

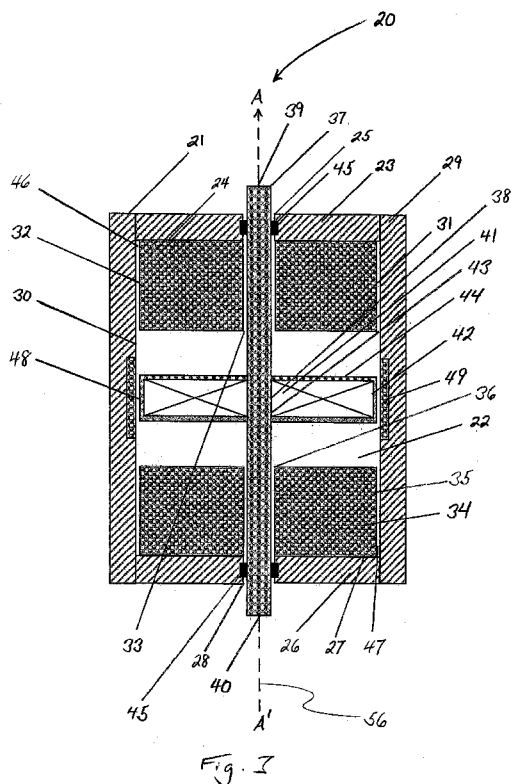


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- (71) **Applicant: ACTIVE SIGNAL TECHNOLOGIES, INC.**
[US/US]; 611 Hammonds Ferry Road, Unit Q, Linthicum,
Maryland 21090 (US).
- (72) **Inventor: KOHLHAFFER, Dennis John;** 4406 Columbia
Road, Ellicott City, Maryland 21042 (US).
- (74) **Agent: STITZEL, David P.;** Pietragallo Gordon Alfano
Bosick & Raspani, LLP, One Oxford Centre, 38th Floor,
301 Grant Street, Pittsburgh, Pennsylvania 15219 (US).

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[Continued on nextpage]

(54) **Title:** ELECTROMAGNETIC OPPOSING FIELD ACTUATORS

(57) **Abstract:** Electromagnetic actuators capable of generating a symmetrical bidirectional force are disclosed. The electromagnetic actuators include a housing made of a ferromagnetic material and a shaft made of a magnetically inert material movable along an axis within the housing. In one type of actuator, captive permanent magnets are arranged on opposite interior end walls of the housing and an electromagnetic coil is mounted on a central portion of the shaft. The electromagnetic coil is capable of generating a force when energized that causes linear displacement of the shaft in either direction along its axis depending on the direction of current through the electromagnetic coil. In another type of actuator, captive electromagnetic coils are arranged on opposing inner end walls of the housing, and a permanent magnet is mounted on a central portion of the shaft. The electromagnetic coils are capable of generating a force when energized that causes linear displacement of the shaft in either direction along its axis depending on a direction of current through the electromagnetic coils.

Declarations under Rule 4.17:

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.1 7(H))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.1 7(Hi))

— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

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INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER INV. H01F7/06 H02K33/18 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) H01F H02K F02M		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal , WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2004/093718 A1 (TAKEUCHI TOSHIE [JP] ET AL) 20 May 2004 (2004-05-20) paragraphs [0047] - [0049] , [0054] , [0055], [0057] - [0059], [0061], [0064] -----	1-23, 41
A	US 2011/248804 A1 (WYGNANSKI WLADYSLAW [GB]) 13 October 2011 (2011-10-13) paragraphs [0039] - [0042], [0045] - [0047] -----	1-23, 41
A	US 4 439 700 A (MENZEL KLAUS [DE] ET AL) 27 March 1984 (1984-03-27) column 2, line 22 - column 3, line 38 -----	1-23, 41
A	US 2012/007448 A1 (GOSVENER KENDALL C [US]) 12 January 2012 (2012-01-12) paragraphs [0044] - [0046] , [0048] , [0049], [0050] - [0053] ----- <div style="text-align: right;">-/--</div>	1-23, 41
<div style="display: flex; justify-content: space-between;"> <input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex. </div>		
<div style="display: flex;"> <div style="flex: 1;"> <p>* Special categories of cited documents :</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="flex: 1;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&" document member of the same patent family</p> </div> </div>		
Date of the actual completion of the international search <div style="text-align: center;">5 November 2014</div>		Date of mailing of the international search report <div style="text-align: center;">20/01/2015</div>
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer <div style="text-align: center;">Gols, Jan</div>

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/040091

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>US 5 535 853 A (SKALSKI CLEMENT A [US]) 16 July 1996 (1996-07-16) col umn 4, line 35 - col umn 5, line 60 col umn 10, lines 35-39 -----</p>	1-23 ,41

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/040091

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos. :

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos. :

1-23 , 41

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-23, 41

An electromagnet ic actuator capable of generati ng a symmetri cal bi directi onal force comprising:
 a housi ng comprising a ferromagnet ic materi al , wherei n the housi ng has a first end wal l , a second end wal l opposi te the first end wal l , and a si de wal l interconnecti ng the first and second end wal ls;
 a first capti ve permanent magnet arranged on the first end wal l and having an i nward faci ng pole;
 a second capti ve permanent magnet arranged on the second end wal l and having an i nward faci ng pole arranged to repel the i nward faci ng pole of the first permanent magnet causi ng the first and second permanent magnets to have opposi ng magneti c fi elds;
 a shaft comprising a magneti cally i nert materi al , wherei n the shaft is movable al ong a l ongi tudi nal axi s extendi ng between the first and second end wal ls, and comprises a central porti on i nterposed between the first and second permanent magnets; and
 an electromagnet ic coi l arranged on the central porti on of the shaft,
 wherei n the electromagnet ic coi l is capable of generati ng a force when energi zed that causes l i near di splaceme nt of the shaft i n ei ther directi on al ong the l ongi tudi nal axi s dependi ng on a directi on of current through the electromagnet ic coi l .

2. claims: 24-40, 42

An electromagnet ic actuator capable of generati ng a symmetri cal bi directi onal force comprising:
 a housi ng comprising a ferromagnet ic materi al , wherei n the housi ng has a first end wal l , a second end wal l opposi te the first end wal l , and a si de wal l interconnecti ng the first and second end wal ls;
 a first capti ve electromagnet ic coi l arranged on the first end wal l ;
 a second capti ve electromagnet ic coi l arranged on the second end wal l , wherei n the first and second electromagnet ic coi ls have opposi ng electromagnet ic fi elds when energi zed;
 a shaft comprising a magneti cally i nert materi al , wherei n the shaft is movable al ong a l ongi tudi nal axi s extendi ng between the first and second end wal ls, and comprises a central porti on i nterposed between the first and second electromagnet ic coi ls; and
 a permanent magnet arranged on the central porti on of the shaft,
 wherei n the first and second electromagnet ic coi ls are capable of generati ng a force when energi zed that causes a l i near di splaceme nt of the shaft i n ei ther directi on al ong

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

the longitudinal axis depending on a direction of current
through the first and second electromagnetic coils.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2014/040091

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