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(54) **SOLENOID PUMP DRIVER**

MAGNETPUMPENANTRIEB

DISPOSITIF DE COMMANDE DE POMPE À SOLÉNOÏDE

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Description

[0001] This invention relates to a method and apparatus for driving an electromagnetic pump.

BACKGROUND

[0002] Figure 1 is a sectional view of a known construction of an electromagnetic (or solenoid) pump, for example as shown in US 9,028,227. The pump is configured to pump fluid, such as water, from an input connection 1 to an output connection 2 in the direction of the arrow A. The input connection 1 is formed as a plastics moulding, which defines a chamber in which is received a power spring 3 and a shuttle 4. An electrical solenoid 5 surrounds the chamber. An outer magnetic core 6 surrounds the solenoid 5. A non-magnetic spacer 7 breaks the magnetic circuit of the outer magnetic core 6. The shuttle 4 is made of stainless steel and is therefore moveable magnetically by the solenoid 5. The shuttle 4 provides a core and a piston. The core is received within the chamber and engages the power spring 3 at its proximal end. The piston extends from the core and is received within a cylinder 8. The shuttle 4 is hollow and provides a fluid passage through the core and the piston. The fluid passage is closed at the distal end of the piston by a piston non-return valve 9, which is retained in position by a spring within the fluid passage. A retaining washer 10 locates the piston within the cylinder 8 and a sealing O-ring 11 seals the proximal end of the cylinder 8. A non-return valve 12 is provided between the cylinder 8 and the output connection 2 to seal the distal end of the cylinder 8. A secondary spring 13 is provided between the core and the distal wall of the chamber to cushion movement of the shuttle 4.

[0003] In operation, the solenoid 5 is energised electrically, which moves the core (and thus the entire shuttle 4) towards the input connection 1, compressing the power spring 3. The shuttle 4 is moved up to and between the gap created in the outer magnetic core 6 by the non-magnetic spacer 7. The movement of the shuttle 4 reduces the pressure within the cylinder 8, which is closed by the non-return valve 12. The reduced pressure in the cylinder 8 opens the piston non-return valve 9, which allows fluid to pass from the input connection 1 through the chamber and the fluid passage within the shuttle 4 into the cylinder 8. On the return stroke of the pump, the power spring 3 pushes the core (and thus the entire shuttle 4) towards the output connection 1. The piston non-return valve 9 closes against the pressure of the fluid in the cylinder 8 and this pressure causes the non-return valve 12 to open so that the piston forces the fluid out of the cylinder 8 through the output connection 2 under the action of the power spring 3.

[0004] Although the presently described pump uses the electromagnet to fill the cylinder 8 and load the power spring 3, and uses the loaded power spring 3 to force the fluid out of the cylinder 8 through the output connection

2, it is known to have a pump operating in the opposite sense. That is, it is known to use the spring to draw fluid into the cylinder, and use the electromagnet to force the fluid out of the cylinder through the output connection.

[0005] Typically, the electrical solenoid 5 is driven by a half-wave rectified voltage at mains frequency (50 Hz in Europe), which provides a simple drive voltage signal to the solenoid 5.

[0006] The present invention, at least in its preferred embodiments, provides an alternative method of driving a solenoid pump.

BRIEF SUMMARY OF THE DISCLOSURE

[0007] In accordance with the present invention there is provided a method of driving a solenoid pump of the type comprising a metal shuttle urged by a solenoid against a spring with the spring providing the force for a pumping stroke of the shuttle, for example the solenoid pump described with reference to Figure 1. The method comprises applying a periodic driving voltage to the solenoid by outputting the periodic driving voltage from a driver circuit. Each period of the driving voltage comprises a first portion during which the driving voltage increases from a minimum voltage to a maximum voltage to compress the spring, a second portion during which the driving voltage decreases from the maximum voltage to the minimum voltage to release the spring, and a third portion during which the driving voltage is maintained at the minimum voltage. The duration of the second portion is substantially less than the duration of the first portion. The method further comprises providing a required flow rate through the pump by controlling one or more of: the duration of the third portion; the maximum voltage; and the frequency of the driving voltage.

[0008] Thus, in accordance with the invention, the driving voltage is reduced relatively quickly from the maximum voltage to the minimum voltage during the second portion. In this way, the spring is quickly freed to provide the force for the pumping stroke of the shuttle with the minimum energy being wasted by the driving voltage causing the solenoid to act against the released spring.

[0009] The driving voltage may decrease from the maximum voltage to the minimum voltage gradually, for example linearly. The duration of the second portion may be less than half of the duration of the first portion, particularly less than 10% of the duration of the second portion. In a particular embodiment, the driving voltage may decrease from the maximum voltage to the minimum voltage substantially instantaneously during the second portion. Thus, the duration of the second portion may be negligible compared to the duration of the first portion.

[0010] In embodiments of the invention, the driving voltage increases from the minimum voltage to the maximum voltage substantially linearly during the first portion. Although this configuration is presently preferred, it is possible for the driving voltage to increase otherwise than linearly during the first portion. In embodiments of the

invention, the driving voltage has a sawtooth waveform.

[0011] The frequency of the driving voltage may be different to the frequency of a supply voltage providing electrical power for the driving voltage. Thus, the frequency of the supply voltage is not limited to 50 Hz / 60 Hz. Therefore, where the frequency of the driving voltage is controlled to provide the required flow rate, the frequency of the driving voltage may comprise controlling the frequency of the driving voltage to be different to the frequency of the supply voltage providing electrical power for the driving voltage.

[0012] Typically, the minimum voltage is zero volts.

[0013] The invention extends to a solenoid pump driver circuit configured to generate a driving voltage in accordance with the method of the invention. The driver circuit may be an analogue circuit, a digital circuit or a combination of analogue and digital circuitry. The driver circuit may use pulse width modulation (PWM) to generate a sawtooth, or other, waveform. The invention further extends to a solenoid pump in combination with the driver circuit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Embodiments of the invention are further described hereinafter with reference to the accompanying drawings, in which:

Figure 1 is a sectional view of an electromagnetic pump;

Figure 2 is a graph showing a comparison between a known driving method for the electromagnetic pump of Figure 1 and a driving method according to an embodiment of the present invention;

Figure 3 is a graph illustrating a driving method according to a further embodiment of the present invention;

Figure 4 is a graph illustrating a driving method according to a yet further embodiment of the present invention; and

Figure 5 is a schematic of a driving circuit according to an embodiment of the present invention.

DETAILED DESCRIPTION

[0015] Figure 2 shows, in the upper graph, a comparison of a sawtooth driving voltage for a solenoid pump according to an embodiment of the invention (dashed line) to a half-wave rectified driving voltage of the prior art (solid line). The solenoid pump may be of the type described in relation to Figure 1. The lower graph in Figure 2 shows the corresponding spring force of the power spring 3. As shown in Figure 2, to achieve the same spring force from the power spring 3, the sawtooth driving volt-

age requires only 60% of the maximum voltage of the rectified driving voltage. Furthermore, the rapid decrease of the sawtooth driving voltage from the (60%) maximum voltage to zero volts, also saves energy. The amount of energy saved by using the sawtooth driving voltage is shaded in Figure 2.

[0016] Figure 3 shows a variation of the sawtooth driving voltage of an embodiment of the invention in a representation corresponding to Figure 2. In this case, the first portion of the sawtooth waveform has a duration of 10ms, as in the waveform of Figure 2. The second portion of the sawtooth waveform, in which the driving voltage drops from a maximum value to zero volts is substantially instantaneous. In Figure 3, the duration of the third portion of the sawtooth waveform in which the driving voltage is maintained at zero volts is reduced relative to the waveform shown in Figure 2 from 10ms to 8ms. In this way, the frequency of the driving voltage is increased from 50 Hz to 56 Hz. The shorter duration of each period of the sawtooth waveform increases the flow rate through the pump.

[0017] Figure 4 shows a variation of the sawtooth driving voltage of an embodiment of the invention in a representation corresponding to Figures 2 and 3. In this case, the first portion of the sawtooth waveform has a duration of 8ms, which is shorter than in the waveform of Figures 2 and 3. The rate of change (gradient) of the driving voltage remains the same, however, such that the maximum voltage achieved during the first portion of the waveform is reduced, compared to Figures 2 and 3. Again, the second portion of the sawtooth waveform, in which the driving voltage drops from a maximum value to zero volts is substantially instantaneous. In Figure 4, the duration of the third portion of the sawtooth waveform in which the driving voltage is maintained at zero volts is longer than in the waveforms of Figures 2 and 3 at 12ms. In this way, the frequency of the driving voltage is maintained at 50 Hz, as in Figure 3, but the flow rate through the pump is reduced as the power spring 3 only reaches 80% of its maximum compression.

[0018] The sawtooth driving voltage has the advantage that it uses less energy to achieve the same spring force than a conventional driving voltage. This means that a smaller power supply can be used and less heat is generated during operation of the pump, which increases the pump duty cycle. Furthermore, the operating frequency of the pump can be "tuned" to achieve the minimum mechanical noise from the pump components. For example, we have found that known pumps can operate at their quietest at a driving frequency of 47 Hz, rather than the conventional 50 Hz. Any suitable driver circuit may be used to generate the required sawtooth waveform.

[0019] Figure 5 is a schematic of a driving circuit according to an embodiment of the present invention. The driving circuit 20 comprises a power supply 22 connected to a microcontroller 24. The microcontroller is connected to a pump solenoid 28 via a switching circuit 26. The pump solenoid is typically the solenoid 5 as described in

Figure 1. The microcontroller 24 comprises a memory and at least one processor. The memory of the microcontroller 24 includes instructions which, when executed, cause the at least one processor to control the switching circuit 26 and the pump solenoid 28 to operate in accordance with methods as described previously. The switching circuit 26 provides inputs for the microcontroller 24 to control the operation of the pump solenoid 28.

[0020] In summary, a method of driving a solenoid pump of the type comprising a metal shuttle urged by a solenoid against a spring with the spring providing the force for the pumping stroke of the shuttle is disclosed. The method comprises applying a periodic driving voltage to the solenoid. Each period of the driving voltage comprises a first portion during which the driving voltage increases from a minimum voltage to a maximum voltage to compress the spring, a second portion during which the driving voltage decreases from the maximum voltage to the minimum voltage to release the spring, and a third portion during which the driving voltage is maintained at the minimum voltage. The duration of the second portion is substantially less than the duration of the first portion and may be substantially instantaneous. The driving voltage increases from the minimum voltage to the maximum voltage substantially linearly during the first portion, such that the driving voltage has a sawtooth waveform.

[0021] Throughout the description and claims of this specification, the words "comprise" and "contain" and variations of them mean "including but not limited to", and they are not intended to (and do not) exclude other components, integers or steps. Throughout the description and claims of this specification, the singular encompasses the plural unless the context otherwise requires. In particular, where the indefinite article is used, the specification is to be understood as contemplating plurality as well as singularity, unless the context requires otherwise.

[0022] Features, integers, characteristics or groups described in conjunction with a particular aspect, embodiment or example of the invention are to be understood to be applicable to any other aspect, embodiment or example described herein unless incompatible therewith. All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive. The invention is not restricted to the details of any foregoing embodiments. The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

Claims

1. A method of driving a solenoid pump of the type com-

prising a metal shuttle urged by a solenoid against a spring with the spring providing the force for a pumping stroke of the shuttle, the method comprising applying a periodic driving voltage to the solenoid by outputting the periodic driving voltage from a driver circuit, wherein each period of the driving voltage comprises a first portion during which the driving voltage is always increasing from a minimum voltage to a maximum voltage to compress the spring, a second portion during which the driving voltage decreases from the maximum voltage to the minimum voltage to release the spring, and a third portion during which the driving voltage is maintained at the minimum voltage, wherein the duration of the second portion is substantially less than the duration of the first portion, the method further comprising providing a required flow rate through the pump by controlling one or more of: the duration of the third portion; the maximum voltage; and the frequency of the driving voltage.

2. A method as claimed in claim 1, wherein the driving voltage decreases from the maximum voltage to the minimum voltage substantially instantaneously during the second portion.
3. A method as claimed in claim 1 or 2, wherein the driving voltage increases from the minimum voltage to the maximum voltage substantially linearly during the first portion.
4. A method as claimed in claim 1, 2 and 3, wherein the driving voltage has a sawtooth waveform.
5. A method as claimed in any preceding claim, wherein where the frequency of the driving voltage is controlled to provide the required flow rate, the frequency of the driving voltage is controlled to be different to the frequency of a supply voltage providing electrical power for the driving voltage.
6. A method as claimed in any preceding claim, wherein the minimum voltage is zero volts.
7. A solenoid pump driver circuit configured to generate a driving voltage in accordance with the method of any preceding claim.
8. A solenoid pump in combination with the driver circuit of claim 7.

Patentansprüche

1. Verfahren zum Antreiben einer Solenoidpumpe des Typs, der einen Metallshuttle umfasst, der von einem Solenoid gegen eine Feder gedrängt wird, wobei die Feder die Kraft für einen Pumpenhub des Shuttles

bereitstellt, wobei das Verfahren das Anlegen einer periodischen Antriebsspannung an das Solenoid durch Ausgeben der periodischen Antriebsspannung von einer Treiberschaltung umfasst, wobei jede Periode der Antriebsspannung einen ersten Abschnitt, während dem die Antriebsspannung immer von einer minimalen Spannung auf eine maximale Spannung ansteigt, um die Feder zu komprimieren, einen zweiten Abschnitt, während dem die Antriebsspannung von der maximalen Spannung auf die minimale Spannung abnimmt, um die Feder freizugeben, und einen dritten Abschnitt umfasst, während dem die Antriebsspannung auf der minimalen Spannung gehalten wird, wobei die Dauer des zweiten Abschnittes wesentlich kürzer als die Dauer des ersten Abschnittes ist, wobei das Verfahren ferner das Bereitstellen einer erforderlichen Flussrate durch die Pumpe umfasst, indem eines oder mehrere des Folgenden gesteuert wird: die Dauer des dritten Abschnittes; die maximale Spannung; und die Frequenz der Antriebsspannung.

2. Verfahren nach Anspruch 1, wobei die Antriebsspannung während des zweiten Abschnittes im Wesentlichen sofort von der maximalen Spannung auf die minimale Spannung abnimmt.
3. Verfahren nach Anspruch 1 oder 2, wobei die Antriebsspannung während des ersten Abschnittes im Wesentlichen linear von der minimalen Spannung auf die maximale Spannung ansteigt.
4. Verfahren nach Anspruch 1, 2 und 3, wobei die Antriebsspannung eine Sägezahnwellenform aufweist.
5. Verfahren nach einem vorhergehenden Anspruch, wobei, wenn die Frequenz der Antriebsspannung gesteuert wird, um die erforderliche Flussrate bereitzustellen, die Frequenz der Antriebsspannung gesteuert wird, sodass sie sich von der Frequenz einer Versorgungsspannung unterscheidet, die elektrische Leistung für die Antriebsspannung bereitstellt.
6. Verfahren nach einem vorhergehenden Anspruch, wobei die Mindestspannung null Volt beträgt.
7. Solenoidpumpen-Treiberschaltung, die konfiguriert ist, um eine Antriebsspannung gemäß dem Verfahren nach einem vorhergehenden Anspruch zu erzeugen.
8. Solenoidpumpe in Kombination mit der Treiberschaltung nach Anspruch 7.

Revendications

1. Procédé d'entraînement d'une pompe à solénoïde

du type comprenant une navette métallique poussée par un solénoïde contre un ressort, le ressort fournissant la force pour une course de pompage de la navette, le procédé comprenant l'application d'une tension d'entraînement périodique au solénoïde en produisant la tension d'entraînement périodique à partir d'un circuit de commande, dans lequel chaque période de la tension d'entraînement comprend une première partie pendant laquelle la tension d'entraînement augmente toujours d'une tension minimale à une tension maximale pour comprimer le ressort, une deuxième partie pendant laquelle la tension d'entraînement diminue de la tension maximale à la tension minimale pour relâcher le ressort, et une troisième partie pendant laquelle la tension d'entraînement est maintenue à la tension minimale, dans lequel la durée de la deuxième partie est sensiblement inférieure à la durée de la première partie, le procédé comprenant en outre la fourniture d'un débit requis à travers la pompe en commandant l'un ou plusieurs des éléments suivants : la durée de la troisième partie ; la tension maximale ; et la fréquence de la tension d'entraînement.

2. Procédé selon la revendication 1, dans lequel la tension d'entraînement diminue de la tension maximale à la tension minimale sensiblement instantanément pendant la deuxième partie.
3. Procédé selon la revendication 1 ou 2, dans lequel la tension d'entraînement augmente de la tension minimale à la tension maximale sensiblement linéairement pendant la première partie.
4. Procédé selon les revendications 1, 2 et 3, dans lequel la tension d'entraînement a une forme d'onde en dents de scie.
5. Procédé selon l'une quelconque des revendications précédentes, dans lequel, lorsque la fréquence de la tension d'entraînement est commandée pour fournir le débit requis, la fréquence de la tension d'entraînement est commandée pour être différente de la fréquence d'une tension d'alimentation fournissant l'énergie électrique pour la tension d'entraînement.
6. Procédé selon l'une quelconque des revendications précédentes, dans lequel la tension minimale est zéro volt.
7. Circuit d'entraînement de pompe à solénoïde configuré pour générer une tension d'entraînement conformément au procédé de l'une quelconque des revendications précédentes.
8. Pompe à solénoïde en combinaison avec le circuit d'entraînement selon la revendication 7.

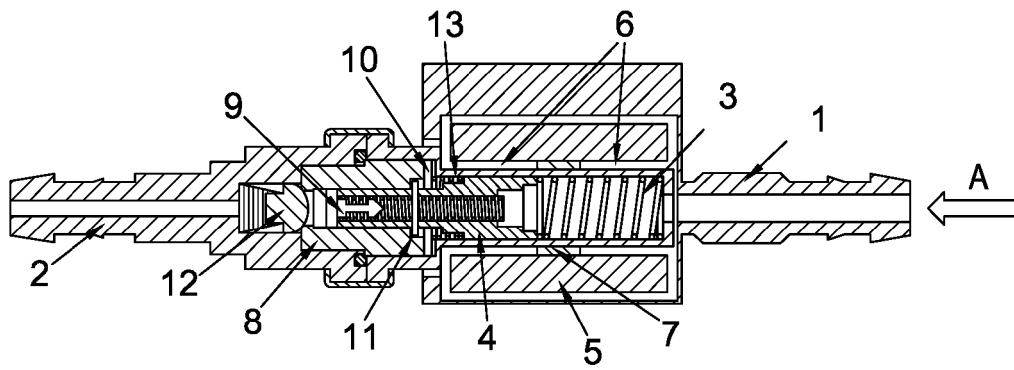


FIG. 1

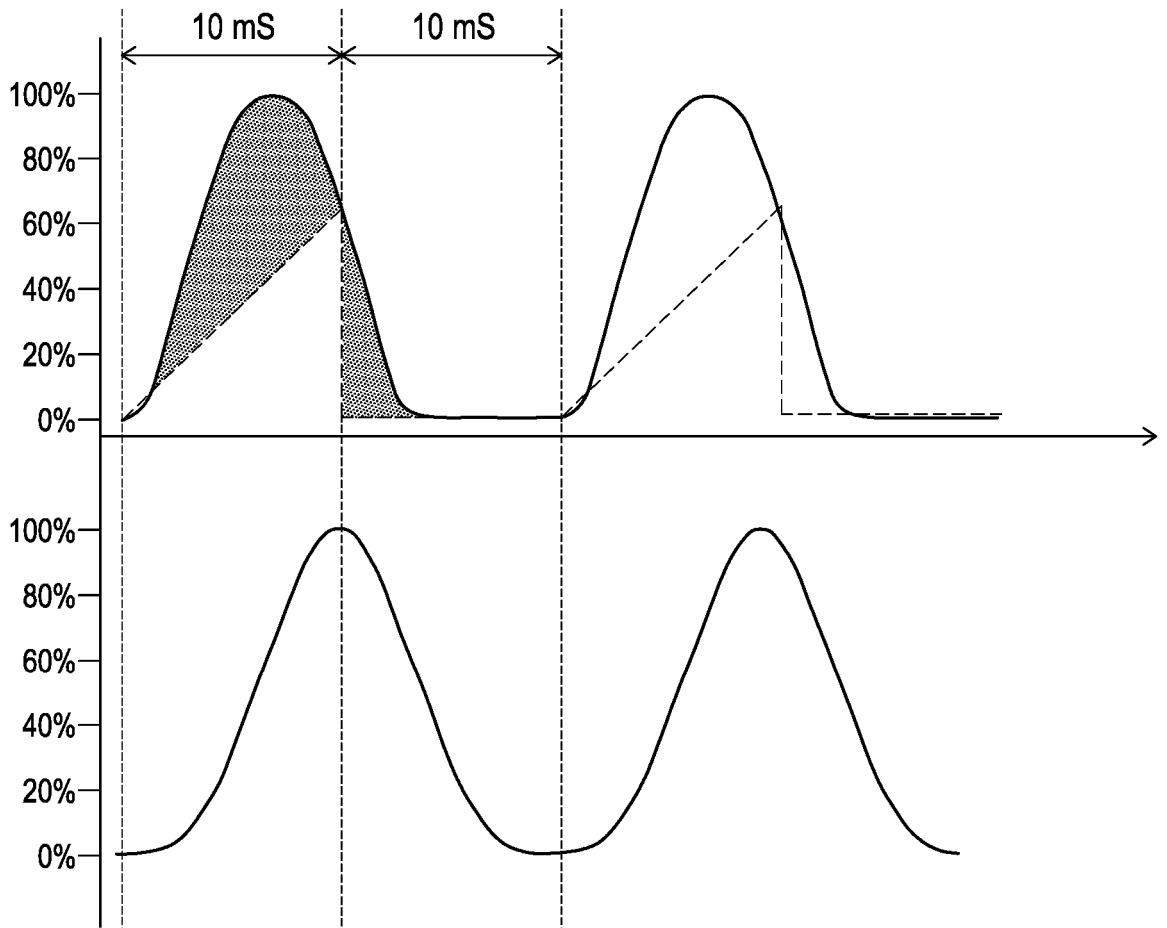


FIG. 2

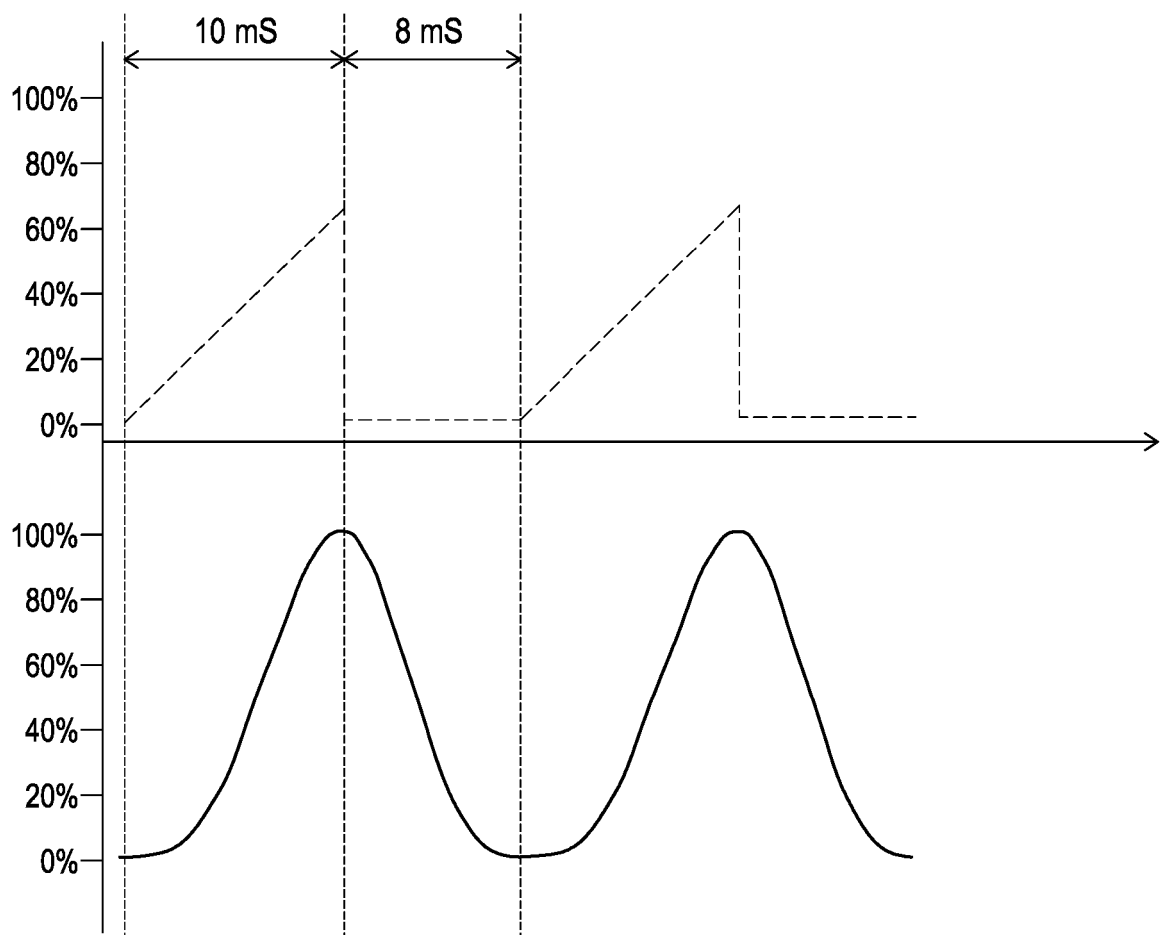


FIG. 3

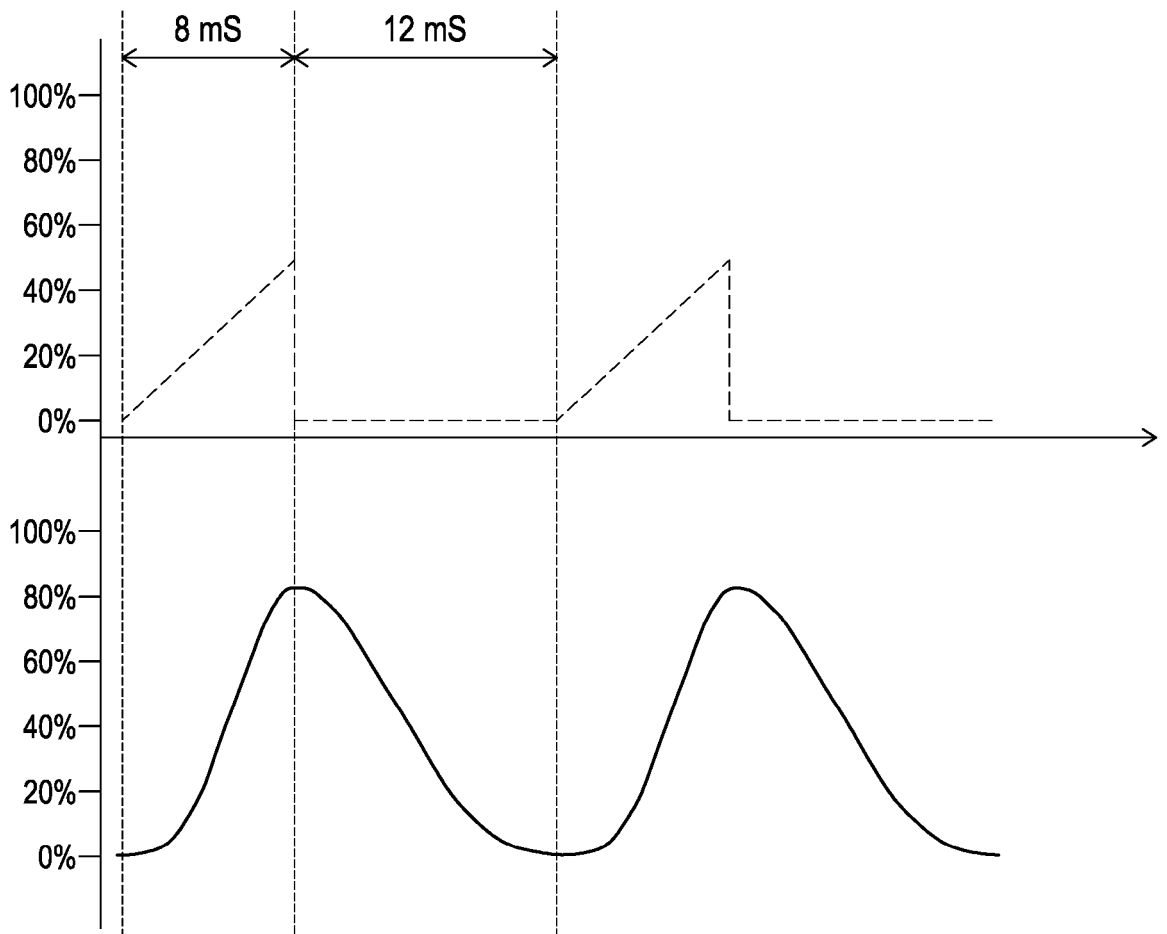


FIG. 4

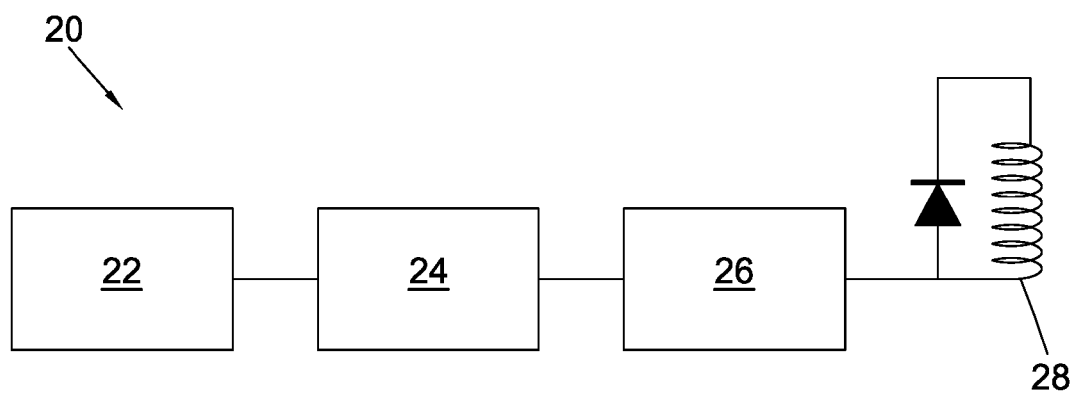


FIG. 5

REFERENCES CITED IN THE DESCRIPTION

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