(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 031 937**
A1

(12) # EUROPEAN PATENT APPLICATION

(21) Application number: **80108033.4**

(22) Date of filing: **18.12.80**

(51) Int. Cl.³: **F 15 C 3/14**
F 15 C 3/12

(30) Priority: **21.12.79 FI 794041**

(43) Date of publication of application:
15.07.81 Bulletin 81/28

(84) Designated Contracting States:
AT BE CH DE FR GB IT LI LU NL SE

(71) Applicant: **S-INSTALLATION Ky**
Pyssymiehenkatu 13
SF-40630 Jyväskylä 63(FI)

(72) Inventor: **Seppänen, Alpo, Dipl.-Ing.**
Pyssymiehenkatu 13
SF-40630 Jyväskylä 63(FI)

(74) Representative: **Tiedtke, Harro, Dipl.-Ing. et al,**
Patentanwaltsbüro Tiedtke-Bühling-Kinne-
Grupe-Pellmann Bavariaring 4
D-8000 München 2(DE)

(54) **An electro-pneumatic or electro-hydraulic converter or actuator.**

(57) Disclosed is an electro-pneumatic or electro-hydraulic converter or actuator with a pneumatic or hydraulic nozzle-flap system or similar, which is controlled by an electric control signal. The electric control signal is a pulse sequence signal oscillating at a constant or variable frequency, the duty-cycle of which is varied proportionally to an input signal. The flap or similar is essentially arranged to oscillate in the linear range of its characteristic curve, so that it never completely opens or closes the nozzle or similar, which feature is provided by mechanical stoppers and/or by selecting said frequency sufficiently high.

The invention thus provides a converter or actuator, with improved response speed and linearity and which shows minimal hysteresis.

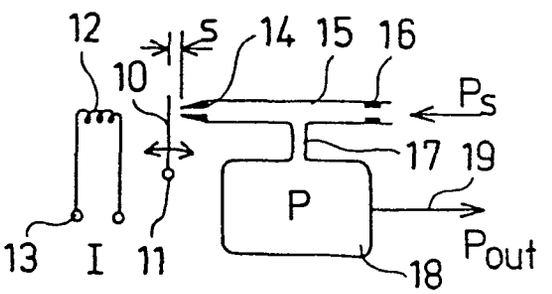

FIG. 1

EP 0 031 937 A1

An electro-pneumatic or electro-hydraulic converter or actuator

The present invention relates to an electro-pneumatic or electro-hydraulic converter or actuator, in which there is a pneumatic or hydraulic nozzle-flap system or similar, as for instance a jet pipe, and which flap or similar is controlled by an electric control signal.

Electro-pneumatic or electro-hydraulic converters or actuators known so far are usually based on the use of a coil submerged in a magnetic field (a so called submerged coil). The force which is directed to said coil is, among other things, approximately proportional to the electric current signal conducted to the coil. The following drawbacks are typical to this well-known system:

A relatively large permanent magnet circuit and a heavy moving coil system in order to provide a sufficient force.

Because of the relatively large mass, the resonance frequency is rather low, which results in a need of special damping that reduces the response speed.

The feedback loop is short as it extends only to the mechanical side and not to the electrical input signal, which results in inaccuracy in system operation.

As to the state of art, a reference is made to the following patent literature: DE-AS 1 295 896, DE-OS 2 239 060 and 2 553 515, CH-PS 597 642, and US-PS 3 456 669.

An objective of the present invention is to provide such a converter or actuator, in which the above-mentioned drawbacks are mostly eliminated. Another objective is to provide such a converter or actuator in which it is possible to structurally use the same primary elements as in converters and actuators now commonly used.

An example of these primary elements is a pneumatic nozzle-flap device.

For attaining the objectives mentioned above and to be expressed later, the principal characteristic feature of the invention is that the electrical control signal is a pulse sequence oscillating at a certain frequence, constant or variable, in which pulse sequence the duty-cycle of the pulse that changes the pneumatic or hydraulic output pressure is varied proportionally to the input signal and within the cycle corresponding to said frequency, and that said flap or similar is essentially arranged to oscillate in the linear range of its characteristic curve so that said flap or similar never completely opens or closes the nozzle, which feature is provided by mechanical stoppers and/or by selecting said basic frequency sufficiently high. In some applications it is also possible to use amplitude modulation of the pulse that varies the output pressure.

The following practically important advantages are attained with a converter or actuator in accordance with the invention.

- the oscillating mass can be made extremely low; therefore the device will not be sensitive to vibrations and no damping is required, which improves the response speed;

- the feedback, when required, can be extended to the electric signal and compared with the input signal, which improves the repeatability and linearity;

- required unlinearities, e.g. in connection with a valve actuator, can easily be brought about by means of an electronic unit;

- the actuating direction can be easily reversed;

- the accuracy requirements when manufacturing mechanical components are not as high as when manufacturing components for known analogical systems, as the control is carried out in pulse form and as the feedback loop, when required, is essentially longer than in

known arrangements;

- in oscillating elements the hysteresis evoked by static friction is minimal.

Embodiments of the invention will now be described in detail, by way of examples only, with no intention to restrict the invention to these details.

Figure 1 is an exemplary embodiment of an electro-pneumatic converter in accordance with the invention.

Figure 2 is a qualitative representation of the characteristic curve of a pneumatic nozzle-flap system in accordance with the invention.

Figure 3 shows three control signals of the primary element.

Figure 4 illustrates an electro-pneumatic converter.

Figure 5 illustrates an electro-hydraulic actuator of a hydraulic cylinder.

Figure 6 illustrates an electro-pneumatic actuator of a valve.

An electro-pneumatic converter illustrated in Figure 1 comprises a nozzle-flap device, essentially known as such. This device comprises flap 10 made of flexible material or supported by bearings at 11. The nozzle-flap device comprises pipe 15 with choke 16 and, near flap 10, nozzle 14. Nozzle pipe 15 is connected by pipe 17 to variable-pressure tank (pressure p), where the output pressure P_{out} of the converter is taken from. On the other side of flap 10, opposite to nozzle 14, there is an electromagnetic coil 12. An electric pulse sequence $I(\tau)$, illustrated in Figure 3, oscillating at a certain basic frequence f_o or alternately at a variable frequency, and of an amplitude I_o as constant as possible, is conducted to terminals 13 of electromagnetic coil 12. In accordance

with the invention, and as shown in Fig. 3, the duty-cycle of the pulse that raises and lowers the pneumatic or hydraulic pressure proportionally to input signal I_{in} is varied within basic cycle T_o corresponding to basic frequence f_o. As illustrated in Figure 3, in its top curve, pulse τ_i which is for instance a pulse for raising the pressure and whose amplitude is I_o is very short compared with the length T_o of the basic cycle; therefore the output pressure P_{out} of Figure 1 is rather low. In the middle curve the pressure-raising pulse τ_2 is approx. 0,5 x T_o and p_{out} then is in the middle area of its dynamic range. In the bottom curve of Figure 3, the pressure-raising pulse τ_3 is relatively long, and output pressure p_{out} is in the top area of its dynamic range. It has to be emphasized that pulses can of course be pressure-lowering pulses as well.

Figure 2 illustrates the ratio of the adjusted pressure p and the input pressure p_s as a function of the length of nozzle slit s of nozzle-flap system 10,14. ΔS illustrates the normal linear operation range, on which the converters and actuators in accordance with the invention function. Thus nozzle 14 is never completely closed or opened much enough to enter the unlinear bottom section of the characteristic curve. In the figure, $2p/p_s = 1$ naturally represents the position in which flap 10 is completely closed, and $p/p_s = 0$ represents the position in which flap 10 is completely open. In a converter in accordance with the invention, the primary element, for instance nozzle-flap device 10,14, is made vibrate, for instance magnetically. Due to electrical and mechanical quantities, such as resistance, inductance, and the masses of the moving springs of the primary element and the pneumatic or hydraulic amplifying unit possibly following it, the primary element will not, when vibrating, reach the extreme positions (Figure 2). According to Figure 2, reaching the extreme positions would not be practical, as this would impair the amplification factor or the system linearity. In practice it has also been found out that the response speed of a converter or an actuator in accordance with the invention will, to a certain extent, be increased as the basic frequency f_o increases.

In control system illustrated in Figures 4,5, and 6, there is an

electronic unit 20, which works as a combined signal/pulse converter and as a difference organ (Σ). Because of facts described above, pulses leaving the electronic unit 20 tend to integrate in mechanical and pneumatic or hydraulic circuits that follow unit 20. A mathematical representation of this phenomenon is:

$$k \cdot p = \frac{1}{T_o} \int_o^{\tau} I dt$$

where k = proportionality factor

p = pneumatic or hydraulic pressure

T_o = basic cycle

τ = length of the pulse raising or lowering the pulse

I = electrical pulse quantity leaving the electronic unit (e.g. a constant current of the magnetic circuit).

An electro-pneumatic converter illustrated in Figure 4 comprises a pneumatic amplifier relay 21, to which the pneumatic input pressure p_s is brought. Output pressure p_{out} of the nozzle-flap system 10,12, 14 operating as described above is adjusted so to be proportional to input signal I_n. The feedback loop of the system comprises pneumatic bellows 27 and organ 37 which converts the force into an electrical signal. Feedback signal I_{in} is conducted via wire 26 to unit 20. Control signal $I(\tau)$ illustrated in Figure 3, is formed according to the difference signal $I_{in}-I_1$.

Figure 5 shows an actuator of an electro-hydraulic cylinder, in accordance with the invention. The actuator comprises a hydraulic cylinder 30 that has piston 31 and piston rod 32, whose position or movement d_{out} is the output signal. The system comprises organ 28 which converts the position-information to an electric signal. The feedback signal is conducted from this organ 28 via wire 26 to unit 20. A control system shown in Figure 5 also comprises a jet pipe 10', oscillating in accordance with the invention, through whose nozzle 34 hydraulic fluid is conducted to pipes 33a and 33b merging

in mouthpiece 35. Pipes 33a and 33b are connected to opposite sides of piston 31 in cylinder 30 so that, according to the position of nozzle 34 of the vibrating jet pipe 10', piston 31 of cylinder 31 moves to the position corresponding to control signal $I(\tau)$. This control system comprises hydraulic pump 29 and tank 36 with hydraulic fluid, whose level is indicated by 0.

Figure 6 illustrates an electro-pneumatic valve actuator in accordance with the invention, comprising a pneumatic amplifier relay 21, whose pressure is conducted to diaphragm motor 22 actuating the control valve 23. The feedback loop of the actuator comprises organ 24 that converts the position of valve 23 into an electrical signal. This organ 24 conducts the feedback signal I_1 via wire 26 to unit 20.

The output quantity of the system 12 for instance the flow F_{out} controlled by valve 23.

Though, in Figure 3, the control signal is a current signal $I(\tau)$, it should be noted that the control signal can also be something else than electric current. The same applies to the set value signal or input signal I_{in}. If a current signal is used as the input signal, it should be within range 4...20 mA.

By using a sufficiently high frequency the nozzle-flap system 10,14 or similar can be made operate in the linear area ΔS shown in Figure 2 in such a way that nozzle 14 is never completely closed or opened. In some cases the lower limit of frequency f_o is approx. 15 Hz. However, the most favourable frequency range from the point of view of the invention is over 20 Hz, for instance 30...50 Hz. In some cases the frequency can be of the order of 100 Hz.

If, for some reason, it is not desired to maintain the frequency in said linear range by choosing a sufficiently high frequency f_o, which, however, is usually the best solution, it is possible, in addition to a sufficiently high frequency, to use mechanical stoppers which limit the vibration amplitude of flap 10. In a converter or actuator in accordance with the invention, feedback cannot usually

be favourably used, though it is not impossible, as the feedback reduces the size of the linear area ΔS.

Altough a basic frequency f_o has been under consideration, it should be emphasized that the invention can also be applied in such a way as to make frequency $f_o = 1/T_o$ variable. Thus it is possible to maintain pulse τ constant and, instead of frequency f_o, change the output pressure p_{out} or corresponding d_{out} by varying the cycle $T_o = 1/f_o$ and consequently also the duty-cycle $\frac{\tau}{T_o - \tau}$. In the framework of the invention both the pulse length τ and cycle T_o (i.e. frequency f_o) can also be used as a control signal. In some applications amplitude F_o can also be varied for control purposes.

Claims

1. An electro-pneumatic or electro-hydraulic converter or actuator, in which there is a pneumatic or hydraulic nozzle-flap system (10,11,14) or similar, as for instance a jet pipe (10',34,35), and which flap (10) or similar (10') is controlled by an electric control signal, wherein the electrical control signal is a pulse sequence ($I(\tau)$) oscillating at a certain frequence (f_o), constant or variable, in which pulse sequence the duty-cycle ($\tau/T_o - \tau$) of the pulse that changes the pneumatic or hydraulic output pressure (p_{out}) or similar (d_{out}) is varied proportionally to the input signal (I_{in}) and within the cycle (T_o) corresponding to said frequency (f_o), and that said flap (10) or similar (10') is essentially arranged to oscillate in the linear range (ΔS) of its characteristic curve (Figure 2) so that said flap (10) or similar (10') never completely opens or closes the nozzle (14), which feature is provided by mechanical stoppers and/or by selecting said frequency (f_o) sufficiently high.

2. A converter or actuator in accordance with claim 1, wherein said basic frequency (f_o) is higher than approx. 30 Hz.

3. A converter or actuator in accordance with claim 1 or 2, wherein the primary element is a pneumatic nozzle-flap combination (10,14) known as such, in which the flap (10) is made oscillate by means of said pulse sequence ($I(\tau)$), which is conducted to an electromagnetic coil (12) or similar installed in connection with the flap (10).

4. A converter or actuator in accordance with claim 1, wherein the primary element is an oscillating jet pipe (10'), whose nozzle (34) oscillates near a mouthpiece (35), in which the pipes (33a,33b) leading to the two sides of the piston (31) of the hydraulic cylinder (30) merges.

5. A converter or actuator in accordance with claim 1,2,3, or 4, wherein the basic frequency (f_o) of said electric pulse sequence

($I(\tau)$) is within range 30...40 Hz.

6. A converter or actuator in accordance with claim 1,2,3,4, or 5, wherein an electric feedback signal (I_1) is formed from the output signal (p_{out}) of the converter or from the position (d_{out}) of the hydraulic or pneumatic cylinder (22;30,31,32) of the actuator, and that said feedback signal (I_1) is conducted to an electronic unit (20) arranged so as to function as a combined difference organ (Σ) and converter, which converts an analogical input signal (I_{in}) into a pulse sequence ($I(\tau)$).

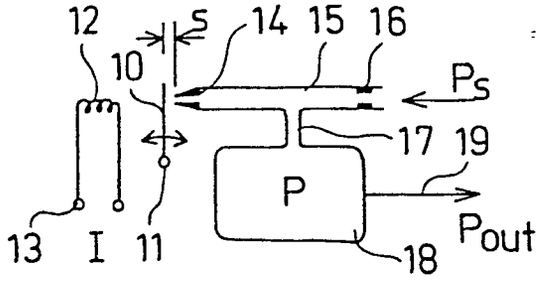

FIG. 1

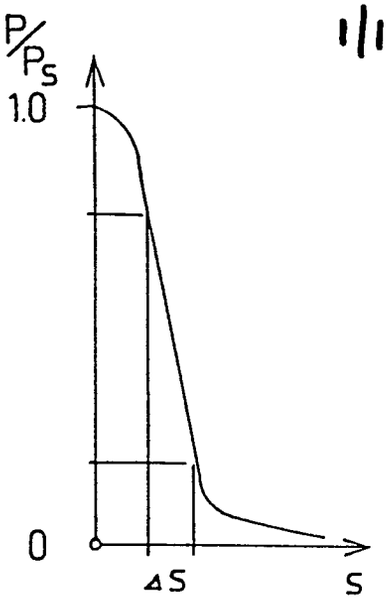

FIG. 2

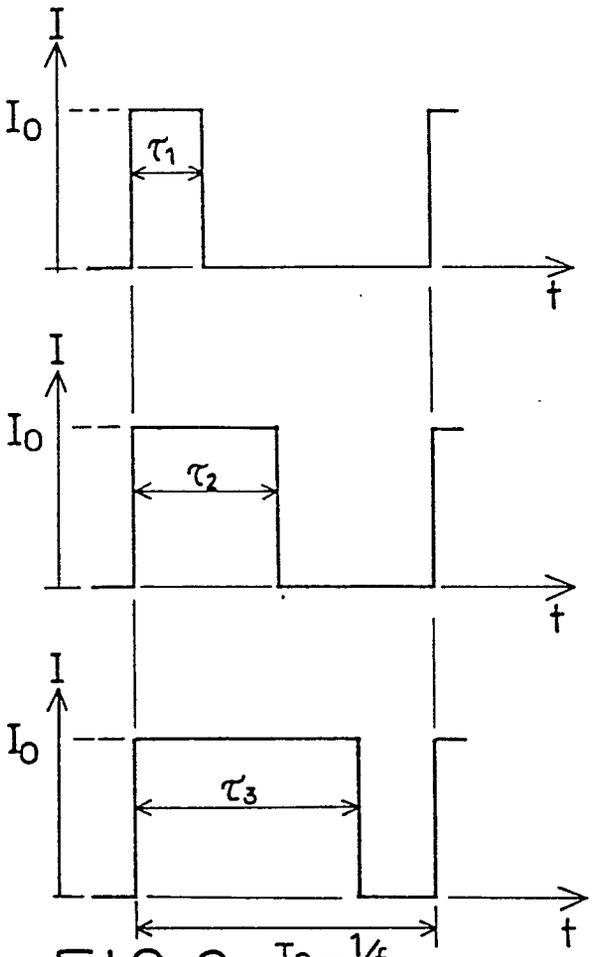

FIG. 3

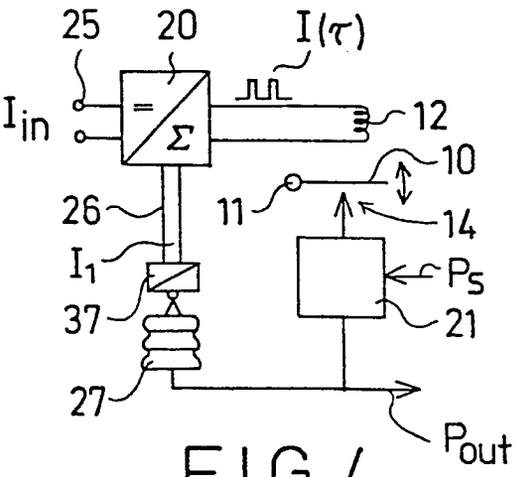

FIG. 4

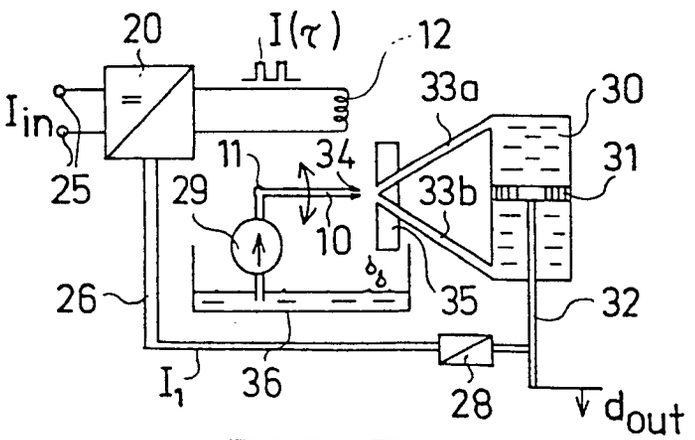

FIG. 5

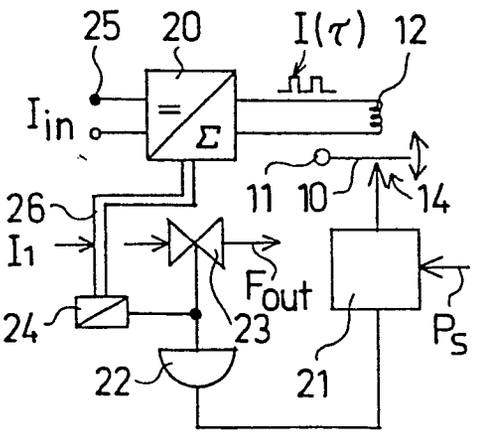

FIG. 6

European Patent Office

EUROPEAN SEARCH REPORT

0031937

Application number
EP 80 10 8033

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
	GB - A - 2 016 746 (KNORR) * page 1, lines 97-116; page 4, lines 39-103 *	1-3,6
	US - A - 3 099 995 (JOENS) * column 1, lines 19-37; column 3, lines 48-63 *	1,3,4
D	DE - A - 2 239 060 (MACHIDA) * claim 1 *	1,6
	DE - A - 2 511 752 (VFW-FOKKER) * page 4, line 5 - page 5, line 9 *	4,6

CLASSIFICATION OF THE APPLICATION (Int. Cl.³)

F 15 C 3/14
3/12

TECHNICAL FIELDS SEARCHED (Int. Cl.³)

F 15 C 3/14
3/12
3/10
F 15 B 5/00
G 05 D 16/20
G 01 D 5/44
5/46
5/54
5/56

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	09-04-1981	THOMAES

EPO Form 1503.1 06.78