

March 14, 1939.

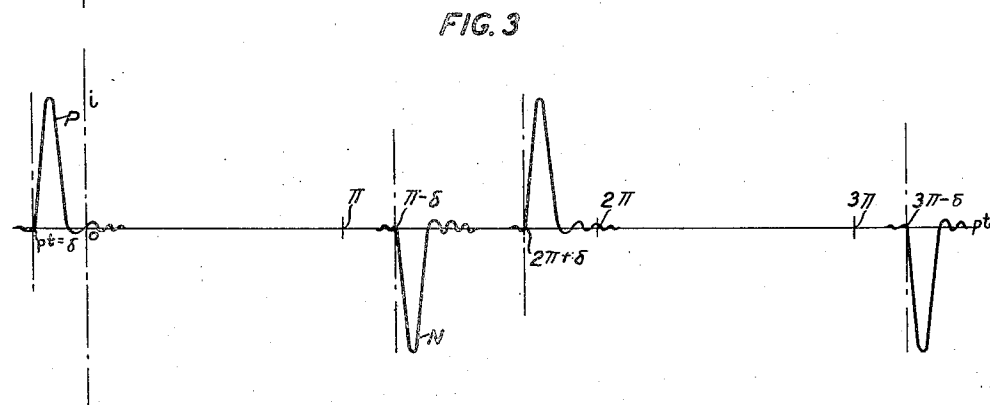
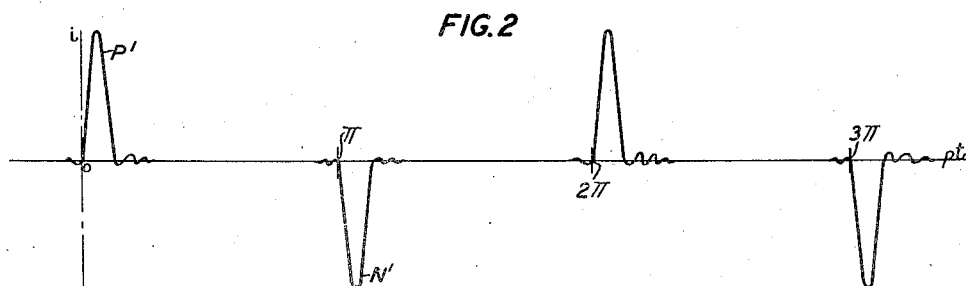
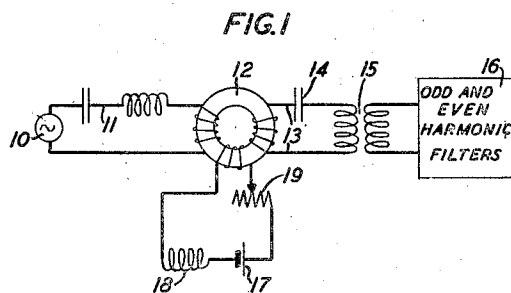
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2,150,386

HARMONIC PRODUCER

Filed Sept. 30, 1937

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FIG. 5

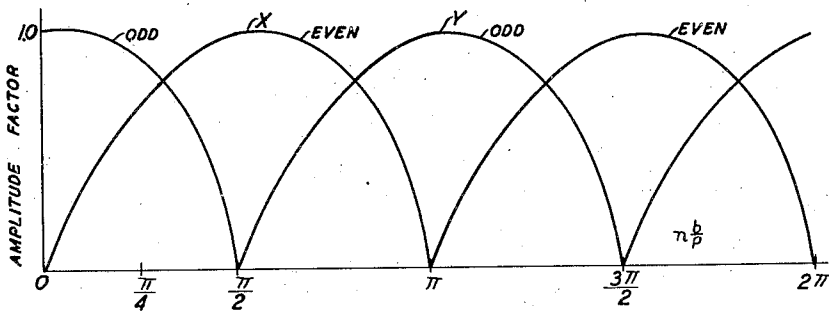
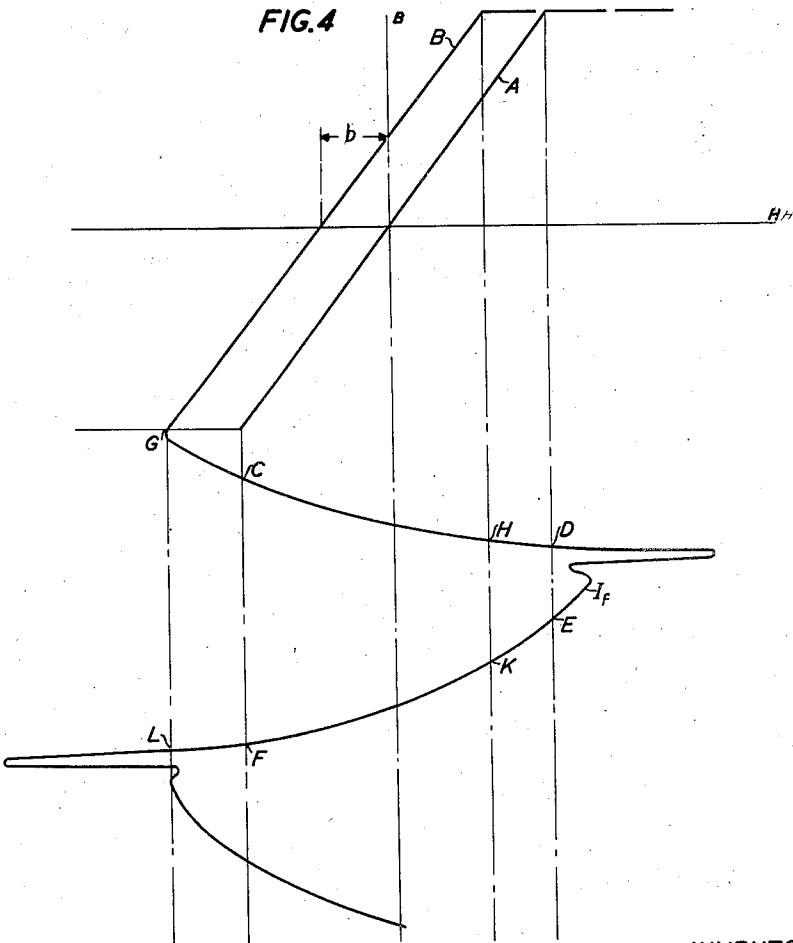


FIG. 4



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HARMONIC PRODUCER

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Application September 30, 1937, Serial No. 166,519

7 Claims. (Cl. 172-281)

This invention relates to harmonic generators and more particularly to harmonic generators of the magnetic type utilizing a direct current bias to produce both odd and even harmonics and to

accentuate a preselected harmonic. In the copending application of L. R. Wrathall, Serial No. 77,989, filed May 5, 1936, and assigned to applicant's assignee, a system utilizing a saturable-core coil is described for producing a series of relatively sharp pulses having a uniform time spacing therebetween and whereby a range of odd harmonics is produced. The present invention contemplates the provisions of applying a direct current bias to the saturable-core coil to shift each of the pulses by a predetermined amount depending on the magnitude of the bias. This shift of the pulses provides a wave form such that both odd and even harmonics are produced in the output circuit. Also, the bias may be so proportioned that the amplitude of an even harmonic is produced with a maximum value while the amplitudes of the odd harmonics lying adjacent thereto are suppressed or that the amplitude of an odd harmonic is produced with a maximum value while the amplitude of the even harmonics lying adjacent thereto are suppressed. A harmonic having a maximum amplitude relative to the suppressed amplitudes of adjacent harmonics is useful in certain systems for synchronizing purposes, particularly in systems where the synchronizing harmonic is changed from time to time over a range of odd and even harmonics.

It is an object of this invention to simultaneously produce odd and even harmonics.

It is another object of this invention to accentuate the amplitude of a preselected harmonic while at the same time suppressing the amplitudes of the harmonics lying adjacent thereto.

It is a further object of this invention to produce a certain range of both odd and even harmonics having uniformly large amplitudes.

The invention will be more readily understood from the following description taken together with the accompanying drawings in which:

Fig. 1 is a diagrammatic circuit illustrating the preferred form of the invention;

Fig. 2 shows a wave form resulting from the operation of Fig. 1 without bias; and

Figs. 3, 4 and 5 illustrate the operation of Fig. 1 with bias in accordance with the invention.

Referring to Fig. 1, an alternating current source 10 applies a fundamental wave through a tuned circuit 11 to the primary of a saturable-core coil 12. A secondary or output circuit 13

for the coil comprises a condenser 14, coupling transformer 15 and a group 16 of odd and even harmonic-selective filters. As described in the aforementioned copending application of L. R. Wrathall the constants of the output circuit are so proportioned as to produce a series of alternating pulses, each of brief duration and representing the discharge of condenser 14 through a substantially resistive output circuit. These pulses illustrated in Fig. 2 have a uniform time spacing therebetween and occur periodically with the period of the fundamental wave to produce in the output circuit a group of odd harmonics having uniformly large amplitudes. Curve A in Fig. 4 shows the magnetization characteristic of the saturable-core of the coil 12 as the fundamental current I_1 is impressed thereon to effect the wave form illustrated in Fig. 2. In curve A of Fig. 4, it is seen that the inductance of the coil 12 is a maximum for the positive half-cycle between the points C and D, and again a maximum for the negative half-cycle between the points E and F.

In the present invention a source 17 of direct current is applied to the saturable-core coil through a choke coil 18 and an adjustable resistance 19. This direct current bias serves to shift the magnetization characteristic of the saturable-core coil shown by curve A of Fig. 4 to that illustrated by curve B of Fig. 4 by an amount b that depends on the magnitude of the direct current voltage.

The wave shape shown in Fig. 3 and resulting from the magnetization characteristic curve B produces in the output circuit both odd and even harmonics whose range is substantially the same as that produced by the wave shown in Fig. 2. The amount of the pulse shift in pt can be readily determined from the following equation:

$$\delta = -\frac{b}{P}$$

where

$$\frac{b}{P} < \frac{1}{6}$$

δ is the pulse shift, b is the magnetization force of the direct current bias and P is the amplitude of the magnetization force of the wave I_1 . The equation is approximately correct if

$$\frac{b}{P} > \frac{1}{6}$$

It is to be understood that the relative heights of the peaks of the pulses illustrated in both Figs.

2 and 3 are substantially identical. This is true since the shape of the pulse is determined by the constants of the saturable-core coil and output circuits in Fig. 1 and these are unchanged for the waves shown in Figs. 2, 3 and 4.

Referring to curve B of Fig. 4, the inductance of the saturable-core coil is a maximum for the positive half-cycle of the fundamental current I_1 between the points G and H and again a maximum for the negative half-cycle between the points K and L. Thus in curve B the saturable-core coil attains minimum inductance in a positive direction sooner than in curve A and in a negative direction later than in curve A. In other words, according to curve B the condenser discharges in a positive direction sooner than in curve A and in a negative direction later than in curve A. Consequently, the positive pulse P of Fig. 3 occurs sooner than the corresponding pulse P' of Fig. 2 and the negative pulse N of Fig. 3 occurs later than the corresponding pulse N' of Fig. 2.

The direct current bias b may be proportioned to suppress or accentuate a particular odd or even harmonic of the fundamental alternating current wave I_1 as desired. That is, a particular odd harmonic is produced with maximum amplitude while the even harmonics lying adjacent thereto are suppressed or a particular even harmonic is produced with maximum amplitude while the odd harmonics lying adjacent thereto are suppressed. The amount of direct current bias b required to produce a preselected harmonic with maximum amplitude can be readily calculated from the following equations:

$$(a) \quad n \frac{b}{P} = \frac{\pi}{2} \quad (b) \quad n \frac{b}{P} = \pi$$

where

$$\frac{b}{P} < \frac{1}{6}$$

b is the magnetizing force due to the biasing voltage, P is the amplitude of the magnetizing force of the wave I_1 and n in Equation a is a particular even harmonic while n in Equation b is a particular odd harmonic. If

$$\frac{b}{P} > \frac{1}{6}$$

the above equations are approximately correct.

In Fig. 5 it is seen that when an even harmonic, say, for example, harmonic X has a maximum amplitude, the two odd harmonics lying adjacent thereto are suppressed and that when an odd harmonic, say, for example, harmonic Y has a maximum amplitude, the even harmonics lying adjacent thereto are suppressed. It is understood that the distribution of harmonics shown in Fig. 5 is an amplitude factor to be applied to the distribution of harmonics obtained by the wave shape of Fig. 2, which is produced in accordance with the copending application of L. R. Wrathall, supra. Thus the factor, whose maximum value is 1.0, must be multiplied by the harmonic amplitudes obtained in Wrathall's harmonic distribution in order to ascertain the actual value of the amplitudes.

In Fig. 5 it is also seen that for a limited range in the vicinity of the intersections of the odd and even factors, the amplitudes of both odd and even harmonics will be relatively large and substantially uniform, depending in an inverse manner on the width of the range of harmonics.

Having ascertained the amplitude of an attenuated harmonic in the manner indicated above,

the extent of the suppression of the adjacent harmonics can be determined as follows:

If the amplitude of an even harmonic n_0 is produced with maximum value, then the ratio of the amplitude of the odd harmonics $n_0 \pm 1$ to the even harmonic n_0 is

$$\frac{I_{n_0 \pm 1}}{I_{n_0}} = \frac{\pi}{2n_0}, \text{ if } \frac{\pi}{2n_0} \ll 1$$

If, for example, the twenty-fourth harmonic of the fundamental wave I_1 is produced with maximum value, the amplitudes of the twenty-third and twenty-fifth harmonics are suppressed 23.7 decibels relative to the amplitude of the twenty-fourth harmonic.

If the amplitude of an odd harmonic n_0 is produced with maximum value, then the ratio of the amplitudes of the even harmonics $n_0 \pm 1$ to the odd harmonic n_0 is

$$\frac{I_{n_0 \pm 1}}{I_{n_0}} = \frac{\pi}{n_0}, \text{ if } \frac{\pi}{n_0} \ll 1$$

If, for example, the thirty-fifth harmonic of the fundamental wave I_1 is produced with maximum value, the amplitudes of the thirty-fourth and thirty-sixth are suppressed 21.0 decibels relative to the amplitude of the thirty-fifth harmonic.

What is claimed is:

1. In a harmonic producer including a source of alternating current waves of fundamental frequency, a saturable-core coil connected to said alternating current source, and an output circuit for said coil having a condenser and a substantially resistive load proportioned to produce therein a series of relatively sharp pulses of current occurring in a predetermined time relation; means comprising a direct current source for biasing said saturable-core coil to change the time relation of the occurrence of said pulses of current such that successive pulses are shifted the same amount of time.

2. In a harmonic producer including a saturable-core coil, a source for applying an alternating current wave of fundamental frequency thereto and an output circuit therefor, said output circuit including a condenser and a substantially resistive load proportioned to produce therein a series of relatively sharp positive and negative pulses occurring in a certain time relation; means comprising a direct current source for biasing said coil to vary the time relation of the occurrence of said pulses so that the positive and negative pulses are respectively advanced and delayed in predetermined equal amounts of time.

3. In a harmonic producer including a source of alternating current waves of fundamental frequency, a saturable-core inductance connected to said alternating current source, and an output circuit for said inductance and having a condenser and a substantially resistive load connected therein and proportioned to provide in the inductance a magnetization characteristic such that successive pulses of current have equal time spacings therebetween; and means comprising a unidirectional current source for biasing the inductance to shift the magnetization characteristic in a manner such that the successive pulses of current have unequal time spacings therebetween.

4. In a harmonic producer comprising a saturable-core inductance, a source for impressing thereon an alternating current wave of fundamental frequency and an output circuit for the inductance, said output circuit including a condenser and a highly resistive load proportioned to

5 produce therein a broad range of odd harmonic
frequency currents having uniformly large am-
plitudes; means connected to the inductance and
including a source of unidirectional current for
10 producing a predetermined range of both odd and
even harmonics, the current applied to the inductance
from said source of unidirectional current
being proportioned so that the amplitude of a
preselected harmonic is produced with a max-
imum value relative to the amplitudes of adjacent
harmonics in the produced range of harmonics.

5 5. In a harmonic producer including a satu-
rable-core inductance, a source for impressing
thereon an alternating current wave of funda-
mental frequency and an output circuit for the
15 inductance, said output circuit including a con-
denser and a highly resistive load proportioned
to produce therein a broad range of odd harmonic
frequency currents of uniformly large amplitudes;
20 means connected to the inductance and including
a source of unidirectional current for biasing the
inductance to produce odd and even harmonics
of a range substantially equal to the range of
odd harmonics, the current applied to the in-
25 ductance from said source of unidirectional cur-
rent being so proportioned that the amplitude of
a preselected odd harmonic is produced with a

predetermined maximum value while the ampli-
tudes of the even harmonics adjacent thereto are
suppressed.

6. In the harmonic producer according to claim
5 in which the unidirectional current is so pro-
portioned that the amplitude of a preselected
even harmonic is produced with a predetermined
maximum value while the amplitudes of the odd
harmonics lying adjacent thereto are suppressed.

7. In a harmonic producer comprising a satu-
10 rable-core inductance, a source for impressing
thereon an alternating current wave of funda-
mental frequency and an output circuit for said
inductance, said output circuit including a con-
denser and a highly resistive load proportioned
15 to produce therein a broad range of odd harmonic
frequency current having uniformly large ampli-
tudes; means connected to the inductance and
including a source of unidirectional current for
producing a predetermined range of both odd and
20 even harmonics, the current applied to the in-
ductance from said source of unidirectional cur-
rent being proportioned so that a preselected
group of both odd and even harmonics is pro-
duced with substantially uniform amplitudes. 25

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