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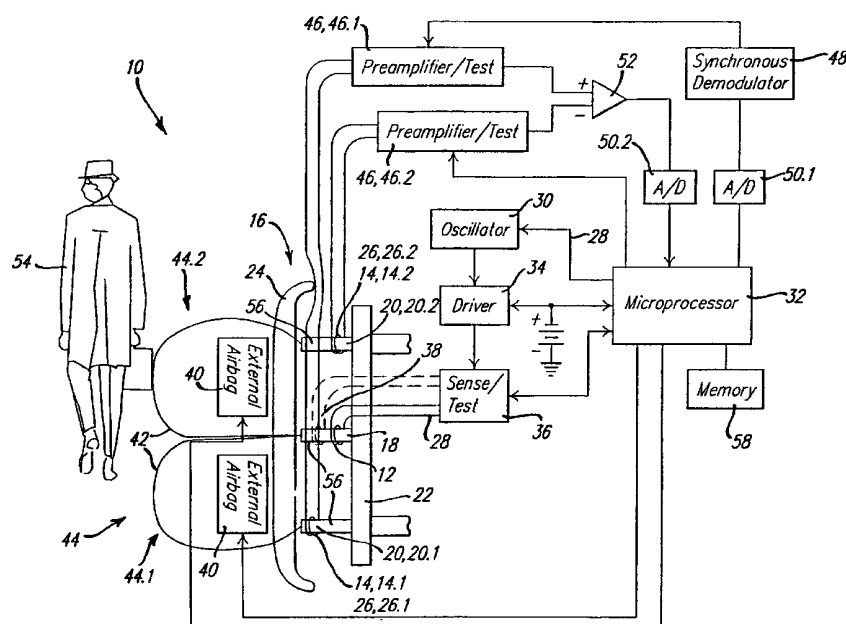
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(54) Title: MAGNETIC SENSOR



(57) Abstract: A pedestrian (54) is sensed in a region of space external to a vehicle (16) by generating a first magnetic flux (42) at a first location (18) on the vehicle (16) so that the first magnetic flux (42) extends into a region of space external of the vehicle (16), conducting the first magnetic flux (42) through the region of space external to the vehicle (42) to a second location (20) on the vehicle (12), sensing the first magnetic flux (42) at the second location (20), generating a signal responsive to the magnetic flux (42) sensed at the second location (20), and discriminating a pedestrian (54) when the pedestrian is located within the first magnetic flux (42), wherein the operation of discriminating is responsive to the signal.

MAGNETIC SENSOR

In the accompanying drawing:

FIG. 1 illustrates a first embodiment of a magnetic sensor.

Referring to **Fig. 1**, a **magnetic sensor 10** comprises at least one **first coil 12** and at least one **magnetic sensing element 14** incorporated on a **vehicle 16** proximate to the exterior thereof at respective **first 18** and **second 20** locations. For example, a **first coil 12** is mounted at the center of a **lateral ferromagnetic beam 22**, such as a radiator support beam, at the front of the **vehicle 16** proximate to and behind the **front bumper 24**, and a plurality of **magnetic sensing elements 14.1, 14.2**, for example a plurality of **second coils 26.1, 26.2**, are mounted at on the same **lateral ferromagnetic beam 18** at **left 20.1** and **right 20.2** locations that are relatively distal with respect to the **first location 18**.

The at least one **first coil 12** is operatively connected to a corresponding at least one **first signal 28** comprising a sinusoidal voltage generated by an **oscillator 30**. For example, the **oscillator 30** may comprise a crystal stabilized (i.e. substantially drift-free) TTL square wave signal generated by a **microprocessor 32** and subsequently filtered by a band-pass filter. The oscillation frequency of the **oscillator 30** is selected, as a function of the expected noise sources, to enhance system performance. For example, a frequency different from that of AC power lines (e.g. 60 Hz) would be chosen to avoid interference therefrom. For example, an ultrasonic frequency might be used. The **oscillator 30** may be modulated in amplitude, frequency, or by bursting. The signal from the **oscillator 30** is fed to a **coil driver 34**, for example, through a buffer amplifier.

Each at least one **first coil 12** is driven by an associated **coil driver 34** that provides sufficient power at an impedance compatible with the **first coil 12** so that the resulting magnetic field is sufficiently strong to be detected by the at least one **magnetic sensing element 14**. The **coil driver 34** is also, for example, provided with short circuit protection and is operated so as to avoid saturation or clipping of the **first signal 28**. The **coil driver 34** is designed to operate in an automotive environment, for example to operate over an associated range of possible battery voltages. The **first signal 28** from the **coil driver 34** may, for example, be either a voltage signal or a current signal.

The **coil driver 34** drives the **first coil 12** through a **sense/test circuit 36**. The **sense/test circuit 36** senses either a current or voltage from the **first coil 12**, or a signal from a supplemental **sense coil 38**, or a combination of the three, to confirm or test the operation of the **first coil 12**. For example, a supplemental **sense coil 38** would directly
5 sense the **magnetic flux 42** generated by the **first coil 12**. The **sense/test circuit 36** may also, for example, test the **first coil 12** for an open or short so as to improve the reliability of the **magnetic sensor 10**, particularly when used to control the actuation of a **safety restraint actuator 40**, so as to prevent a false deployment or a failure to deploy when necessary. The integrity, or health, of the at least one **first coil 12** is tested every
10 measurement cycle. The **sense/test circuit 36** can also provide a measure of the power delivered to the **first coil 12** which can provide an indication of the presence and type of object proximate thereto.

The at least one **first coil 12** may, for example, be series resonated to increase the current flow therein, thereby increasing the amount of **magnetic flux 42** generated by the
15 at least one **first coil 12**. The **magnetic flux 42** from the at least one **first coil 12** extends into the region of space proximate thereto, in front of the **vehicle 16**, and is attracted to materials of relatively high permeance therein. The at least one **first coil 12** is part of a **magnetic circuit 44** that further comprises the regions of space between the at least one **first coil 12** and the at least one **magnetic sensing element 14**. With a first coil 12
20 spanned by a plurality of **magnetic sensing elements 14.1, 14.2**, the **magnetic circuit 44** can be considered as a superposition of **left 44.1** and **right 44.2 magnetic subcircuits**. Increased **magnetic flux 42** in the **magnetic circuit 44** provides for a higher signal to noise ratio in the signal or signals received or detected by the **magnetic sensor 10**. The at least one **first coil 12** may be compensated for variations in temperature by incorporating
25 an associated temperature sensor.

The at least one **magnetic sensing element 14** is responsive to the **magnetic flux 42** at the at least one **second location 20**. An output from the at least one **magnetic sensing element 14** is operatively connected to a **preamplifier/test circuit 46** which, for example, buffers the **magnetic sensing element 14** from loading by the subsequent circuitry and
30 provides a relatively low impedance output so as to reduce noise. The **preamplifier/test circuit 46** also amplifies the signal from the at least one **magnetic sensing element 14** to a level sufficiently high to permit appropriate signal processing and demodulation before

subsequent analog-to-digital conversion for processing by the **microprocessor 32**. The **microprocessor 32** gathers data, monitors system health and integrity, and determines whether or not to actuate the **safety restraint actuator 40**.

The **preamplifier/test circuit 46** also monitors the integrity of the **magnetic sensing element 14**, for example by comparing the signal therefrom with "expected" levels and expected wave shapes (e.g. a sinusoidal shape), providing a continuous test of the integrity of the **magnetic sensing element 14**. The **preamplifier/test circuit 46** may also, for example, test the at least one **magnetic sensing element 14**, for example a **second coil 26**, for an open or short so as to improve the reliability of the **magnetic sensor 10**, particularly when used to control the actuation of a **safety restraint actuator 40**, so as to prevent a false deployment or a failure to deploy when necessary. The integrity, or health, of the at least one **magnetic sensing element 14** is tested every measurement cycle.

The **magnetic sensing element 14** senses from the **magnetic flux 42** a sinusoidal carrier that is modulated responsive to the reluctance of the **magnetic circuit 44**.

In accordance with one aspect, the signal from the **magnetic sensing element 14** is amplified by the **preamplifier/test circuit 46**, and a **synchronous demodulator 48** operatively connected thereto extracts the modulation signal from the sinusoidal carrier. The output from the **synchronous demodulator 48** is DC coupled the **microprocessor 32** through an **A/D converter 50.1**.

Respective **preamplifier/test circuits 46.1** and **46.2** are operatively coupled to respective **magnetic sensing elements 14.1** and **14.2**, and outputs from the respective **preamplifier/test circuits 46.1** and **46.2** are operatively coupled to respective differential inputs of a **differential amplifier 52**, the output of which is operatively connected the **microprocessor 32** through an **A/D converter 50.2**.

The above described **magnetic sensor 10** can be embodied in various ways. The particular circuitry, whether analog, digital or optical is not considered to be limiting and can be designed by one of ordinary skill in the art in accordance with the teachings herein. For example, where used, an oscillator, amplifier, logic element, modulator, demodulator, A/D converter can be of any known type, for example using transistors, for example field effect or bipolar, or other discrete components; integrated circuits; operational amplifiers,

or logic circuits, or custom integrated circuits. Moreover, where used, a microprocessor can be any computing device.

Responsive to the at least one **first signal 28**, the at least one **first coil 12** generates a magnetomotive force in the **magnetic circuit 44** so as to generate a **magnetic flux 42** therein. The at least one **magnetic sensing element 14** at the at least one **second location 20** senses the **magnetic flux 42** thereat, which is responsive to the magnetomotive force from the at least one **first coil 12** and to the magnetic properties of the **magnetic circuit 44**.

In operation, the at least one **first signal 28** operatively coupled to the associated at least one **first coil 12** by the associated at least one **coil driver 34** causes a current flow in the at least one **first coil 12** which generates a **magnetic flux 42** in the **magnetic circuit 44**. A **magnetic circuit 44** is characterized by a reluctance **R**, wherein the amount of flux in a magnetic circuit for a given magnetomotive force **F** is given by $\Phi = F/R$. The reluctance **R** of a series magnetic circuit is given by the sum of the respective reluctances of the respective elements in series. The reluctance of air is significantly greater than that of a ferromagnetic material, and a ferromagnetic material entering the **magnetic circuit 44** affects the reluctance **R** of the **magnetic circuit 44**, which in turn affects the amount of flux to which the **magnetic sensing element 14** is exposed, and which is sensed thereby. A **pedestrian 54** proximate to the front of the **vehicle 16** can be sensed by the **magnetic sensor 10** from the permeance of iron containing blood, which is sufficient to influence the **magnetic flux 42** in the **magnetic circuit 44** enough to be detectable by the **magnetic sensing element 14**.

The **first coil 12** has a self-inductance having one value when the **first coil 12** is in free space, and another when the coil is part of the **magnetic circuit 44**. In the latter case, the self inductance of the **first coil 12** is dependent upon the magnetic properties of the **magnetic circuit 44**. Moreover, the magnetic properties of the **magnetic circuit 44** are altered if ferromagnetic elements are brought in proximity with the **magnetic circuit 44**. Accordingly, a **pedestrian 54** proximate to the front of the **vehicle 16** can influence the self-inductance of the **first coil 12**, and can change the magnetic coupling between a **first coil 12** at a **first location 22** and the **magnetic sensing element 14** at a **second location 20**.

The ferromagnetic elements in the front of the **vehicle 16**, can act as a magnetic lens to concentrate or focus the **magnetic flux 42** within a region to be sensed. The **magnetic flux 42** generally follows a path of least reluctance, which typically would correspond to sections of greatest amounts of magnetically permeable material. Accordingly, the **magnetic circuit 44** may be augmented with ferrite or mu-metal elements, or permanent magnets, to further adjust the shape and extent of the magnetic field. For example, the **first 12** and **second 26.1, 26.2** coils can be wound around **ferrite cores 56** to enhance their performance.

Both the power applied to the at least one **first coil 12**, and the gain and/or phase of the signal from the at least one **magnetic sensing element 14** in relation to the at least one **first signal 28**, may be continuously monitored and stored in a **memory 58** of a **microprocessor 32** as a real-time magnetic signature of the seat occupancy condition. The real-time magnetic signature is compared with at least one other comparable magnetic signature -- for example at least one normal magnetic signature representing an unobstructed vehicle or various magnetic signatures representing various pedestrian scenarios, or other obstructions -- in order to determine if an associated **safety restraint actuator 40**, for example at least one external air bag, should be deployed to protect a **pedestrian 54** from injury by the **vehicle 18**. The normal signature may be updated over time so as to track minor perturbations of the **vehicle 16**.

The **magnetic sensor 10** provides a real-time validation of the health and integrity of the respective at least one **first coil 12** and the at the **second coils 26.1 and 26.2**, by testing the respective coils for shorts or open conditions, or by using a separate **sense coil 38** to detect the **magnetic flux 42** generated by the at least one **first coil 12**.

The coils or sensing elements may incorporate a ferrite or other high permeability magnetic core. Also, highly-tuned coils can be used for magnetic signal generation. Moreover, the width and length of coil bobbins can be adapted to steer the **magnetic flux 12**.

The location, diameter and spacing of the at least one **first coil 12** and the at least one **second coil 26** can be adapted to maximize the performance of a signal from a human locator. Moreover, **first 12** or **second 26** coils located in the bumper, grill, hood and wiper

gutter would allow the **magnetic sensor 10** to follow the trajectory of the **pedestrian 54** so as prior to impact so as to deploy the proper **safety restrain system 40** at the proper time.

The signals associated with the **magnetic sensor 10** can be generated, adapted or processed in a variety of ways, including but not limited to:

- 5 1. AM, FM or pulsed demodulation of the magnetic signature;
2. Multi-tone, multi-phase electronics;
3. A magnetically-biased, phase-shift oscillator for low-cost pure sine wave generation;
- 10 4. A coherent synthetic or phased-locked carrier hardware- or microprocessor-based system;
5. A system of microprocessor gain-or offset-tuning through D/A then A/D self-adjust or self-test algorithm;
6. Placing a "standard" in the system safing field for magnetic calibration;
7. Inaudible frequencies;
- 15 8. Microprocessor-generated crystal stabilized frequencies for stability, including microprocessor D/A converter for coherent sine-wave generation;
9. Wide-band system electronics;
10. Closed loop gain- and phase-control of the signal to a sending-coil (i.e. AGC with the magnetic circuit acting as a delay line), wherein the gain- and phase-control signals are used as sensor outputs;
- 20 11. Monitoring the power delivered by the coil driver, particularly the bypass power, in order to detect impacts near or at the hinge(s) magnetically energized with the at least one first coil;
12. A series-resonant coil driver-circuit to increase current to flow to the at least one
25 **first coil 12** so as to improve the signal-to-noise ratio, wherein the associated current to the at least one **first coil 12** is monitored to provide a continuous self-test of the at least one **first coil 12**, as well as a measure of the power drawn by the at least one **first coil 12**; and

13. Using another type of **magnetic sensing element 14**, for example a Hall effect device, instead of a **second coil 26**.

The **magnetic sensor 10** may be further adapted to detect a **pedestrian 54** proximate to the **vehicle 16** from the Doppler shift of the frequency of the **magnetic flux 42** responsive
5 to the pulsating blood flow of the **pedestrian 54**, so as to distinguish between animate and inanimate objects on the seat. Infants are known to have a relatively fast heart rate which could be expected to provide a larger Doppler shift.

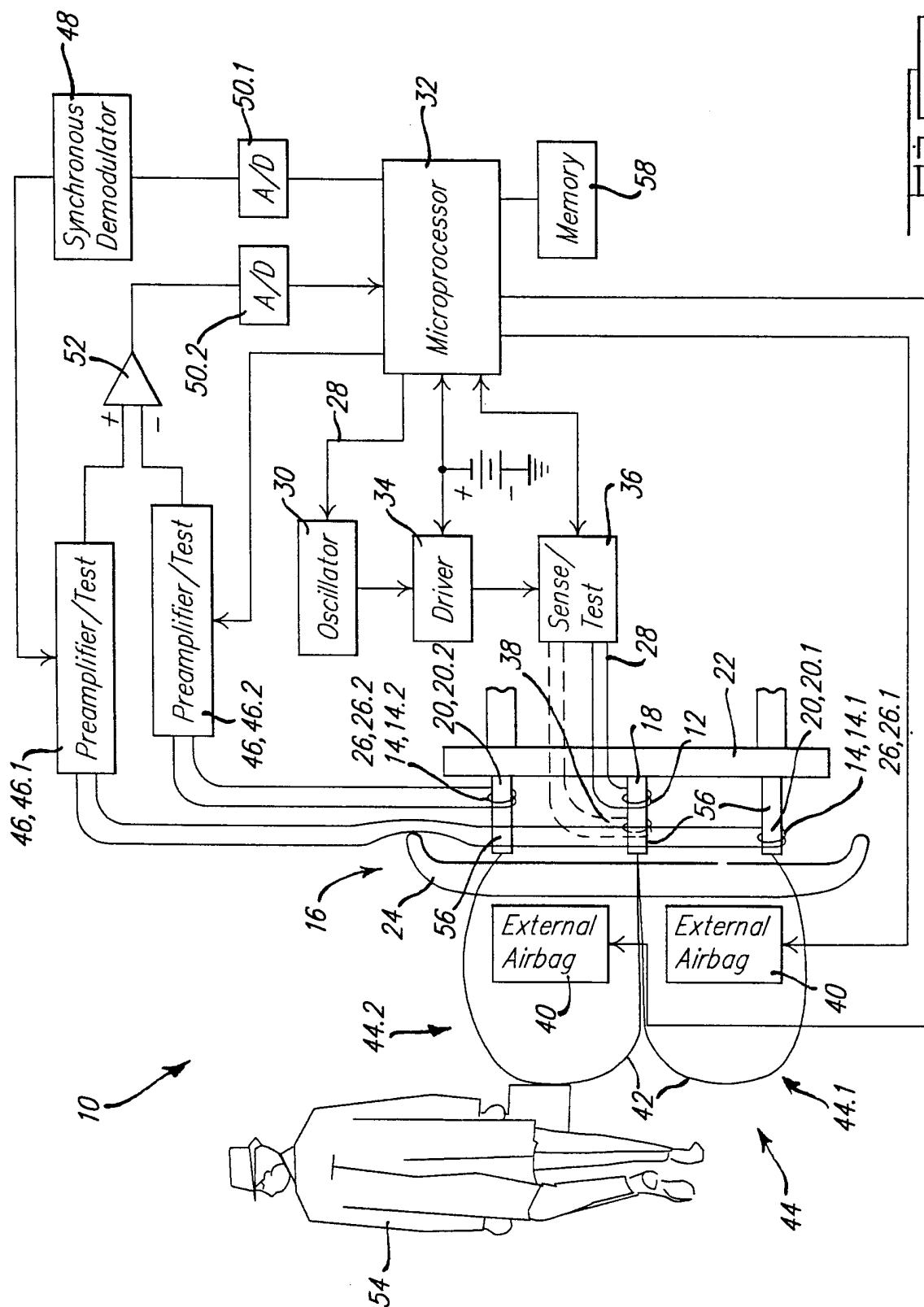
While specific embodiments have been described in detail in the foregoing detailed description and illustrated in the accompanying drawings, those with ordinary skill in the
10 art will appreciate that various modifications and alternatives to those details could be developed in light of the overall teachings of the disclosure. Accordingly, the particular arrangements disclosed are meant to be illustrative only and not limiting as to the scope of the invention, which is to be given the full breadth of the appended claims and any and all equivalents thereof.

WE CLAIM:

1. A method of sensing a pedestrian in a region of space external to a vehicle, comprising:

- a. generating a first magnetic flux at a first location on said vehicle so that said first magnetic flux extends into a region of space external of said vehicle;
- b. conducting said first magnetic flux through said region of space external to said vehicle to a second location on said vehicle;
- c. sensing said first magnetic flux at said second location;
- d. generating a signal responsive to said magnetic flux sensed at said second location; and
- e. discriminating a pedestrian when said pedestrian is located within said first magnetic flux, wherein said operation of discriminating is responsive to said signal.

2. A method of sensing a pedestrian in a region of space external to a vehicle as recited in claim 1, further comprising controlling the actuation of a safety restraint actuator to protect said pedestrian from a collision with the vehicle, wherein the operation of controlling the actuation of a safety restraint actuator is responsive to said operation of discriminating.



INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G08B 21/00, 13/08; B60Q 1/00; B60K 28/10; B60R 21/32; B60L 1/00

US CL : 340/540, 547, 436; 180/274; 280/735; 307/10.1

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)

U.S. : 340/540, 547, 436, 435, 438, 545.1, 545.2, 430; 180/274, 282; 280/735; 307/10.1; 324/212, 252; 73/35.12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EAST

search terms: magnet, electromagnetic, flux, coil, vehicle, car, automobile

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,580,084 A (GIOUTSOS) 03 December 1996, abstract, columns 2-3.	1-2
Y	US 5,646,613 A (CHO) 08 July 1997, figures 2, 13, and col. 7.	1-2
A	US 4,087,782 A (OISHI et al) 02 May 1978, col. 1-2.	1-2

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	"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
"A" document defining the general state of the art which is not considered to be of particular relevance	"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
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"P" document published prior to the international filing date but later than the priority date claimed	

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