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T. T. EATON

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FREQUENCY MULTIPLIER

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Fig. 1.

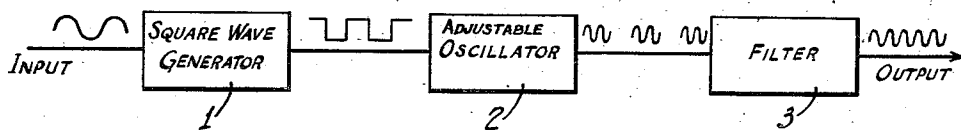


Fig. 2.

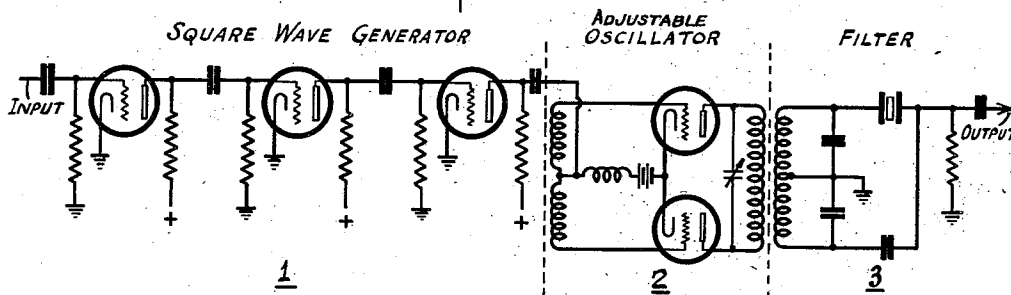


Fig. 3.

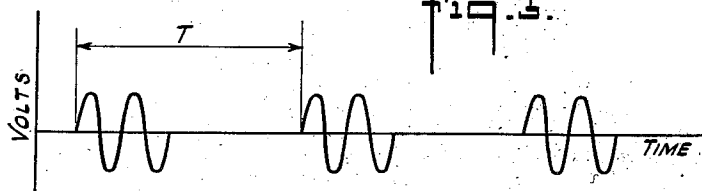
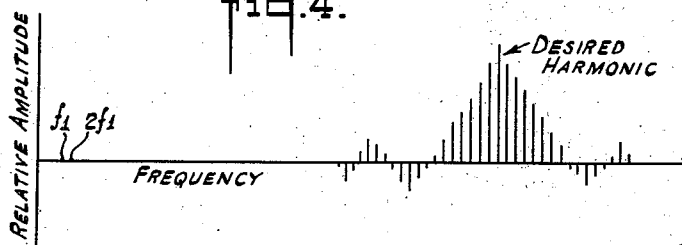


Fig. 4.



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FREQUENCY MULTIPLIER

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5 Claims. (Cl. 250—36)

1 This invention relates to improvements in frequency multipliers.

It is known to produce multiplication of frequencies by the distortion of a sine wave. The harmonics obtained by this known method decrease with increasing frequency. Consequently, frequency multiplications of appreciably greater than five per stage, by the distortion method, are usually not feasible because harmonics higher than this are so weak that it is not practicable to amplify them. Further, the decrement in the anode-circuit of the multiplier tube is also a limitation. If multiplications greater than five-fold are required, according to this known method, it has been customary to use several multiplier stages in cascade.

An object of the present invention is to enable the production of a train of harmonics having a maximum energy content at any desired point in the harmonic frequency spectrum.

Another object is to produce directly in the output of an oscillator a high harmonic frequency whose amplitude is larger than those of the lower or higher harmonic frequencies.

According to the present invention, a wave is produced which has its largest components near the frequency which is desired as a final result. This wave is of recurring nature and is a periodic function of time. The components of the wave are sinusoidal currents of frequencies which are integral multiples of the frequency of the source to be multiplied but the energy of these components is greatest in the region of the frequency adjacent to that of the oscillator producing them.

One embodiment of the invention requires the application of a periodically repeated pulse to an oscillator for starting and stopping the oscillator at regular intervals. This pulse may be of square wave or sine wave form, and serves to produce in the output of the oscillator a cyclically recurring train of waves which contains only frequencies which are multiply related to the period of the pulses. The pulses applied to the oscillator permit the oscillator to oscillate only during the positive peaks. During the negative peaks, the oscillations are extinguished. By using a sharply selective filter in the output of the oscillator it is possible to filter out or derive only the desired multiplied frequency of largest amplitude.

A more detailed description of the invention follows in conjunction with a drawing, wherein:

Fig. 1 shows, by way of example only, one frequency multiplier embodiment of the present invention, the constituent elements of which are illustrated in box form, appropriately labeled;

Fig. 2 shows in more detail the circuits which the elements of Fig. 1 may take;

Fig. 3 shows graphically the output of the os-

2 cillator of Figs. 1 and 2, and illustrates the periodic recurring wave trains; and

Fig. 4 illustrates graphically the relative amplitudes of the important components of the output of the oscillator of Figs. 1 and 2.

The frequency multiplier system of Fig. 1 includes a source of sinusoidal waves of a frequency to be multiplied, labeled "Input," a square wave generator 1 for converting the sinusoidal input wave to a rectangular wave, a high frequency oscillator 2 upon which the square waves are impressed, and a highly selective narrow frequency band filter 3 in the output of the oscillator 2 for passing the desired harmonic which has the maximum energy content. The wave forms of the energy in the connections between the apparatus elements of the system are illustrated in the space immediately above the respective connections.

In the operation of the system of Fig. 1, a relatively low frequency sinusoidal input wave (let us say 5000 cycles per second, by way of example) is impressed on the square wave generator 1, the latter in turn converting the sinusoidal waves to square waves of the same frequency as the input waves. The high frequency oscillator 2 is caused to oscillate only during the positive peaks of the impressed square waves, and the oscillations are extinguished during the negative peaks. If desired, the starting and stopping of the oscillator may be produced by the negative and positive peaks, respectively, of the square wave input, instead of the reverse.

Fig. 3 illustrates the wave trains produced in the output of the oscillator. The only frequencies present in these wave trains are integral multiples of the fundamental frequency corresponding to input frequency. This can be proved by a Fourier analysis of the wave train. The relative amplitudes of the component frequencies are shown in Fig. 4. It should be noticed that the amplitude of the components with frequencies f_1 and $2f_1$ are very small, whereas the amplitudes for the higher harmonic components are very large. These higher harmonic components may be, for example, 100 to 200 times the fundamental frequency. The largest components, i. e., those having the maximum energy content, appear near the frequency which it is desired to select. Thus, if the oscillator 2 produces oscillations at a frequency of 500 to 1000 kilocycles ($\frac{1}{2}$ to 1 megacycle), the harmonic output of the system (that is, the frequency multiplication) is 100 to 200 times the input frequency at a very large amplitude, in the region of the desired harmonic.

The filter 3, preferably a narrow band crystal filter, selects the particular high amplitude harmonic which it is desired to utilize.

Suitable different harmonics of maximum am-

plitude can be selected by returning the filter 3, and if the new frequency is much different from the old, then the oscillator 2 must also be retuned. For this reason, it is preferred that the oscillator 2 be capable of being adjustable to different frequencies of oscillation. Thus, for a simple crystal filter several hundred fold multiplication of the original frequency can be obtained, depending upon the narrowness of the filter.

The ratio of the maximum amplitude harmonic to the amplitude of oscillation is equal to the duty cycle, or the percentage of time the oscillator is turned on. For other than a square wave pulse, the above ratio is somewhat less but still of the same order of magnitude.

Fig. 2 illustrates one form which the system of Fig. 1 may take. The square wave generator 1 is here shown as comprising three vacuum tube amplifier stages working at saturation. The output of the multistage amplifier reaches a saturation value which it holds throughout the major portion of each half cycle of input. Three stages can usually be arranged to convert a sine wave into a square wave, although more or fewer stages may be used depending upon how good the square wave must be.

Although one embodiment of the invention has been described as using a square wave generator to pulse the oscillator, it should be understood that the square wave is not essential since, if desired, a sine wave can be used for the same purpose, in which case the square wave generator can be eliminated and the oscillator controlled directly by the sine wave input.

The invention is particularly useful where it is desired to generate harmonics of a master frequency and wherein the energy is concentrated in a relatively narrow group of harmonics whose position in the scale of harmonics may be adjusted. Thus, the frequency multiplier of the invention may be used as a signal generator.

What is claimed is:

1. A signal generator system comprising a source of fundamental frequency, a square wave generator for converting said fundamental frequency to a square wave form having the same period as said fundamental frequency, an adjustable oscillator capable of producing harmonic frequencies near the desired harmonic frequency of said fundamental for utilization in the output of said system and of amplitude larger than those of lower and higher frequencies, and means for causing said oscillator to start and stop including a circuit for applying square waves from the output of said square wave generator to an element of said oscillator of such polarity and magnitude as to cause said oscillator to produce oscillations only during at most one-half the cycle of the applied square waves, whereby the output of said oscillator contains a desired frequency of large amplitude near the frequency of said oscillator, and a highly selective filter coupled to the output of said oscillator for passing substantially only said desired harmonic frequency.

2. A frequency multiplier comprising a source of sinusoidal waves of the frequency to be multiplied, a square wave generator for converting said sinusoidal waves to square waves of the same period, an oscillator so adjusted that when constrained to oscillate it generates a frequency which is near the desired harmonic frequency of

the sinusoidal wave frequency and of an amplitude larger than those of the lower and higher frequencies, and means for causing said oscillator to start and stop including a circuit for applying to said oscillator square waves from the output of said square wave generator of such polarity and magnitude as to overcome the bias on said oscillator and cause said oscillator to produce oscillations only during at most one-half the cycle of the applied square waves, whereby the output of said oscillator contains harmonic frequencies of large amplitude near the frequency of said oscillator, and a highly selective filter coupled to the output of said oscillator for passing substantially only one harmonic frequency of large amplitude.

3. A frequency multiplier comprising a source of waves of a constant frequency to be multiplied, an oscillator so adjusted that when constrained to oscillate it generates oscillations of a frequency which is near the desired harmonic frequency of the source and of amplitude larger than those of the lower and higher frequencies, means for causing said oscillator to start and stop including a circuit for applying the waves of said source to said oscillator of such polarity and magnitude as to overcome the bias on said oscillator and cause said oscillator to produce a periodically recurring complex wave having harmonics of large amplitude compared to the frequency to be multiplied, and a narrow band-pass crystal filter for passing the desired large amplitude harmonic.

4. A frequency multiplier comprising a source of audio frequency waves of the frequency to be multiplied, an oscillator having tuning means to adjust it to produce a frequency which is near the desired harmonic frequency of said audio frequency waves when said oscillator is constrained to produce oscillations and of an amplitude larger than those of the lower and higher frequencies, means for causing said oscillator to start and stop including a circuit for apply waves representative of said source to said oscillator and of such polarity and magnitude as to cause the operation thereof at the period of said source, whereby said oscillator produces a periodically recurring complex wave having harmonics of large amplitude compared to the frequency to be multiplied, and a narrow band-pass filter for passing substantially only the desired large amplitude harmonic.

5. A harmonic generator system comprising a source of audio frequency waves of a constant fundamental frequency, an adjustable radio frequency oscillator having a maximum energy content in a harmonic frequency region near the desired frequency of output of said system, means for causing said oscillator to start and stop, including a circuit for applying waves representative of said source to an element of said oscillator of such polarity and magnitude as to cause said oscillator to operate at the period of said source, whereby the oscillator produces a periodically recurring complex wave having harmonics of large amplitude compared to that of the frequency of said source, and a highly selective filter coupled to the output of said oscillator for passing substantially only the desired large amplitude harmonic frequency which is a harmonic of the frequency of said source of audio waves.

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