March 23, 1948. A. W. VANCE 2,438,425

COMPUTING DEVICE

Filed Nov. 26, 1942 2 Sheets-Sheet 1

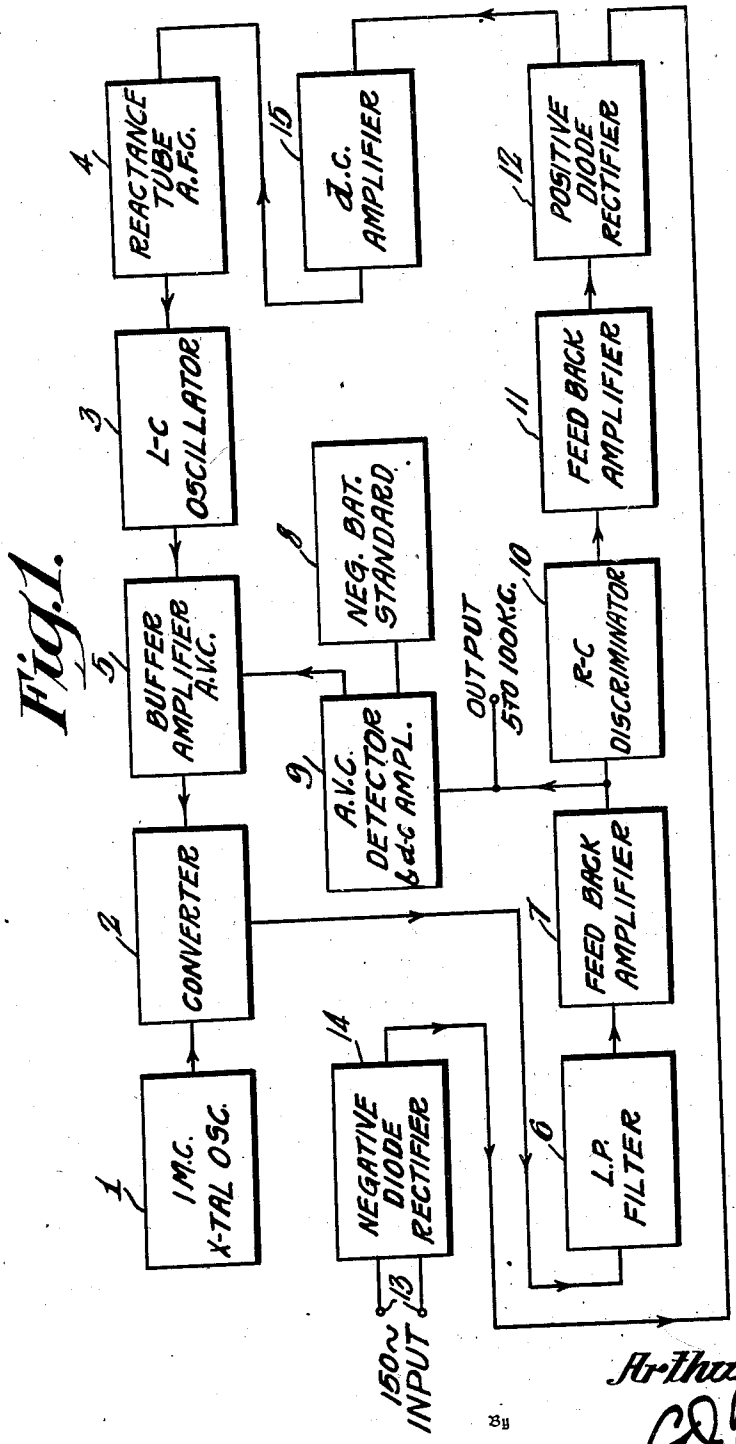


Fig. 1.

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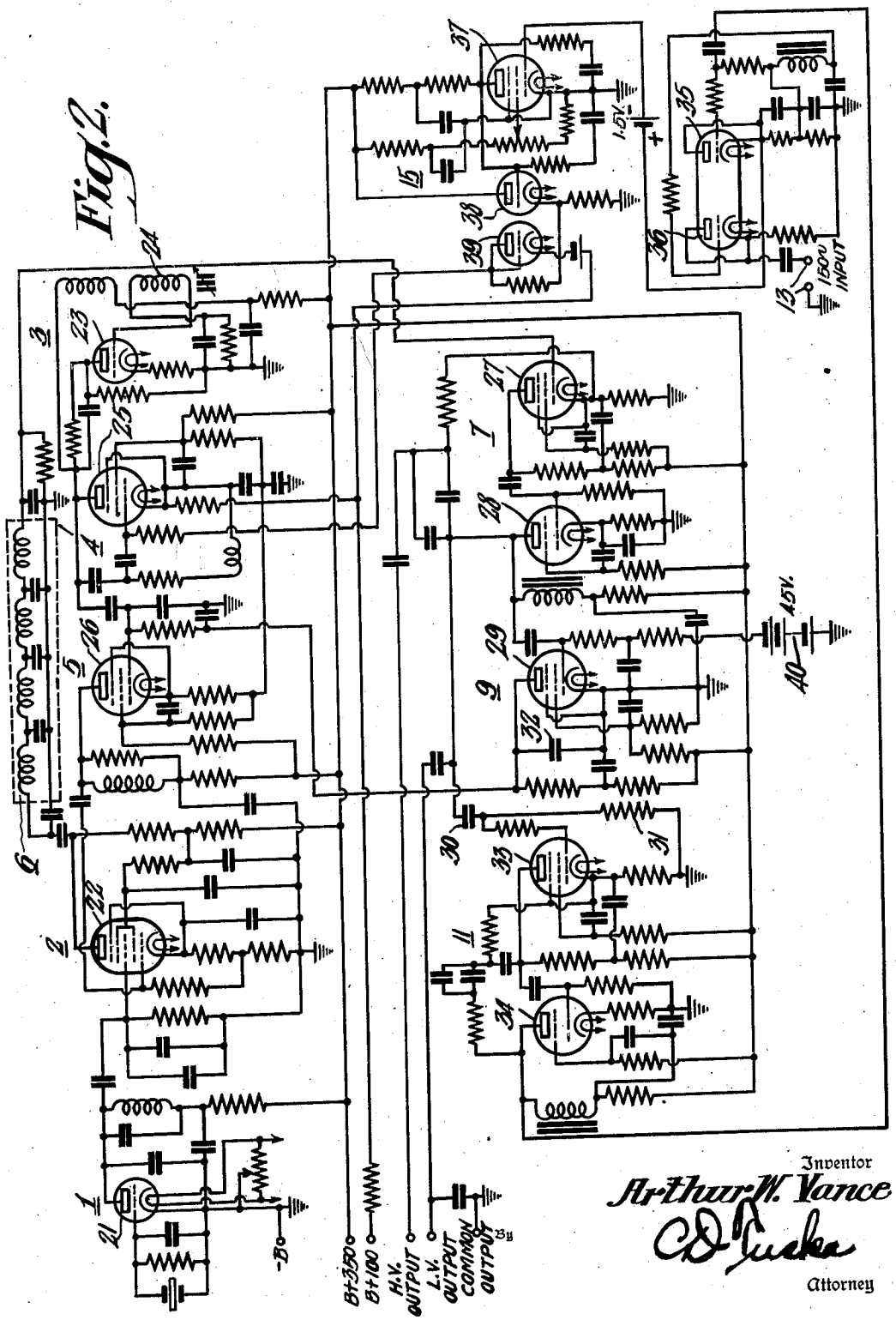
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Fig. 2.



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COMPUTING DEVICE

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5 Claims. (Cl. 250—36)

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This invention relates generally to frequency modulated thermionic tube generators, and particularly to a variable frequency oscillator in which the output frequency is a predetermined function of the voltage amplitude of a low frequency alternating current source.

The invention has general utility wherever variable frequency oscillators are used, and is particularly adapted for use in electronic predictors which utilize direct and alternating potentials of varying amplitude in the solution of complex mathematical operations. Briefly, the invention comprises a beat frequency oscillator comprising a constant frequency source and a variable frequency source wherein the frequency of the variable frequency source is a predetermined function of the voltage amplitude of an applied low frequency alternating potential. Since electronic computers of the type mentioned heretofore require considerable accuracy in the solution of the mathematical operations, high linearity and stability is required in all frequency modulation circuits which are utilized. Therefore, the present invention includes automatic gain control and automatic frequency control circuits whereby applied alternating potentials are stabilized with respect to substantially constant D.-C. voltage sources such as batteries. The batteries are used exclusively for the purpose of stabilization and are operated at substantially no load, whereby long life and high voltage stability is obtained in the battery standard.

Among the objects of the invention are to provide a new and improved method of and means for generating alternating potentials of variable frequency. Another object is to provide an improved method of and means for generating variable frequency alternating potentials wherein the frequency is determined by the amplitude of an applied low frequency alternating potential. Another object is to provide an improved method of and means for frequency modulating an A.-C. thermionic tube generator of the beat frequency type wherein the output frequency is a predetermined function of the amplitude of an applied low frequency A.-C. potential, and which includes means for controlling automatically the gain and controlling the frequency of all circuits which will affect the overall linearity of the circuit operation. Still another object of the invention is to provide an improved frequency modulated generator operating upon the beat frequency principle, utilizing a constant frequency source and a variable frequency oscillator, wherein the output frequency is a predetermined function of the amplitude of an applied low frequency potential, and wherein automatic gain control and frequency control are obtained by comparing the amplitudes of control potentials to standard voltages to overcome inherent non-linearity in selected critical circuits.

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The invention will be described by reference to the accompanying drawings of which Figure 1 is a block schematic diagram of the invention, and Figure 2 is a schematic circuit diagram of a preferred embodiment of the invention. Similar reference numerals are applied to similar elements throughout the drawings.

Referring to Figure 1, a constant frequency source, such as a crystal controlled thermionic tube oscillator 1, having an output frequency of 1 mc., is connected to the input of a converter or modulator 2. A variable frequency oscillator 3, preferably having a high ratio of inductance to capacitance in its tank circuit, is connected to a reactance tube circuit 4, which may be of the general type used in automatic frequency control circuits in radio receivers. The output of the variable frequency oscillator 3 is also applied to the input of the converter 2 through a variable gain buffer amplifier 5. The beat frequency output of the converter 2 is applied to the input of a low pass filter 6, which is tuned to pass only the desired band of beat frequencies. The amplitude of the beat frequency currents is amplified substantially linearly by applying the currents derived from the output of the low pass filter 6 to the input of a feedback amplifier 7. The output of the feedback amplifier 7 is compared with a substantially constant negative voltage source 8, such as a battery, and applied to the input of an automatic gain control rectifier circuit 9 which also provides D.-C. amplification. The output of the rectifier-D.-C. amplifier 9 is applied to control the gain of the buffer amplifier 5. It will therefore be understood that the voltage amplitude of the beat frequency will be substantially stabilized.

The output of the feedback amplifier 7 is next applied to a frequency discriminator 10, comprising a substantially constant non-inductive resistor and a substantially constant capacitor. The discriminator output is applied through a second feedback amplifier 11 to a diode rectifier 12, which is arranged to provide a positive potential proportional to the amplitude of the currents derived from the feedback amplifier 11. A source of low frequency potentials of variable amplitude is connected to the terminals 13 of a second

diode rectifier 14, from which is derived a negative potential proportional to the voltage amplitude of the applied low frequency source. The difference between the rectified outputs of the diode rectifiers 12 and 14 is applied to the input of a D.-C. amplifier 15 which preferably includes a voltage limiter circuit. The limited output of the D.-C. amplifier 15 is then applied to control the reactance tube 4.

Thus an automatic frequency control feedback loop of high gain in included, which adjusts the beat frequency so that the amplified output of the discriminator 10 almost exactly equals the amplitude of the low frequency applied signal. Under these conditions the output beat frequency, which may be derived from any suitable point prior to the discriminator circuit, is substantially linearly proportional to the input voltage of the low frequency source. It should be understood that if the discriminator characteristic is non-linear, the output beat frequency will be a predetermined function of the applied control potential, which function will be determined by the response characteristic of the selected discriminator.

Since in some electronic predictors it is essential that the derived function of the variables under computation be linear to within at least $\frac{1}{10}$ of one percent, the apparatus described must meet several rather stringent conditions. For example, the discriminator must be linear to the order of one part in ten thousand. For this degree of linearity, it is essential that the reactance of the capacitor must be very much larger than the discriminator resistance for all values of output frequency. The capacitor losses must be substantially negligible, and the capacitor should have a negligible temperature coefficient. Similarly, the resistance should have negligible inductance and should be substantially independent of frequency. A special non-inductive wire wound resistor having negligible skin effect is preferable.

In addition, the feedback amplifiers must be extremely linear and provide very low distortion. These conditions apply especially to the feedback amplifier 7 which precedes the discriminator circuit, since the discriminator accentuates harmonics in direct proportion to their frequency. Furthermore, the feedbox amplifiers should have negligible variation in gain with respect to frequency, be exceedingly stable and have very low output impedance. The latter conditions apply especially to the feedback amplifier 11 which follows the discriminator circuit, since variations in frequency response or gain are translated directly into the output beat frequency.

The frequency converter should have very low harmonic output since low order harmonics of the beat frequency may be passed by the low pass filter 6 if the beat frequency covers an extensive band, such as for example, 100 kc.

The automatic gain control detector 9 should have a substantially constant threshold to prevent spurious changes in level which would be translated into output frequency variations. Similarly, the variable frequency oscillator 3 should provide substantially constant output potentials at all operating frequencies.

Time delay in both feedback loops should be calculated to exclude singing or "motor boating." Overall and individual circuit conditions, and the feedback circuits as a whole must be exceedingly stable. Similarly, spurious voltages,

hum and noise should be maintained at minimum values, since they may provide both amplitude and frequency modulation of the output beat frequency.

The operation of Figure 2 is substantially identical to that described for Figure 1. A triode 21, which includes a tuned anode circuit and a piezo crystal control electrode circuit, provides a source of constant frequency 1, as described heretofore. The output of the tube 21 is applied to the second control electrode of a converter tube 22. The variable frequency oscillator 3 includes a triode 23 which has a permeability tuned inductance 24 in its control electrode circuit. The value of this inductance is varied for adjusting the variable frequency oscillator output to zero, or minimum, beat frequency with the crystal controlled oscillator output when no low frequency potentials are applied to the input circuit. A reactance tube 25 is connected to the variable frequency oscillator circuit 3 in a manner well known in the radio receiver art.

The output of the variable frequency oscillator tube 23 is connected to the first control electrode of a variable gain buffer amplifier tube 26, the output of which is connected to the first control electrode of the converter tube 22. The anode circuit of the converter tube 22 is connected, through the low pass filter 6, to the input of a conventional feedback amplifier which includes the tubes 27 and 28 arranged in cascade. It should be understood that any conventional type of feedback circuit may be employed in the amplifier which will provide the required gain stability. The output of the second feedback amplifier tube 28 is applied to the control electrode of a rectifier and D.-C. amplifier tube 29. A source of substantially constant negative potential, such as a battery 40, is also connected to the control electrode of the rectifier-D.-C. amplifier 29, whereby the algebraic sum of the constant D.-C. potential and the output of the feedback amplifier tube 28 is rectified, amplified and then connected to the control grid of the variable gain buffer amplifier tube 26 to control the amplitude of the variable frequency oscilations applied to the first control grid of the converter tube 22. A by-pass capacitor 32 is connected across the output of the D.-C. amplifier 29 to segregate the undesired A.-C. component in the control potential applied to the control electrode of the buffer amplifier 26.

The output of the feedback amplifier tube 28 is also applied to a frequency discriminator circuit which includes the capacitor 30 and the resistor 31, which are described in detail heretofore. The discriminator circuit is connected to the input of the first tube 33 of a second two stage feedback amplifier 11, which includes the tube 33 and a second amplifier tube 34. The output of the second tube 34 of the second feedback amplifier 11 is applied to the control grid of a triode 35, which is connected to act as a simple diode.

A source of low frequency input control potential is connected to the input terminals 13, and applied to the anode of a second triode 36 which is also connected to act as a simple diode. The output potentials derived from the two diodes 35, 36 will be of opposite polarity. The difference between the two rectified potentials derived from the diodes is applied to the input of a first tube 37 of a second D.-C. amplifier 15, which is

normally in equilibrium. Since the polarity of the two diodes 35, 36 is opposite, any distortion which occurs therein is substantially neutralized. Fixed resistors may be connected across the two diodes to provide a constant current, thereby reducing undesired harmonic and noise components. The output of the D.-C. amplifier tube 37 is applied through a cathode follower tube 38 to the input of a voltage limiter tube 39. The limited voltage derived from the tube 39 is then applied to the control grid of the reactance tube 25 to complete the automatic frequency control feedback loop.

It should be understood that specially regulated anode and bias voltage sources are highly desirable to secure maximum stability from the circuit described.

Beat frequency output signals may be derived from any suitable point prior to the frequency discriminator circuit. The best connection will depend upon the voltage and impedance considerations of the load circuit.

The circuit described is capable of generating a beat frequency which may be varied between 5 kc. and 100 kc. while utilizing a 1 mc. constant frequency source. Measurements have indicated that the beat frequency varies linearly with the amplitude of the low frequency input alternating potential to within plus or minus 100 cycles. The time of response is of the order of 10^6 cycles per second. The frequency control sensitivity is of the order of 1 kc. per peak volt of applied low frequency potential. It should be understood that the applied control potential may be either A.-C. or D.-C., and that equally satisfactory operation may be obtained with either type.

Thus the invention described comprises a frequency modulated thermionic tube generator wherein the output beat frequency is substantially linearly proportional to, or a predetermined function of, the voltage amplitude of an applied low frequency potential, and in which linearity and stability of operation are maintained by the use of automatic gain and automatic frequency feedback loop circuits.

I claim as my invention:

1. In the production of a potential having a frequency which is proportional to the amplitude of an alternating control voltage, the method which includes combining a substantially constant frequency signal with a variable frequency signal to produce a beat frequency signal, stabilizing the amplitude of said beat frequency signal, deriving from said beat frequency signal a first unidirectional potential which is proportional to said beat frequency, deriving a second unidirectional potential which is proportional to the amplitude of said alternating control voltage, and combining said first and second unidirectional potentials in opposed relationship to derive a resultant potential for controlling the frequency of said variable frequency signal.

2. In the production of a potential having a frequency which is proportional to the amplitude of an alternating control voltage, the method which includes combining a substantially constant frequency signal with a variable frequency signal to produce a beat frequency signal, deriving from said beat frequency signal a first unidirectional potential which is proportional to said beat frequency, deriving a second unidirectional potential which is proportional to the amplitude of said alternating control voltage, and combining said first and second unidirectional potentials in opposed relationship to derive a resultant potential for controlling the frequency of said variable frequency signal.

3. In the production of a potential having a frequency which is proportional to the amplitude of an alternating control voltage, the method which includes combining a substantially constant frequency signal with a variable frequency signal to produce a beat frequency signal, comparing a detected component potential of said beat frequency signal with a standard unidirectional potential to derive a potential for regulating the amplitude of said variable frequency signal, deriving from said beat frequency signal a first unidirectional potential which is proportional to said beat frequency, deriving a second unidirectional potential which is proportional to the amplitude of said alternating control voltage, and combining said first and second unidirectional potentials in opposed relationship to derive a resultant potential for controlling the frequency of said variable frequency signal.

4. The combination of means for generating and combining a substantially constant frequency signal and a variable frequency signal to produce a beat frequency signal, means for deriving from said beat frequency signal a first unidirectional potential which is proportional to said beat frequency, means for applying an alternating control voltage, means for deriving a second unidirectional potential which is proportional to the amplitude of said alternating control voltage, and means for combining said first and second unidirectional potentials to derive a resultant potential for controlling the frequency of said variable frequency signal in accordance with the amplitude of said alternating control voltage.

5. The combination of means for generating and combining a substantially constant frequency signal and a variable frequency signal to produce a beat frequency signal, means for applying an alternating control voltage, and means including first and second rectifier elements which are responsive respectively to said alternating control voltage and to said beat frequency signal for controlling the frequency of said beat frequency signal in accordance with the amplitude of said alternating control voltage, a detector responsive to a component of said beat frequency signal, a source of standard voltage, and means for controlling the amplitude of said variable frequency signal in accordance with the resultant of said standard voltage and the output voltage of said detector.

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