May 10, 1949. W. E. BRADLEY ET AL 2,469,811

OSCILLATOR CIRCUITS

Filed Sept. 17, 1946

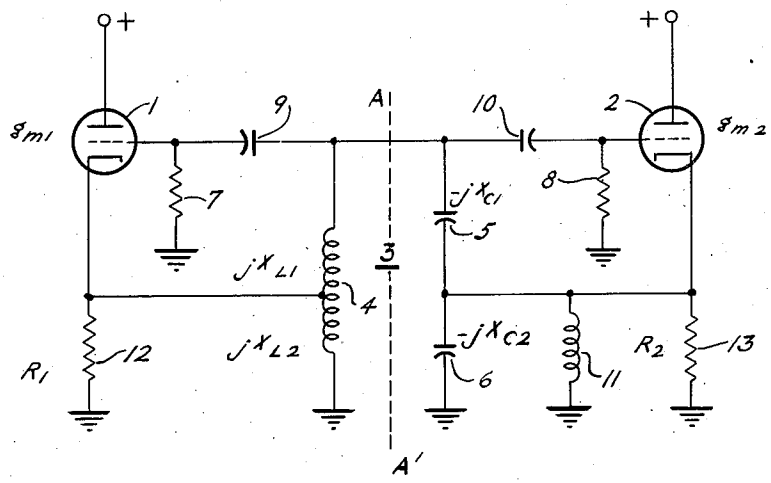


FIG. 1.

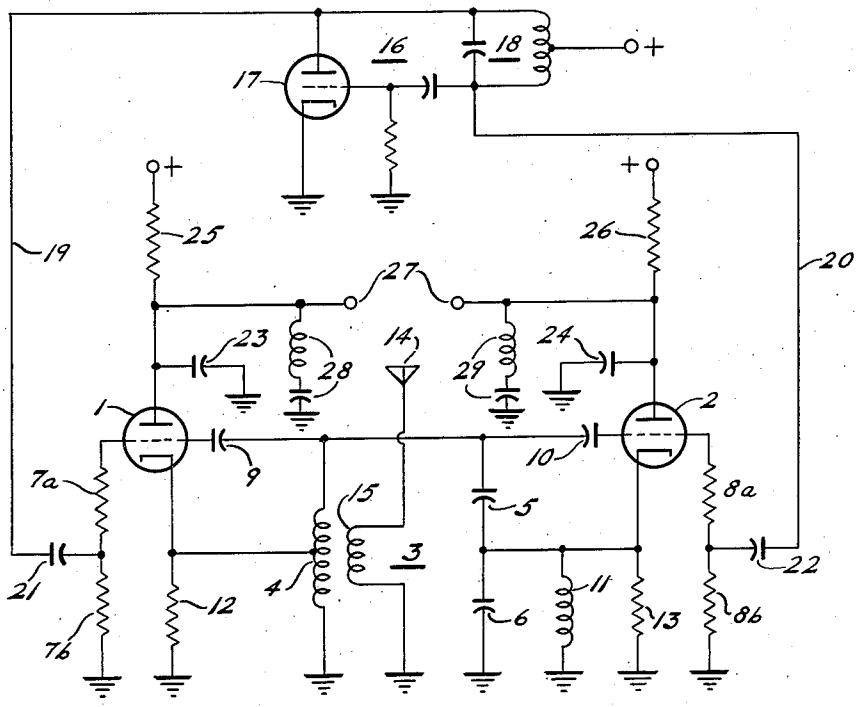


FIG. 2.

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Patented May 10, 1949 2,469,811

UNITED STATES PATENT OFFICE

2,469,811

OSCILLATOR CIRCUITS

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Application September 17, 1946, Serial No. 697,434

12 Claims. (Cl. 250—36)

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This invention relates to vacuum tube oscillators. More specifically it relates to an oscillator which is adapted selectively to generate electrical wave signals at either of two slightly different frequencies, the desired frequency at any particular instant of time being readily determinable, in response to a control signal supplied to the oscillator from an external source.

Frequently in the communications and radar art it is desired selectively to provide signals of two slightly and precisely differing frequencies. Although it is quite feasible to do this by using any one of a number of conventional means, the amount of equipment required and the complexity of the circuits may prove to be objectionable. Accordingly, it is the primary object of our invention to provide a simple, convenient and reliable oscillator for yielding the desired result while employing a minimum of equipment. The oscillator hereinafter disclosed employs but a pair of vacuum tube sections, or their equivalent, and a single tank circuit, plus a few additional components. It is extremely simple in operation and readily controllable, for example in response to a signal of alternating rectangular waveform, for operation selectively at either of two differing frequencies. Also it is eminently adapted for incorporation into other circuits in which, while performing its primary function as a generator, it may also be made to cooperate in other ways to bring about additional desired results.

Thus, for example, as set forth hereinafter, the two tubes of the oscillator circuit may be made to function alternately as superregenerative amplifiers at two slightly different frequencies. Such an arrangement has particular application in a detector of angular-velocity modulated carrier wave signals, one form of which is hereinafter shown and described.

The principle of our invention and the construction, mode of operation and application of a representative embodiment, as well as other features and advantages thereof will be fully understood from consideration of the following specification with reference to the drawings in which:

Figure 1 is a schematic diagram of a circuit according to the invention, and

Figure 2 illustrates schematically the application of the circuit of Figure 1 to a superregenerative detector of angular-velocity modulated carrier wave signals.

Referring to Figure 1, the oscillator circuit shown comprises a pair of triode vacuum tubes 1 and 2 connected so as to form, in cooperation

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with a common tank circuit 3, separate oscillator circuits which are, respectively, of the well-known Hartley and Colpitts forms. Thus tank circuit inductor 4 is connected between the grid of tube 1 and ground, and the cathode of tube 1 is connected to a tap on inductor 4 so that the lower portion of the latter is included in the cathode circuit of the tube and provides the feedback necessary for oscillation. Tube 1, in cooperation with tank circuit 3, therefore forms a conventional Hartley circuit. On the other hand, tank circuit condenser 5 is connected between the grid and cathode of tube 2, and condenser 6, also part of tank circuit 3, is connected between the cathode of tube 2 and ground, as in a conventional Colpitts circuit. Conventional grid resistors 7 and 8 and grid condensers 9 and 10 are likewise provided for both tubes 1 and 2.

By application of a suitable controlling signal to appropriate elements of either or both of tubes 1 and 2, one tube may be cut off during prescribed intervals, while the other tube is conductive, and vice versa. Thus each tube may be permitted to oscillate separately and independently of the other during predetermined intervals. The mode of operation of the circuit incorporating tube 1 is that of a conventional Hartley and, of the circuit incorporating tube 2, that of a conventional Colpitts. So generally understood is the operation of these circuits, it is not deemed necessary to devote further discussion to them here.

In accordance with the purpose of the invention, each of the separate oscillators is to operate at a slightly different frequency and, to this end, resistors 12 and 13 are connected respectively from the cathodes of tubes 1 and 2 to ground. This will effect, in the instance of tube 1, a slight decrease in its frequency of oscillation, and, in the instance of tube 2 a slight increase. In order that each circuit shall continue to be capable of sustaining oscillations, it is essential that the magnitudes of resistors 12 and 13 be not too small. Furthermore, by appropriate selection of the values of these resistors, it is possible to achieve a maximum, or any desired smaller, frequency difference between the two oscillators. The manner in which the shifts in frequency of the two oscillators is effected and the criteria for choosing the values of resistors 12 and 13 will be apparent from the following theoretical considerations.

Assuming the circuit of Figure 1 to be divided into two parts by broken line A—A', the im-

pedance looking into the left-hand portion is given by the expression:

$$Z_L=j\left[X_{L1}+\frac{R_1^2X_{L2}}{R_1^2+X_{L2}^2}+g_{m1}\frac{R_1X_{L1}X_{L2}^2}{R_1^2+X_{L1}^2}\right]+\frac{R_1X_{L2}^2}{R_1^2+X_{L2}^2}\left(1-g_{m1}\frac{R_1X_{L1}}{X_{L2}}\right) \quad (1)$$

The impedance looking into the right-hand portion is given likewise by the expression:

$$Z_R=-j\left[X_{C1}+\frac{R_2^2X_{C2}}{R_2^2+X_{C2}^2}+g_{m2}\frac{R_2X_{C1}X_{C2}^2}{R_2^2+X_{C2}^2}\right]+\frac{R_2X_{C2}^2}{R_2^2+X_{C2}^2}\left(1-\frac{g_{m2}R_2X_{C1}}{X_{C2}}\right) \quad (2)$$

The shift in frequency of the Hartley portion of the circuit owing to the presence of resistor 12 is directly attributable to the term

$$g_{m1}\frac{R_1X_{L1}X_{L2}^2}{R_1^2+X_{L2}^2}$$

in the imaginary part of the expression (1) for Z_L. This term is maximum, and the Hartley section experiences maximum frequency shift when $R_1=X_{L2}$. Likewise, for the Colpitts portion of the circuit, the maximum frequency shift will obtain when the term

$$g_{m2}\frac{R_2X_{C1}X_{C2}^2}{R_2^2+X_{C2}^2}$$

is maximum. This will be the case when $R_2=X_{C2}$.

Other values of R_1 and R_2 may, of course, be used if maximum shift is not required. However, as already mentioned, in order that each of the circuits shall continue to be capable of sustaining oscillations, the values of resistors 12 and 13 must not be made too small. In the instance of the Hartley circuit, the value of resistor 12 must satisfy the condition:

$$R_1g_{m1}>\frac{X_{L2}}{X_{L1}} \quad (3)$$

while, in the instance of the Colpitts circuit, the condition to be satisfied by resistor 13 is:

$$R_2g_{m2}>\frac{X_{C2}}{X_{C1}} \quad (4)$$

Values of resistors 12 and 13 satisfying relations (3) and (4) are such as to make the real parts of the expressions (1) and (2) for Z_L and Z_R respectively negative (i. e. to make the resistance of each oscillator circuit negative).

The inclusion of resistor 13 in the cathode circuit of tube 2 makes desirable the connection in shunt therewith of a resonant choke 11, tuned to the oscillating frequency of the Colpitts section, to provide a low impedance D.-C. path from the cathode of tube 2 to ground.

It is to be noted also that, although the primary functions of resistors 12 and 13 are to alter the frequencies of the oscillators with which they are respectively associated, each also tends to modify the frequency of the oscillator with which it is not directly associated, and this effect must be taken into account in designing the circuit for oscillation at two specific frequencies.

The circuit above described has numerous applications such as will readily occur to those skilled in the communications art. One such application, which will now be set forth for purposes of illustration, is in a detector of angular-velocity modulated carrier wave signals based on the method described in Patent 2,351,193 of June 13, 1944, to Murray G. Crosby for a Frequency modulation detector circuit. According

to this method two superregenerative detectors are operated at different frequencies respectively above and below the center, or carrier, frequency of the modulated carrier wave signal to be detected. The two detectors are alternately quenched and unquenched to permit oscillations to build up in their tank circuits at a rate determined by the extent of modulation of the carrier wave signal at the time of unquenching. The outputs of the two detectors are combined so as to yield a signal which varies in accordance with the angular-velocity modulation of the input carrier, but which is substantially independent of variations in the amplitude of said carrier. The circuit shown in the patent for applying this method employs separate tubes for the two superregenerative oscillators, two additional tubes comprising a quench controlling oscillator, and yet another tube to vary the tuning of a common tank circuit used in conjunction with both superregenerative oscillators.

Following this same method, in the circuit of Figure 1 of the present specification, tubes 1 and 2 may be made to operate alternately as superregenerative detectors at two slightly differing frequencies respectively above and below the carrier frequency of the modulated signal to be detected. A complete embodiment of a circuit for this purpose is shown in Figure 2 where the various components of the circuit of Figure 1 are designated by like reference characters. In this circuit a frequency- or phase-modulated carrier wave signal intercepted by antenna 14 is supplied to tank circuit 3 through inductor 15 coupled to tank circuit inductor 4. A low frequency quench controlling signal generated by oscillator 16, comprising triode 17 and tank circuit 18, and which may be of substantially sinusoidal waveform, is supplied in opposite phases, through connections 19 and 20 including condensers 21 and 22, to the grids of tubes 1 and 2 respectively. The latter are thereby rendered alternately conductive to permit oscillations to build up at the respective frequencies of oscillation of the Hartley and Colpitts circuits in which they are connected. In each circuit oscillations will begin to build up at a time following unquenching determined by the extent to which the instantaneous frequency of the modulated carrier wave signal departs from the normal frequency of oscillation of the particular oscillator circuit. In the absence of modulation, the outputs of the two superregenerators will be essentially equal and, when supplied to a conventional push-pull subtractor circuit (not shown), will cancel. However, when the input signal is phase- or frequency-modulated and assuming the frequencies of oscillation of the two oscillator sections to have been displaced by equal amounts respectively above and below the carrier frequency, oscillations will build up to appreciable amplitude in one circuit sooner than in the other during successive alternations of the quench controlling signal, and subtraction of the two outputs will give rise to a resultant signal indicative of the instantaneous value of modulation.

As shown, the plates of tubes 1 and 2 are preferably by-passed to ground at their respective frequencies of oscillation by condensers 23 and 24, and at quench frequency by series tuned circuits 28 and 29 resonant at the latter frequency. Detected output is developed across resistors 25 and 26 in the respective plate circuits of tubes 1 and 2, and is available at terminals 27 for

supply to a push-pull subtractor circuit (not shown).

For illustrative purposes only, and with no thought of imposing any limitations upon the invention, the following values are given for the components of the circuit of Figure 2. They are applicable to an instance in which the carrier frequency of the input signal is 50 megacycles and it is desired to provide a difference between the frequencies of oscillation of the two oscillators of 160 kilocycles (which, however, is not the maximum obtainable from the circuit):

Tubes 1 and 2	Type 6SN7
Inductor 4 (upper portion)	⅔ μ-henry
Inductor 4 (lower portion)	⅓ μ-henry
Condenser 5	15 $\mu\mu$-farads
Condenser 6	30 $\mu\mu$-farads
Resistors 7*a* and 8*a*	10,000 ohms
Resistors 7*b* and 8*b*	100,000 ohms
Condensers 9 and 10	50 $\mu\mu$-farads
Choke 11	Self resonant at 50 megacycles
Resistors 12 and 13	5,000 ohms
Tank circuit 18	resonant at 50 kilocycles
Condensers 21 and 22	1,000 $\mu\mu$-farads
Condensers 23 and 24	100 $\mu\mu$-farads
Resistors 25 and 26	1,000 ohms
Series circuits 28 and 29	resonant at 50 kilocycles

It will of course be understood that the invention is susceptible of embodiment in physical forms other than the one here shown, such as will occur to those skilled in the art upon reading this specification. Accordingly the scope of this invention is to be regarded as subject only to the limitations imposed by the appended claims.

We claim:

1. In a vacuum tube oscillator, a pair of vacuum tubes having at least triode elements, a tank circuit comprising a pair of conjugate reactive branches, a portion of each of said branches being connected in the cathode circuit of one of said tubes and cooperating with said tube to form a separate oscillator adapted to oscillate independently when said other tube is cut off, and means included in the cathode circuit of one of said tubes and operative when said tube is conductive to modify the frequency of oscillation of the oscillator circuit which includes said one tube.

2. In a vacuum tube oscillator, a pair of vacuum tubes having at least triode elements, a tank circuit comprising a pair of conjugate reactive branches, said tank circuit being connected so as to form, in cooperation with each of said tubes, separate oscillator circuits, each adapted to oscillate independently when the other tube is cut off and, in each of which, one of said reactive branches cooperates to provide the feedback necessary for oscillation, and means comprising a resistor connected in the cathode circuit of one of said tubes for causing said oscillators to oscillate at different frequencies.

3. In a vacuum tube oscillator, a pair of vacuum tubes having at least triode elements, a tank circuit comprising a pair of conjugate reactive branches, said tank circuit being connected so as to form, in cooperation with each of said tubes, separate oscillator circuits, each adapted to oscillate independently when the other tube is cut off and, in each of which, one of said reactive branches cooperates to provide the feedback necessary for oscillation, and means comprising resistors connected in the cathode circuits of said tubes for causing said oscillators to oscillate at different frequencies.

4. In a vacuum tube oscillator, a pair of vacuum tubes having at least triode elements, a tank circuit comprising an inductance and a capacitance connected in parallel, a resistance connected in parallel with a component of said inductance in the cathode circuit of one of said tubes to form an oscillator adapted to oscillate at a predetermined frequency, the product of said resistance and the mutual conductance of said tube being greater than the ratio of the impedance of said component to the impedance of the remainder of said inductance at said frequency, and a second resistance connected in parallel with a component of said capacitance in the cathode circuit of the other of said tubes to form a second oscillator adapted to oscillate at a predetermined second frequency different from said first frequency, the product of said second resistance and the mutual conductance of said last-named tube being greater than the ratio of the impedance of said component to the remainder of said capacitance at said second frequency.

5. In a vacuum tube oscillator, a pair of vacuum tubes having at least triode elements, a tank circuit comprising an inductance and a capacitance connected in parallel, a resistance connected in parallel with a component of said inductance in the cathode circuit of one of said tubes to form an oscillator adapted to oscillate at a predetermined frequency, said resistance being comparable in magnitude to the impedance of said component inductance at said frequency, and a second resistance connected in parallel with a component of said capacitance in the cathode circuit of the other of said tubes to form a second oscillator adapted to oscillate at a predetermined second frequency different from said first frequency, said resistance being comparable in magnitude to the impedance of said component capacitance at said second frequency.

6. In a vacuum tube oscillator, a pair of vacuum tubes having at least triode elements, a tank circuit comprising a pair of conjugate reactive branches, said tank circuit being connected so as to form, in cooperation with each of said tubes, separate oscillator circuits, each adapted to oscillate independently when the other tube is cut off and, in each of which, one of said reactive branches cooperates to provide the feedback necessary for oscillation, and means comprising substantially equal resistors connected in the cathode circuits of said tubes for causing said oscillators to oscillate at different frequencies.

7. In a vacuum tube oscillator, a pair of vacuum tubes, each having a plurality of electrodes and each being adapted to be rendered conductive or non-conductive, a tank circuit reasonant at a predetermined frequency, means coupling said tank circuit to electrodes of one of said tubes to form an oscillatory circuit adapted to oscillate when said one tube is conductive, the frequency of oscillation of said oscillatory circuit being determined by the resonant frequency of said tank circuit, means coupling said tank circuit to electrodes of the other of said tubes to form a second oscillatory circuit adapted to oscillate when said other tube is conductive, the frequency of oscillation of said second oscillatory circuit being determined by the resonant frequency of said tank circuit, and means operative when one

of said tubes is conductive to alter the resonant frequency of said tank circuit.

8. In a vacuum tube oscillator, a pair of vacuum tubes, each having at least triode elements and each being adapted to be rendered conductive or non-conductive, a tank circuit resonant at a predetermined frequency and comprising a pair of conjugate reactive branches, means coupling said tank circuit to electrodes of one of said tubes to form an oscillator circuit adapted to oscillate when said one tube is conductive, said coupling being made so as to include at least a portion of one of said reactive branches in the cathode circuit of said tube and the frequency of oscillation of said oscillatory circuit being determined by the resonant frequency of said tank circuit, means coupling said tank circuit to electrodes of the other of said tubes to form a second oscillatory circuit adapted to oscillate when said other tube is conductive, the frequency of oscillation of said second oscillatory circuit being determined by the resonant frequency of said tank circuit, and means included in the cathode circuit of said first tube and operative when said tube is conductive to alter the resonant frequency of said tank circuit.

9. In a vacuum tube oscillator, a pair of vacuum tubes having at least triode elements, a tank circuit comprising an inductance and a capacitance connected in parallel, a resistance connected in parallel with a component of said inductance in the cathode circuit of one of said tubes to form an oscillator adapted to oscillate at a predetermined frequency, and a second resistance connected in parallel with a component of said capacitance in the cathode circuit of the other of said tubes to form a second oscillator adapted to oscillate at a predetermined second frequency different from said first frequency.

10. In a vacuum tube oscillator, a pair of vacuum tubes having at least triode elements, a tank circuit comprising a pair of conjugate reactive branches, a resistance connected in parallel with at least a portion of one of said branches in the cathode circuit of one of said tubes to form an oscillator adapted to oscillate at a predetermined frequency, and a second resistance connected in parallel with at least a portion of the other of said branches in the cathode circuit of the other of said tubes to form a second oscillator adapted to oscillate at a predetermined second frequency different from said first frequency.

11. In a vacuum tube oscillator, a pair of vacuum tubes each having at least triode elements, a tank circuit comprising an inductance and a capacitance connected in parallel, means coupling said tank circuit to one of said tubes to form a Colpitts circuit adapted to oscillate at a predetermined frequency, and means coupling said tank circuit to said other tube to form a Hartley circuit adapted to oscillate at a different frequency.

12. In a vacuum tube oscillator, a pair of vacuum tubes having at least triode elements, a tank circuit comprising an inductance and a capacitance connected in parallel, a resistance connected in parallel with a component of said inductance in the cathode circuit of one of said tubes to form an oscillator adapted to oscillate at a predetermined frequency, a resistance connected in parallel with a component of said capacitance in the cathode circuit of said other tube to form a second oscillator adapted to oscillate at a second frequency, and a choke substantially resonant at said second frequency connected in shunt with said last-named resistance and said component of said capacitance.

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No references cited.

Certificate of Correction

May 10, 1949.

Patent No. 2,469,811.

WILLIAM E. BRADLEY ET AL.

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 3, line 5, Equation (1) for "X_{L1}^{2}" read X_{L2}^{2}; lines 13 and 14, Equation (2) at the end thereof, insert a closing parenthesis;

and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 11th day of October, A. D. 1949.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.