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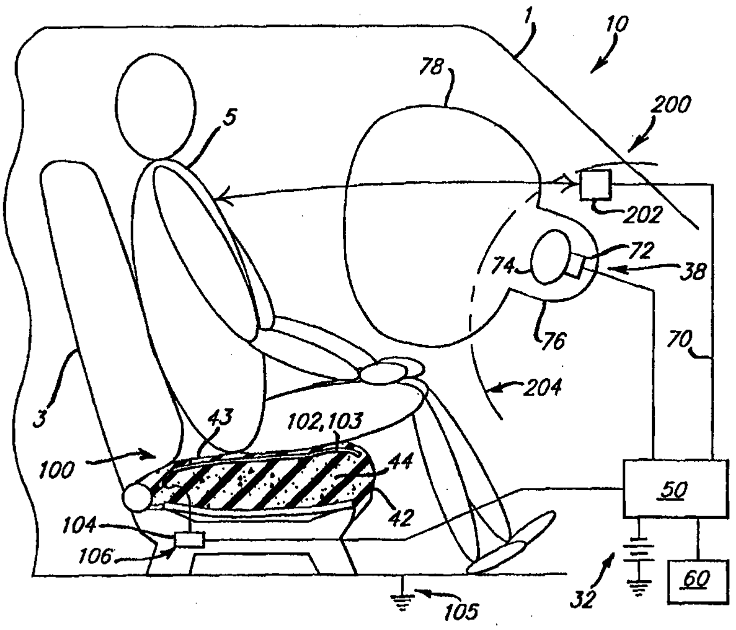

(57) Abstract

An occupant detection system (10) comprises an electric field sensor (100) in the seat bottom (42) of a vehicle seat (3) for discriminating objects on the seat (3), and a range/proximity sensor (200) for sensing the presence of an object proximate to a restraint actuator (39). The electric field sensor (100) discriminates normally seated occupants from other seating conditions, and disables the restraint actuator (39) unless a normally seated occupant (5) is present. The range/proximity sensor (200) disables the restraint actuator (39) if an occupant (5) is located in an at-risk zone (204) so as to be susceptible to injury by the restraint actuator.

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Occupant Detection System

TECHNICAL ART

The instant invention generally relates to occupant detection systems for controlling the activation of vehicular safety restraint systems and, more particularly, for determining the presence and position of an occupant for purposes of influencing the deployment of a safety restraint system responsive to a crash.

BACKGROUND OF THE INVENTION

A vehicle may contain automatic safety restraint actuators that are activated responsive to a vehicle crash for purposes of mitigating occupant injury. Examples of such automatic safety restraint actuators include air bags, seat belt pretensioners, and deployable knee bolsters. One objective of an automatic restraint system is to mitigate occupant injury, thereby not causing more injury with the automatic restraint system than would be caused by the crash had the automatic restraint system not been activated. Generally, it is desirable to only activate automatic safety restraint actuators when needed to mitigate injury because of the expense of replacing the associated components of the safety restraint system, and because of the potential for such activations to harm occupants. This is particularly true of air bag restraint systems, wherein occupants too close to the air bag at the time of deployment – i.e. out-of-position occupants -- are vulnerable to injury or death from the deploying air bag even when the associated vehicle crash is relatively mild. For example, unbelted occupants subjected to severe pre-impact braking are particularly vulnerable to being out-of-position at the time of deployment. Moreover, occupants who are of small stature or with weak constitution, such as children, small adults or people with frail bones are particularly vulnerable to injury induced by the air bag inflator. Furthermore, infants properly secured in a normally positioned rear facing infant seat (RFIS) in proximity to a front seat passenger-side air bag are also vulnerable to injury or death from the deploying air bag because of the close proximity of the infant seat's rear surface to the air bag inflator module.

Yet another technique for mitigating injury to occupants by the air bag inflator is to control the activation of the inflator responsive to the presence and position of the occupant, thereby activating the inflator only when an occupant is positioned outside the associated at-risk zone of the inflator. NHTSA data suggests that severe injuries due to close proximity with the inflator can be reduced or eliminated if the air bag is disabled when the occupant is closer than approximately 4 to 10 inches from the inflator door. Such a system for disabling the air bag inflator requires an occupant sensor that is sufficiently sensitive and robust to make such a determination, while not causing the air bag inflator to be disabled when otherwise required for providing occupant restraint.

Except for some cases of oblique or side-impact crashes, it is generally desirable to not activate an automatic safety restraint actuator if an associated occupant is not present because of the otherwise unnecessary costs and inconveniences associated with the replacement of a deployed air bag inflation system. The prior art teaches various means for detecting the presence of an occupant, or the recognition of an inanimate object in the passenger-seat of a vehicle for purposes of implementing such a system. For example, weight sensors can be incorporated into the seat to detect the presence of an occupant.

Yet another technique for mitigating injury to occupants by the air bag inflator is to control the inflation rate or inflation capacity of the air bag inflator responsive to presence and position of an occupant. Such a control system would most preferentially be used in conjunction with a controllable inflation system responsive to crash severity, such as described above, wherein the occupant position inputs can be used to override otherwise overly aggressive air bag inflator controls which might otherwise be indicated by the particular crash severity level but which could be injurious to occupants of small stature or weight, or to infants in rear facing infant seats. Such a system for controlling the air bag inflator requires an occupant position sensor that is robust and sufficiently accurate, and that can distinguish and discriminate various occupant seating configurations and conditions.

U.S. Patents 5,071,160 and **5,118,134** teach the combination of sensing occupant position and/or velocity, and vehicle acceleration for purposes of controlling an inflator. Both of these patents teach by example the use of ultrasonic ranging to sense occupant position. **U.S. Patent 5,071,160** also teaches by example the use of a passive infrared occupant position sensor, while **U.S. Patent 5,118,134** teaches the use of a microwave sensor. **U.S. Patent 5,398,185** teaches the use of a plurality of occupant position sensors in a system for controlling safety restraint actuators in response thereto.

The prior art teaches the use of one or more ultrasonic beams reflected off the surface of an object to sense the location of the surface of the object. **U.S. Patent 5,330,226** teaches the combination of an ultrasonic ranging sensor mounted in the instrument panel and an overhead passive infrared sensor to sense occupant position for controlling a multi-stage air bag inflator or a vent valve connected thereto. **U.S. Patents 5,413,378, 5,439,249**, and **5,626,359** teach the combination of ultrasonic sensor sensors mounted in the dash and seat in combination with other seat sensors to detect the position and weight of the occupant for purposes of controlling an air bag inflator module. **U.S. Patent 5,482,314** teaches the combination of ultrasonic and passive infrared sensors together with associated signal processing for purposes of determining whether or not to deactivate a passive restraint system.

The prior art also teaches the use of infrared beams reflected off the surface of an object to sense the location of the surface of the object. **U.S. Patents 5,446,661,** and **5,490,069** teach an infrared beam directed by a transmitter at a point of reflection on the object. A receiver detects the radiation scattered from the point of reflection, and measures the distance of the point of reflection from the transmitter based upon a triangulation of the transmitted and received beams for purposes of controlling the activation of a safety restraint system. These patents also teach the combination of an infrared beam occupant position sensor with an acceleration sensor for purposes of controlling an air bag inflation system. **U.S. Patent 5,549,322** teaches the incorporation of a light beam occupant sensor into an air bag door. Furthermore, infrared beam sensors are commonly used as range-finders in automatic focusing cameras.

The prior art of **U.S. Patents 4,625,329**, **5,528,698**, and **5,531,472** teach the use of imaging systems to detect occupant position, the later two of which use this information for purposes of controlling an air bag inflator. **U.S. Patents 5,528,698**, **5,454,591**, **5,515,933**, **5,570,903**, and **5,618,056** teach various means of detecting the presence of a rear facing infant seat for purposes of disabling an associated air bag inflator.

The prior art also teaches the use of capacitive sensing to detect the presence, proximity, or position of an occupant. **U.S. Patent 3,740,567** teaches the use of electrodes incorporated into the base and back of the seat respectively, together with a capacitance responsive circuit, for purposes of discriminating between human occupants and animals or packages resting on an automobile seat. **U.S. Patent 3,898,472** teaches an occupant detection apparatus which includes a metallic electrode which is disposed to cooperate with the body of an automobile to form an occupant sensing capacitor, together with related circuitry which senses variations in the associated capacitance responsive to the presence of an occupant. **U.S. Patent 4,300,116** teaches the use of a capacitive sensor to detect people proximate the exterior of a vehicle. **U.S. Patent 4,796,013** teaches a capacitive occupancy detector wherein the capacitance is sensed between the base of the seat and the roof of the vehicle. **U.S. Patent 4,831,279** teaches a capacity responsive control circuit for detecting transient capacitive changes related to the presence of a person. **U.S. Patents 4,980,519** and **5,214,388** teach the use of an array of capacitive sensors for detecting the proximity of an object. **U.S. Patent 5,247,261** teaches the use of an electric field responsive sensor to measure the position of a point with respect to at least one axis. **U.S. Patent 5,411,289** teaches the use of a capacitive sensor incorporated into the back rest of the seat to detect occupant presence. **U.S. Patent 5,525,843** teaches the use of electrodes incorporated into the base and back of the seat for purpose of detecting the presence of an occupant, whereby the electrodes are substantially insulated from the vehicle chassis when the detection circuit is active. **U.S. Patents 5,602,734** and **5,802,479** teach an array of electrodes mounted above the occupant for purposes of sensing occupant position based upon the influence of the occupant on the capacitance among the electrodes. **U.S. Patent 5,166,679** teaches a capacitive proximity sensor with a reflector driven at the same voltage as to sensing element to modify the sensing characteristic of the sensor. **U.S. Patent 5,770,997** teaches a capacitive vehicle occupant position sensing system wherein the sensor generates a reflected electric field for generating an output signal indicative of the presence of an object. **U.S. Patents 3,943,376, 3,898,472, 5,722,686,** and **5,724,024** also teach capacitive-based systems for sensing occupants in motor vehicles.

In addition to methods taught by the above referenced U.S. Patents, the prior art also teaches various means of measuring capacitance, as for example given in *the Standard Handbook for Electrical Engineers 12th edition*, D.G. Fink and H. W. Beaty editors, McGraw Hill, 1987, pp. 3-57 through 3-65 or in Reference Data for Engineers: Radio, Electronics, Computer, and Communications 7th edition, E.C. Jordon editor in chief, Howard W. Sams, 1985, pp. 12-3 through 12-12, both included herein by reference.

The technical paper "Field mice: Extracting hand geometry from electric field measurements" by J. R. Smith, published in IBM Systems Journal, Vol. 35, Nos. 3 &4, 1996, pp. 587-608, incorporated herein by reference, describes the concept of Electric Field Sensing as used for making non-contact three-dimensional position measurements, and more particularly for sensing the position of a human hand for purposes of providing three dimensional positional inputs to a computer. What has commonly been referred to as capacitive sensing actually comprises the distinct mechanisms of what the author refers to as "loading mode", "shunt mode", and "transmit mode" which correspond to various possible electric current pathways. In the shunt mode, a voltage oscillating at low frequency is applied to a transmit electrode, and the displacement current induced at a receive electrode is measured with a current amplifier, whereby the displacement current may be modified by the body being sensed. In the "loading mode", the object to be sensed modifies the capacitance of a transmit electrode relative to ground. In the transmit mode, the transmit electrode is put in contact with the user's body, which then becomes a transmitter relative to a receiver, either by direct electrical connection or via capacitive coupling.

In one embodiment, a plurality of capacitive sensors are used to sense distances to the occupant, which in combination with the known locations of the fixed sensor elements are triangulated to locate the position of the occupant. One problem with such capacitive sensor arrangements is that they make use of the dielectric constant of known stability to detect the distance between a sensor and the occupant. Furthermore, the occupant position measurement tends to be associated with the center of mass of the sensed object. However, the sensor can be confused by large metal devices or arms/limbs in close proximity. Therefore, while these sensors may perform satisfactorily as an automatic "on/off" switch to either disable the air bag inflator based upon occupant position, or enable the air bag inflator to be fired responsive to the activation signal from the vehicle crash sensor, the present embodiments of capacitive occupant position sensors may not be sufficiently accurate and robust to provide for controllable inflation based upon occupant position.

Occupant sensing systems that use capacitive sensors have significant problems when the sensor is wet and especially when the water near the sensor has good coupling to ground. The frequency dependent response of wet objects is discussed in an article describing capacitive sensing techniques by H. Philipp, entitiled "The Charge Transfer Sensor", from the November, 1996 issue of *Sensors* magazine, incorporated by reference herein. One prior-art capacitive sensing system that uses sensors in the seat back and the seat bottom reportedly has problems because the seat back angle creates changes in the sensor signals independent of the occupant situation.

Sensors which measure the distance between a point of reference and the surface of an object, such as ultrasonic or infrared beam sensors, are also vulnerable to false measurements, as would be caused for example by the presence of the extremities of an occupant, or by the presence of an object such as a scarf or newspaper held thereby, in proximity to the sensor. These types of sensors could be used to monitor the at-risk zone proximate the inflator door, but are subject to several disadvantages. In particular, infrared based systems usually incorporate a beam much narrower than the volume of the at-risk zone such that multiple beams may be required to reliably sense an object anywhere inside the at-risk zone. The incorporation of multiple beams results in extra cost, complexity, and potentially slowed response. Furthermore, both infrared beam and ultrasonic base sensors would require a significant amount of hardware proximate the inflator door if the at-risk zone proximate the inflator is to be monitored.

Some prior-art occupant detection systems attempt to identify the type of occupant or object in the passenger side seat, for example to discriminate a rear facing infant seat from a normally seated adult in the passenger seat. This is a very challenging task as there are a large variety of possible situations. Sensor systems that use distance measurements to identify occupant situations attempt to use information about relatively few points in space to identify the type of occupant in the seat from among many possibilities. Since the outer surface of any particular situation can change dramatically by doing something as simple as tossing a blanket over the occupant or changing the seat position, results are sometimes unreliable. Sensing systems that use some form of range sensing across significant distances within the occupant compartment can be blocked by objects such as newspapers, maps or floating balloons. Some occupant detection systems incorporate a complex algorithm that, while sometimes compensating for the lack of direct sensory information, can cause unpredictable or anomalous performance.

One disadvantage of many occupant detection systems is that they do not gather the most relevant information to determine if the occupant is in an at-risk zone around the inflator module. Occupant detection systems that are mounted above the passenger and look down on the seat area have the wrong physical perspective to directly monitor the region around the inflator door. Even if an ideal set of roof mounted sensors can reliably determine the occupant's gross position -- which is a very challenging task, -- the actual volume between the inflator door and the occupant may be blocked to the sensors by the occupant's body. If the criteria for controlling the activation of an air bag inflator were in part based on the proximity of the occupant's body to the air bag inflator door, then overhead sensors simply cannot reliably obtain the relevant information. Systems that only use ultrasonic and optical sensing mechanisms can be blocked by newspapers. Ultrasonic sensors in some configurations will be affected by environmental conditions (temperature, humidity, altitude) because the speed of sound changes depending on the environment. Any sensing system that needs a clear line of sight between the sensor and the occupant requires the sensor to be visible to the occupant.

NHTSA recommends the use of towels under child seats to make them stable. Some prior-art sensing systems discriminate between child seats and occupants seated directly on the seat by their corresponding pressure patterns. A towel, or other object, placed under a child seat could make the child seat's pressure pattern appear like an occupant seated directly on the seat, but would have relatively little effect on the electric field sensor of the capacitive sensing subsystem.

Another problem with some prior-art occupant detection systems is their inability to disable the air bag during a pre-impact breaking event.

SUMMARY OF THE INVENTION

The instant invention overcomes the above-noted problems by providing an occupant detection system comprising an electric field sensor and a range/proximity sensor. The electric field sensor comprises at least one electrode mountable in a seat bottom of a vehicle seat. The range proximity sensor comprises either a ranging sensor or a proximity sensor that senses the presence of an object within a region proximate to a restraint actuator of the safety restraint system, particularly within an at-risk region within which occupants could be at risk of injury by the deployment of the restraint actuator. A sensing circuit operatively coupled to the at least one electrode of the electric field sensor generates a signal responsive to an electric-field-influencing property of an object on the vehicle seat. A controller operatively coupled to the electric field sensor and to the range/proximity sensor discriminates the type of object on the vehicle seat from the signal from the electric field sensor, and controls the activation of the safety restraint system responsive to the type of object, and responsive to a signal from the range/proximity sensor indicating if a portion of an occupant is located within the at-risk zone proximate to the safety restraint system. More particularly, the controller disables the restraint system if either a normally seated occupant is not detected on the vehicle seat, or if an occupant is too close to the restraint system.

Accordingly, one object of the instant invention is to provide an occupant detection system that can discriminate normally seated occupants from other seat occupancy conditions.

A further object of the instant invention is to provide an occupant detection system that can detect whether an occupant is susceptible to injury by being located within an at-risk zone of a restraint actuator of a safety restraint system.

A yet further object of the instant invention is to provide an occupant detection system that can disable a restraint actuator if a normally seated occupant is not present on a vehicle seat or if an occupant is located within an at-risk zone proximate to the restraint actuator.

A yet further object of the instant invention is to provide an improved means of sensing the capacitance of an electrode in a vehicle seat of an electric field sensor for discriminating objects on a vehicle seat.

The electric field sensor in the seat bottom detects whether there is a large body immediately above the seat bottom cover as, for example, opposed to a child seat mounted on the passenger seat. The electric field sensor disables the air bag whenever no forward facing occupant is detected near the seat bottom, as would occur when any child seat (including RFIS, forward facing child seats and booster seats) is present on the seat, or when the seat is empty. Accordingly, the electric field sensor provides a simple direct measure of whether there is a normally seated forward facing occupant in the front passenger seat. The electric field sensor in the seat bottom has a short range and only senses an occupant when a large surface of the occupant is very close to the sensor. Occupants normally seated directly on the seat cover always have a large surface of their body very close to the sensor. Infants or children in child seats have all, or most, of their body elevated several inches off the seat bottom surface which has relatively little effect on the sensor, whereby a failure to detect a normally seated occupant causes the air bag to be disabled. The electric field sensor senses characteristics of the normally seated occupant that are readily distinguished from a child in a child seat on the passenger seat. This method of sensing is highly advantageous in that the sensor signal is dependent on the dielectric characteristics of the passenger and does not simply sense the outer profile of the occupant in the same way as do optical or ultrasonic sensors. For example, the profile can change dramatically simply by throwing a blanket over the occupant or changing the seat position. This is even true of an empty seat situation. The dielectric characteristics proximate the seat bottom are relatively unaffected by changes in the profile of occupants and objects on the seat, such as caused by blankets. The sensor moves with the seat bottom so seat position or seat back angle do not affect the deployment decision.

Objects that are placed under child seats to stabilize the child seats don't affect the deployment decision by the electric field sensor in the seat bottom, as can be the case for systems that incorporate seat weight sensors. A towel, or other object, placed under a child seat has relatively little effect on the electric field of the electric field sensor in the seat bottom.

The electric field sensor is preferably implemented as a capacitive sensor, wherein the associated sensing circuit is adapted to measure the capacitance of at least one electrode of the sensor within the vehicle seat bottom. A plurality of electrodes may be used and separately measured so as to provide a measure of the distribution of an object on the vehicle seat bottom. The capacitance of the electrodes is relatively small, and the sensing circuit is adapted to provide calibrated capacitance measurements of the electrode by repeatedly comparing the measurement of the sensor electrode with measurements from one or more temperature stable reference capacitors. For example, a first reference capacitor is switched into the measurement circuit for a period of time. Then, an additional second capacitor is switched into the measurement circuit for an additional period of time, and the transient response to the combined capacitance is measured. Finally, the reference capacitors are switched out of the measurement circuit, and the at least one sensing electrode is switched into the measurement circuit so as to provide a measure of capacitance of the at least one sensing electrode. The sensing circuit is able to measure the absolute capacitance of the sensing electrode from this calibration incorporating two distinct and known reference capacitors in the measurement circuit. The sensing circuit is relatively robust and insensitive to temperature and temporal drift of the associated electronic components – excepting the reference capacitors – because the sensing circuit is adapted to filter out D.C. offsets, and measurements are made during transients. More over, the sensing circuit incorporates a voltage follower and associated FET switches in a manner by which the capacitive elements that are not being measured can be effectively isolated from those which are being measured.

The electric field sensor can be adapted with additional electrodes, for example in the form of a driven shield, so as to reduce the influence upon the capacitance of the sensing electrode of liquids wetting the vehicle seat.

The instant invention can be used with any actuable safety restraint system, particularly air bag restraint systems wherein the range/proximity sensor detects objects within the at-risk zone of the air bag inflator module. The range/proximity sensor determines if an occupant is located within a predetermined at-risk zone proximate to the associated air bag inflator module using capacitive, ultrasonic, optical (including infrared, or vision based systems), or radar sensing technologies.

The range/proximity sensor works independently to disable the air bag if a person's body is too close to the inflator door at the time of deployment. This sensor detects the presence of the passenger near the inflator in a short enough time period to disable the air bag while the passenger is still "flying" through the air during this pre-impact breaking event. The ranging sensor can be realized using various sensing technologies, including but not limited to capacitive sensing, optical or ultrasonic range finding, radar sensing, or any other technique that can detect the range between the inflator door and the occupant. If the sensor is located on, or very near to, the inflator door itself, the danger zone can be constantly monitored. The response of the sensor is sufficiently fast to disable the air bag if the occupant enters a "danger zone" immediately prior to the deployment, as could occur during pre-impact braking. The ranging sensor in or near the air bag inflator door makes a direct measure of whether an occupant is located within the danger zone of the air bag inflator. Preferably, this sensor is responsive to a portion of the occupant's body being near the inflator, but is not responsive to low density objects such as newspapers. For example, both capacitive and some lower frequency radar sensors exhibit this type of performance. Responsive to the ranging sensor detecting a large mass of the occupant's body being near the inflator, the system of the instant invention either disables the air bag or modifies the inflation characteristic thereof, for example by reducing the inflation rate of the air bag inflator.

Accordingly, the instant invention directly measures characteristics that are important for assessing whether the air bag deployment could be dangerous, i.e. if there is an occupant seated directly on the seat bottom, and whether the occupant is positioned sufficiently close to the air bag inflator so as to be at risk of injury by an inflating air bag. The air bag deployment decision is based on direct measurements and not on probabilistic predictions using indirect measures, resulting in more predictable and reliable performance. The instant invention disables the air bag for infants or children seated in infant or child seats on the passenger seat proximate the air bag. The instant invention also detects if a human body part is located within a predefined "danger zone" at the time of deployment, and if so, either disables the air bag or modifies the inflation rate thereof. The instant invention provides a relatively simple system -- unaffected by seat position or seat back angle -- for disabling the passenger air bag in nearly all situations where the air bag can be a hazard. The occupant's head and torso need not be against the seat back for the system to accurately identify the occupant. Furthermore, objects that are placed under child seats to stabilize the child seats don't affect the air bag inflator deployment decision.

These and other objects, features, and advantages of the instant invention will be more fully understood after reading the following detailed description of the preferred embodiment with reference to the accompanying drawings and viewed in accordance with the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates one possible environment of the instant invention.

FIG. 2 is a side view of a vehicle illustrating an embodiment of the instant invention incorporating a infrared beam position sensor.

FIG. 3 is a side view of a vehicle illustrating an embodiment of the instant invention incorporating an ultrasonic position sensor.

FIG. 4 is a block diagram of the instant invention.

FIG. 5 illustrates an algorithm in accordance with the instant invention.

FIG. 6 illustrates a child in a typical rear facing child seat placed on a vehicle seat incorporating an electric field sensor in accordance with the instant invention.

FIG. 7 illustrates a cross section of one embodiment of an electric field sensor in accordance with the instant invention.

FIG. 8 illustrates a sensing circuit in accordance with the instant invention.

FIG. 9 illustrates the operation of various elements of the sensing circuit of **FIG. 8**.

FIGS. 10a-j illustrates various seat occupancy scenarios sensed by the instant invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

Referring to **Fig. 1**, an **occupant detection system 10** comprises an **electric field sensor 100** for identifying whether there is normally seated, forward facing **occupant 5** on the **seat 3** of a **vehicle 1**, and a **range/proximity sensor 200** for determining if a part of the **occupant 5** is within a **region 204** -- also known as an **at-risk zone 204** -- proximate to a restraint actuator of an associated **safety restraint system 38**. Occupants within the **at-risk zone 204** of the associated **safety restraint system 38** are susceptible to injury by the **restraint actuator 39** of a **safety restraint system 38**, which in **Fig. 1** is illustrated comprising **air bag inflator module 76**.

The **electric field sensor 100** is placed in the **seat bottom 42** under the **seat cover 43** and close to the top of the **foam cushion 44**. Typically, the **electric field sensor 100** is located in the **seat bottom 42** of the passenger **seat 3**, although it may also be located in other seat locations where a child seat might be located that would need to be detected. The **electric field sensor 100** comprises for example a **capacitive sensing pad 102**, comprising at least one **electrode 103**, connected to an **electronics module 104** containing a **sensing circuit 106** necessary to make the capacitance measurement, wherein preferably the capacitance of at least one **electrode 103** is measured with respect to a **circuit ground 105**. The **electric field sensor 100** is operatively coupled to a **controller 50**, which controls the actuation of the **safety restraint system 38** responsive to a detected type and seating configuration of an object or **occupant 5** on the **seat 3**.

The **range/proximity sensor 200** determines if the **occupant 5** is within a predetermined **at-risk zone 204** proximate to the **air bag inflator module 76**. For example, the **range/proximity sensor 200** comprises a **range sensor 202** that measures the distance between the **occupant 5** and the **air bag inflator module 76**, either directly or indirectly. Alternately, the **range/proximity sensor 200** comprises a proximity sensor that senses the proximity of an object or **occupant 5** to the **restraint actuator**, for example using a second electric field sensor as taught by **U.S. Patent 5,964,478**, which is incorporated by reference herein. The **range/proximity sensor 200** operates in accordance with known range sensing technologies including, but not limited to, electric field, capacitive, ultrasonic, optical (including infrared, or vision based systems), radar, or inductive sensors.

In operation, an **occupant 5** seated on the **seat bottom 42** of **seat 3** sufficiently increases the capacitance of the **electric field sensor 100** so as to indicate to the **controller 50** from the **sensing circuit 106** that an **occupant 5** is seated against the **seat 3**. The **range/proximity sensor 200** determines if a portion of the **occupant 5** is located within the **at-risk zone 204** of the **air bag inflator module 76**. The signals from the **electric field sensor 100** and the **range/proximity sensor 200** are operatively coupled to a **controller 50** which operates in accordance with known analog, digital, or microprocessor circuitry and software. A **crash sensor 60** is also operatively coupled to the **controller 50**. Responsive to a crash detected by the **crash sensor 60**, if an **occupant 5** is seated on the **seat 3** and is not located within the **at-risk zone 204** of the **air bag inflator module 76,** the **controller 50** generates a **signal 70** which is operatively coupled to one or more **initiators 72** of one or more **gas generators 74** mounted in an **air bag inflator module 76**, thereby controlling the actuation of the **air bag inflator module 76** so as to inflate the **air bag 78** as necessary to protect the **occupant 5** from injury which might otherwise be caused by the crash. The electrical power necessary to carry out these operations is provided by a **source of power 32**, preferably the vehicle battery.

Referring to **Fig. 2**, a **vehicle 1** is equipped with an **occupant detection system 10** for controlling the activation of an air bag inflator **safety restraint system 38** for purposes of protecting an **occupant 5** in a crash. An **electric field sensor 100** and **range/proximity sensor 200** are connected to the **controller 50**, which generates a **signal 70** responsive to the outputs from the **electric field sensor 100** and **range/proximity sensor 200** for controlling the **safety restraint system 38**, and which generates an **output 30** for activating a **warming device 40** such as a light or buzzer.

The **range/proximity sensor 200** comprises an **active infrared position sensor 12**, which comprises a **modulator 14** connected to an **optical transmitter 16** powered by a **source of power 32**, and an **optical receiver 18** connected to a synchronous **demodulator 20** in accordance with **U.S. Patent 5,490,069**, which is incorporated herein by reference. The **demodulator 20** generates an **output 22** indicative of the distance between an **occupant 5** and a potential impact point within the vehicle responsive to the detection of the reflection of an infrared beam generated by the **optical transmitter 16** from the surface of an **occupant 5**. The **output 22** is supplied to a **controller 50** for storage in a **memory 36**. The **active infrared position sensor 12** operates in accordance with known principles, methods, and structures of active infrared beam position sensors understood by one of ordinary skill in the art.

Referring to **Fig. 3**, an **ultrasonic range sensor 52** is substituted for the **active infrared position sensor 12** of **Fig. 2** as the **range sensor 202**, whereby the operation of the **occupant detection system 10** in conjunction with **electric field sensor 100** is otherwise the same as described above in conjunction with the **active infrared position sensor 12** of **Fig. 2**.

Fig. 4 illustrates the general principle of instant invention. A **range/proximity sensor 200** senses whether part of the **occupant 5** is located within the **at-risk zone 204** of the **safety restraint system 38**, and outputs a **signal 208** representative thereof to a **controller 50**. An **electric field sensor 100** senses if an **occupant 5** is seated on the **seat 3** and outputs a **signal 108** representative thereof to the **controller 50**. The **controller 50** determines from the **range/proximity sensor 200** and the **electric field sensor 100** whether or not to activate the **safety restraint system 38**. If an **occupant 5** is within the **at-risk zone 204** of the **safety restraint system 38** so as to likely be harmed by the activation of the **safety restraint system 38**, then such activation is inhibited. Alternately, if the capacitance sensed by the **electric field sensor 100** is less than a threshold, the activation of the **safety restraint system 38** is also inhibited. Otherwise, if a **crash sensor 60** detects a crash of sufficient severity that the **safety restraint system 38** should be activated, then the **controller 50** generates an **activation signal 110** to activate the **safety restraint system 38**. One of ordinary skill in the art will appreciate that the **crash sensor 60** can be incorporated into the **controller 50**.

In accordance with the steps illustrated in **Fig. 5**, in step **(502)** the **occupant detection system 10** reads the **range/proximity sensor 200** to determine if a large body part near to the **air bag inflator module 110**. In step **(504)**, if a large body part is within the **at-risk zone 204** of the **air bag inflator module 110**, the **air bag inflator module 110** is disabled in step **(512)**. Otherwise, in step **(506)** the **occupant detection system 10** reads the **electric field sensor 100** to determine if a large surface of a human body is seated directly on the **seat bottom 42**. In step **(508)**, if the capacitance, $\mathbf{C_{meas}}$, of the **electric field sensor 100** is greater than or equal to a threshold, $\mathbf{C_{norm}}$ -- indicating the presence of a seated **occupant 5** -- then the **air bag inflator module 110** is enabled in step **(510)**. Otherwise, the **air bag inflator module 110** is disabled in step **(512)**.

The **occupant detection system 10** is effective in sensing a **rear facing child or infant seat (RFIS) 600** because the **child 602** in a rear facing child seat never has a large surface of its body very near to the **seat bottom 42** and the **capacitive sensing pad 102** contained therein. For example, **Fig. 6** illustrates the orientation of a **child 602** in a typical **rear facing infant seat 600**. The **seating contour 604** inside the **rear facing child or infant seat 600** is such that the buttocks of the **child 602** is closest to the **seat bottom 42** of the **vehicle seat 3**. Usually there is a significant **gap 606**, up to several inches, between the **child 602** and the **seat bottom 42** of the **vehicle seat 3**. Since **child seats 600** are made of plastic, the seats themselves are not sensed directly by the **electric field sensor 100**. Even for **rear facing infant seats 600** for which the **gap 606** between the **child 602** and the **seat bottom 42** of the **vehicle seat 3** is relatively small, the inside **seating contour 604** still creates a significant gap between the **capacitive sensing pad 102** and all parts of the **child 602** except the buttocks. Since only a small portion of the surface of the **child 602** is near to the **capacitive sensing pad 102**, the capacitance measured by the **electric field sensor 100** is relatively low, and more particularly, less than the threshold capacitance, $\mathbf{C_{norm}}$.

One potential weakness of an **electric field sensor 100** is the significant effect that liquids proximate to the **electrode 103** can have on the capacitance of the **electrode 103** with respect to the **circuit ground 105**, or with respect to a second electrode. For example, liquids spilled on and absorbed by the **foam cushion 44** can increase the capacitance of the **electrode 103** with respect to the **circuit ground 105**. Referring to **Fig. 7**, the **electric field sensor 100** can be adapted to reduce the effect of a wetting of the **foam cushion 44** by incorporating a **driven shield 704** and/or a **ground plane 706** under the **sensor electrode 702** in an alternate **capacitive sensing pad 102.1**. The **driven shield 704** is simply a second conductor under the conductor of the **sensing electrode 702** that is driven at the same potential as the **sensing electrode 702**. The result will be that there is no electric field between the **sensing electrode 702** and the **driven shield 704**. The **driven shield 704** eliminates the capacitance sensing capability of the **capacitive sensing pad 102.1** on the side of the **sensing electrode 702** where the **driven shield 704** is located. The **capacitive sensing pad 102.1** is further improved with a **ground plane 706** under the **driven shield 704** so that the circuit driving the **driven shield 704** drives a consistent load.

As distinguished from the capacitive proximity sensor of **U.S. Patent 5,166,679**, the **driven shield 704** and/or **ground plane 706** are for example near to or slightly larger than the **sensing electrode 702**, and are provided to minimize the effects of liquid in the **foam cushion 44** below the **driven shield 704** and/or **ground plane 706** on the capacitance of the **sensing electrode 702**, rather than to extend the range and sensitivity of the electric field sensor. The **driven shield 704** and the **sensing electrode 702** essentially covers the entire area to be sensed on the **seat 3**.

Alternately, the elements of the **capacitive sensing pad 102** distributed sparsely across the **seat 3**, thereby covering a smaller area than the entire area to be sensed on the **seat 3**. One of ordinary skill in the art will recognize that the **capacitive sensing pad 102**, and the elements thereof, can be embodied in a variety of shapes without departing from the teachings of the instant invention.

The capacitance of the **capacitive sensing pad 102** relative to **circuit ground 105** is relatively small, for example less than about 300 picofarads. The temperature range that is possible in an automotive environment can significantly affect the components of the **sensing circuit 106**, causing drift that can be erroneously interpreted as a measurement that could enable the **safety restraint system 38** to be erroneously enabled by the **controller 50**. The effects of this drift can be mitigated by incorporating a temperature stable reference capacitor in the **sensing circuit 106** that is switched in place of the **sensing electrode 103** so as to provide a means for making comparative capacitive measurements. Since the reference capacitor can be selected such that its value is very stable over temperature, any drift can be identified and quantified, and this information can be used to alter the decision threshold.

Referring to **Fig. 8**, illustrating an exemplary **sensing circuit 106**, an **oscillator 802** generates an oscillating signal, for example a sinusoidal signal, that is filtered by a first **bandpass filter 804** so as to create a **first oscillating signal 806**. The **first oscillating signal 806** is applied to a **capacitive voltage divider 808** comprising **capacitor C1**, **resistors R1** and **R2**, and one or more capacitive elements to be measured, selected from the group consisting of the **capacitive sensing pad 102**, a **first reference capacitor CR1**, and a **second reference capacitor CR2**, wherein the capacitive elements to be measured are included or excluded responsive to the states of respective **FET switches Q1a**, **Q1b,** **Q2a**, **Q2b**, **Q3a**, and **Q3b**. **Capacitor C1**, **resistors R1** and **R2**, and the **FET switches Q1a, Q2a, and Q3a** -- that when active switch in the respective capacitive elements to be measured, -- are all connected to one another at a **first node 810**, which is connected to the **input 812** of a **voltage follower U1**. The **output 814** of the **voltage follower U1** is connected to **FET switches Q1b**, **Q2b**, and **Q3b** that when active, switch out the respective capacitive elements so as to not be measured. The activation of the FET switch elements of FET switch pairs **Q1a** and **Q1b**, **Q2a** and **Q2b**, and **Q3a** and **Q3b** are respectively mutually exclusive. For example if **FET switch Q1a** is activated or closed, then **FET switch Q1b** is deactivated or open. A capacitive element being measured adds to the capacitance at the first node, thereby affecting the strength of the signal at the **input 812** to the **voltage follower U1**. A capacitive element not being measured is disconnected from the first node by its respective first FET switch element, and connected to the **output 814** of the **voltage follower U1** by its respective second FET switch element, wherein, in accordance with the characteristics of the associated operational amplifier of the **voltage follower U1**, the **output 814** of the **voltage follower U1** follows the signal of the first node without that respective capacitive element connected, and **voltage follower U1** provides a current through the associated capacitive element through the second respective FET switch element. Moreover, when the respective second FET switch element is activated, the source and drain of the respective first FET switch element are separately coupled to the respective operational amplifier inputs, so that to each is applied the same potential, thereby eliminating the effect of the capacitance of the respective first FET switch on the capacitance measurement.

The **output 814** of the **voltage follower U1** is then coupled to a **second bandpass filter 816** of the same pass band as the **first bandpass filter 804**, the output of which is detected by a **detector 818** comprising diode D1, **resistor R3** and **capacitor C2**, and filtered by a **first low pass filter 820**. The **output 822** of the **first low pass filter 820** has a DC component corresponding to the capacitance at the **first node 810**. This DC component is filtered by blocking **capacitor C3**, and the resulting signal is filtered by a **second low pass filter 824** to provide the **amplitude 826** of the oscillating signal at the **first node 810**, which is related to the total capacitance at that location. The blocking capacitor C3 is adapted so as to provide for a transitory measurement of the **amplitude 826**.

In operation, a **microprocessor U2** controls the activation of **FET switches Q1a, Q1b, Q2a**, **Q2b**, **Q3a**, and **Q3b**, for example in accordance with the control logic illustrated in **Fig. 9**. With the **first reference capacitor CR1** switched in by **microprocessor U2**, i.e. with **Q2a** activated and **Q2b** deactivated, the controller measures a first amplitude. Then with the **second reference capacitor CR2** also switched in by **microprocessor U2**, the controller measures a second amplitude corresponding to an incremental increase of capacitance at the first node by the capacitance of **capacitor CR2**. Then the controller computes a sensitivity factor in Volts/picofarad given the known values of capacitance of **capacitors CR1** and **CR2**. Then, the **microprocessor U2** switches out the **first CR1** and **second reference capacitor CR2**, switches in the **capacitve sensing pad 102**, measures a third amplitude, and calculates the capacitance of the **capacitve sensing pad 102** using the calculated sensitivity factor. The **controller 50** compares this capacitance with a threshold so as to discriminate normally seated occupants from other seat occupancy conditions. If a normally seated **occupant 5** is present, and if the **range/proximity sensor 200** does not disable the safety restraint system, the **restraint actuator 39** is actuated responsive to the detection of a crash by the **crash sensor 60**. Whereas **Fig. 8** illustrates the **microprocessor U2** and **controller 50** as separate elements that communicate with one another, alternate arrangements are possible. For example, both may be combined in one controller, or the microprocessor may be adapted to sense the amplitude measurements, calculate the capacitance of the capacitive sensing pad, and then output only this capacitance value to the **controller 50**.

The **capacitive sensing pad 102** is modeled as a first capacitance **CS1** in parallel with a series combination of a second capacitance **CS2** and a resistance **RS**, wherein the **resistance RS** is inversely related to the wetness of the seat. The capacitance of the capacitive sensor is dominated by **CS1** for a dry seat, but becomes affected by **CS2** and **RS** as the wetness of the seat increases.

The values of capacitance for **capacitors C1**, **CR1**, and **CR2** are adapted to maximize the dynamic range of the capacitance measurement over the range of expected capacitances of the **capacitive sensor 102.**

Information from the **range/proximity sensor 200** can provide useful information to verify or diagnose the performance of the **electric field sensor 100**.

Referring to **Figs. 10a-j**, the **occupant detection system 10** of the instant invention provides the appropriate enable decision for nearly all typical situations. For example, in **Fig. 10a** illustrating an empty seat and in **Fig. 10b** illustrating a rear facing infant seat on the vehicle seat, the **electric field sensor 100** would disable the **restraint actuator 39**. In **Fig. 10c**, illustrating a normally seated adult, and in **Fig. 10h**, illustrating an adult seated in a reclined position, the **restraint actuator 39** would be enabled because the **electric field sensor 100** would detect an **occupant 5** seated on the **seat bottom 42** and the **range/proximity sensor 200** would not detect the presence of an object within the at-risk zone. In **Fig. 10d**, illustrating a normally seated adult reading a newspaper, the **restraint actuator 39** would be enabled because the **electric field sensor 100** would detect an **occupant 5** seated on the **seat bottom 42** and the **range/proximity sensor 200** –for example a capacitive, electric field, or radar sensor -- would not detect the presence of an object of sufficient density within the at-risk zone. However, if the **range/proximity sensor 200** were an active infrared or ultrasonic ranging sensor, the **restraint actuator 39** could become disabled by this sensor in this situation, depending upon the sensor's ability to discriminate such objects. In **Fig. 10e**, illustrating a normally seated adult with a hand in the at-risk zone, the **restraint actuator 39** would be enabled if the **range/proximity**

sensor 200 were preferably calibrated so as to not be responsive to an object the size of a human hand. In **Fig. 10f**, illustrating a small **occupant 5** standing proximate to the **restraint actuator 39**, the **restraint actuator 39** would be disabled by both the **electric field sensor 100**, sensing an empty seat, and by the **range/proximity sensor 200**, sensing an object in the at-risk zone. In **Fig. 10g**, illustrating a normally seated adult and a standing child; and in **Fig. 10j**, illustrating an adult leaning and seated forward, the **restraint actuator 39** would be disabled by the **range/proximity sensor 200**. Finally, in **Fig. 10i**, illustrated a seated adult leaning forward, the **restraint actuator 39** would be enabled by the **electric field sensor 100**, but possibly with reduced power if the **range/proximity sensor 200** is adapted to quantify distances outside the at-risk zone.

If it is mandatory that the air bag be suppressed for all small occupants, the at-risk zone sensing can prevent injuries when there is an out-of-position child between the air bag and an adult **occupant 5** (child on lap) or when an adult is out-of-position. If it is acceptable to deploy the air bag when children are seated far from air bag module, then the electric field sensor in the seat bottom could be used along with the at-risk zone sensor to form a complete dynamic suppression system.

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 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 system for detecting an occupant in a vehicle with a safety restraint system, comprising:

a. a first electric field sensor comprising at least one first electrode mountable in a seat bottom of a vehicle seat, wherein said first electric field sensor is responsive to at least one electric field influencing property of an object on said vehicle seat;

b. a first **sensing circuit 106** operatively coupled to at least one said first electrode of said first electric field sensor wherein said first **sensing circuit 106** generates a first signal responsive to said at least one electric field influencing property of an object proximate to said first electric field sensor;

c. a first range/proximity sensor for sensing the presence of an object within a region proximate to a **restraint actuator 39** of the safety restraint system; and

d. a controller operatively coupled to said first electric field sensor and to said first range/proximity sensor, wherein said controller discriminates a type of object on said seat responsive to said first signal and to said first range/proximity sensor, and said controller controls the actuation of the safety restraint system responsive to said type of object.

2. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said at least one first electrode is adapted so that the capacitance of said at least one first electrode with respect to a circuit ground is substantially greater for a seating condition selected from the group consisting of an occupant seated in substantially normal seating position on the vehicle seat and a large body immediately above said seat bottom; than for a seating condition selected from the group consisting of an empty said vehicle seat, an infant seat on said vehicle seat, a child seat on said vehicle seat, a booster seat on said vehicle seat, an infant seated in an infant seat on said vehicle seat, a child seated in a child seat on said vehicle seat, a child seated in a booster seat on said vehicle seat, and an occupant on said vehicle seat in a position that is substantially different from a normal seating position.

3. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein the size of said at least one first electrode is substantially equal to an area to be sensed on said vehicle seat.

4. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said first electric field sensor is substantially non-responsive to objects that are more than 50 mm above said seat bottom.

5. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said at least one first electrode is mounted proximate to the location of an object selected from the group consisting of an infant seat on said vehicle seat, a child seat on said vehicle seat, a booster seat on said vehicle seat, and an occupant seated on said vehicle seat.

6. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said at least one first electrode is mounted under a seat cover of said vehicle seat.

7. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said at least one first electrode is mounted above a foam cushion in said vehicle seat.

8. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said at least one electric field influencing property comprise a dielectric characteristic.

9. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said vehicle seat comprises a seat frame, and said seat frame is connected to said circuit ground.

10. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said first electric field sensor is adapted to mitigate the effect of a liquid wetting said vehicle seat.

11. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said first **sensing circuit 106** is operatively coupled to each said first electrode so as to provide a measure of the distribution of an object on said vehicle seat.

12. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said first electric field sensor further comprises at least one second electrode and at least one third electrode, wherein said at least one third electrode is located between said at least one first electrode and a foam cushion of said vehicle seat and aid at least one second electrode is located between said at least one first electrode and said at least one third electrode.

13. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **12**, wherein said at least one second electrode is substantially the same size as said at least one first electrode.

14. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **12**, wherein said at least one third electrode is electrically connected to a circuit ground.

15. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **12**, wherein said first **sensing circuit 106** is operatively coupled to at least one said second electrode.

16. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **15**, wherein said first **sensing circuit 106** applies a first applied signal to said first electrode and applies a second applied signal to said second electrode.

17. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **16**, wherein said second applied signal is equal so said first applied signal.

18. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **12**, wherein said first **sensing circuit 106** is operatively coupled to at least one said third electrode and said first **sensing circuit 106** applies a third applied signal to said third electrode.

19. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **18**, wherein said third applied signal is a circuit ground potential.

20. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said first signal is responsive to the capacitance between said at least one first electrode and a circuit ground.

21. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said first **sensing circuit 106** applies a first applied signal to said at least one first electrode.

22. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **21**, wherein said first applied signal comprises a **first oscillating signal**.

23. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said first **sensing circuit 106** further comprises:

a. a reference capacitor wherein the capacitance of said reference capacitor is stable over a range of temperatures; and

b. a switch for switching said reference capacitor in place of said first electric field sensor, wherein said first **sensing circuit 106** compares the measurement of said reference capacitor with the measurement of said first electric field sensor, calibrates said first signal responsive to said comparison, and adapts a decision threshold responsive to said comparison.

24. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said first range/proximity sensor is selected from the group consisting of an electric field sensor, a capacitive sensor, a radar sensor, an optical range sensor, an active infrared sensor, a passive infrared sensor, a vision sensor, an ultrasonic range sensor, and an inductive sensor.

25. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **24**, wherein said capacitive sensor is responsive to the capacitance between at least one first electrode and a circuit ground.

26. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **24**, wherein said capacitive sensor comprises a plurality of electrodes proximate to a **restraint actuator 39** of the safety restraint system.

27. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said first range/proximity sensor is located proximate to a **restraint actuator 39** of said safety restraint system.

28. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said first range/proximity sensor is responsive to a portion of the occupant's body within a region proximate to a **restraint actuator 39** of the safety restraint system.

29. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said first range/proximity sensor is substantially non-responsive to low density objects.

30. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said first electric field sensor is diagnosed responsive to at least one measurement from said first range/proximity sensor.

31. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said controller disables the safety restraint system if an occupant is not detected as seated on said vehicle seat by said first electric field sensor.

32. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said controller disables the safety restraint system if an occupant is not detected as seated on said vehicle seat by said first electric field sensor for a period of time greater than a threshold.

33. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said controller enables the safety restraint system if said first electric field sensor detects an occupant seated on said vehicle seat and said first range/proximity sensor does not detect a portion of the occupant within said region proximate to said restraint actuator.

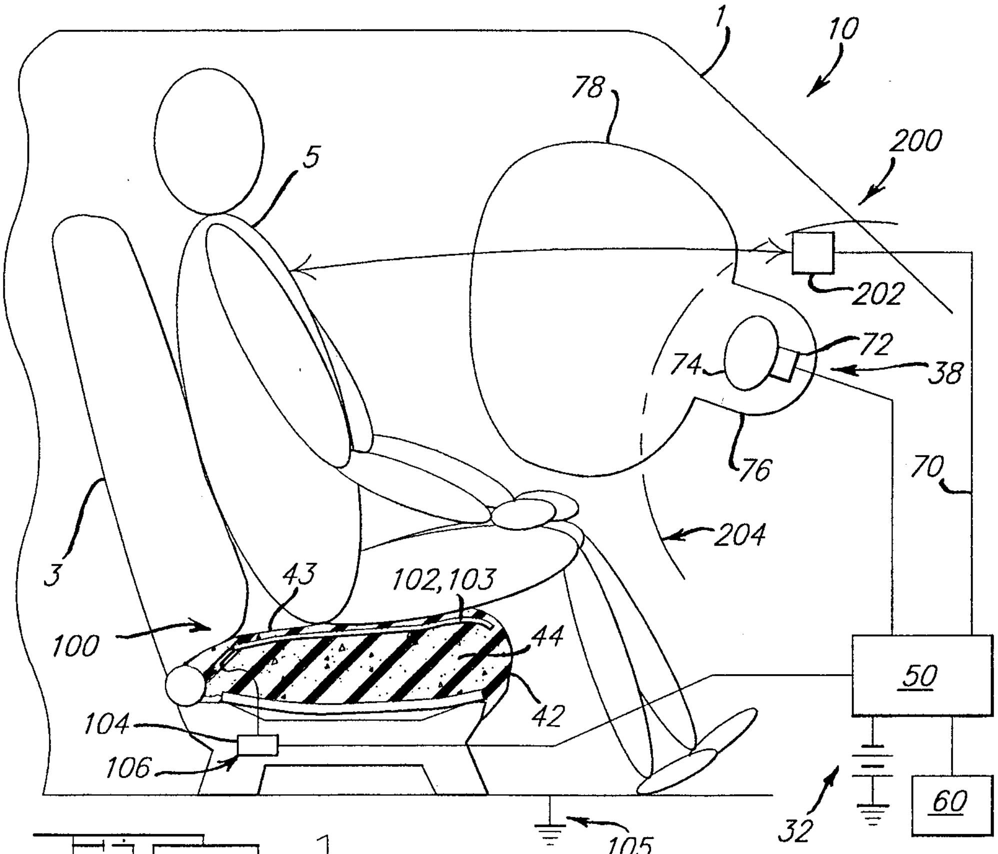
34. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said first range/proximity sensor generates a range measurement and said controller adapts an actuation characteristic of the safety restraint system if said range measurement is less than a threshold.

35. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **34**, wherein said actuation characteristic is adapted responsive to said range measurement at a time of a collision.

36. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **34**, wherein said threshold corresponds to a range from a **restraint actuator 39** for which an occupant is likely to experience an injury from said safety restraint system, wherein said injury is greater than a second threshold.

37. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said first range/proximity sensor operates at a sufficiently fast rate to be responsive to the effects of pre-impact braking on said occupant.

38. A system for detecting an occupant in a vehicle with a safety restraint system as recited in claim **1**, wherein said controller is further responsive to said first signal from said first electric field sensor if said first signal indicates that an occupant is not seated on said vehicle seat wherein said first signal is the capacitance of said occupant on said vehicle seat and said safety restraint system is disabled if said capacitance is less than a threshold.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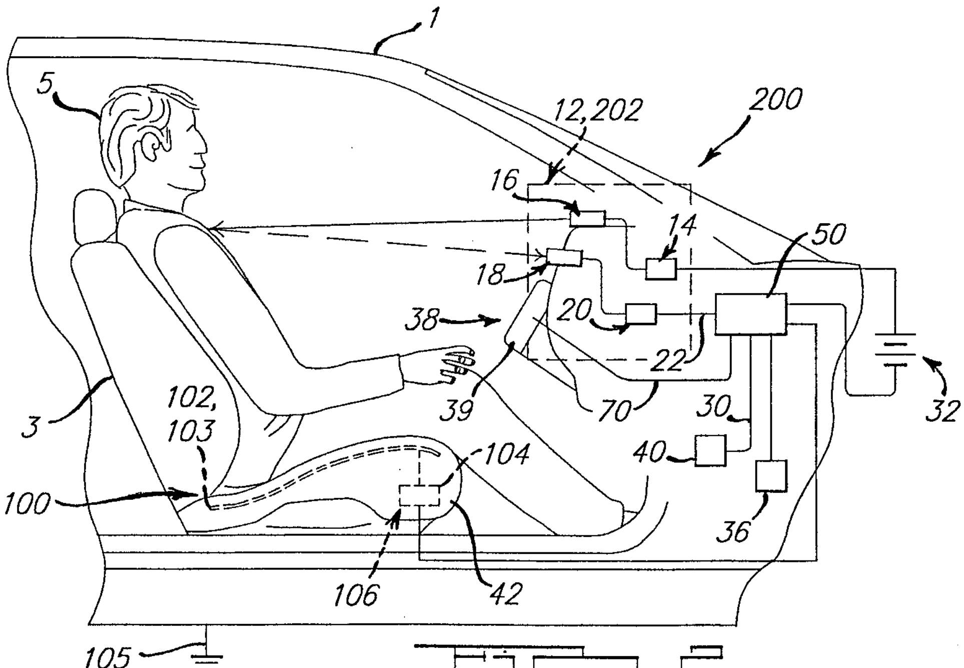
60
105
32

FIG. 1.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105

FIG. 2.

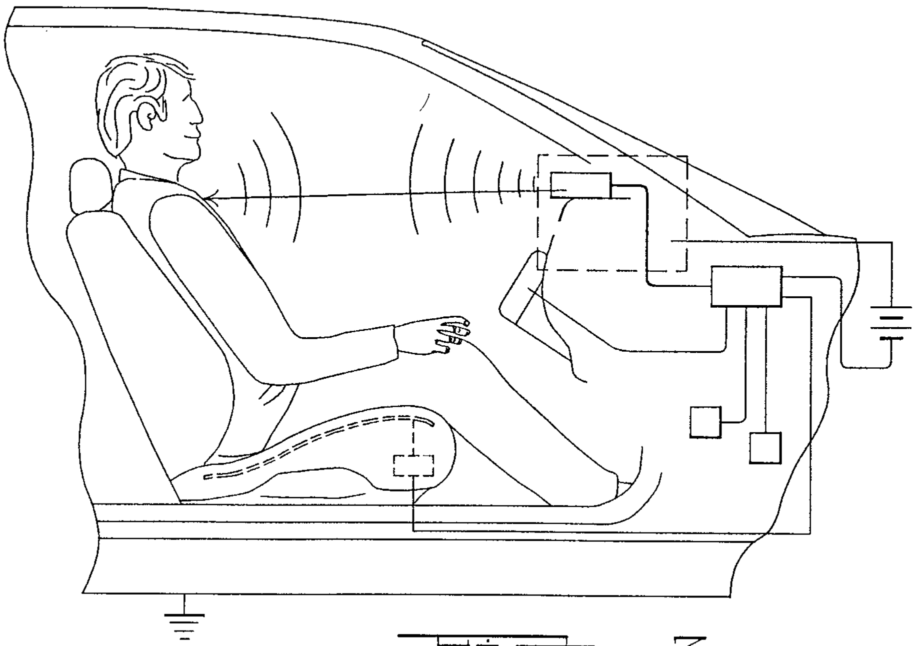


FIG. 3.

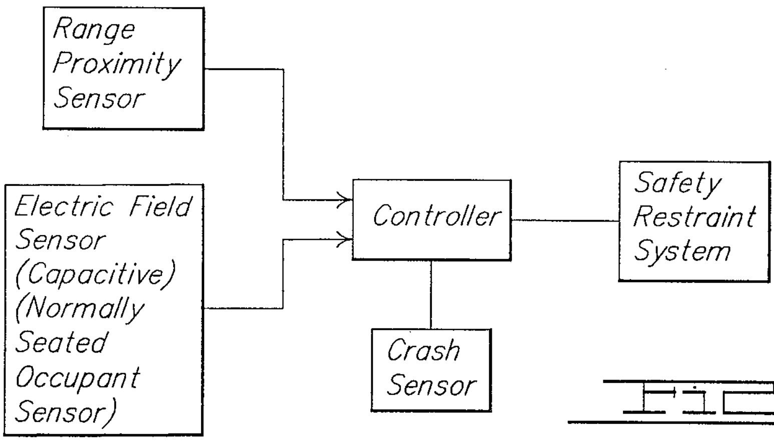


FIG. 4.

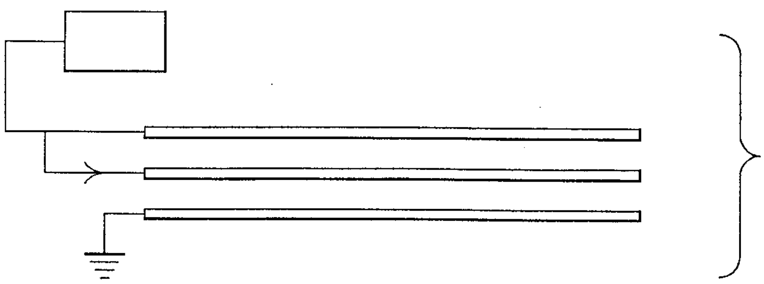


FIG. 7.

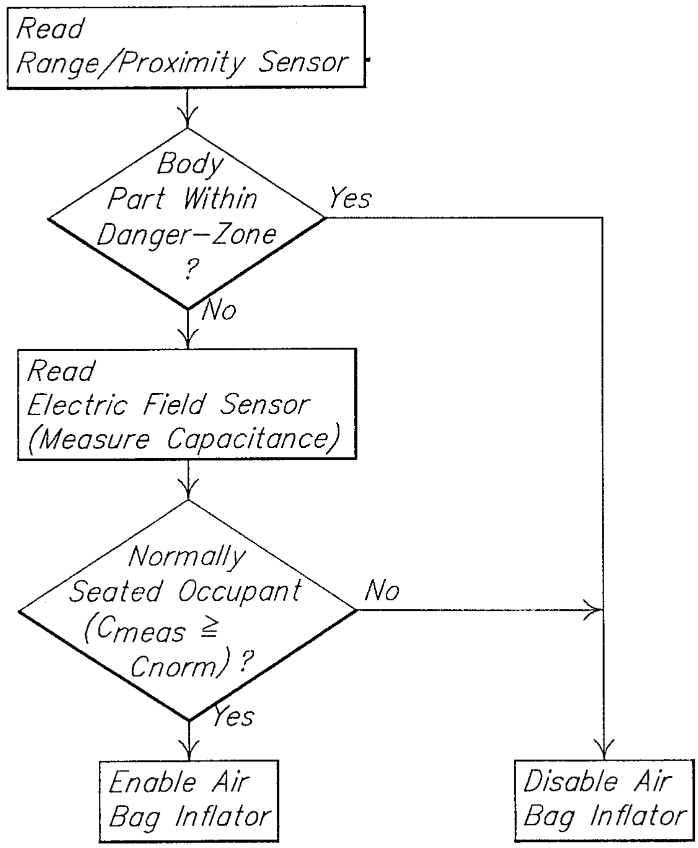

Read
Range/Proximity Sensor
Body
Part Within
Danger–Zone
?
Yes
No
Read
Electric Field Sensor
(Measure Capacitance)
Normally
Seated Occupant
(Cmeas ≥
Cnorm) ?
No
Yes
Enable Air
Bag Inflator
Disable Air
Bag Inflator

FIG. 5.

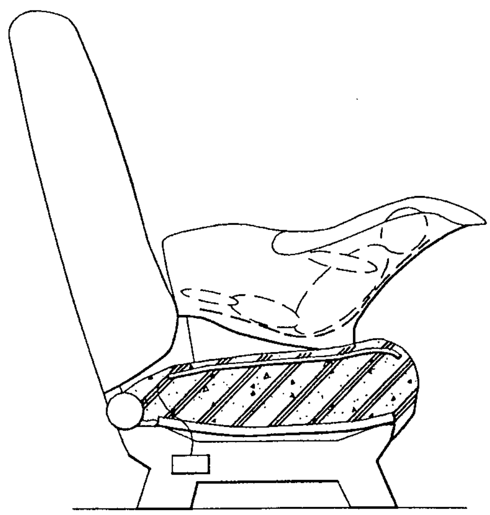
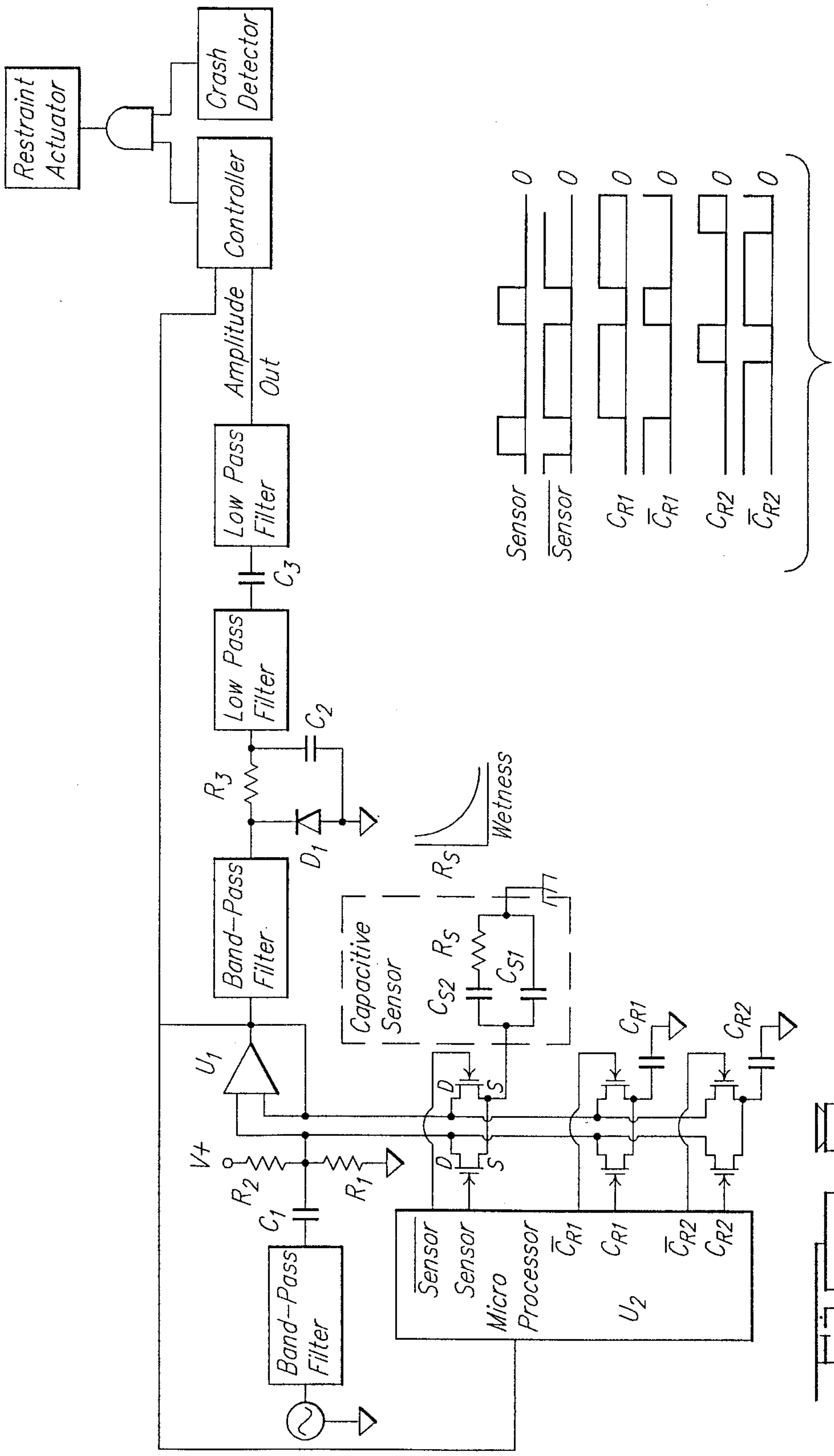


FIG. 6.


Restraint Actuator
Crash Detector
Controller
Amplitude Out
Low Pass Filter
C_3
Low Pass Filter
C_2
R_3
D_1
Band-Pass Filter
R_S
Wetness
Capacitive Sensor
R_S
C_{S2}
C_{S1}
U_1
C_{R1}
C_{R2}
V+
R_2
R_1
C_1
D
S
Band-Pass Filter
$\overline{Sensor}$
Sensor
Micro Processor
$\overline{C}_{R1}$
C_{R1}
$\overline{C}_{R2}$
C_{R2}
U_2
Sensor
$\overline{Sensor}$
C_{R1}
$\overline{C}_{R1}$
C_{R2}
$\overline{C}_{R2}$
0
0
0
0
0
0

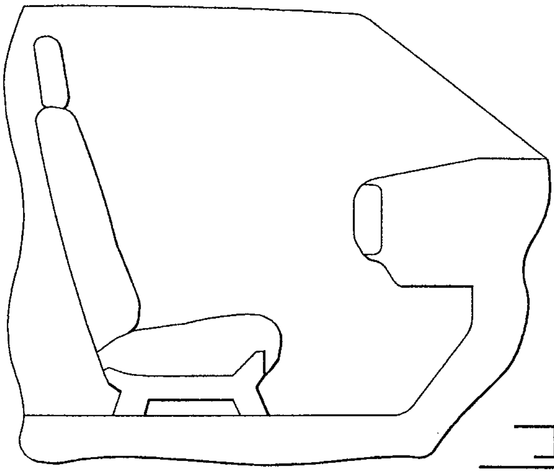


Fig. 10a.

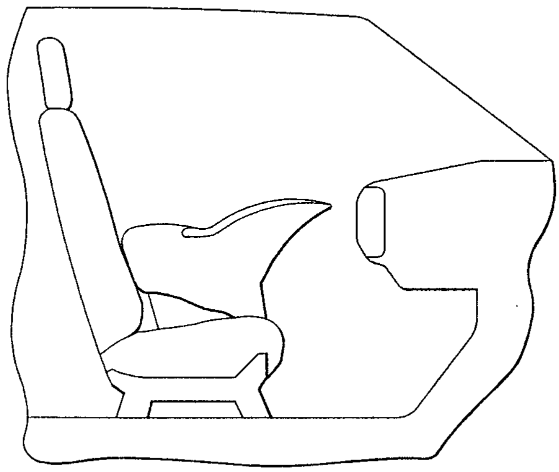


Fig. 10b.

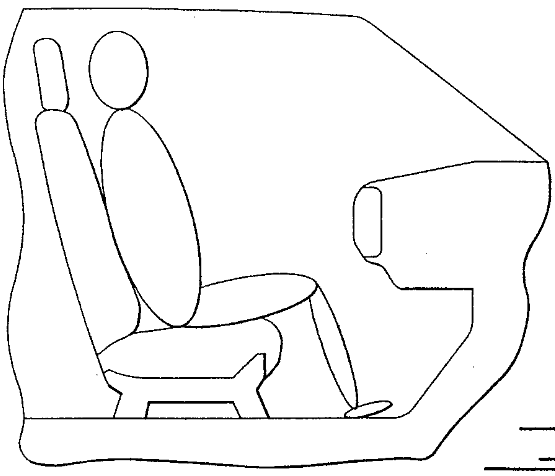


Fig. 10c.

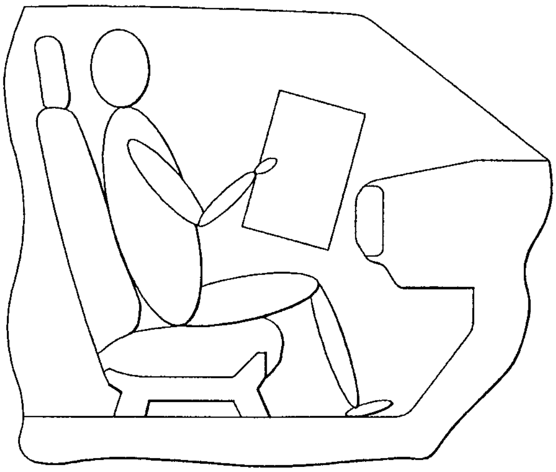


FIG. 10d.

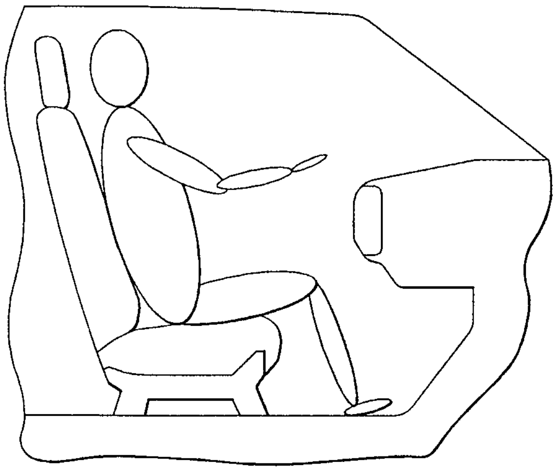


FIG. 10e.

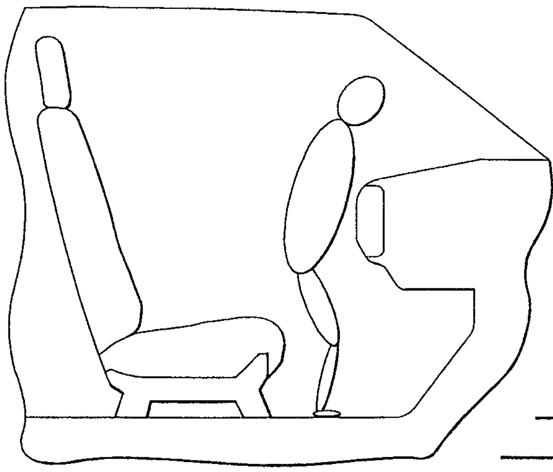


FIG. 10f.

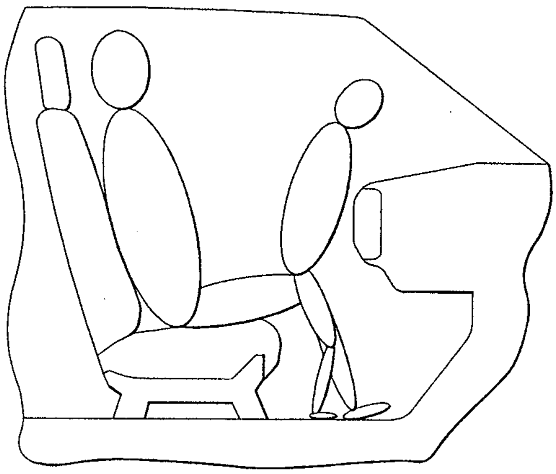


Fig. 10g.

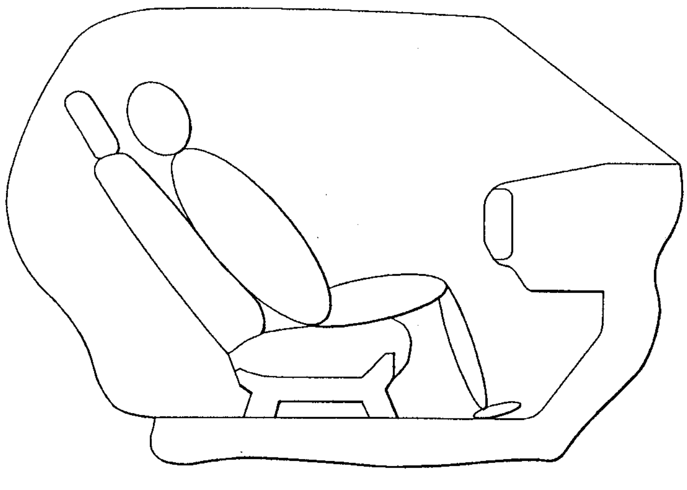


Fig. 10h.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/31306

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :B60R 21/26, 21/32
US CL : 280/735; 180/273
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. : 280/735; 180/273,180/272

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)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,413,378 A (STEFFENS, JR. et al) 09 May 1995, see Figure 1, and col. 3, lines 29-51.	1-31, 33-38
Y, P	US 5,948,031 A (JINNO et al) 07 September 1999, see entire document.	1-31, 33-38
Y	US 5,722,686 A (BLACKBURN et al) 03 MARCH 1998, see the abstract and Figures 1-3 and col. 2, lines 14-32.	24-26 and 29
Y	US 5,770,997 A (KLEINBERG et al) 23 June 1998, see Fig (5a).	34-37
Y	US 5,525,843 A (HOWING) 11 JUNE 1996, see entire document.	1-6,8-11, 20-22 24-31, 33-38

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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

"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

"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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
09 MARCH 2000	14 APR 2000

Name and mailing address of the ISA/US	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/31306

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim
A	US 5,624,132 A (BLACKBURN et al) 29 April 1997, see Figure 4, col. 1, line 64-col. 2, line16.	1,3,5-7,9, 10, :
A, E	US 6,024,378 A (FU) 15 February 2000, see entire document.	1-38

Form PCT/ISA/210 (continuation of second sheet) (July 1998)★