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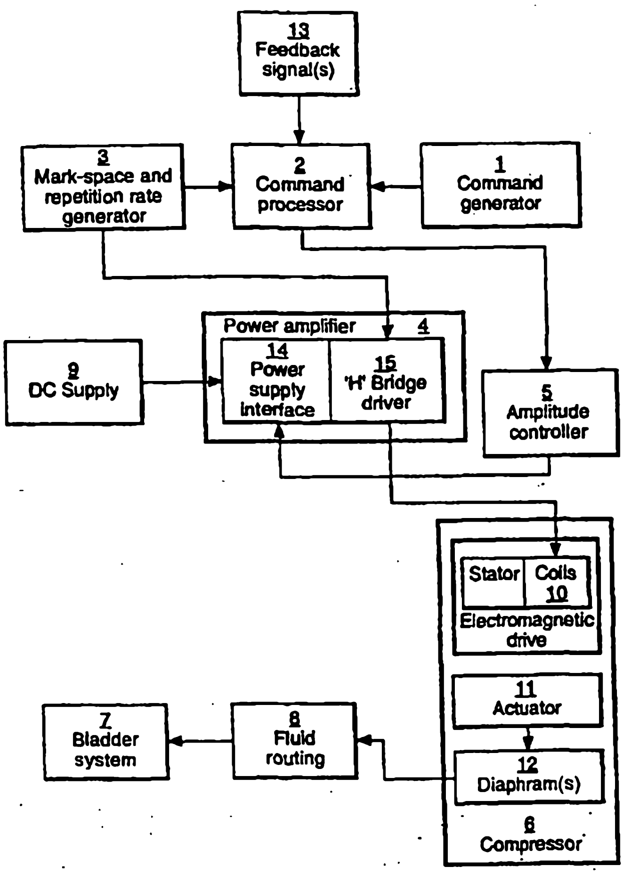
(54) Title: COMPRESSOR DRIVE



(57) Abstract: A fluid flow control system for an electromagnetic pump having an electromagnetic drive (11) and a compressor (6). The control system establishes a required current in the compressor coils (10) to control the position and movement of the actuator (11), the actuator deflecting a diaphragm within the pump to provide the required flow. The control system includes a command signal generator (1) to create a signal representing the required flow, the signal is applied to a command processor (2) with any feedback signal(s) (13) for example, coil current, actuator displacement. The command processor (2) calculates the appropriate drive signal defined by mark-space ratio, repetition rate and amplitude. The drive signal controls the voltage supplied to the compressor coils (11) resulting in a required coil current to provide the desired flow. A dc power supply is used to avoid problems regarding mains power supply and frequency.

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COMPRESSOR DRIVE

The present invention relates to an air flow control system and particularly an air flow control system for a compressor to provide a desired variable air flow rate.

Conventionally electromagnetic pumps operate from mains power and the compressors within the electromagnetic pumps operate directly from this single phase mains power which provides the compressor electrical drive input voltage and frequency. Therefore these compressors operate at constant air flow, and any air flow control depends merely on on/off control or on air loading conditions. The necessary air flow rates are obtained by the control and design of the air routing system.

Such compressors include linear or arcuate motion reciprocating actuators driven by electromagnetic drive means supplied by the mains power voltage and frequency. The electromagnetic drive means drive the actuators into reciprocating mechanical motion which is translated by diaphragms and valves into air flow from one or more compressor inputs to one or more compressor outputs.

This approach has a number of problems including the design of the compressor having to vary with the value of mains power voltage and frequency, complicating manufacture and driving up costs. Furthermore, flow control only by air routing comprises the compressors' life, the compressors having to be operated continually at maximum capacity with the consequence of maximum noise and vibrating during use.

Furthermore, the performance of the compressors is largely dependent on the mechanical characteristics of its components, for example the diaphragm stiffness, the moving mass, and also the stiffness of the compressed air within the pump.

Any variation either between units of manufacture or within environmental operating conditions or through use will cause additional performance variation.

The aim of the present invention is to provide an air flow control system for a compressor that is not dependent on the voltage and frequency of the mains power supply and provides the desired air flow with the optimum performance of the compressor.

Accordingly, the present invention provides an air flow control system for a compressor having electromagnetic drive means, the control system supplying a pulse width modulated low voltage drive signal generated from a dc voltage supply to the electromagnetic drive means, the drive signal controlling the amplitude and repetition rate of the instantaneous current in the coils of the electromagnetic drive means, the current driving a reciprocating actuator in order to generate a desired flow rate output from the compressor.

Preferably, the pulse width modulated drive signal is of substantially constant amplitude. Pulse width modulated control from a dc power supply ensures the compressor is always operating with optimum efficiency for any application, the compressor performance being independent of mains power type or variations and allowing the possibility of using batteries to operate the pumps. Therefore, the problems associated with existing fixed frequency mains voltage driven compressors and pumps are avoided.

Preferably, the electromagnetic drive means includes stator(s) of magnetic material, excitation winding(s) for magnetically exciting the stator(s) and a movable magnetic member connected to the reciprocating actuator of the compressor, the actuator deflection resulting in a corresponding deflection of the attached diaphragm(s), thereby providing flow of any air in contact with the diaphragm(s).

Preferably, the control system includes a command generator creating a command signal corresponding to a predetermined desired air flow rate, sensor(s) to sense status of the system and provide feedback signal(s), the command signal and feedback signal(s) being processed by a command processor, the command processor providing a drive signal output, the drive signal defined by mark-space ratio, repetition rate and amplitude and controlling the voltage to be applied to the compressor windings.

Additionally, the sensor(s) provides feedback of instantaneous coil current or actuator displacement or bladder system pressure or air flow into-out of the bladder system.

Preferred embodiments of the present invention will now be described in detail by way of example only, with reference to the accompanying drawings of which:

Figure 1 shows a block diagram of the air flow control system according to the present invention;

Figure 2a shows the bipolar voltage drive signal;

Figure 2b shows the unipolar drive signal from the mark space/repetition rate generator;

Figure 2c shows actuator current;

Figure 3 shows a block diagram of one embodiment of a control system of Figure 1 supplying air to a bladder;

Figure 4 shows a block diagram of another embodiment of a control system of Figure 1 supplying air to a bladder;

Figure 5 shows a block of a further embodiment of a control system of Figure 1 supplying air to a bladder; and

Figure 6 shows a block diagram of a further embodiment of a control system of Figure 1 supplying air to a bladder.

Referring to the block diagram at Figure 1 there is shown a controlled air flow system comprising a control system, air routing, a bladder system (7) and a compressor comprising one or more diaphragms (12) attached to one or more electromagnetic actuator(s) (11).

The control system establishes a required current in the compressor (6) coil or coils (10) at any instant in time. The coil current controls the position of the actuator (11) which deflects the diaphragm(s) (12) appropriately thereby providing flow of any air in contact with the diaphragm(s) (12). Controlling the current in the coil(s) (10) controls the air flow from the compressor (6).

A command signal representing the required air flow is created in the command generator (1) and applied to the command processor (2) in conjunction with any feedback signal(s) (13) derived from the coil current sensor, actuator position sensor, bladder flow sensor and bladder pressure sensor. They provide signals representing instantaneous coil(s) current, actuator displacement flow into or out of the bladder system (7) and bladder system (7) pressure.

The output of the command generator (1) and the feedback signals (13) are processed in the command processor (2) using a control algorithm which is representative of the pneumatic, mechanical and electrical characteristics of the compressor that is to be driven. From the control algorithm an appropriate drive signal is calculated, defined by mark-space ratio, repetition rate and amplitude parameters.

Drive signal amplitude is obtained via the amplitude controller (5) appropriately changing the power supply interface (14) within the power amplifier (4)to change the dc supply voltage of the 'H' bridge driver (15). The drive signal mark-space ratio and repetition rate are obtained by the mark-space and repetition rate generator operating on the appropriate parameter values. The generator provides a unipolar drive signal to the 'H' bridge driver (15) which then provides a bipolar voltage drive signal to the compressor coil(s) (10).

This bipolar voltage drive signal (Figure 2a) across the compressor coils may be represented by repetition rate 1/A, mark-space ratio B/A and amplitude switching between +V and -V. V is a voltage closely approximating the supply voltage to the 'H' bridge driver (15). Typically V might be around 12 volts with a repetition rate of several kilohertz an mark-space ratio varying from below one per cent to above 99 per cent.

If for the purpose of obtaining appropriate compressor air flow an actuator current of period x is required

(Figure 2c) then over a time period of x the generator (3) will provide mark-space ratio values approximating two half sinusoids (Figure 2b), each over a period of x/2 and with uniform repetition rate. This drive signal combined with the switching action of the 'H' bridge driver (Figure 2-a) will create a complete bipolar near sinusoidal actuator coil current with a period of x as required. Typically x will be ten to a hundred times greater than A requiring a drive signal repetition rate equally much higher than 1/x.

The bipolar current in the compressor coil(s) enables the actuator to be displaced both positively and negatively with respect to its non-energised position. The actuator displacement results in the air pumping diaphragm(s) (12) being deflected to the required amount to provide the required flow rate of the air. The power amplifier (4) is supplied from mains power via a regulated or unregulated dc supply or from a dc battery.

It will be apparent to skilled practitioners of the art that for the invention except where indicated otherwise the command generator, mark-space and repetition rate generator, command processor, dc supply, power amplifier and amplitude controller can be implemented in any combination of analogue circuitry, digital circuitry or state machines including microprocessor systems.

It will also be apparent to skilled practitioners of the art that instead of diaphragms one can use other air displacement devices such as pistons, vanes, spirals, and that air flow out of as well as into the bladder system can be controlled.

Figure 3 shows a preferred embodiment of the invention where the characteristics of the compressor output air flow are known for varying loads, temperatures and pressures. In this case, a command signal representing the required air flow is created in the command generator (1) and applied to the command processor (2). The command processor (2) determines the repetition rate and mark-space ratio required from the mark-space and repetition rate generator (3). This results in a variable repetition rate and time varying mark-space ratio waveform representative of the current required in the compressor (6) coil or coils. The waveform is applied to the power amplifier (4) where it is controlled in amplitude by the amplitude controller (5), the amplitude being determined by the command processor (2). The output of the power amplifier (4) provides a voltage with the amplitude repetition rate and mark-space ratio controlled by the command processor. This voltage is applied to the compressor (6) coil or coils resulting in a known current, therefore a known deflection of the compressor bellows and thus a known amount of air flow to the bladder system (7) by way of the air routing system (8). A dc power supply (9) is used.

Figure 4 shows the control of the air flow system as described in Figure 3 but applied to the control of the actuator position within the compressor by actuator position feedback. This control approach removes the effect of unknown variations within the electromagnetic drive means between drive signal and resulting actuator deflection.

A command signal representing the required air flow is created in the command generator (1) and added to the actuator position sensor (10) signal in the command processor (2) thus providing an error signal to ensure that the actuator position is achieved. This error signal from the command processor (2) determines the repetition rate and mark-space ratio required from the mark-space and repetition rate generator (3). This results in a variable repetition rate and time varying mark-space ratio waveform representative of the current required in the compressor (6) coil or coils. This waveform is applied to the power amplifier (4) where it is controlled in amplitude by the amplitude controller (5), the amplitude being determined by the command processor (2). The output of the power amplifier (4) provides a voltage with the amplitude repetition rate and mark-space ratio controlled by the command processor (2) and the actuator position sensor (10). This voltage is applied to the compressor (6) coil or coils resulting in a known deflection of the compressor bellows and thus an amount of air flow to the bladder system (7) by way of the air routing system (8). A dc power supply (9) is used.

Figure 5 shows flow control based on the principle that the actual air flow into a bladder is monitored to maintain the required air flow.

A command signal representing the required air flow is created in the command generator (1) and added to the information from the flow sensor (10) in the command processor (2) thus providing an error signal to correct any error in the required flow. This error signal from the command processor (2) determines the repetition rate and mark-space ratio required from the mark-space and repetition rate generator (3). This results in a variable repetition rate and time varying mark-space ratio waveform representative of the current required in the compressor (6) coil and coils. This waveform is applied to the power amplifier (4) where it is controlled in amplitude by the amplitude controller (5), the amplitude being determined by the command processor (2). The output of the power amplifier (4) provides a voltage with the amplitude repetition rate and mark-space ratio controlled by the command processor (2) and the flow sensor (10). This voltage is applied to the compressor (6) coil or coils resulting in a deflection of the compressor bellows and thus an amount of air flow to the bladder system (7) by way of the air routing system (8). Any errors in the flow being detected by the flow sensor (10) and being used as a correction signal into the command processor (2). A dc power supply (9) is used.

Alternatively, instead of flow being monitored, the actual pressure in the bladder may be monitored as shown in Figure 6.

Referring to Figure 6, a command signal representing the required bladder pressure is created in the command generator (1) and added to the information from the pressure sensor (10) in the command processor (2) thus providing an error signal that can be used to correct any error in the required bladder system (7) pressure. This error signal from command processor (2) determines the repetition rate and mark-space ratio required from the mark-space and repetition rate generator (3). This results in a variable repetition rate and time varying mark-space ratio waveform representative of the current required in the compressor (6) coil or coils. This waveform is applied to the power amplifier (4) where it is controlled in amplitude by the amplitude controller (5), the amplitude being determined by the command processor (2). The output of the power amplifier (4) provides a voltage with the amplitude repetition rate and mark-space ratio controlled by the command processor (2) and the pressure sensor (10). This voltage is applied to the compressor (6) coil or coils resulting in a deflection of the compressor bellows and thus an amount of air flow to the bladder system (7) by way of the air routing system (9). Any errors in the pressure detected by the pressure sensor (10) is then used as a correction signal into the command processor (2). A dc power supply is used (9).

Claims:

1. An air flow control system for a compressor having electromagnetic drive means, the control system supplying a pulse width modulated low voltage drive signal generated from a dc voltage supply to the electromagnetic drive means, the drive signal controlling the amplitude and repetition rate of the instantaneous current in the coils of the electromagnetic drive means, the current driving a reciprocating actuator to generate a desired flow rate output from the compressor.

2. An air flow control system as claimed in claim 1, wherein the pulse width modulated drive signal is of substantially constant amplitude.

3. An air flow control system as claimed in claims 1 or 2 2 wherein the electromagnetic drive means includes stator(s) of magnetic material, excitation winding(s) for magnetically exciting the stator(s) and movable magnetic member connected to the reciprocating actuator, the actuator deflection resulting in corresponding deflection of diaphragm(s) attached thereto, thereby providing flow of any air in contact with the diaphragm(s).

4. An air flow control system for a compressor as claimed in claim 1, the control system including a command generator creating a command signal

corresponding to a predetermined desired air flow rate, sensor(s) to sense status of the system and provide feedback signal(s), the command signal and feedback signal(s) being processed by a command processor, the command processor providing a drive signal output, the drive signal defined by mark-space ratio, repetition rate and amplitude and controlling the voltage to be applied to the compressor windings.

5. An air flow control system as claimed in claim 4, wherein the sensor(s) provides feedback of instantaneous coil current.

6. An air flow control system as claimed in claim 4, wherein the sensor(s) provides feedback of actuator displacement.

7. An air flow control system as claimed in claim 4, wherein the sensor(s) provides feedback of bladder system pressure.

8. An air flow control system as claimed in claim 6, wherein the sensor(s) provides feedback of air flow into-out of bladder system.

9. An air flow control system substantially as hereinbefore described and with reference to the accompanying Figures 1 to 6.

10. A fluid flow control system as claimed in claim 9, wherein the sensor(s) provides feedback of instantaneous coil current.

11. A fluid flow control system as claimed in claim 9, wherein the sensor(s) provides feedback of actuator displacement.

12. A fluid flow control system as claimed in claim 9, wherein the sensor(s) provides feedback of bladder system pressure.

13. A fluid flow control system as claimed in claim 9, wherein the sensor(s) provides feedback of fluid flow into/out of bladder system.

14. A fluid flow control system substantially as hereinbefore described and with reference to the accompanying Figures 1 to 6.

Fig.1.

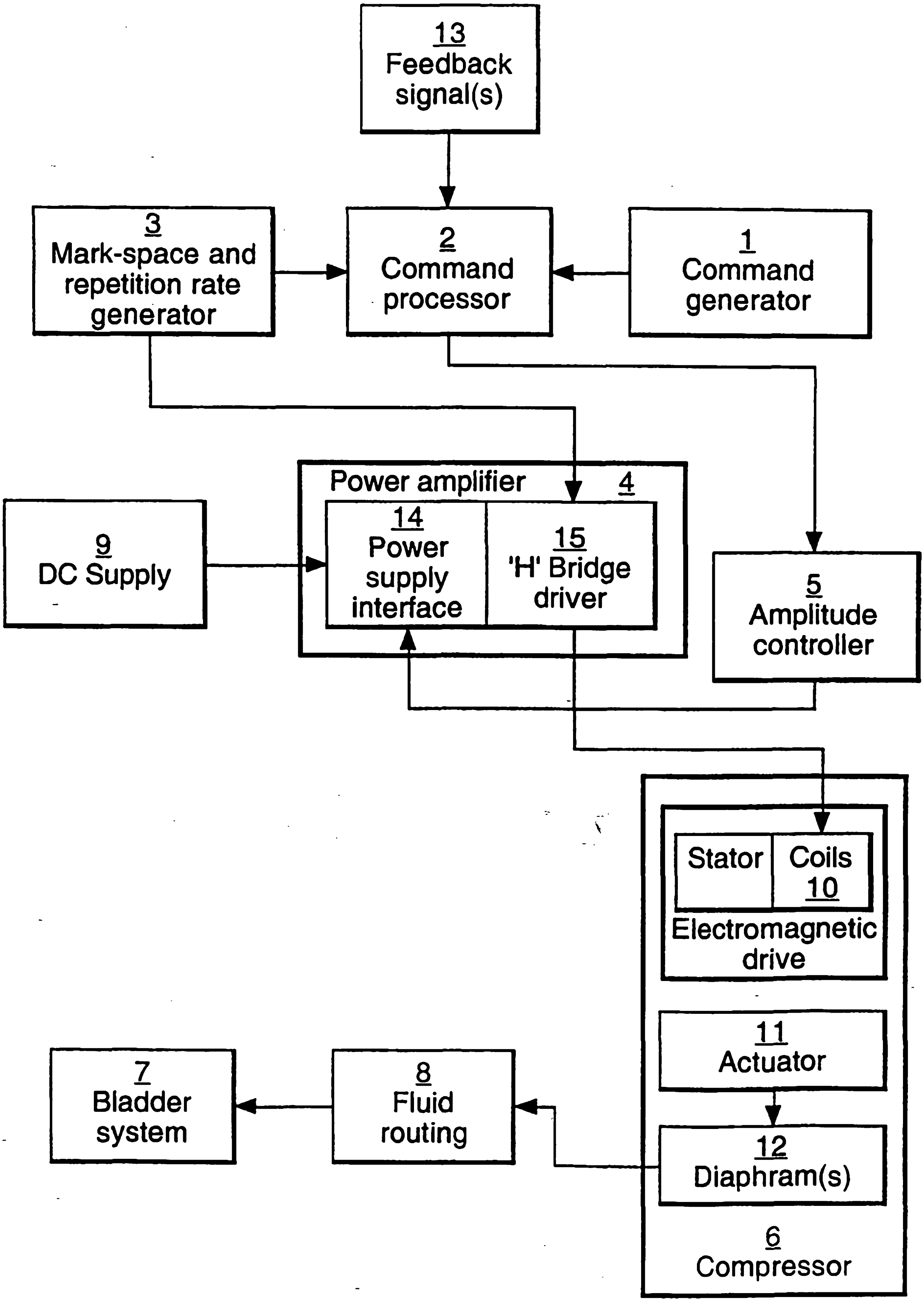

13
Feedback
signal(s)
3
Mark-space and
repetition rate
generator
2
Command
processor
1
Command
generator
Power amplifier
4
14
Power
supply
interface
15
'H' Bridge
driver
9
DC Supply
5
Amplitude
controller
Stator
Coils
10
Electromagnetic
drive
11
Actuator
12
Diaphram(s)
6
Compressor
7
Bladder
system
8
Fluid
routing

Fig.2a.

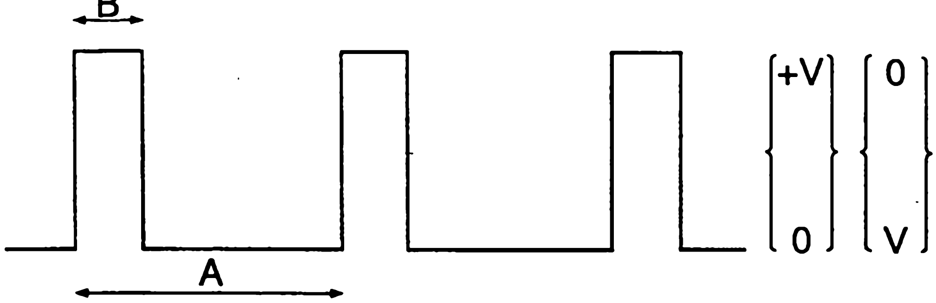


Fig.2b.

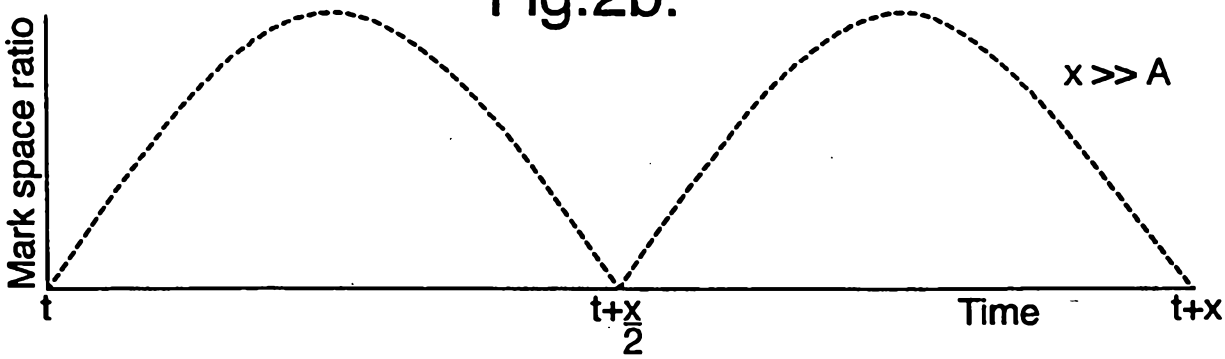


Fig.2c.

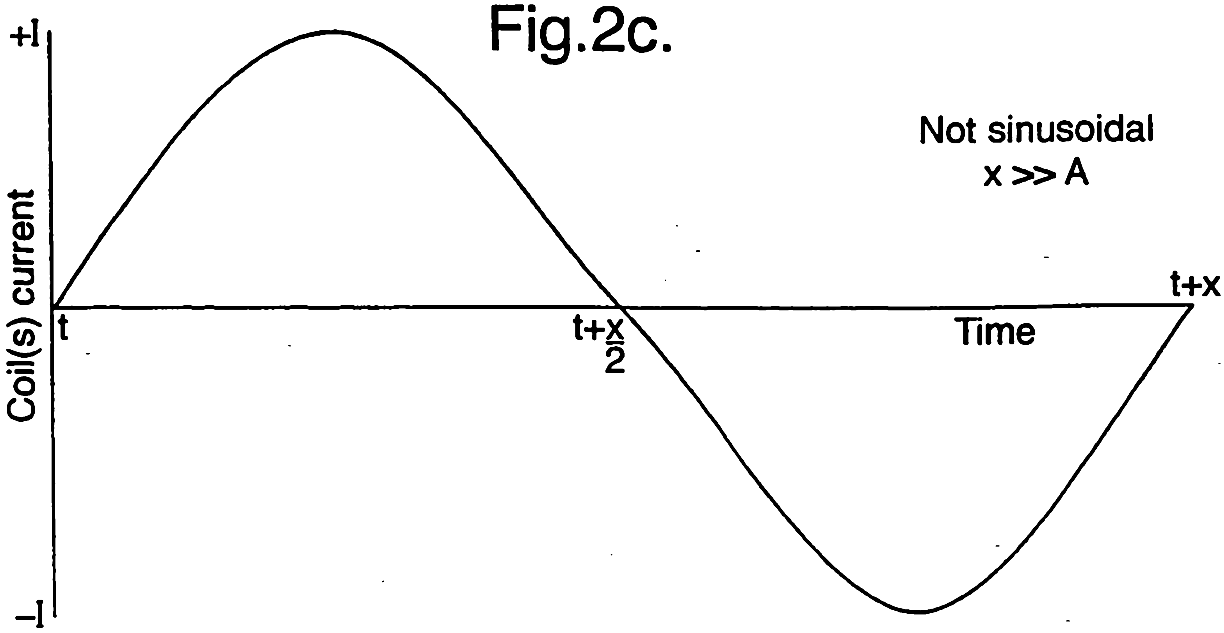


Fig.3.

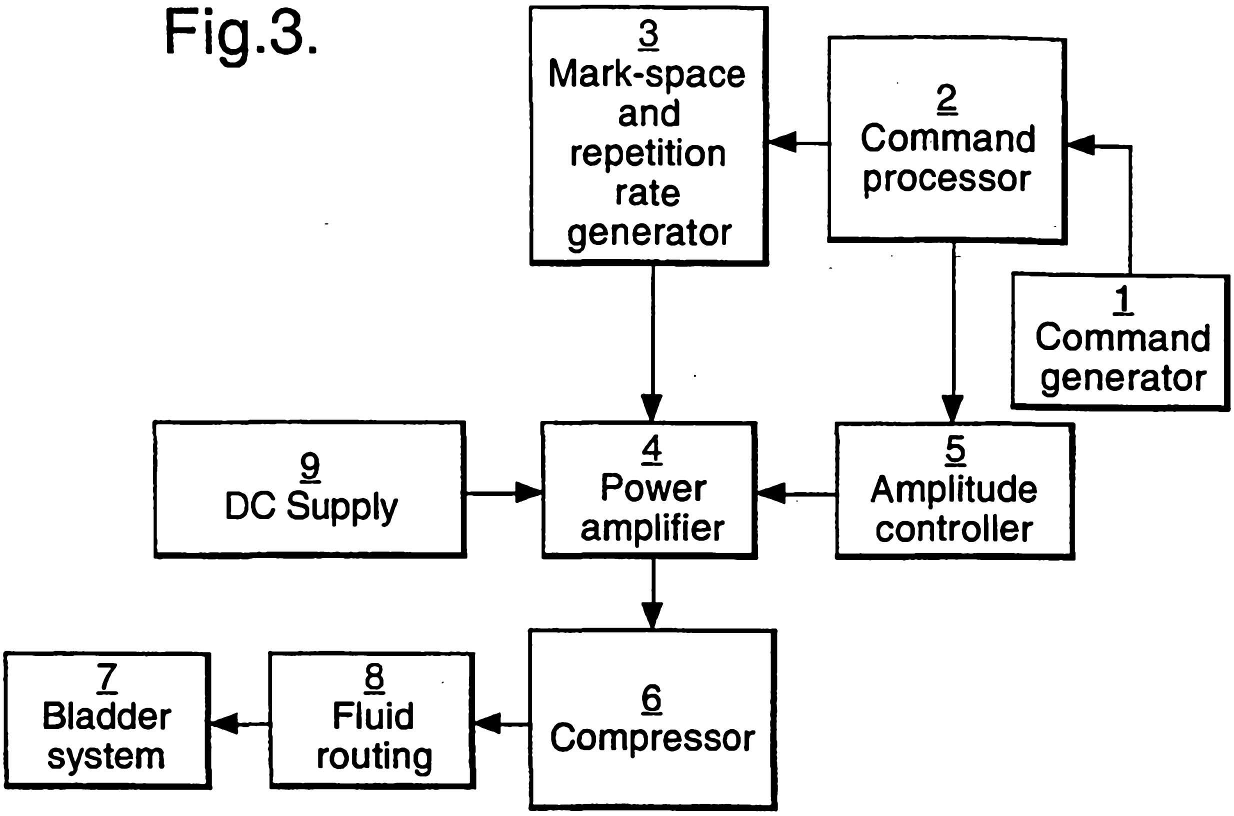

3
Mark-space and repetition rate generator
2
Command processor
1
Command generator
9
DC Supply
4
Power amplifier
5
Amplitude controller
7
Bladder system
8
Fluid routing
6
Compressor

Fig.4.

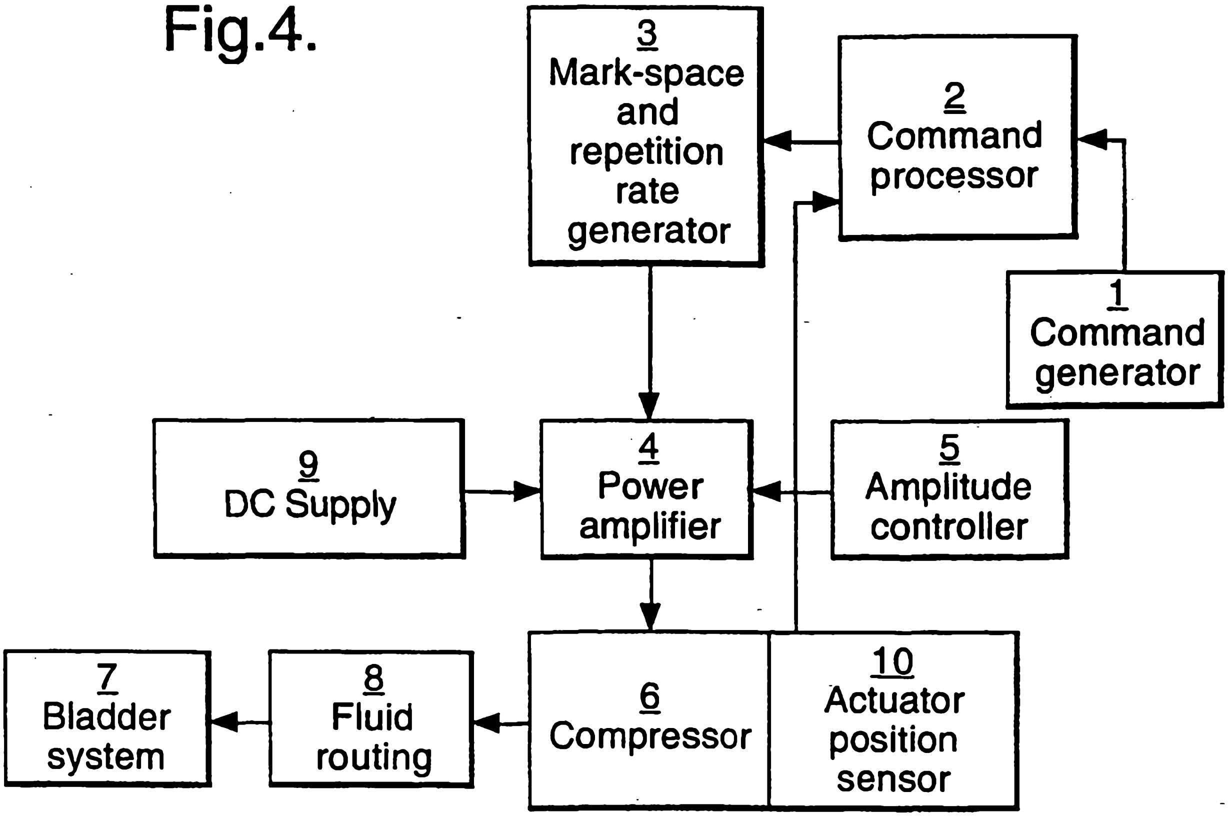
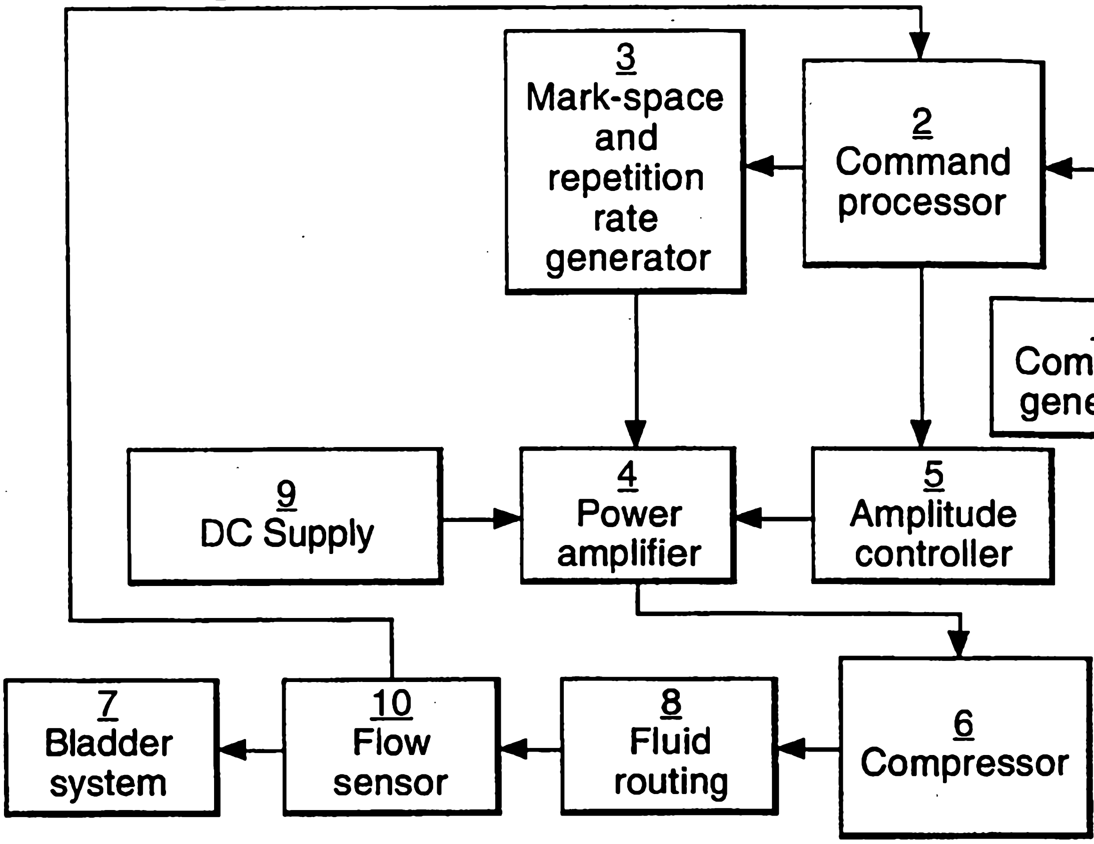

3
Mark-space and repetition rate generator
2
Command processor
1
Command generator
9
DC Supply
4
Power amplifier
5
Amplitude controller
7
Bladder system
8
Fluid routing
6
Compressor
10
Actuator position sensor

Fig.5.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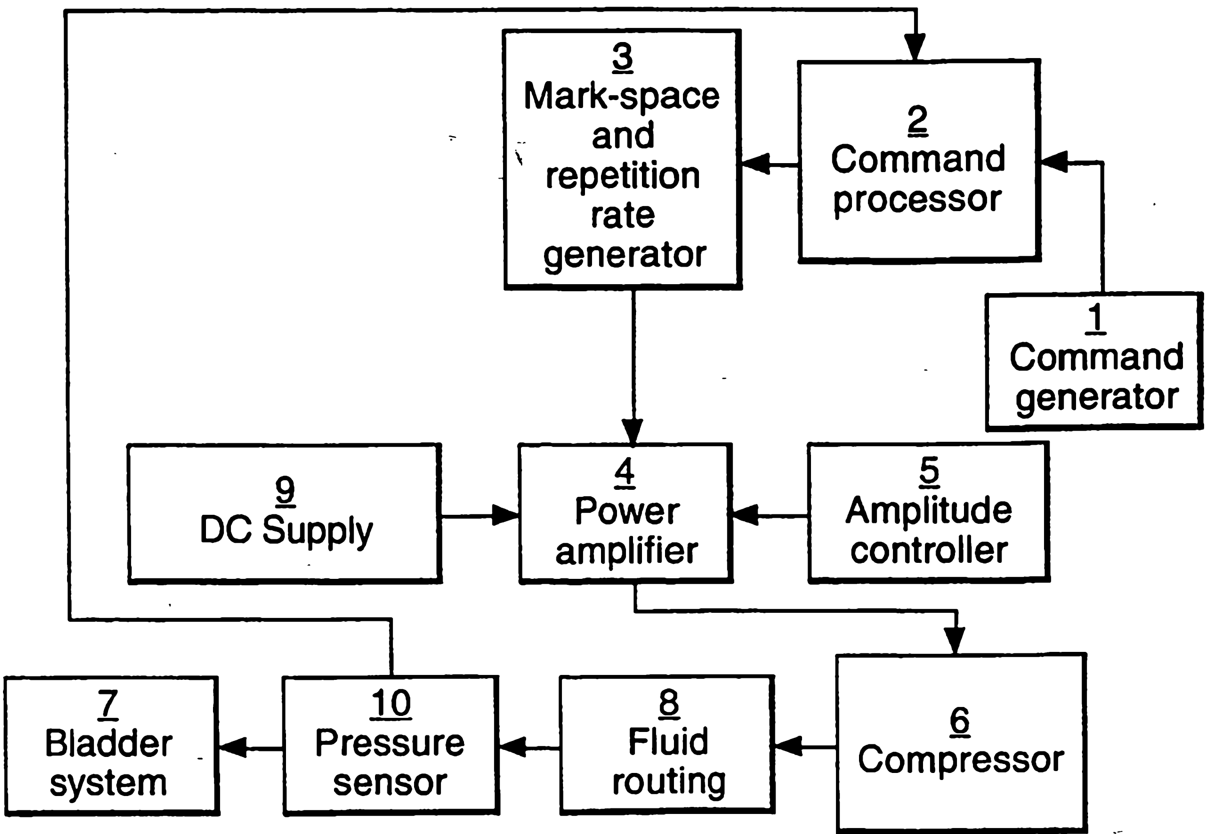
Mark-space and repetition rate generator
2
Command processor
1
Command generator
9
DC Supply
4
Power amplifier
5
Amplitude controller
7
Bladder system
10
Flow sensor
8
Fluid routing
6
Compressor

Fig.6.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Mark-space and repetition rate generator
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Command processor
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Command generator
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DC Supply
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Power amplifier
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Amplitude controller
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Bladder system
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Pressure sensor
8
Fluid routing
6
Compressor