Sept. 14, 1954 H. J. BROWN 2,689,280

APERIODIC VIBRATOR

Filed June 29, 1951 2 Sheets-Sheet 1

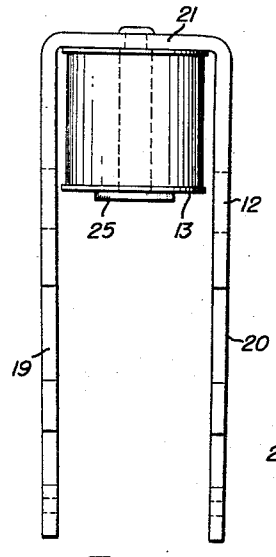


Fig. 1

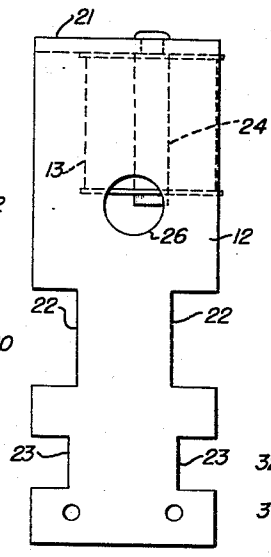


Fig. 2

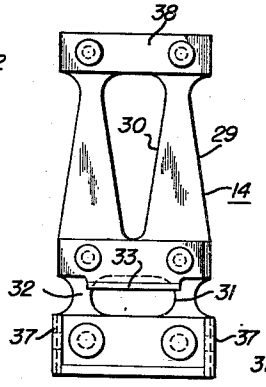


Fig. 3

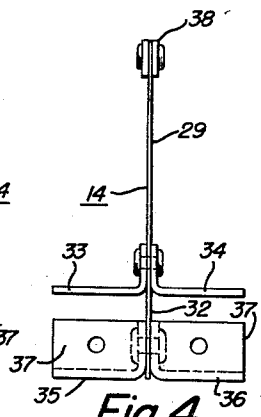


Fig. 4

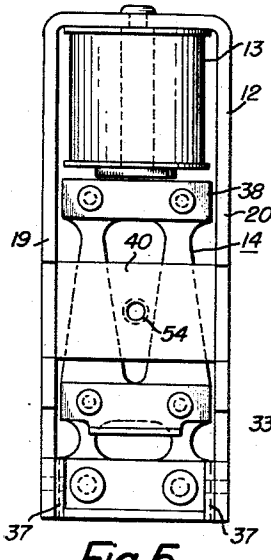


Fig. 5

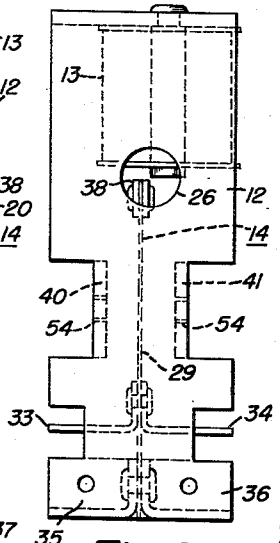


Fig. 6

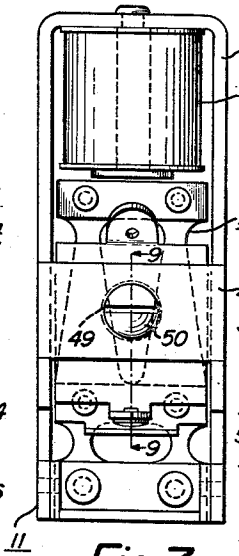


Fig. 7

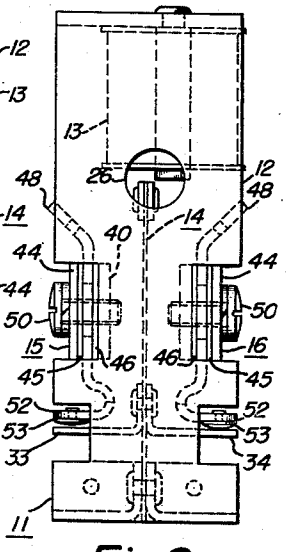


Fig. 8

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Sept. 14, 1954 H. J. BROWN 2,689,280

APERIODIC VIBRATOR

Filed June 29, 1951 2 Sheets-Sheet 2

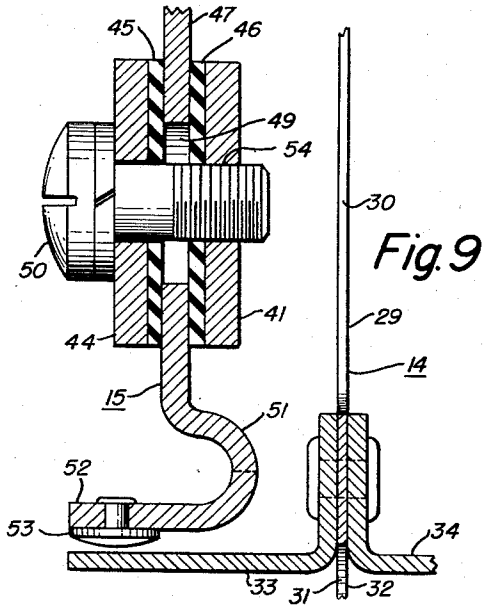


Fig. 9

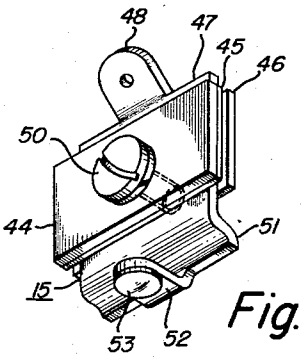


Fig. 10

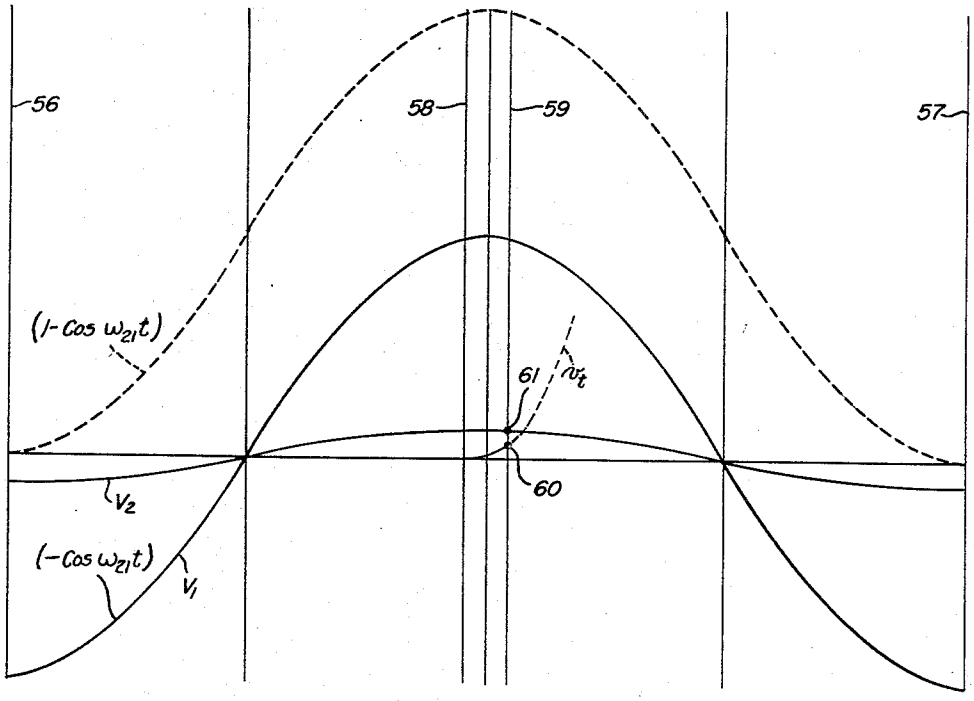


Fig. 11

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UNITED STATES PATENT OFFICE

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APERIODIC VIBRATOR

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Application June 29, 1951, Serial No. 234,387

10 Claims. (Cl. 200—90)

1

The invention relates in general to vibrating reed structures and in particular to the well-known electromechanical vibrator which has a vibrating reed carrying movable contacts wherein provision is made to prevent any appreciable secondary vibration in the movable contacts to thus gain the term "aperiodic vibrator."

In general, in the prior art structures, the vibrating reed drives movable contacts to cooperate with fixed contacts and the fundamental frequency of the vibrating reed is generally lower than the resonant frequency of the movable contacts. This is principally because the length of the movable contact arm is less than the length of the vibrating reed for a given mass and compliance. In the past, attempts have been made to utilize the higher resonant frequency of the movable contact arms by establishing this frequency at a third or fifth harmonic. Normally, the interval during which the contacts are open is small compared to the displacement or excursion of the weighted end of the vibrating reed. It has been found that as the contacts separate, the movable contacts are accelerated by a transient acceleration which is imparted to the movable contact by reason of its being connected to the vibrating reed. The greater the spacing between the contacts, the more the contacts have a chance to accelerate before they again reclose and hence again stop movement. In the prior art vibrators, the spacing in the contacts was sufficiently great that the transient velocity could become much larger than the average velocity, wherein this average velocity is that which is obtained by the fact that it is driven from the vibrating reed.

Accordingly, it is an object of the invention to provide a vibrator structure wherein a minimum of energy is transferred to the movable contacts from the vibrating reed so that there may be a chatter-free or bounce-free closure of the contacts.

Another object of the invention is to provide a vibrator structure wherein the contact spacing is kept to a minimum and wherein the structure provides the necessary rigidity to maintain this close spacing.

Another object of the invention is to provide a rigid vibrator structure to permit a close spacing of the contacts wherein this spacing is less than the displacement of the reed divided by $50a$, wherein "a" is the ratio of the length of the reed to the length of the movable contact arms.

Still another object of the invention is to provide a U-shaped frame for a vibrator with a reed

2

disposed parallel to and vibrating into and out of the plane of the U-shaped frame such that a weighted permeable end on the vibrating reed always maintains a close spacing with the legs of the frame to maintain a magnetic circuit of high efficiency.

Still another object of the invention is to provide a vibrator structure which may be assembled easily, is rigid after being assembled, and wherein the parts are assembled in a consecutive order to permit adjustment of these parts at the time of assembly rather than having to resort to final adjustment by bending the various parts after assembly.

Still another object of the invention is to provide a method for assembling a vibrator structure wherein a reed sub-assembly is placed in and frictionally held in a U-shaped frame so that this subassembly may be precisely positioned and then dipped in solder to fasten it in place, and further wherein the fixed contact arms may be next fastened to the legs of the U-shaped frame and adjusted for spacing and parallelism with the movable contact arms on the reed sub-assembly.

Other objects and a fuller understanding of my invention may be had by referring to the following description and claims, taken in conjunction with the accompanying drawing, in which:

Figure 1 is a front view of the U-shaped frame and coil mounted in the closed end;

Figure 2 is a side view of the frame of Figure 1;

Figure 3 is a front view of a reed sub-assembly;

Figure 4 is a side view of the sub-assembly of Figure 3;

Figure 5 is a front view combining Figures 1 and 3 and including fixed contact mounting blocks;

Figure 6 is a side view of the assembly of Figure 5;

Figure 7 is a front view of the completely assembled vibrator;

Figure 8 is a side view of Figure 7;

Figure 9 is an enlarged partial view taken on line 9—9 of Figure 7, showing the movable contact on the reed in cooperation with the fixed contact;

Figure 10 is an isometric view of the fixed contact sub-assembly; and

Figure 11 is a graph showing the velocities of the reed and movable contact through one cycle of operation.

The complete vibrator 11 is shown in Figures

7 and 8 and includes generally a U-shaped frame 12, a driver coil 13, a reed sub-assembly 14 and first and second fixed contact sub-assemblies 15 and 16, respectively. The Figures 1 to 6 show various stages in the assembly of the complete vibrator 11. Hence, these may be referred to for better understanding of the components of the various sub-assemblies. The Figures 1 and 2 show the U-shaped frame 12 which has first and second legs 19 and 20, respectively, and a closed end 21. The Figure 2 shows that this frame has first notches 22 and second notches 23. The driver coil 13 has a permeable core 24 which is used to fasten this coil to the closed end 21 and further has an elongated rectangular head 25. The frame 12 additionally has a hole 26 adjacent the head 25.

The Figures 3 and 4 show the reed sub-assembly 14 which includes generally the flexible vibrating reed 29 having first and second apertures 30 and 31. The first aperture 30 adds flexibility to the reed to make it limber and the aperture 31 creates an effective hinge portion 32. First and second movable contact arms 33 and 34 are fastened to the reed 29 just above the hing portion 32 by any suitable means such as riveting. These contact arms extend out substantially perpendicular to the plane of the reed 29. The movable contact arms 33 and 34 are provided with a silver overlay on the upper side thereof near the tips to act as the actual contact material.

The lower end of the reed 29 is fastened to first and second bracket arms 35 and 36 by any suitable means, such as riveting. These bracket arms have upturned legs 37 which are disposed substantially parallel in planes which are perpendicular to the plane of the reed 29. The reed 29 also has at the upper end thereof a mass or weight 38 which is permeable and which is attached to the reed by any suitable means, such as riveting.

The Figures 5 and 6 show the reed sub-assembly 14 in place in the frame 12 and this frame is shown as having contact blocks 40 and 41 at the notches 22. It will be observed that both contact blocks bridge from one leg to the other and are fastened to these legs by any suitable means, such as soldering or brazing, or may even be press-fitted into place. The notches 22 thus provide shoulders or abutment means to establish these contact blocks 40 and 41 in a fixed position.

In the Figures 5 and 6, it will be seen that the reed sub-assembly 14 has been positioned in the U-shaped frame with the upturned legs 37 in contact with the inside of the open end of the legs 19 and 20 of the frame 12. These legs 37 give a large bearing surface between the reed sub-assembly 14 and the frame 12 so that this sub-assembly may be accurately positioned and fastened to the frame such as by soldering. The Figures 5 and 6 further show that the mass or weight 38 is positioned closely to the head 25 of the core 24. The hole 26 permits one to observe the off-center position of the mass 38 relative to the head 25.

The Figure 10 is an isometric view of one of the fixed contact subassemblies 15 or 16 and these sub-assemblies are identical. Figure 9 also shows the details of this sub-assembly. This sub-assembly includes a washer block 44, first and second insulator blocks 45 and 46 with a contact arm 47 sandwiched between these insulator blocks. The contact arm 47 has a terminal ear 48 to provide external electric connection to the vibrator. The contact arm further has an enlarged hole 49 through which a mounting screw 50 may pass. This mounting screw passes through apertures in the washer block 44 and the two insulator blocks 45 and 46 and because of the insulator blocks and the enlarged hole 49, the contact arm 47 is electrically insulated from the remainder of the fixed contact sub-assembly 15.

The contact arm 47 has a C-shaped portion 51 just below the insulator blocks 45 and 46 and then a narrow contact foot 52 extends from this C-shaped portion 51. The contact foot 52 is disposed at right angles to the plane of the insulator blocks 45 and 46 and this contact foot carries an electrical contact 53 preferably of a platinum alloy.

The Figures 7 and 8 show the completely assembled vibrator with the fixed contact sub-assemblies 15 and 16 mounted on the contact blocks 40 and 41 so that the electrical contacts 53 cooperate with the movable contact arms 33 and 34. The contact blocks 40 and 41 have a threaded aperture 54 to receive the mounting screw 50 and thus provide means to fasten the fixed contact sub-assemblies to the frame 12.

The complete vibrator shown in Figures 7 and 8 is a rigid structure which permits the contact spacing to be maintained throughout the life of the vibrator even though it is subjected to rough usage and handling. This is effected because the fixed and movable contacts are firmly built and held in the frame and because the frame itself is a rigid structure. Further the complete vibrator 11 permits the parts of the vibrator to be consecutively assembled wherein a part is adjusted and firmly fastened before the next part is brought into the assembly. This permits a much more rugged structure since the parts are not first assembled and then adjusted by bending, rather they are adjusted as they are assembled. The method of assembly of the complete vibrator starts with the U-shaped frame 12 and then the driver coil 13 is added at the closed end 21 thereof. The core 24 is placed through a hole in the closed end 21 and riveted over to fasten this coil 13 to the frame 12. It will be noted that the coil 13 is off-center in Figure 2 and further it will be noted that the rectangular head 25 has the length thereof extending between the legs 19 and 20.

The reed sub-assembly is fabricated in a more or less conventional manner by riveting on the weight 38, the movable contact arms 33 and 34, and the bracket arms 35 and 36. Next, this reed sub-assembly 14 is placed in the frame 12 with the upturned legs 37 in frictional engagement with the ends of the legs 19 and 20 of the frame 12. The Figure 1 shows these legs initially bent slightly inwardly and thus the natural resiliency of these legs 19 and 20 will temporarily hold the reed sub-assembly 14 in any desired position. The reed sub-assembly is next adjusted longitudinally as seen in Figure 5 for close spacing with the head 25 and is adjusted laterally as seen in Figure 6 through the hole 26 to place the weight 38 just off to one side of the head 25. After this precise positioning, the open end of the frame 12 may be dipped in molten solder to permanently fasten the reed sub-assembly 14 into the frame 12. By this method of assembly, there is thus no danger of moving the reed sub-assembly 14 relative to the frame 12 after the precise positioning, such as might occur

if this reed sub-assembly were to be riveted to the frame 12.

The contact blocks 40 and 41 are next firmly fastened to the frame 12 by press-fitting them in place or by brazing and these contact blocks 40 and 41 thus provide a firm foundation for the fixed contact sub-assemblies 15 and 16.

Alternatively, the contact blocks 40 and 41 could be fastened to the frame 12 and then the reed sub-assembly 14 could be adjustably positioned and soldered in position in the frame 12.

Next, the fixed contact sub-assemblies 15 and 16 are fastened to the contact blocks 40 and 41 by the mounting screws 50. The screws 50 would be turned not quite tight so that the contact arms 47 may be longitudinally adjusted to provide the correct and close spacing relative to the movable contact arms 33 and 34. Such spacing may be observed through the notches 23. Upon achieving the correct adjustment, the screws 50 would be tightened.

The contact feet 52 may in some cases need to be bent slightly to obtain parallelism between these feet and the movable contact arms 33 and 34. Since these feet are quite narrow relative to the main body portion of the contact arms 47, it will be seen that any bending will occur at the heel of these feet rather than up in the main portion of the contact arms 47. This provides that any slight bending will only affect the parallelism and will not change the original distance between the electrical contacts 53 and the reed 29.

The fact that the contact blocks 40 and 41 bridge the legs 19 and 20 provides a rigid frame structure for the vibrator 11 which will not be bent out of shape by any rough handling and further any such rough handling will not affect the spacing between the elyectrical contacts 53 and the movable contact arms 33 and 34. Further, the large cooperating surface areas between the upturned legs 37 and the frame legs 19 and 20 permit a good soldering bond to be established therebetween so that the reed sub-assembly 14 cannot move relative to the frame 12. All this provides a structure which is very rigid, which will not change its dimensions during its useful life, and wherein the critical dimensions are consecutively established and locked in place before the next component of the vibrator is placed in the assembly.

The U-shaped frame 12 provides a magnetic circuit of high efficiency since the weight 38 extends into close proximity to the legs 19 and 20 and because the reed 29 is in a plane parallel to the plane which passes through both legs 19 and 20. This means that the excursion or displacement of the weight 38 is not limited by the physical spacing between the legs 19 and 20 which would be the case if the reed 29 were disposed at right angles to the position shown in the drawing. Further, the ends of the weight 38 are in close proximity to the legs 19 and 20 so that the flux lines go down through the core 24, through the head 25, jump the small air gap to the mass 38 and again jump the small air gaps from the mass 38 to the legs 19 and 20 to return to the core 24. It is therefore seen that the flux lines do not need to pass through the length of the vibrating reed 29.

To better understand the novel results obtained, the following mathematical analysis is offered as a theory of operation. Consider a mass M_2 which includes the contact arms 33 and 34 and the lower reed.

This mass is restrained by the very flexible hinge portion 32 and the inertia of the weight M_1, which is principally the weight 38. Further, consider this mass M_2 to rotate around an effective pivot, and hence, the frequency of vibration of this mass is

$$f_2=\frac{l}{2\pi\sqrt{M_2C_2}}$$

where

M_2=effective mass of movable contacts 33 and 34,

C_2=compliance of movable contacts 33 and 34.

Also,

$$f_1=\frac{l}{2\pi\sqrt{M_1C_1}}=\text{frequency of reed 29}$$

where

M_1=effective mass of reed 29 and mass 38,

C_1=compliance of reed 29 and mass 38.

Also,

$$f_{21}=\frac{l}{2\pi\sqrt{M_2C_1/a^2}} \quad (1)$$

where a=ratio of l_1/l_2, l_1 being the length of the reed 29, and l_2 being the length of the contact arms 33 and 34. f_{21} is the frequency at which the undesired or parasitic mass M_2 will vibrate if the contacts are open, and f_2 is the frequency at which it will vibrate if the contacts are closed. In the frequencies f_1 and f_2, the length ratio "a" will vanish. Since $\omega=2\pi f$, one gets from Equation 1:

$$\omega_{21}^2=\frac{a^2}{M_2C_1} \quad (2)$$

For the sake of simplicity, assume "a" equals 1, which will be reinserted at the end of the analysis to determine actual dimensions.

When the vibrator contacts separate at the end of a contacting interval, the velocity of the mass M_2 due to the fundamental mode of vibration is:

$$V_2=P_2\omega_1C_2 \quad (3)$$

where

$\omega_1=2\pi f_1$, and

P_2=maximum contact pressure reaction due to f_1.

Since the principal weight M_1 moves many times faster than the contact and its equivalent associated mass, the velocity of this contact portion of the vibrator will increase according to the relationship:

$$v_t=V_1(1-\cos\omega_{21}t) \quad (4)$$

where V_1 is the velocity of the mass M_1, and where v_t is the transient velocity of the contacts.

The cosine function may be expanded, and if only small angles are involved,

$$\cos\omega_{21}t=1-\frac{(\omega_{21}t)^2}{2!}$$

Therefore,

$$1-\cos\omega_{21}t=\frac{(\omega_{21}t)^2}{2}$$

Hence:

$$v_t=\tfrac{1}{2}V_1(\omega_{21}t)^2 \quad (5)$$

since $\omega_{21}t$ is small in the present vibrator.

We will assume that when the velocity v_t is smaller than V_2, the effects of the transient vibration will be damped out.

Referring to the graph of Figure 11, V_1 and V_2

are plotted for one cycle, with V_1 having a maximum amplitude about 10 times as great as the maximum amplitude of V_2, the velocity of the contacts **33** and **34**, which is the desired condition, since one wants the energy primarily in the reed **29**. Lines **56** and **57** represent the beginning and end of one period of vibration. Lines **58** and **59** represents the beginning and end of the open contact interval of the period. In this open contact interval, v_t is plotted, since the transient velocity commences at this point **58**. It will be seen that v_t gets to a maximum at a point **60**, and the rest of this curve is shown dotted indicating the path thereof if this transient velocity were permitted to continue to build up. Point **61** shows the instantaneous velocity of V_2 when the contacts reclose. To make sure that the transient v_t does not affect the velocity V_2 appreciably, so that there is no perceptible change in V_1, we will choose v_t at point **60** to be only one-half V_2 at point **61**. This one-half value will be used to make a determination of the required order of magnitude.

By substituting Equation 2 into Equation 5:

$$v_t=\frac{V_1t^2}{2M_2C_1} \tag{6}$$

This equation gives the transient component of velocity in terms of the velocity of the main weight and the mass of the lower portion of the vibrator and the reed compliance. It varies as the square of the time.

The velocity v_t which is a function of time may be then equated to the constant component due to the fundamental frequency f_1.

$$\frac{V_1t^2}{2M_2C_1}=\tfrac{1}{2}P_2\omega_1C_2 \tag{7}$$

since the maximum transient velocity v_t is assumed to be one-half the average velocity V_2.

Since

$$V_1 \text{ equals } S_1\omega_1 \tag{8}$$

where S_1 equals displacement or excursion of weight M_1 of the reed,

$$\frac{S_1\omega_1t^2}{2M_2C_1}=\frac{\tfrac{1}{2}S_1\omega_1C_2}{C_1} \tag{9}$$

The contact pressure P_2 is determined by:

$$P_2=\frac{S_1}{C_1} \tag{10}$$

since it is directly proportional to the excursion of the weight M_1 and inversely proportional to the compliance C_1 of the reed, assuming *"a"* equals 1.

Hence

$$\frac{t^2}{M_2} \text{ equals } C_2 \tag{11}$$

or

$$t^2 \text{ equals } M_2C_2 \tag{12}$$

Also,

$$t \text{ equals } \frac{2S_2}{V_2} \tag{13}$$

namely, the total spacing of the two contacts, divided by the velocity of the contacts.

Therefore,

$$t \text{ equals } \frac{2S_2}{P_2\omega_1C_2} \tag{14}$$

by substituting Equation 3 in Equation 13, and

$$t \text{ equals } \frac{2S_2C_1}{S_1\omega_1C_2} \tag{15}$$

by substituting Equation 10 in Equation 14.

This is the time taken to cross the gap in terms of the spacing, and other factors if there were no transient effect. Actually while this transient affects the velocity, it has small effect here on the displacement.

So the two *"t's"* are equated by combining Equations 12 and 15:

$$M_2C_2=4\left(\frac{S_2}{S_1}\right)^2\frac{1}{\omega_1^2}\left(\frac{C_1}{C_2}\right)^2 \tag{16}$$

and

$$S_2^2=\frac{M_2C_2S_1^2\omega_1^2C_2^2}{4C_1^2} \tag{17}$$

Since

$$\omega_1^2 \text{ equals } \frac{1}{M_1C_1} \tag{18}$$

$$S_2^2=\frac{M_2C_2^3S_1^2}{4M_1C_1^3} \tag{19}$$

and

$$S_2=\frac{S_1C_2}{2C_1}\sqrt{\frac{M_2C_2}{M_1C_1}} \tag{20}$$

and reinserting *"a"*:

$$S_2=\left(\frac{S_1}{2a}\right)\left(\frac{a^2C_2}{C_1}\right)\sqrt{\frac{M_2C_2}{M_1C_1}} \tag{21}$$

or

$$S_2=\left(\frac{S_1}{2a}\right)\left(\frac{a^2C_2}{C_1}\right)\left(\frac{f_1}{f_2}\right) \tag{22}$$

Equation 21 is obtained from Equation 20 by reinserting *"a,"* which occurs in the first power in the ratio of the spacings S_1 and S_2, and occurs in the second power in the ratios of the compliances. The expression:

$$\frac{C_1}{a^2C_2}$$

is known as the spring ratio, and hence the Equations 21 and 22 give the maximum spacing in terms of the displacement of the mass **38** and the frequency and spring ratios.

Ordinarily a vibrator of practical design would have a spring ratio of from 5 to 10 and a frequency ratio as defined under the radical, of the same order.

Thus the maximum displacement of the vibrator weight will be from $50a$ to $200a$ times the contact spacing to meet these requirements. Since in most cases *"a"* equals 2, or in the present case it equals 2.5, the required spacing is of the order of .001'' to .002'' for an amplitude of S_1 equaling about ¼ inch.

Most vibrators have about one-half of this amplitude with .005'' or so practical spacing. It can be seen that the operation of the vibrator **11** is entirely different, and that an aperiodic unit is achieved with the close spacing of S_2, while prior art vibrators will be seriously affected by the high frequency harmonics which will be generated by impulse associated with the off contact velocity transient.

The silver overlay contacts **33** and **34** have a small mass of, say, 30 milligrams compared with the prior art tungsten contacts of, say, 300 milligrams. This permits the contact mass M_2 to be small and thus have a high resonant frequency. In accordance with Equation 22, and the fact that

$$S_2=\frac{S_1}{50a}$$

the contact spacing can be made sufficiently small to keep the transient velocity v_t less than half of V_2. By examining the curve of v_t in

Figure 11, it will be seen that the beginning of this curve follows a square law. If the contact spacing were made .005", as per prior art practices, rather than about .002", the transient velocity v_t would be about five or six times that presently obtained. Since the energy in a moving system is proportional to the mass times the square of the velocity, it can be seen that the energy of the driver coil **13** need be only a small fraction of that in the prior art devices, which generally required about ¼ to ½ watt. Only about 30 to 50 milliwatts of power are required for the driver coil **13**, or about one-tenth that formerly required. This is due to keeping the transient velocity low, hence keeping low the resultant or total velocity of the contacts **33** and **34**. Since the transient velocity is kept at a value less than the maximum of V_2, there is a negligible effect on V_1, and hence an aperiodic vibrator is obtained.

Although the invention has been described in its preferred form with a certain degree of particularity, it is understood that the present disclosure of the preferred form has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

What is claimed is:

1. A vibratory interrupter for converting a unidirectional current into an interrupted current comprising a substantially U-shaped permeable frame having an open and a closed end, a driver coil, means for mounting said coil in said closed end of said frame, a contact base, means for mounting said contact base between said open end of said frame and said driver coil, a bracket arm mounted on and extending across said open end of said frame, an armature having first and second ends, means for mounting said first end of said armature on said bracket arm with said second end of said armature extending toward said closed end of said frame, said second end of said armature extending in close proximity to said coil, at least one spring contact having first and second ends turned substantially at right angles relative to each other, means for mounting said first end of said spring contact on said armature with said second end thereof extending away from said closed end of said frame, at least one side arm having first and second ends turned substantially at right angles to each other, means for mounting said first end of said side arm on the outer surface of said contact base with said second end thereof extending away from said closed end of said frame, and contact means mounted on said second end of said side arm for cooperating with said second end of said spring contact.

2. A vibratory interrupter comprising a frame having first and second legs and a closed end for a substantially U-shaped form having an open end, each of said legs having abutment means thereon, a driver coil, means for mounting said coil on said closed end of said frame, contact base means having outer surfaces, means for mounting said contact base means to said frame abutting said abutment means, a bracket having a main portion extending across said open end of said frame and having arms perpendicular to said main portion to lie parallel to and engage said first and second legs, an armature having first and second ends and having a spring hinge portion, means for mounting said first end of said armature on said bracket arm with said second end of said armature extending toward said closed end of said frame, said second end of said armature extending in close proximity to said coil, said parallel disposition of the arms of said bracket and the legs of said frame permitting longitudinal adjustment of said bracket and armature relative to said frame during assembly, movable contact arm means having contact surface means and having first and second ends at an angle relative to each other, means for mounting said first ends of said contact arm means on said armature for movement therewith, side arm means having first and second ends at an angle to each other, means adjustably mounting said first ends of said side arm means on the outer surfaces of said contact base means, contact means mounted on said second ends of said side arm means for cooperating with the contact surface means of said spring arm means with a spacing therebetween according to

$$S_2 \text{ equals } \frac{S_1 C_1 a^2}{2C_2 a}\sqrt{\frac{M_2 C_2}{M_1 C_1}}$$

where S_2 equals the normal spacing between the respective contact surface means and contact means, S_1 equals the excursion of the movable end of the armature, C_1 and C_2 equal the compliance of the armature and movable contact arm means, respectively, M_1 and M_2 equal the effective mass of the armature and movable contact arm means, respectively, "a" equals the ratio of the length of the armature to the length of the contact arm means, and where S_1 equals at least $50aS_2$.

3. A vibratory interrupter comprising a frame having first and second legs and a closed end for a substantially U-shaped form having an open end, each of said legs having a shoulder therein, a driver coil, means for mounting said coil on said closed end of said frame, contact base means having outer surfaces, means for mounting said contact base means in said frame abutting said shoulders, a bracket arm mounted on and extending across said open end of said frame, an armature having first and second ends and having a spring hinge portion, means for mounting said first end of said armature on said bracket arm with said second end of said armature extending toward said closed end of said frame, said second end of said armature extending in close proximity to said coil, first and second spring arms each having a contact surface and having first and second ends substantially at right angles relative to each other, means for mounting said first ends of said spring arms on said armature between said second end thereof and said hinge portion, said second end of said spring arms extending away from said closed end of said frame, said contact surfaces being in a plane passing substantially through said spring hinge portion and being substantially perpendicular thereto, first and second side arms each having first and second ends substantially at right angles to each other, means adjustably mounting said first ends of said side arms on the outer surfaces of said contact base means with said second ends thereof extending away from said closed end of said frame, and contact means mounted on said second ends of said side arms for cooperating with the contact surfaces of said spring arms with a spacing therebetween, said first ends of said side arms having a width substantially equal to the spacing between the legs of the U-shaped frame for rigidity and said second ends of said

side arms having a width less than one-third the width of the first ends of said side arms to permit relatively greater flexibility of said first ends to allow for adjustment by bending of the parallelism between the respective contact means and contact surfaces, according to

$$S_2 \leq \frac{S_1}{50a}$$

where S_2 is the spacing between the contact means and contact surfaces, S_1 is the excursion of the second end of the armature, and "a" is the ratio of the length of the armature to the length of the side arms.

4. The method of assembling a vibrator having a U-shaped frame, a vibrating reed having a weighted end, and a driver coil with a permeable core, said method comprising fabricating a reed sub-assembly by fastening movable contact means on said reed and fastening a mounting bracket to one end of the reed, mounting the driver coil on the closed end of said frame with said core extending in the direction of the side legs of the frame, placing the reed sub-assembly within the legs of the frame with said mounting bracket at the ends of the legs of the frame and with said reed extending toward said coil, adjusting said reed sub-assembly longitudinally for close spacing with said core of said coil and adjusting said reed sub-assembly laterally for an offset condition of said reed weighted end and the core of said coil, and securing said reed sub-assembly in place in said frame in said adjusted position.

5. The method of assembling a vibrator having a U-shaped frame, a vibrating reed having a weighted end, a driver coil, a movable contact and a fixed contact, said method comprising fabricating a reed sub-assembly by fastening a movable contact on one side of said reed and fastening a mounting bracket to one end of the reed, mounting the driver coil on the inner side of the closed end of said frame, placing the reed sub-assembly within the legs of the frame with said mounting bracket in frictional engagement with the ends of the legs of the frame and with said reed extending toward said coil, the elasticity of said legs of said frame frictionally holding said reed sub-assembly in any desired position, adjusting said reed sub-assembly longitudinally and laterally for close spacing with said coil and for an offset condition of said reed weighted end and said coil, soldering said reed sub-assembly in place in said frame in said adjusted position, adjustably mounting a fixed contact on said frame for cooperation with said movable contact, and longitudinally shifting said fixed contact to obtain a spacing between said fixed contact and said movable contact less than

$$\frac{S_1}{50a}$$

where S_1 is the excursion of the weighted end of the reed and "a" is the ratio of the length of the reed to the length of the movable contact.

6. The method of assembling a vibrator having a U-shaped permeable frame, a vibrating reed having a weighted end, a driver coil with a permeable core, cross members, movable contacts and fixed contacts, said method comprising fabricating a reed sub-assembly by fastening first and second movable contacts on opposite sides of said reed and fastening a mounting bracket to one end of the reed, mounting the driver coil on the inner side of the closed end of said frame with said core extending in the direction of the side legs of the frame, placing the reed sub-assembly within the legs of the frame with said mounting bracket in frictional engagement with the ends of the legs of the frame and with said reed extending toward said coil, the elasticity of said legs of said frame frictionally holding said reed sub-assembly in any desired position, adjusting said reed sub-assembly longitudinally and laterally for close spacing with said core of said coil to provide an efficient magnetic structure with a minimum air gap and for a longitudinal offset condition of said reed weighted end and the core of said coil, securing said reed sub-assembly in place in said frame in said adjusted position, fastening cross members on said frame each bridging the two legs of the frame on opposite sides of said vibrating reed, insulatingly mounting by an adjusting screw a fixed contact on each of said cross members for cooperation with said movable contacts, and bending and longitudinally shifting said fixed contacts to obtain parallelism between said fixed contacts and said movable contacts and to obtain a neutral spacing therebetween less than

$$\frac{S_1}{50a}$$

where S_1 is the excursion of the weighted end of the reed and "a" is the ratio of the length of the reed to the length of the movable contacts.

7. The method of assembling a vibrator having a U-shaped permeable frame, a vibrating reed having a weighted end, a driver coil with a permeable core, cross members, movable contacts and fixed contacts, said method comprising fabricating a reed sub-assembly by fastening first and second movable contacts on opposite sides of said reed substantially in a plane perpendicular to said reed and fastening a mounting bracket to one end of the reed, mounting the driver coil on the inner side of the closed end of said frame with said core extending in the direction of the side legs of the frame, placing the reed sub-assembly within the legs of the frame with said mounting bracket in frictional engagement with the ends of the legs of the frame and with said reed extending toward said coil, the elasticity of said legs of said frame frictionally holding said reed sub-assembly in any desired position, longitudinally adjusting said reed sub-assembly for close spacing with said core of said coil to provide an efficient magnetic structure with a minimum air gap, laterally adjusting said reed sub-assembly for an offset condition of said reed weighted end and the core of said coil, dipping the open end of said frame in molten solder to secure said reed sub-assembly in place in said frame in said adjusted position, brazing cross members on opposite sides of said frame each bridging the two legs of the frame near said vibrating reed, insulatingly mounting by an adjusting screw a fixed contact on each of said cross-members for cooperation with said movable contacts, and bending and longitudinally shifting said fixed contacts to obtain parallelism between said fixed contacts and said movable contacts and to obtain a neutral spacing therebetween less than

$$\frac{S_1}{50a}$$

where S_1 is the excursion of the weighted end of the reed and "a" is the ratio of the length of the reed to the length of the movable contacts.

8. In a vibrator having a vibrating reed and a

driver coil mounted in close proximity thereto for vibrating one end of said reed, the provision of a frame carrying said reed and said coil and having first and second legs defining a U-shape at least at the end carrying said coil, said two legs having a width dimension which is large relative to the thickness thereof, said reed being flat and the said one end of the reed vibrating in a path generally perpendicular to the plane of the reed and generally parallel to the width dimension of said legs, and a permeable weight on said one end of said reed extending into close proximity with the two legs of the frame in all positions of vibration of said weight to establish a low reluctance permeable path for said driver coil.

9. A vibrator, including a permeable frame having first and second legs and a closed end defining a U-shape at least at a first end thereof, a vibrating flexible reed having first and second ends, means for mounting said reed first end on said frame with said second end extending toward said closed end of said frame, a driving system including a driver coil mounted on said first end of said frame and having a permeable core extending into close proximity with the second end of said reed, said reed having an apparent hinge portion with an axis about which the reed flexes, said two legs having a width dimension which is large relative to the thickness thereof, said axis lying in a plane passing through the two legs of said U-shaped frame and generally perpendicular to said width dimension, a permeable weight on the second end of said reed having a longitudinal dimension substantially parallel to said axis, said weight extending into close proximity to the two legs of said frame in all positions of vibration of said reed for high magnetic efficiency of the driving system.

10. A vibrator structure, including a frame, a vibrating reed mounted in said frame, a movable contact arm carried by and vibrating with said vibrating reed, said contact arm having a resonant frequency with a periodic velocity, a relatively fixed contact cooperating with said movable contact arm for open and closed conditions as said contact arm vibrates, said contact arm having a transient velocity during the open condition of said contacts, and adjustment means for establishing the transient velocity less than the maximum of said periodic velocity.

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