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PULSE-TIME MODULATION CIRCUITS AND METHOD

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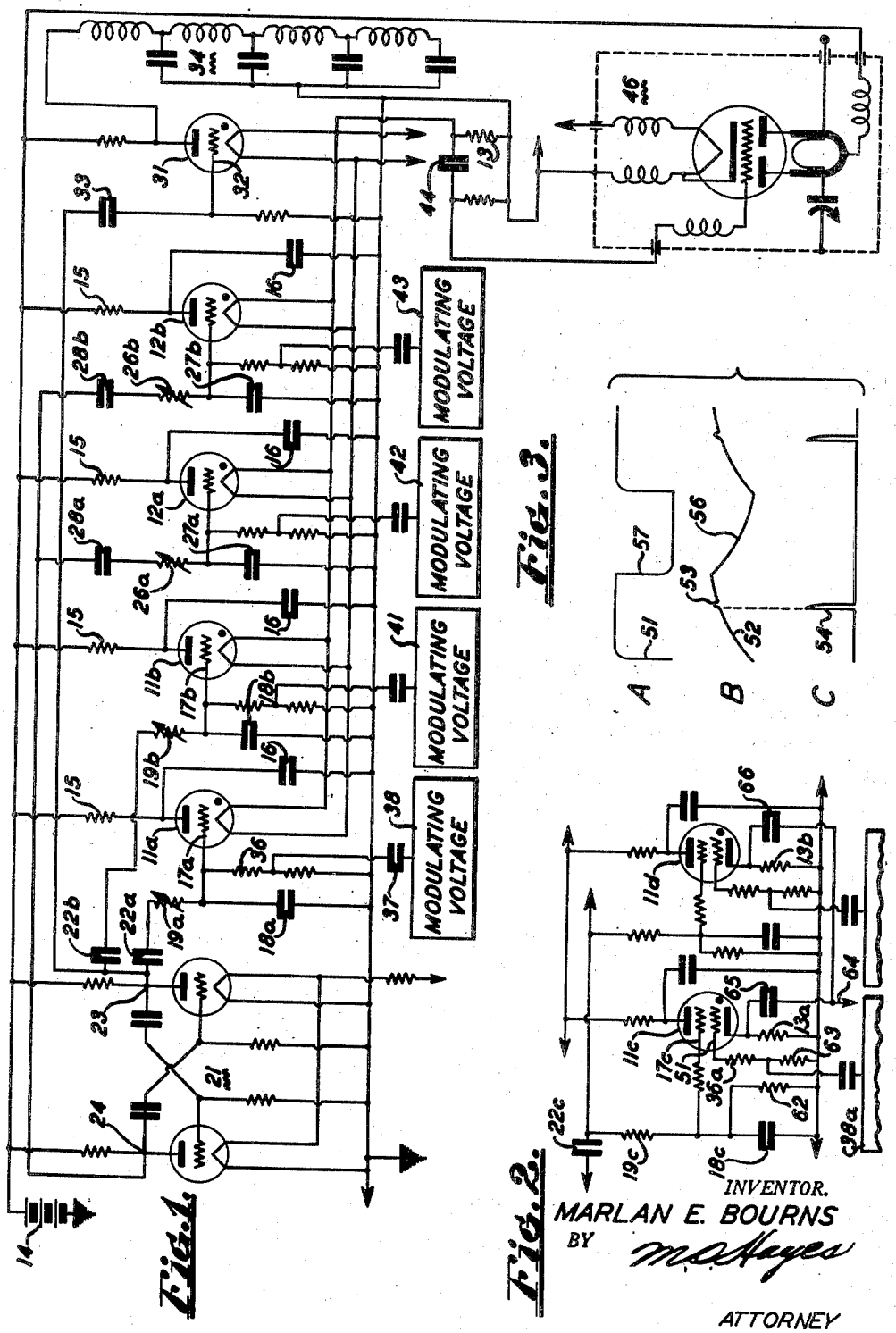


Fig. 1.

Fig. 3.

Fig. 2.

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PULSE-TIME MODULATION CIRCUITS AND METHODS

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This invention relates to pulse-time modulation circuits and methods, and more particularly to multiplex pulse-time modulation circuits, wherein a plurality of substantially evenly spaced pulses are generated in each cycle of operation, the instantaneous time position of each pulse relative to a master pulse being a function of the nature of the modulation applied to each pulse channel. By the use of the instant invention a single communication channel suffices to simultaneously convey a plurality of independent messages.

It is an object of this invention to provide a multiplex pulse-time modulation system which is simple, compact, and reliable, employing a fewer number of components than have been necessary in past circuits to achieve a generally similar result.

It is another object of this invention to provide such a circuit having a high input impedance for the several modulating signals applied to each channel of intelligence to be communicated.

It is another object of this invention to provide such a circuit as will have a low output impedance suitable for pulsing a low impedance radio frequency oscillator, such as a grid modulated oscillator.

It is a further object of this invention to provide such a circuit and method as will most efficiently employ the energy drawn from the energy source of the equipment.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following description.

In accordance with this invention the circuit comprises a plurality of tubes, preferably gas-filled tubes, one for each intelligence channel to be applied to the single carrier wave. The voltage on a control grid of each tube is caused to repetitively rise steadily and then drop, i. e. a saw tooth wave is used. To achieve this, it is preferred to constitute the grid circuits of each of the tubes of a series-connected resistor-capacitor (R. C.) combination, to which is applied a positive square wave voltage that is integrated in the R. C. combination to produce an individual rising voltage on each grid. The rates of rise of the several voltages are so adjusted that the tubes are rendered conductive, or fire, at spaced successive intervals, thereby producing spaced discrete pulses at their common output terminal. It is preferred to generate the output signals across an impedance, or impedances, connected to the cathodes of the tubes.

The positive square wave voltage comes from

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the output of a multivibrator, to which are connected in parallel the several R. C. circuits supplying the control grids. In order to achieve greater precision in firing intervals, half the tubes are connected to one terminal of the multivibrator and half the tubes are connected to the other. The first half cycle of multivibrator operation starts the several rising voltages on half of the tubes causing them to fire in succession. Then the other terminal of the multivibrator puts out its positive square wave voltage, causing the remaining half of the tubes to fire in spaced succession, in accordance with the several

The individual modulating voltages are applied, cuits.

The individual modulating voltages are applied, through a high resistance, to each of the several tubes, either to the same grid that receives the rising saw-tooth voltages or else to a different grid. In this way, the moment at which any particular tube fires to produce its discrete output pulse is modulated by the modulating voltages. The rate of variation of the modulating voltage is low compared to the periodicity of the multivibrator, so that for practical purposes the modulation may be regarded as a substantially constant voltage which is slowly adjusted to produce the modulation of the individual pulse intervals.

Short, discrete, output pulses may be formed across a single impedance connected to all of the cathodes, or alternatively, each tube may be provided with its own output impedance, the individual pulse output from each output impedance then being applied to the pulse input terminal of an R. F. oscillator.

One of the several gas-filled tubes is unmodulated and is provided with a pulse-shaping line in its plate circuit, so that its pulse is somewhat longer than the other pulses, thereby providing a master pulse to identify the start of a cycle. Output from one of the multivibrator terminals is applied directly to the grid of the master pulse generating tube, so that the cycle is started without any time delay.

In accordance with the above objects and general description, two specific embodiments of the instant invention have been shown in the drawings, wherein:

Fig. 1 shows a preferred species of a circuit embodying the instant invention;

Fig. 2 illustrates a modification of a portion of the circuit of Fig. 1; and

Fig. 3 shows certain wave forms created by the circuit of Fig. 1.

In the drawings, 11*a*, 11*b*, 12*a*, and 12*b* repre-

sent gas-filled tubes, the cathodes of which are connected together and to a relatively low output impedance 13, the other end of which is connected to ground. The plates of the tubes, 11a, 11b, 12a, and 12b are connected to a suitable source of plate potential 14, through individual plate resistors 15. Paralleling the plate-cathode circuits of the several tubes are individual energy storage elements in the form of capacitors 16, which are charged through the plate resistors 15 from source 14, and which discharge through the several tubes 11a, 11b, 12a, and 12b when the respective grids of the tubes receive a voltage sufficiently large to cause the tubes to be rendered conductive, or to fire. Upon firing of a tube, the grid loses control, and a short, discrete pulse is formed across the output impedance 13 by the discharge of the capacitor 16, which following termination of the pulse begins to slowly recharge through the resistor 15.

Each tube is rendered conductive in succession by the application to its grid of an individual rising saw tooth voltage, produced by its individual R. C. circuit, which integrates a positive square wave into a steadily rising saw tooth voltage. The grid 17a, for example, is connected to a capacitor 18a, the other side of which is grounded. The capacitor 18a is charged through a resistor 19a by a positive square wave voltage applied from a multivibrator through a coupling capacitor 22a. Together the resistor 19a and the capacitor 18a constitute an R. C. circuit for integrating the square wave voltage forming the output of the multivibator 21 to thereby place on the grid 17a a steadily rising voltage. The grid 17b of the tube 11b likewise receives a steadily rising voltage from the R. C. circuit 19b, 18b. The time constant of the R. C. circuit 19b, 18b is longer than that of the R. C. circuit 19a, 18a; so that with equal grid biases the tube 11a will fire first to produce a short discrete output pulse, followed at a predetermined interval thereafter by the firing of the tube 11b.

While it would be possible to apply the same positive square wave voltage to the R. C. grid circuits of all of the tubes 11a, 11b, 12a, and 12b from the output terminal 23 of the multivibrator 21, it is preferred for greater precision to use the other output terminal 24 of the multivibrator 21 to initiate action in the other two tubes, 12a and 12b. To this end, the R. C. circuit 26a, 27a of the tube 12a is coupled through coupling capacitor 28a to the terminal 24 of multivibrator 21, as is the R. C. circuit 26b, 27b which has its coupling capacitor 28b also connected to the terminal 24.

Multivibrator 21 is a conventional plate coupled free-running multivibrator, the square wave form from which is designed to be symmetrical, so that the time interval from a positive going voltage on the terminal 23 to a positive going voltage on the terminal 24 is the same as the time interval to the next positive going voltage on the terminal 23, as shown in Fig. 3(A).

In order to identify the start of a cycle, another channel tube 31, also gas-filled, is introduced into the circuit. The grid 32 of tube 31 is energized directly from the terminal 23 of the multivibrator 21 through a coupling capacitor 33, without the intervention of an R. C. circuit. Thus there is no appreciable time interval between the abrupt voltage rise at terminal 23 and the firing of tube 31. The current pulse in the output impedance 13 resulting from the firing of tube 31 is made somewhat longer than the other pulses (from the tube 11a through 12b, inclusive) by the provision of a pulse-forming line 34, connected between the plate of the tube 31 and ground.

It will now be seen that the circuit described thus far operates to produce across the impedance 13 a cycle of five pulses. The first pulse results from the firing of the tube 31, and is somewhat longer in duration than the succeeding pulses, by virtue of the charged line 34. The next pulse is a short, discrete pulse resulting from the firing of the tube 11a, the grid circuit of which has a relatively short time constant. The next pulse comes from the tube 11b, the grid circuit of which has a relatively long time constant. At this point the multivibrator 21 flips over, and a positive square wave voltage appears on the terminal 24. This starts the R. C. voltage rises for the tubes 12a and 12b, the former firing first, followed at a spaced interval by the last tube 12b. The cycle is repeated when the multivibrator flips back to again produce a positive square wave voltage at the terminal 23.

The time, or position, modulation of the four pulses produced by the tubes 11a, 11b, 12a, and 12b, respectively is affected by applying to the several grids of these tubes a modulating bias voltage which varies slowly in comparison with the pulse cycle, so that for any given cycle it may be regarded as a substantially constant control potential. The grid 17a of the tube 11a, for example, is modulated through a high value resistor 36, to which is applied through a coupling capacitor 37 a modulating voltage from a source 38. This modulating voltage, being superimposed on the steadily rising grid voltage applied through the R. C. circuit 19a, 18a, constitutes in effect the base voltage from which the rise starts. Thus the magnitude of the modulating voltage determines the time interval between the start of the rising voltage, and the moment when the grid 17a reaches a potential sufficient to fire the tube 11a. In this manner discrete pulses put out by the tube 11a are varied back and forth in time position in accordance with the magnitude of the modulating voltage applied to the tube by the source 38, this time position being measured from the occurrence of the master pulse from the tube 31, which is simultaneous with the start of the positive square wave voltage at the terminal 23. Each of the tubes 11b, 12a and 12b has its own individual modulating source represented by the numerals 41, 42, and 43, respectively, the modulation being applied in a manner identical to that described for the tube 11a.

The string of discrete pulses, each cycle being started by the abnormally long pulse from the tube 31, is applied through a coupling capacitor 44 to the grid of an R. F. oscillator 46. The pulses periodically energize the oscillator and serve as modulation envelopes for the radio frequency energy produced by the oscillator 46.

Operation

The operation of the circuit of Fig. 1 is substantially as follows. Multivibrator 21 oscillates freely, although if desired it may be controlled from an accurate frequency source in any desired well-known manner. As shown in Fig. 3(A), there periodically appears on the output terminal 23 of the multivibrator 21 a positive square wave voltage 51. This voltage serves to initiate at grid 17a of tube 11a a steadily rising voltage 52 (Fig. 3(B)). When the voltage 52 has attained a value represented by the numeral 53, the tube

11a is rendered conductive and fires, thereby passing current from the charged capacitor 16 through the output impedance 13 and producing an output pulse to be applied to the oscillator 46. This output pulse is shown in Fig. 3(C), and is of positive polarity, so that it may be applied directly to the oscillator 46 without going through an inverting stage. The condenser 16 discharges rapidly through the tube 11a so that the pulse 54 is very brief in duration. The voltage on the plate of the tube 11a thus drops rapidly below the extinction value, so that even though the voltage at the grid 17a may continue to rise, as shown in Fig. 3(B), there will be no further passage of plate current, since the charging time constant for the capacitor 16 through the resistor 15 is sufficiently large to preclude further conduction of the tube 11a. By the time the condenser 16 has acquired an appreciable charge, the voltage on the grid 17a has dropped below the firing point, as shown in the portion 56 of the wave form of Fig. 3(B).

Tube 11b is fired in the same manner a predetermined time interval after the tube 11a, since its R. C. grid circuit has a longer time constant.

When the voltage on the terminal 23 of the multivibrator abruptly drops, as shown at 57, a corresponding abrupt rise of voltage appears on the terminal 24 in the well-known multivibrator manner. The positive-going square wave voltage thus initiated is used to energize the grids of the remaining two tubes 12a and 12b in the same manner that the positive square wave voltage on the terminal 23 was employed to energize the grids of the tubes 11a and 11b.

The master tube 31 is fired immediately upon the appearance at 23 of the abrupt voltage rise 51, so that its abnormally long pulse is produced at the start of the cycle.

The individual channels controlled by the tubes 11a to 12b, inclusive, are individually modulated by the sources 38, 41, 42 and 43, respectively, connected to the respective tube grids. These modulating voltages, by determining the voltage level from which the rising voltages, for example the voltage 52, start, determine the time points at which the firing potentials are reached, and thereby determine the time intervals between the master pulse from the tube 31 and the firings of the several tubes 11a through 12b, inclusive. The time constants of the several R. C. circuits are adjusted so that the unmodulated pulses 54 are spaced sufficiently far apart to accommodate the largest modulating voltage that will be received from any of the sources 38, 41, 42, or 43. Thus there is no danger of the channels overlapping.

Were it not for the utilization of both output terminals 23 and 24 of the multivibrator 21, it would be necessary to have twice as many different R. C. time constants injected into the same range, since all of the rising voltages would have to start at the same moment. The use of both multivibrator output terminals thus tends to increase precision in determining the firing time of the several tubes, 11a through 12b.

The time constants of the several R. C. circuits may be varied at will by employing adjustable resistors at 19a, 19b, 26a, and 26b.

Modification

In the Fig. 2 modification, it is illustrated that it is not necessary to apply the modulating voltage to the same grid as that to which the steadily rising saw tooth voltage is applied. As shown in Fig. 2, one of the grids 17c of the tube 11c is energized from the R. C. circuit 19c, 18c, through a coupling capacitor 22c; while modulation from the source 38a is applied to another grid 61 through a resistor 36a. Each of the two grids 17c and 61 has its own grid leak resistor, 62 and 63, respectively.

Another variation introduced in the Fig. 2 circuit is that of employing individual output impedances 13a and 13b in the cathode circuits of the two tubes 11c and 11d, respectively, thereby tending to reduce cross-talk. The outputs from the two impedances 13a and 13b are applied to a common output terminal 64 through individual coupling capacitors 65 and 66.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed is:

1. A pulse-time modulation circuit comprising a gas-filled tube, an output impedance connected to the cathode of said tube, means for applying a steadily rising voltage to a grid of said tube, thereby to fire the tube, and means for applying a modulating voltage to a grid of said tube, thereby to determine the time point in the rise of said rising voltage at which said tube fires to produce a discrete output pulse across said impedance.

2. A pulse-time modulation circuit comprising a gas-filled tube, an energy storage element connected to the plate of said tube, means for charging said element, means for applying a steadily rising voltage to a grid of said tube, thereby to fire the tube, and means for applying a modulating voltage to a grid of said tube, thereby to determine the time point in the rise of said rising voltage at which said tube passes current from said element to produce a discrete output pulse.

3. A pulse-time modulation circuit comprising a gas-filled tube, an energy storage capacitor connected to the plate of said tube, means for charging said capacitor, an output impedance connected to the cathode of said tube, means for applying a steadily rising voltage to a grid of said tube, thereby to fire the tube, and means for applying a modulating voltage to a grid of said tube, thereby to determine the time point in the rise of said rising voltage at which said tube passes current from said capacitor to produce a discrete output pulse across said impedance.

4. A multiplex pulse-time modulation circuit comprising a plurality of tubes, means connected to certain of the grids of said tubes for steadily increasing the voltage thereon, thereby to render the tubes conductive at spaced successive intervals, and a plurality of individual means connected to certain of the grids of said tubes for applying a plurality of individual modulating voltages, one to a grid of each tube, thereby to modulate said intervals.

5. A multiplex pulse-time modulation circuit comprising a plurality of tubes, means connected to certain of the grids of said tubes for steadily increasing the voltage thereon, thereby to render the tubes conductive at spaced successive intervals, a plurality of individual means connected to certain of the grids of said tubes for apply-

ing a plurality of individual modulating voltages, one to a grid of each tube, thereby to modulate said intervals, and output impedance means connected to the cathodes of said tube.

6. A multiplex pulse-time modulation circuit comprising a plurality of gas-filled tubes, means connected to certain of the grids of said tubes for steadily increasing the voltage thereon, thereby to fire the tubes at spaced successive intervals, and a plurality of individual means connected to certain of the grids of said tubes for applying a plurality of individual modulating voltages, one to a grid of each tube, thereby to modulate said intervals.

7. A multiplex pulse-time modulation circuit comprising a plurality of gas-filled tubes, means connected to certain of the grids of said tubes for steadily increasing the voltage thereon, thereby to fire the tubes at spaced successive intervals, a plurality of individual means connected to certain of the grids of said tubes for applying a plurality of individual modulating voltages, one to a grid of each tube, thereby to modulate said intervals, and output impedance means connected to the cathodes of said tubes.

8. A multiplex pulse-time modulation circuit comprising a plurality of tubes, a plurality of circuits connected one to a grid of each tube and effective to apply individual steadily rising voltages to each of the circuit-connected grids in response to an initiating voltage thereby to render the respective tubes conductive, means connected to each of said circuits, for applying an initiating voltage simultaneously to each of said circuits and a plurality of means for applying a plurality of individual modulating voltages one to a grid of each tube, thereby to modulate the several time intervals between the occurrence of the initiating voltage and the conducting of each tube.

9. A circuit according to claim 8 wherein said tubes are gas-filled tubes the conductive-renderings of which fire the tubes to produce discrete pulses of current through the tubes.

10. A multiplex pulse-time modulation circuit comprising a plurality of gas-filled tubes, energy storage elements connected to the plates of said tubes, means for energizing said storage elements, a plurality of circuits connected one to a grid of each tube and effective to apply individual steadily rising voltages to each of the circuit-connected grids in response to an initiating voltage, thereby to render the respective tubes conductive means connected to each of said circuits for applying an initiating voltage simultaneously to each of said circuits and a plurality of means for applying a plurality of individual modulating voltages one to a grid of each tube, thereby to modulate the several time intervals between the occurrence of the initiating voltage and the firing of each tube.

11. A circuit according to claim 10 wherein said storage elements comprise capacitors.

12. A circuit according to claim 8 wherein each of said plurality of circuits comprises a resistor and a capacitor connected in series, the several time constants of each of said circuits being different.

13. A circuit according to claim 9 wherein each of said plurality of circuits comprises a resistor and a capacitor connected in series, the several time constants of each of said circuits being different.

14. A circuit according to claim 10 wherein each of said plurality of circuits comprises a resistor and a capacitor connected in series, the several time constants of each of said circuits being different.

15. A circuit according to claim 11 wherein each of said plurality of circuits comprises a resistor and a capacitor connected in series, the several time constants of each of said circuits being different.

16. A multiplex, pulse-time modulation circuit comprising a multi-vibrator having a plurality of output terminals and effective to repetitively apply to said terminals in succession a positive square wave voltage, a plurality of circuits connected to said plurality of terminals effective to produce in response to said square wave voltage individual steadily rising voltages, a plurality of tubes having grids connected to said circuits to receive said individual rising voltages which successively render said tubes conductive, and a plurality of individual modulating means connected individually, one to a grid of each of said tubes, thereby to individually modulate the time intervals between the start of said square wave voltage and the moments when said tubes are rendered conductive by said several individual rising voltages.

17. A circuit according to claim 16 wherein said tubes are gas-filled tubes the conductive-renderings of which fire the tubes to produce discrete current pulses of predetermined duration.

18. A multiplex, pulse-time modulation circuit comprising a multi-vibrator having a plurality of output terminals and effective to repetitively apply to said terminals in succession a positive square wave voltage, a plurality of circuits connected to said plurality of terminals effective to produce in response to said square wave voltage individual steadily rising voltages, a plurality of gas filled tubes having grids connected to said circuits to receive said individual rising voltages which successively fire said tubes, a plurality of individual modulating means connected individually, one to a grid of each of said tubes, thereby to individually modulate the time intervals between the start of said square wave voltage and the firings of said tubes due to said several individual rising voltages, a plurality of energy storage elements connected to the plates of said tubes, and means for energizing said storage elements.

19. A circuit according to claim 18 wherein said storage elements comprise capacitors.

20. A circuit according to claim 16 wherein each of said plurality of circuits comprises a resistor and a capacitor connected in series, the several time constants of each of said circuits being different.

21. A circuit according to claim 17 wherein each of said plurality of circuits comprises a resistor and a capacitor connected in series, the several time constants of each of said circuits being different.

22. A circuit according to claim 18 wherein each of said plurality of circuits comprises a resistor and a capacitor connected in series, the several time constants of each of said circuits being different.

23. A circuit according to claim 19 wherein each of said plurality of circuits comprises a resistor and a capacitor connected in series, the several time constants of each of said circuits being different.

24. The method of generating multiplex time modulated pulses which comprises producing a positive square wave voltage, initiating in re-

sponse to said square wave voltage a plurality of individual rising voltages which increase at different rates, applying said rising voltages to a corresponding plurality of gas-filled tubes, and applying a corresponding plurality of individual modulating voltages to said tubes, thereby to individually modulate the several time intervals between the start of said square wave voltage and the firing moments of said tubes induced by said individual rising voltages.

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