformer and legs between transformers serving as magnetic by-passes to control the degree of coupling between transformers.

12. The structure claimed in claim 11 wherein said last mentioned legs vary as to cross-sectional dimension.

13. In a generator series comprising a master oscillator and a plurality of controlled generators, each involving a thermionic tube having a plate, a grid and a cathode, and each controlled generator having a transformer comprising primary and secondary windings, a common structure comprising a core of magnetic material with separate legs for each of said transformers, and means providing legs forming magnetic by-passes located between transformers whereby to provide controlled inductive coupling between said several transformers successively.

14. In a system for producing harmonically related electric pulses, the combination of at least two pulse generators in a series, each of said generators including a thermionic tube having a plate, a grid and a cathode, a transformer having windings, a plate-to-cathode circuit containing one of said windings, and a grid-to-cathode circuit containing another of said windings, the transformers of the two adjacent generators being in juxtaposition on a common magnetic core so as to be magnetically coupled, said core having magnetic bypass means between the said transformers whereby pulses in one generator initiate fractional harmonically related pulses in an adjacent generator without the necessity of conductive coupling therebetween.

15. The structure claimed in claim 8 wherein said transformer has a core providing a closed magnetic path about all windings, a separate leg for each pair of windings and legs between said pairs of windings serving as magnetic by-passes to control the degree of coupling between said pairs of windings.

16. The structure claimed in claim 11 wherein said core is composed of interleaved E and I laminations.

17. The structure claimed in claim 13 wherein said core is composed of interleaved E and I laminations.

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