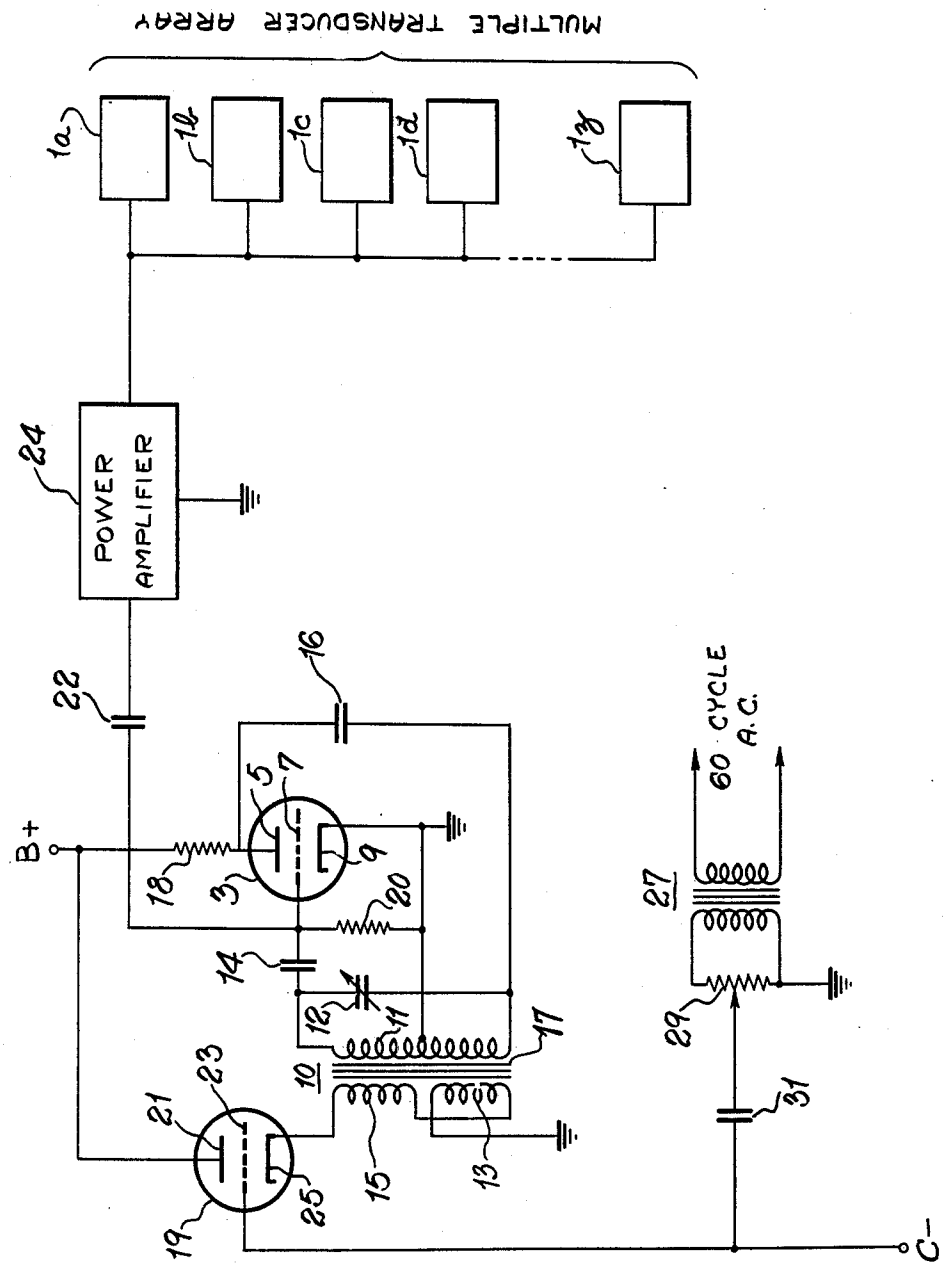
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ULTRASONIC DEVICE

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ULTRASONIC DEVICE

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My invention relates to ultrasonic devices and in particular to a circuit for an ultrasonic generator whereby one is able to excite a plurality of transducers so that for part of the time each transducer is driven at a frequency at which maximum power output is obtained.

In any ultrasonic device using a plurality of transducers connected in parallel, for example, in an ultrasonic cleaner which may use 28 or more transducers, so connected, to drive a cleaning tank, it is usually necessary to select transducers having the same resonant frequency. This is required in order to obtain an even energy distribution among the transducers when they are driven from a conventional generator. Although the transducers normally employed in these applications (cleaning and similar uses) are low enough in Q to tune over a fairly broad range (about 4 kc. wide to the half power points for barium titanate transducers having a nominal resonant frequency of 42 kc.), there exists for each individual transducer a single best frequency at which maximum power output is obtained.

Accordingly, it is an important object of my invention to provide a source of excitation for ultrasonic transducers connected in parallel which will deliver power to the individual transducers at the resonant frequency of each transducer.

It is a further object of my invention to provide such a device which is simple and economical to construct and operate.

These and other objects, features and advantages will be apparent during the course of the following description when taken in connection with the figure which is a schematic drawing of a preferred embodiment of the device of my invention.

Broadly, my invention relates to frequency modulating the oscillator over a narrow band of frequencies, no wider than is necessary to operate at the resonant peaks of all the transducers which are being used so as to insure an equitable distribution of generator output power. By this invention, I am able to relax the requirements which transducers must meet in order to be used in multiple array devices. As a result, the manufacturing requirements are less stringent and a greater, useful production output is obtainable.

In the single FIGURE of drawing, wherein, for the purpose of illustration, is shown a preferred embodiment of my invention, the numerals 1*a*, 1*b*, . . . 1*z* represent a plurality of transducers connected in parallel. While I shall discuss my invention with respect to transducers formed of the ferroelectric ceramic materials such as the metallic titanates, zirconates and niobates and more particularly, barium titanate and lead titanate-zirconate with or without additives, the teachings of my invention may be applied with equally good results to other transducers of the artificial or natural piezoelectrics, magnetostrictives or others which may be driven in parallel. Electron tube 3 comprises plate 5, grid 7 and cathode 9 and is connected as a Hartley oscillator with secondary 11 of transformer 10 as the tank circuit. Core 17 of transformer 10 is made of saturable material such as a ferrite whose permeability varies with the amount of direct current through the primaries 13 and 15. Primaries 13 and 15 are connected in series opposition so that no oscillator signal is coupled out through this circuit. The tank circuit is tuned by means of variable capacitor 12

which is connected across secondary 11. Triode control tube 19, which comprises plate 21, grid 23 and cathode 25, is provided to control the amount of direct current flowing in primaries 13 and 15 which are connected in the circuit of cathode 25. Control tube 19 is connected in a cathode follower circuit.

Negative bias from the source marked C— in the figure is applied to grid 23 of such value so as to set the permeability of core 17 on the linear portion of the B—H curve of the core. A small alternating signal is superimposed on grid 23 by means of transformer 27, potentiometer 29 and coupling capacitor 31. I have chosen 60 c.p.s. as the alternating signal frequency but any other frequency may be used. The amplitude of variation of the signal applied to grid 23 is determined by the position of the slider on potentiometer 29, when it is at the top in the figure, the variation is maximum and when it is at the bottom, the variation is minimum. This small signal is coupled to grid 23 through coupling capacitor 31. The variation on grid 23 causes a corresponding change in the cathode current between cathode 25 and ground and thus causes the permeability of core 17 to vary in accordance with the current in primaries 13 and 15.

As a result of the change in the permeability of core 17, the inductance of secondary 11 is varied at an alternating rate about the resonant frequency of the circuit comprised of secondary 11 and capacitor 12. The frequency deviation from the mean resonant frequency is determined by the change in voltage applied to grid 23 and the frequency at which this deviation occurs is determined by the frequency of the source applied to transformer 27.

Capacitor 14 is provided to couple the tank circuit to grid 7 and capacitor 16 is provided to couple the tank circuit to plate 5. Resistor 20 is the bias resistor for electron tube 3. Resistor 18 is the plate dropping resistor and is connected between the source of plate power B+ and plate 5. Plate 21 is also connected to plate power source B+. The output of the oscillator is coupled through coupling capacitor 22 to power amplifier 24 which I have shown in block form and which may be, for example, an R-C coupled power amplifier with an untuned output transformer.

The output of power amplifier 24 is applied to transducers 1*a*, 1*b*, . . . 1*z* which are connected in parallel. If desired, I can excite the transducers directly from the output of the oscillator and dispense with the power amplifier. In addition, I may use other methods for varying the frequency of the oscillator from that shown and described.

Thus, it can be seen that maximum power output is obtained from each transducer in the array during the time that it is excited at its resonant frequency and a lesser output is obtained from it when it is excited at a frequency other than its resonant frequency. This results in improved operation of the ultrasonic cleaner or other device being driven by the multiple transducer array because all of the transducers are excited at their resonant frequencies for a part of the time. This would not occur if a fixed excitation frequency were used and the transducers in the array had different resonant frequencies.

While I have disclosed my invention in relation to a specific example and in a specific embodiment, I do not wish to be limited thereto, for obvious modifications will occur to those skilled in the art without departing from the spirit and scope of my invention.

I claim:

1. An ultrasonic device comprising an electron tube oscillator having at least a grid, a plate and a cathode; a transformer having a saturable core whose permeability is variable, a secondary and a pair of primaries; said

secondary being tapped; one end of said secondary being coupled to the grid of said electron tube oscillator; the other end of said secondary being coupled to the plate of said electron oscillator; the tap of said secondary being connected to the cathode of said electron tube oscillator; a variable capacitor connected across said secondary; an electron tube cathode follower having at least a grid, a plate and a cathode; the primaries of said transformer being connected in series opposition between the cathode of said electron tube cathode follower and ground; a source of negative bias connected to the grid of said electron tube cathode follower; a source of low frequency voltage and means for varying the output amplitude of said source of low frequency voltage connected to the grid of said electron tube cathode follower; a source of plate voltage connected to the plates of said electron tube oscillator and said electron tube cathode follower; and a plurality of ultrasonic transducers connected to the output of said electron tube oscillator.

2. An ultrasonic device comprising an electron tube oscillator having at least a grid, a plate and a cathode; a transformer having a saturable core whose permeability is variable, a secondary and a pair of primaries; said secondary being tapped; one end of said secondary being coupled to the grid of said electron tube oscillator; the other end of said secondary being coupled to the plate of said electron oscillator; the tap of said secondary being connected to the cathode of said electron tube oscillator; a variable capacitor connected across said secondary; an electron tube cathode follower having at least a grid, a plate and a cathode; the primaries of said transformer being connected in series opposition between the cathode of said electron tube cathode follower and ground; a source of negative bias connected to the grid of said electron tube cathode follower; a source of low frequency voltage and means for varying the output amplitude of said source of low frequency voltage connected to the grid of said electron tube cathode follower; a source of plate voltage connected to the plates of said electron tube oscillator

and said electron tube cathode follower; a power amplifier connected to the output of said electron tube oscillator; and a plurality of ultrasonic transducers connected to the output of said power amplifier.

3. An ultrasonic device as described in claim 2 wherein said power amplifier is of the resistance-capacitance coupled type and has an untuned output transformer.

4. In combination with a plurality of ultrasonic transducers each having a resonant frequency which may differ somewhat from the resonant frequency of each of the other transducers and inputs for receiving electrical signals for driving the same, means connecting all of the inputs of said ultrasonic transducers continuously in parallel, a common ultrasonic generator continuously coupled to all of said transducer inputs for electrically driving the same, and means for frequency modulating said ultrasonic generator in a narrow range of frequencies sufficient to encompass the respectively different resonant frequencies of said transducers.

5. In combination with a plurality of ultrasonic transducers having inputs adapted to receive ultrasonic electrical signals for driving the same, said transducers each having a resonant frequency which may differ somewhat from the resonant frequency of each of the other transducers, a common ultrasonic generator having an output varying in frequency, means coupling the variable frequency output of said generator to each of the transducer inputs to subject each of the transducers to the full range of the frequency variation of the generator output, and said ultrasonic generator including means frequency modulating the output thereof over a narrow range of frequencies sufficient to encompass the respectively different resonant frequencies of said transducers.

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