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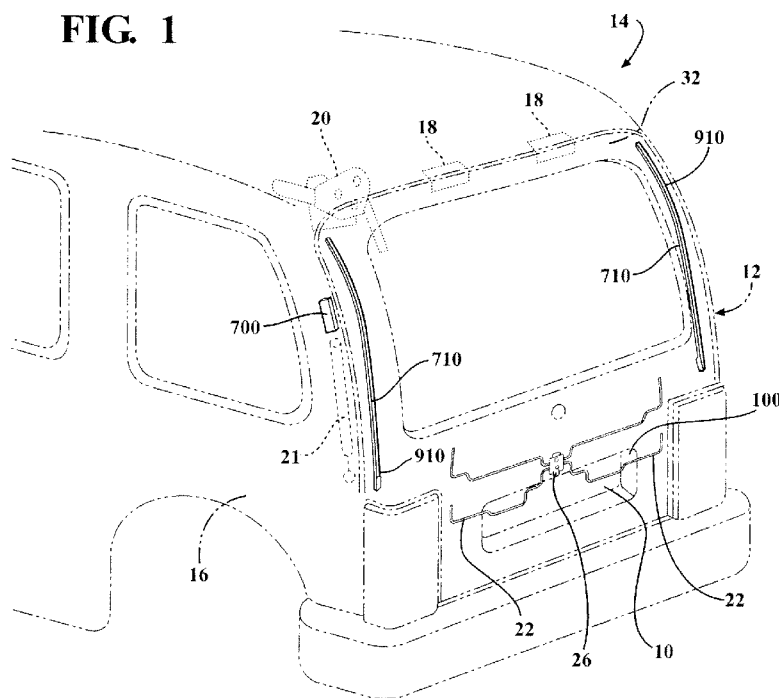
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- (54) Title:** CAPACITIVE TRIM SENSOR AND SYSTEM



- (57) Abstract:** A capacitive sensing system for a liftgate of a vehicle includes at least one elongate capacitive sensor mounted on a trim panel of the liftgate. The at least one elongate capacitive sensor is arranged to extend over an area of the trim panel. The capacitive sensing system also includes a controller coupled to the at least one elongate capacitive sensor for monitoring changes in a capacitance value of the at least one elongate capacitive sensor, with the capacitance value changing when an obstacle approaches the area.



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CAPACITIVE TRIM SENSOR AND SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The subject PCT patent application claims priority to U.S. provisional patent application Serial No. 61/791,322 filed on March 15, 2013 directed to a “Capacitive Trim Sensor and System”, the entire disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] This invention relates to the field of capacitive sensors, and more specifically, to a capacitive sensor and system for use in vehicles and other devices.

BACKGROUND

[0003] In motor vehicles such as minivans, sport utility vehicles and the like, it has become common practice to provide the vehicle body with a large rear opening. A liftgate (also referred to as a tailgate) is typically mounted to the vehicle body or chassis with hinges for pivotal movement about a transversely extending axis between an open position and a closed position. Typically, the liftgate may be operated manually or with a power drive mechanism including a reversible electric motor.

[0004] During power operation of a vehicle liftgate, the liftgate may unexpectedly encounter an object or obstacle in its path. It is therefore desirable to cease its powered movement in that event to prevent damage to the obstacle and/or to the liftgate by impact or by pinching of the obstacle between the liftgate and vehicle body proximate the liftgate hinges.

[0005] Obstacle sensors are used in such vehicles to prevent the liftgate from closing if an obstacle (e.g., a person, etc.) is detected as the liftgate closes. Obstacle sensors come in different forms, including non-contact or proximity sensors which are typically based on capacitance changes.

[0006] Non-contact obstacle sensors typically include a metal strip or wire which is embedded in a plastic or rubber strip which is routed along and adjacent to the periphery of the liftgate. The metal strip or wire and the chassis of the vehicle collectively form the two plates of a sensing capacitor. An obstacle placed between these two electrodes changes the dielectric constant and thus varies the amount of charge stored by the sensing capacitor over a given period of time. The charge stored by the sensing capacitor is transferred to a reference capacitor in order to detect the presence of the obstacle.

[0007] One problem with present non-contact sensors is that they only provide detection of obstacles within a limited area, for example, along the pinch points of the liftgate.

[0008] A need therefore exists for an improved capacitive sensor and system for use in vehicles and other devices. Accordingly, a solution that addresses, at least in part, the above and other shortcomings is desired.

SUMMARY OF THE INVENTION

[0009] According to one aspect of the invention, there is provided a capacitive sensing system for a liftgate of a vehicle, comprising: at least one elongate capacitive sensor mounted on a trim panel of the liftgate, the at least one elongate capacitive sensor arranged to extend over an area of the trim panel; and, a controller coupled to the at least one elongate capacitive sensor for monitoring changes in a capacitance value of the at least one elongate capacitive sensor, the capacitance value changing when an obstacle approaches the area.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Features and advantages of the embodiments of the present invention will become apparent from the following detailed description, taken in combination with the appended drawings, in which:

[0011] FIG. 1 is rear perspective view illustrating a capacitive sensing system for a liftgate of a vehicle in accordance with an embodiment of an aspect of the invention;

[0012] FIG. 2 is a block diagram illustrating the capacitive sensing system of FIG. 1 in accordance with an embodiment of an aspect of the invention;

[0013] FIG. 3 is a plan view illustrating the capacitive sensing system of FIG. 1 in isolation in accordance with an embodiment of an aspect of the invention;

[0014] FIG. 4 is a plan view illustrating the capacitive sensing system of FIG. 3 mounted on a trim panel in accordance with an embodiment of an aspect of the invention;

[0015] FIG. 5 is a cross sectional view illustrating a capacitive sensor in accordance with an embodiment of an aspect of the invention;

[0016] FIG. 6 is a cross sectional view illustrating the capacitive sensor of FIG. 5 installed in a mounting channel on a trim panel in accordance with an embodiment of an aspect of the invention;

[0017] FIG. 7 is rear view illustrating a capacitive sensing system for a liftgate of a vehicle combined with liftgate mounted resistive pinch sensors, in accordance with an embodiment of an aspect of the invention;

[0018] FIG. 8 is rear view illustrating a capacitive sensing system for a liftgate of a vehicle combined with liftgate mounted resistive pinch sensors and body mounted capacitive sensors, in accordance with an embodiment of an aspect of the invention;

[0019] FIG. 9 is rear view illustrating a capacitive sensing system for a liftgate of a vehicle combined with liftgate mounted resistive and capacitive sensors and multiple controllers, in accordance with an embodiment of an aspect of the invention;

[0020] FIG. 10 is rear view illustrating a capacitive sensing system for a liftgate of a vehicle combined with liftgate mounted resistive and capacitive sensors and dual controllers, in accordance with an embodiment of an aspect of the invention; and,

[0021] FIG. 11 is rear view illustrating a capacitive sensing system for a tailgate of a vehicle combined with liftgate mounted resistive pinch and capacitive sensors, in accordance with an embodiment of an aspect of the invention.

[0022] It will be noted that throughout the appended drawings, like features are identified by like reference numerals.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0023] In the following description, details are set forth to provide an understanding of the invention. In some instances, certain circuits, structures and techniques have not been described or shown in detail in order not to obscure the invention.

[0024] FIG. 1 is rear perspective view illustrating a capacitive sensing system **10** for a liftgate **12** of a vehicle **14** in accordance with an embodiment of an aspect of the invention. FIG. 2 is a block diagram illustrating the capacitive sensing system **10** of FIG. 1 in accordance with an embodiment of an aspect of the invention. FIG. 3 is a plan view illustrating the capacitive sensing system **10** of FIG. 1 in isolation in accordance with an embodiment of an aspect of the invention. And, FIG. 4 is a plan view illustrating the capacitive sensing system of FIG. 3 mounted on a trim panel **400** in accordance with an embodiment of an aspect of the invention.

[0025] The capacitive sensing system **10** is shown operatively associated with a closure panel **12** of a motor vehicle **14**. According to one embodiment, the closure panel is a liftgate **12**. It will be understood by those skilled in the art that the capacitive sensing system **10** may be used with other closure panels and windows of a vehicle or other device.

[0026] The liftgate **12** is mounted to the body **16** of the vehicle **14** through a pair of hinges **18** to pivot about a transversely extending pivot axis with respect to a large opening **500** (see FIG. 7) in the rear of the body **16**. The liftgate **12** is mounted to articulate about its hinge axis between a closed position where it closes the opening **500** and an open position where it uncovers the opening **500** for free access to the vehicle body interior and assumes a slightly upwardly angled position above horizontal. The liftgate **12** is secured in its closed position by a latching mechanism (not shown). The liftgate **12** is opened and closed by a drive mechanism **20** with the optional assist of a pair of gas springs **21** connected between the liftgate **12** and the body **16**. The drive mechanism **20** may be similar to that described in PCT International Patent Application No. PCT/CA2012/000870, filed September 20, 2012, and incorporated herein by reference. The drive mechanism **20** may be or include a powered strut as described in United States Patent No. 7,938,473, issued May 20, 2011, and incorporated herein by reference.

[0027] According to one embodiment, the capacitive sensing system **10** includes four sensors **22**, a mounting track or channel **24** for each of the sensors **22**, and a controller **26**. The sensors **22** are positioned to cover a substantial area **100** of the inner side of the liftgate **12**. The sensors **22** extend outwardly from the controller **26** toward the corners of the liftgate **12**. The sensors **22** are electrically coupled to an optional wire harness **430** adapted to plug into the controller **26**. The controller **26** controls the drive mechanism **20** to open the liftgate **12** in the event it receives an electrical signal from one or more of the sensors **22**.

[0028] According to one embodiment, each of the sensors **22** is mounted to the liftgate **12** through a mounting track or channel **24**. According to one embodiment, the sensors **22** are mounted in the mounting channels **24**, which are in turn attached to the liftgate trim panel **400** or molded into the liftgate trim panel **400**. Alternatively, it will be understood that in certain

applications it may be desirable to mount the sensors **22** and their associated channels **24** on the liftgate **12** itself.

[0029] In operation, when the liftgate **12** approaches an obstacle proximate to one or more of the sensors **22** as it is articulated towards its closed position, the one or more sensors **22** are activated. The activation of a sensor **22** is detected by the controller **26**. In response, the controller **26** reverses the drive mechanism **20** to articulate the liftgate **12** to its open position. Advantageously, false positive indications or noise may be reduced by using multiple sensors **22** distributed over an area **100** of the trim panel **400** as the likelihood of an obstacle activating all of the sensors **22** is not large.

[0030] The drive mechanism **20** is controlled in part by the capacitive sensing system **10**. The capacitive sensing system **10** includes elongate sensors **22** that help prevent the liftgate **12** from contacting or impacting an obstacle such a person's head (not shown) that may be extending through the opening **500** when the liftgate **12** lowers towards its closed position. It will be appreciated by those skilled in the art that the capacitive sensing system **10** may be applied to any motorized or automated closure panel structure that moves between an open position and a closed position. For example, a non-exhaustive list of closure panels includes window panes, sliding doors, tailgates, sunroofs and the like. For applications such as window panes or sun roofs, the elongate sensors **22** may be mounted on the body **16** of the vehicle **14**, and for applications such as powered liftgates and sliding doors the elongate sensors **22** may be mounted on the closure panel itself, e.g., within the trim panel **400** of the liftgate **12**.

[0031] FIG. 5 is a cross sectional view illustrating a capacitive sensor **22** in accordance with an embodiment of an aspect of the invention. And, FIG. 6 is a cross sectional view illustrating the capacitive sensor **22** of FIG. 5 installed in a mounting channel **24** on a trim panel **400** in accordance with an embodiment of an aspect of the invention.

[0032] The capacitive sensor **22** is a two electrode sensor that allows for a capacitive mode of obstacle detection. In general, the two electrodes **1**, **2** function in a driven shield configuration (i.e., with the upper electrode **2** being the driven shield). The case **300** positions the two electrodes **1**, **2** in an arrangement that facilitates operation of the sensor **22** in a capacitive mode. The lower electrode **1** (optionally comprising a conductor **1a** embedded in conductive resin **1b**) acts as a capacitive sensor electrode, and the upper electrode **2** (optionally comprising a conductor **2a** embedded in a conductive resin **2b**) acts as a capacitive shield electrode. A dielectric **320** (e.g., a portion **320** of the case **300**) is disposed between the capacitive shield electrode **2** and the capacitive sensor electrode **1** to isolate and maintain the distance between the two. The controller (or sensor processor ("ECU")) **26** is in electrical communication with the electrodes **1**, **2** for processing sense data received therefrom. Accordingly to one embodiment, the capacitive sensor **22** may be similar to that described in United States Patent No. 6,946,853 to Gifford et al., issued September 20, 2005, and incorporated herein by reference.

[0033] According to one embodiment, the capacitive sensor **22** includes an elongate non-conductive case **300** having two elongate conductive electrodes **1**, **2** extending along its length. The electrodes **1**, **2** are encapsulated in the case **300** and are spaced apart. When an obstacle comes between the tailgate **12** and the body **16** of vehicle **14**, it effects the electric field generated by the capacitive sensor electrode **1** which results in a change in capacitance between the two electrodes **1**, **2** which is indicative of the proximity of the obstacle to the liftgate **12**. Hence, the two electrodes **1**, **2** function as a capacitive non-contact or proximity sensor.

[0034] According to one embodiment, the capacitive sensor electrode **1** may include a first conductor **1a** embedded in a first partially conductive body **1b** and the capacitive shield electrode **2** may include a second conductor **2a** embedded in a second partially conductive body **2b**. The conductors **1a**, **2a** may be formed from a metal wire. The partially conductive bodies **1b**,

2b may be formed from a conductive resin. And, the case **300** may be formed from a non-conductive (e.g., dielectric) material (e.g., rubber, etc.). Again, the capacitive sensor electrode **1** is separated from the capacitive shield electrode **2** by a portion **320** of the case **300**.

[0035] According to one embodiment, the sensor **22** is mounted on a trim panel **400** of the liftgate **12** as shown in FIGS. 4 and 6. According to one embodiment, the sensor **22** may be mounted in a channel **24** that is fastened to the trim panel **400** or that is molded into the trim panel **400**. The sensor **22** may be held in the channel **24** by compressive fit. The sensor **22** may include compressive ridges **500** along the outer sides **510** of the case **300** to engage the inner sides **600** of the channel **24** to hold the sensor **22** in place within the channel **24**.

[0036] According to one embodiment, the case **300** may be formed as an extruded, elongate, elastomeric trim piece with co-extruded conductive bodies **1b**, **2b** and with the conductors **1a**, **2a** molded directly into the bodies **1b**, **2b**. The trim piece may be part of the trim panel **400** of the liftgate **12**.

[0037] With respect to capacitive sensing, a portion **320** of the case **300** electrically insulates the capacitive sensor electrode **1** and the capacitive shield electrode **2** so that electrical charge can be stored therebetween in the manner of a conventional capacitor. According to one embodiment, the inner surface **2d** of the capacitive shield electrode **2** may be shaped to improve the shielding function of the electrode **2**. According to one embodiment, the inner surface **2d** may be flat as shown in FIG. 5.

[0038] A capacitive sensor circuit may be formed by the capacitive sensor electrode **1**, a terminal resistor (not shown), and the capacitive shield sensor electrode **2**. The capacitive sensor circuit is coupled to and driven by the controller **26**.

[0039] The sensor **22** is used by the controller **26** to measure a capacitance (or capacitance value) of an electric field extending through the opening **500** under the liftgate **12**. According to one embodiment, the capacitive shield electrode **2** functions as a shielding electrode since it is positioned closer to the sheet metal of the liftgate **12**. As such, the electric field sensed by the capacitive sensor electrode **1** will be more readily influenced by the closer capacitive shield electrode **2** than the vehicle sheet metal. To improve signal quality, the liftgate **12** may be electrically isolated from the remainder of the vehicle **14**. A powered sliding door, for example, may be isolated through the use of non-conductive rollers.

[0040] The capacitance (or capacitance value) of the sensor **22** is measured as follows. The capacitive sensor electrode **1** and the capacitive shield electrode **2** are charged by the controller **26** to the same potential using a pre-determined pulse train. For each cycle, the controller **26** transfers charge accumulated between the electrodes **1, 2** to a larger reference capacitor (see FIG. 2), and records an electrical characteristic indicative of the capacitance of the sensor **22**. The electrical characteristic may be the resultant voltage of the reference capacitor where a fixed number of cycles is used to charge the electrodes **1, 2**, or a cycle count (or time) where a variable number of pulses are used to charge the reference capacitor to a predetermined voltage. The average capacitance of the sensor **22** over the cycles may also be directly computed. When an obstacle enters the opening **500** under the liftgate **12**, the dielectric constant between the electrodes **1, 2** will change, typically increasing the capacitance of the sensor **22** and thus affecting the recorded electrical characteristic. This increase in measured capacitance is indicative of the presence of the obstacle (i.e., its proximity to the liftgate **12**).

[0041] FIG. 7 is rear view illustrating a capacitive sensing system **10** for a liftgate **12** of a vehicle **14** combined with liftgate mounted resistive pinch sensors **710**, in accordance with an embodiment of an aspect of the invention. FIG. 8 is rear view illustrating a capacitive sensing

system **10** for a liftgate **12** of a vehicle **14** combined with liftgate mounted resistive pinch sensors **710** and body mounted capacitive sensors **810**, in accordance with an embodiment of an aspect of the invention. FIG. 9 is rear view illustrating a capacitive sensing system **10** for a liftgate **12** of a vehicle **14** combined with liftgate mounted resistive and capacitive sensors **710**, **910** and multiple controllers **26**, **700**, **900**, in accordance with an embodiment of an aspect of the invention. FIG. 10 is rear view illustrating a capacitive sensing system **10** for a liftgate **12** of a vehicle **14** combined with liftgate **12** mounted resistive and capacitive sensors **710**, **910** and dual controllers **26**, **700**, in accordance with an embodiment of an aspect of the invention. And, FIG. 11 is rear view illustrating a capacitive sensing system **10** for a liftgate **12** of a vehicle **14** combined with liftgate mounted resistive and capacitive sensors **710**, **910**, in accordance with an embodiment of an aspect of the invention.

[0042] As shown in FIGS. 7-11, the capacitive sensing system **10** may be combined with various pinch sensors and systems to provide improved obstacle and pinch sensing. In FIG. 7, the capacitive sensing system **10** is combined with a pair of resistive pinch sensors **710** disposed along opposing sides of the liftgate **12**. The resistive pinch sensors **710** are provided with a separate controller **700** which is in communication with the controller **26** of the capacitive sensing system **10** by way of a LIN communication protocol, or the like.

[0043] In FIG. 8, the capacitive sensing system **10** is combined with a pair of resistive pinch sensors **710** disposed along opposing sides of the liftgate **12**, as well as a pair of capacitive sensors **810** mounted to the body **16** of the vehicle **12**. In a preferred embodiment, the capacitive sensor **810** can be embedded into side trim panels of the body **16** disposed adjacent to the liftgate **12**. The resistive pinch sensors **710** and body mounted capacitive sensors **810** are each provided with separate controllers **700**, **800** which are in communication with the controller **26** of the capacitive sensing system **10** by way of a LIN communication protocol, or the like.

[0044] In FIG. 9, the capacitive sensing system **10** is combined with resistive pinch sensors **710** and liftgate mounted capacitive sensors **910** each extending along opposing sides of the liftgate **12**. In an embodiment, the resistive pinch sensor **710** and the liftgate mounted capacitive sensor **910** can be incorporated into the same sensor, such as is described in U.S. provisional patent application Serial No. 61/791,472, incorporated herein by reference. The resistive pinch sensors **710** and capacitive sensors **910** are provided with separate controllers **700**, **900** which are in communication with the controller **26** of the capacitive sensing system **10**, by way of a LIN communication protocol or the like.

[0045] In FIG. 10, the capacitive sensing system **10** is combined with resistive pinch sensors **710** and liftgate mounted capacitive sensors **910**. The resistive pinch sensors **710** and capacitive sensors **910** each communicate with the same separate controllers **700** which is in communication with the controller **26** of the capacitive sensing system **10** by way of a LIN communication protocol, or the like. Once again, in an embodiment, the resistive pinch sensor **710** and the liftgate mounted capacitive sensor **910** can be incorporated into the same sensor, such as is described in U.S. provisional patent application Serial No. 61/791,472, incorporated herein by reference.

[0046] In FIG. 11, the capacitive sensing system **10** is combined with resistive pinch sensors **710** and liftgate mounted capacitive sensors **910**. Once again, in an embodiment, the resistive pinch sensor **710** and the liftgate mounted capacitive sensor **910** can be incorporated into the same sensor, such as is described in U.S. provisional patent application Serial No. 61/791,472, incorporated herein by reference. Also, the resistive pinch sensors **710**, capacitive sensors **910**, and the at least one elongate capacitive sensor **22** all share a common controller **26**. As a result, an integrated and common controller **26** leads to cost savings for the capacitive sensing system **10**.

[0047] Thus, according to one embodiment, there is provided a capacitive sensing system **10** for a liftgate **12** of a vehicle **14**, comprising: at least one elongate capacitive sensor **22** mounted on a trim panel **400** of the liftgate **12**, the at least one elongate capacitive sensor **22** arranged to extend over an area **100** of the trim panel **400**; and, a controller **26** coupled to the at least one elongate capacitive sensor **22** for monitoring changes in a capacitance value of the at least one elongate capacitive sensor **22**, the capacitance value changing when an obstacle approaches the area **100**. In the above capacitive sensing system, the at least one elongate capacitive sensor **22** may be a plurality of elongate capacitive sensors **22**.

[0048] The above embodiments may contribute to an improved capacitive sensing system **10** and may provide one or more advantages. First, by arranging or distributing the capacitive sensors **22** over an area **100** of the trim panel **400** of the liftgate **10** to improve obstacle detection. Second, the capacitive sensing system **10** may be combined with pinch sensing systems to further improve obstacle detection. Third, false positive indications or noise may be reduced by using multiple sensors **22** distributed over an area **100** of the trim panel **400** as the likelihood of an obstacle activating all of the sensors **22** is not large.

[0049] The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure. Individual elements or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within the scope of the disclosure.

WHAT IS CLAIMED IS:

1. A capacitive sensing system for a liftgate of a vehicle, comprising:
at least one elongate capacitive sensor mounted on a trim panel of the liftgate, said
at least one elongate capacitive sensor arranged to extend over an area of the liftgate trim panel;
and
a controller coupled to said at least one elongate capacitive sensor for monitoring
changes in a capacitance value of said at least one elongate capacitive sensor, the capacitance
value changing when an obstacle approaches the area.
2. The capacitive sensing system of claim 1, wherein said at least one elongate
capacitive sensor includes a plurality of elongate capacitive sensors arranged to extend over a
substantial area of the trim panel, each of said plurality of elongated capacitive sensors
individually coupled to said controller.
3. The capacitive sensing system of claim 2, wherein said plurality of capacitive
sensors includes four elongate capacitive sensors each extending from said controller to a
respective corner of the liftgate trim panel.
4. The capacitive sensing system of claim 1, wherein said at least one sensor is
mounted in a mounting channel extending along the liftgate trim panel.
5. The capacitive sensing system of claim 4, wherein said mounting channel is
attached to the liftgate trim panel.

6. The capacitive sensing system of claim 4, wherein said mounting channel is moulded into the liftgate trim panel.

7. The capacitive sensing system of claim 4, wherein said at least one sensor establishes a compressive fit with said mounting channel.

8. The capacitive sensing system of claim 7, wherein said at least one sensor includes a plurality of compressive ridges extending along outer sides of a case, said compressive ridges disposed in engaging relationship with inner sides of said mounting channel to establish the compressive fit therebetween.

9. The capacitive sensing system of claim 1, further comprising at least one resistive pinch sensor mounted to the liftgate.

10. The capacitive sensing system of claim 9, wherein said at least one resistive pinch sensor is coupled to a second controller separate from but in communication with said controller.

11. The capacitive sensing system of claim 9, further comprising at least one body mounted capacitive sensor mounted to a side trim panel disposed adjacent to the liftgate of the vehicle.

12. The capacitive sensing system of claim 11, wherein said at least one body mounted capacitive sensor is coupled to a third controller separate from but in communication with said controller and said second controller.

13. The capacitive sensing system of claim 9, further comprising at least one liftgate mounted capacitive sensor mounted to the liftgate.

14. The capacitive sensing system of claim 13, wherein said at least one liftgate mounted capacitive sensor is coupled to a third controller separate from but in communication with said controller and said second controller.

15. The capacitive sensing system of claim 14, wherein said at least one liftgate mounted capacitive sensor is coupled to said second controller.

16. The capacitive sensing system of claim 13, wherein said comprising at least one resistive pinch sensor and said at least one liftgate mounted capacitive sensor are coupled to said controller.

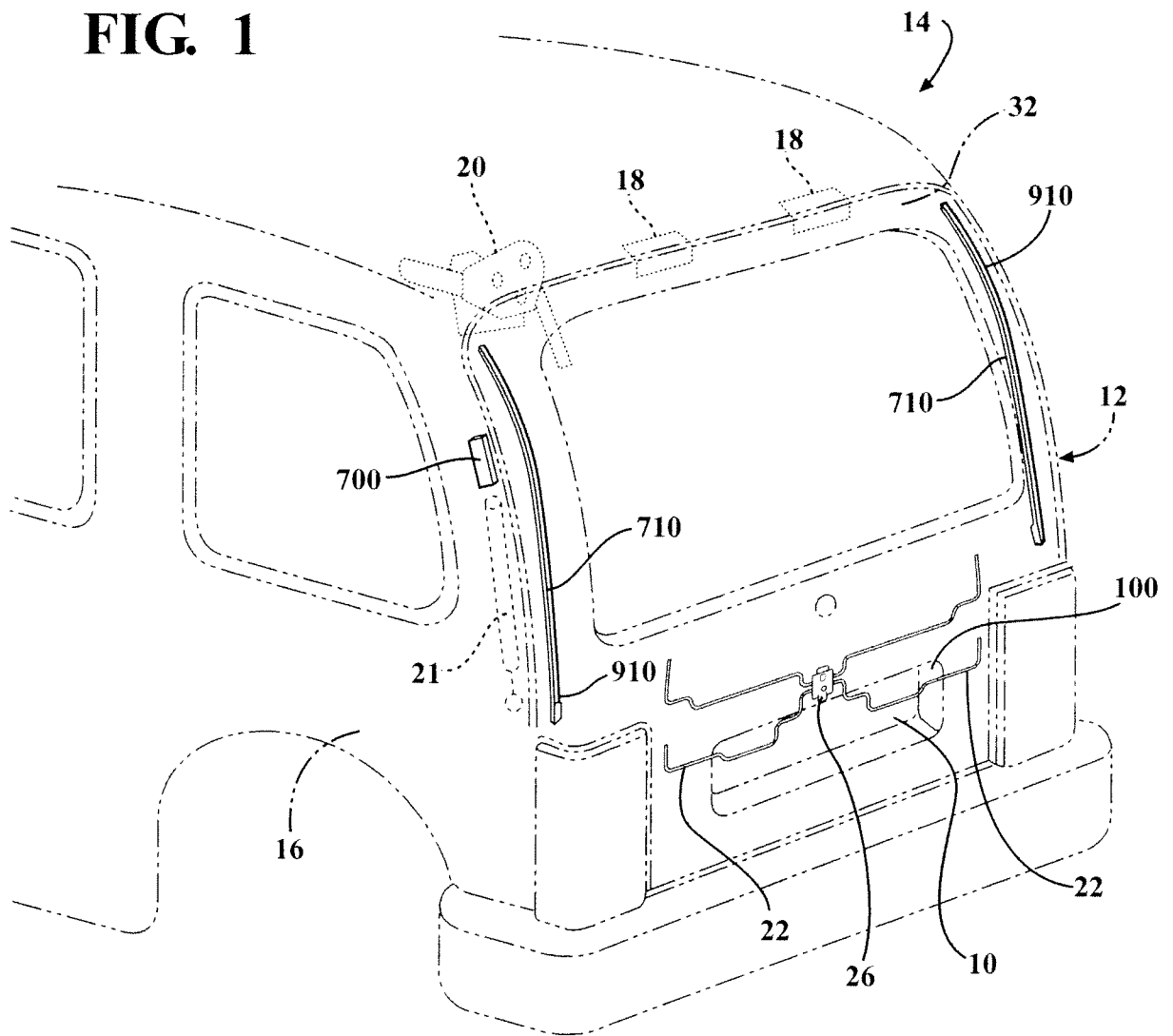
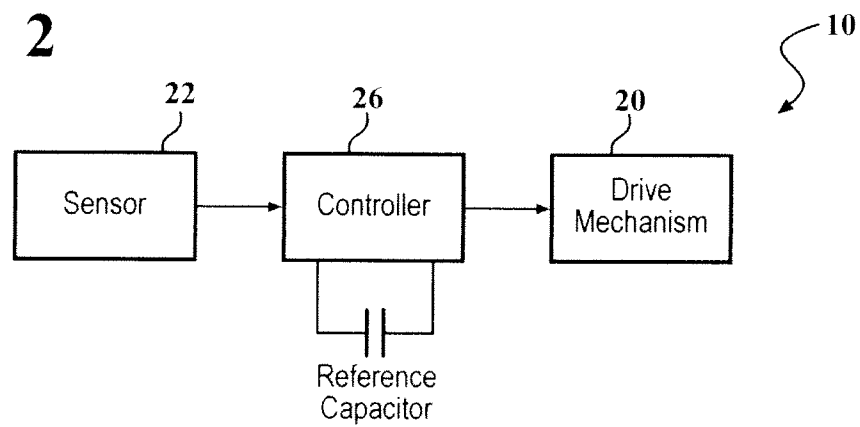
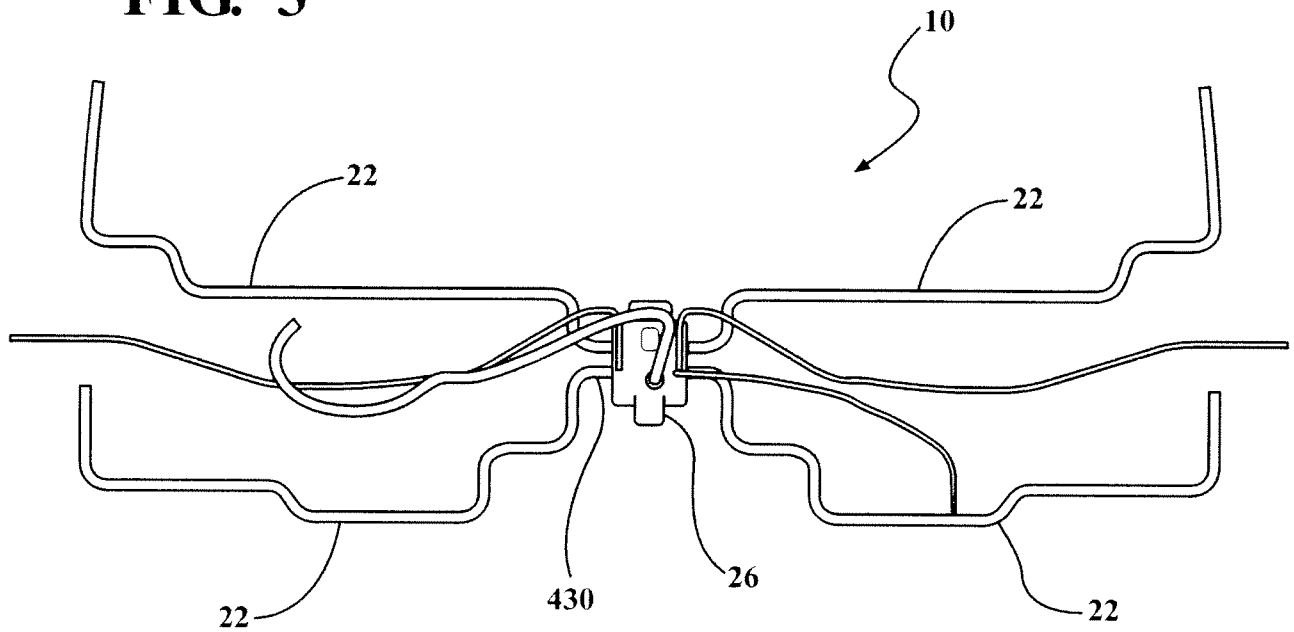
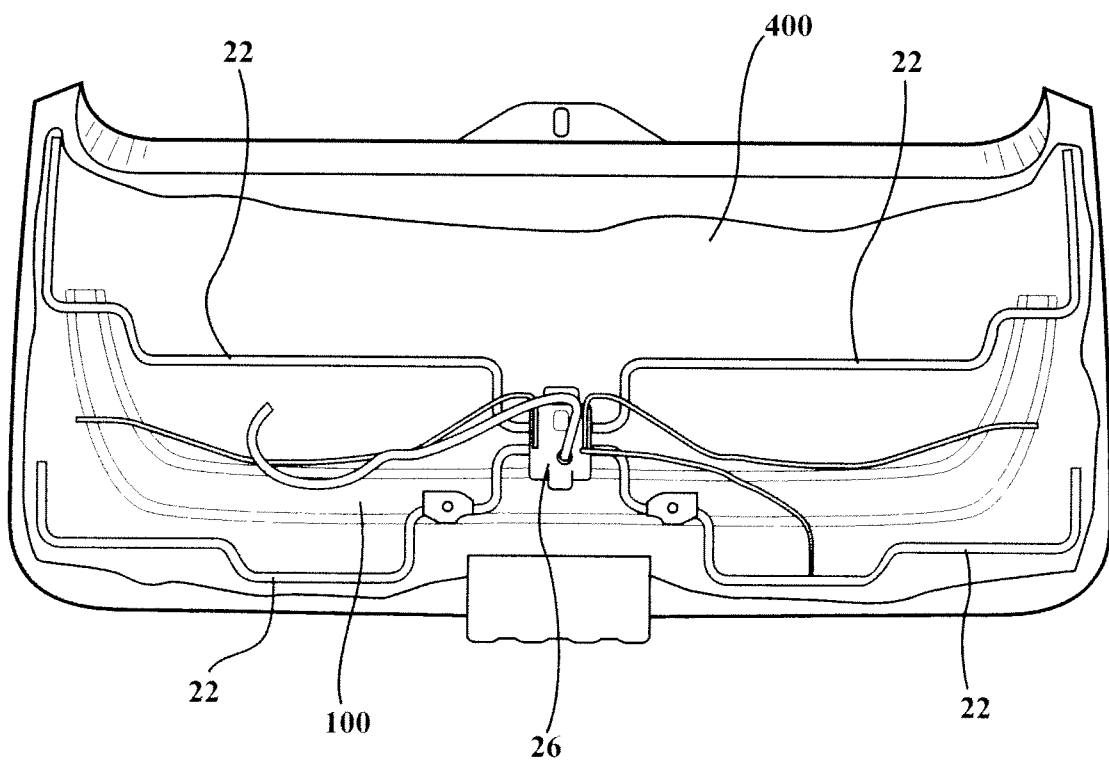
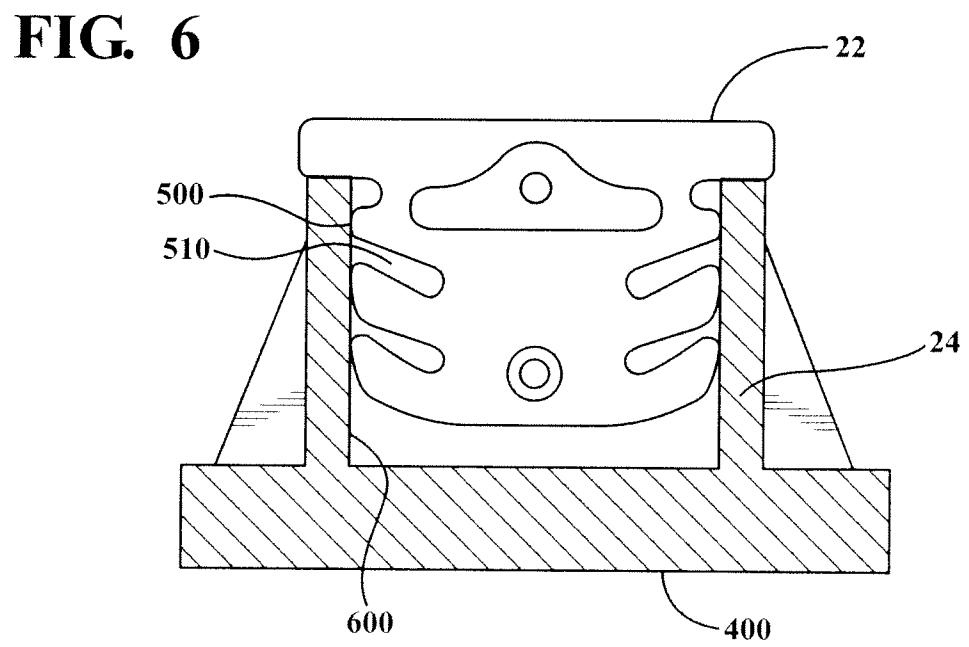
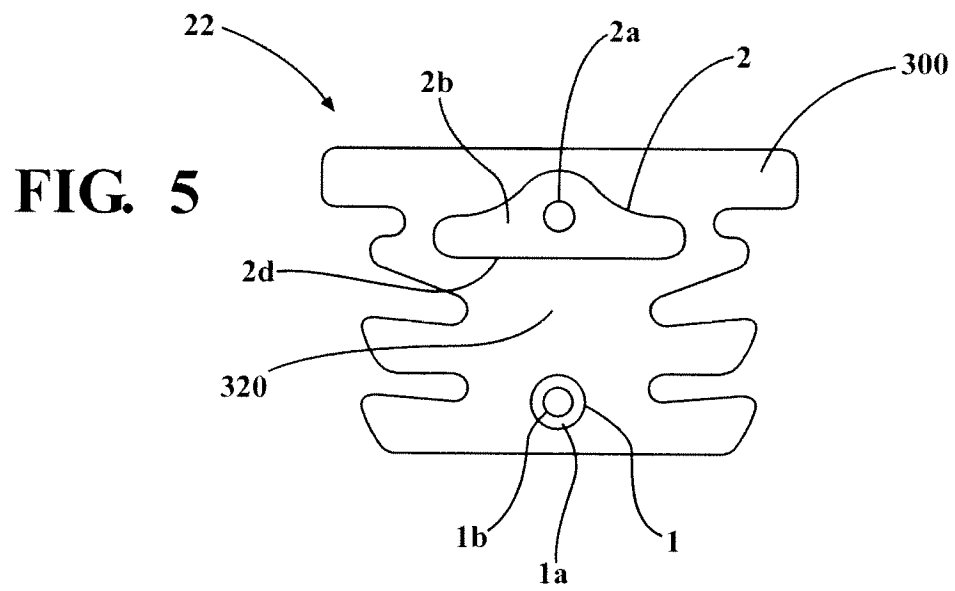
FIG. 1**FIG. 2**

FIG. 3**FIG. 4**



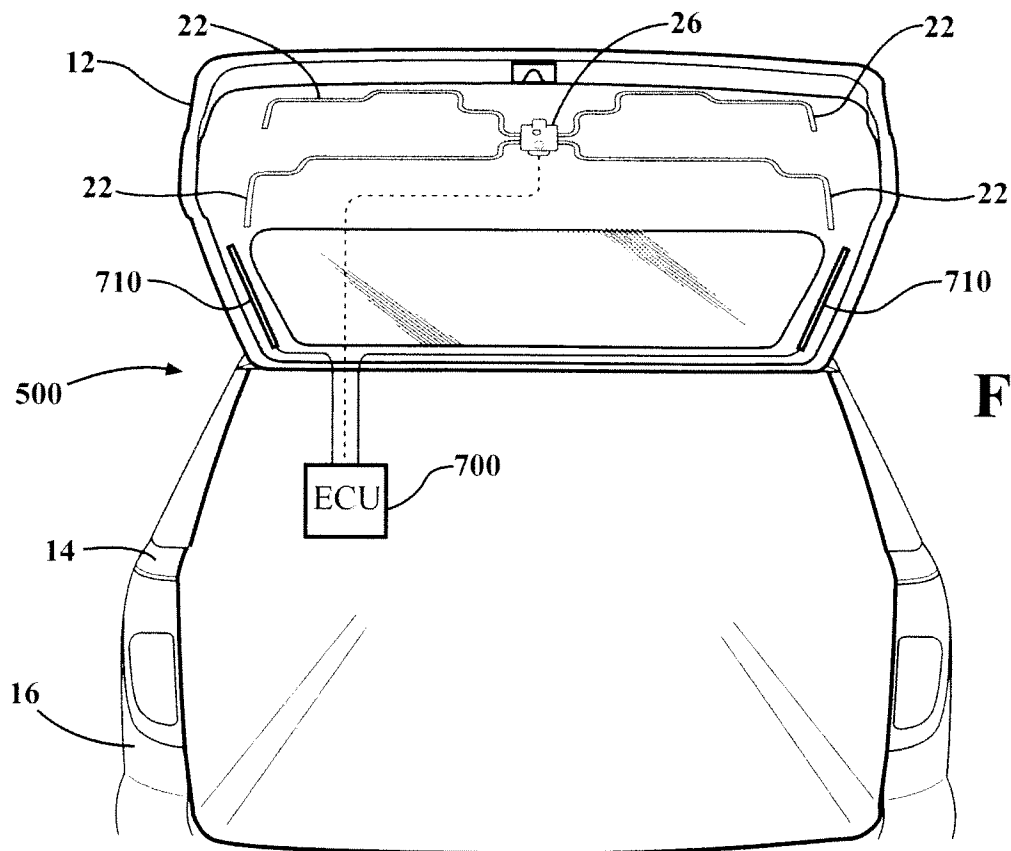


FIG. 7

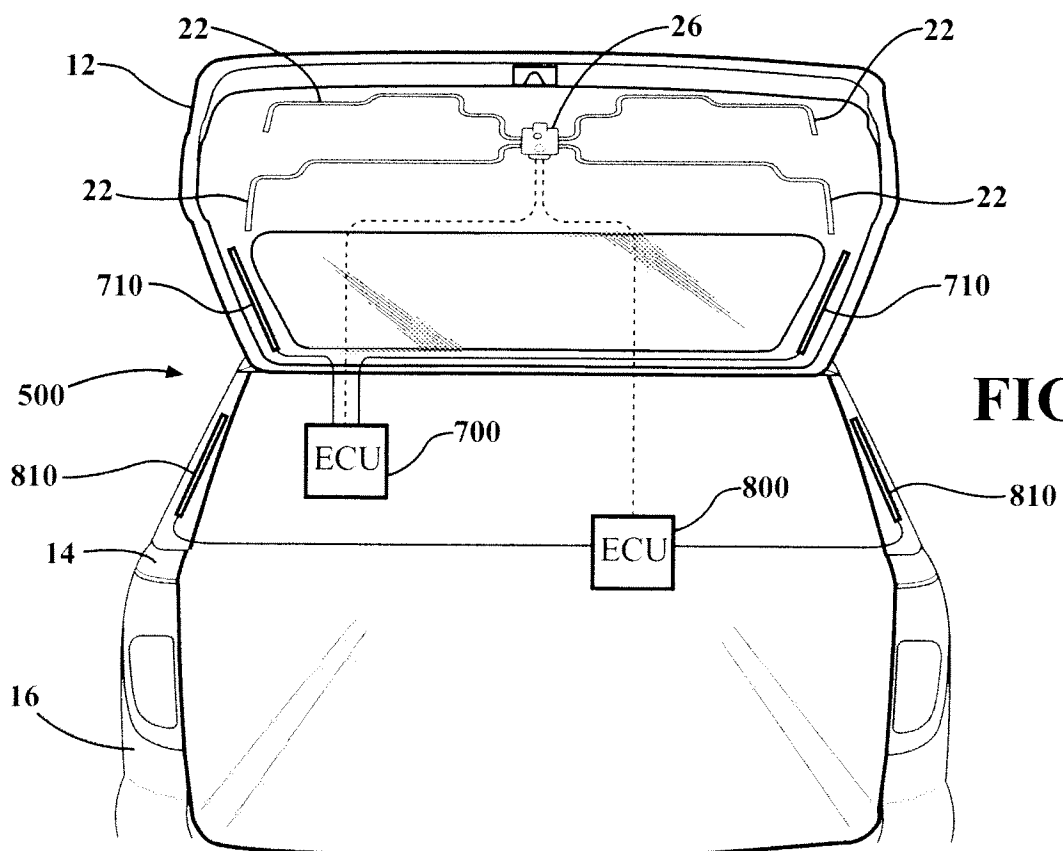
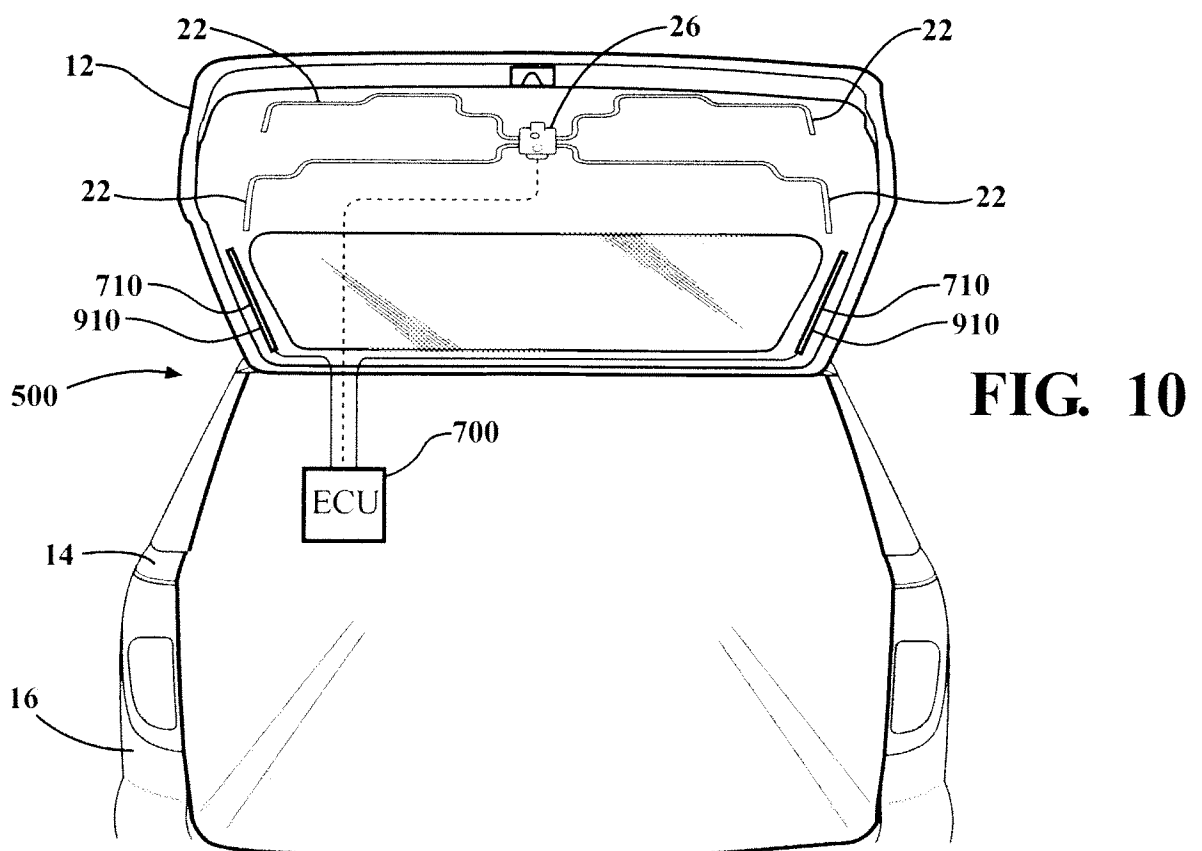
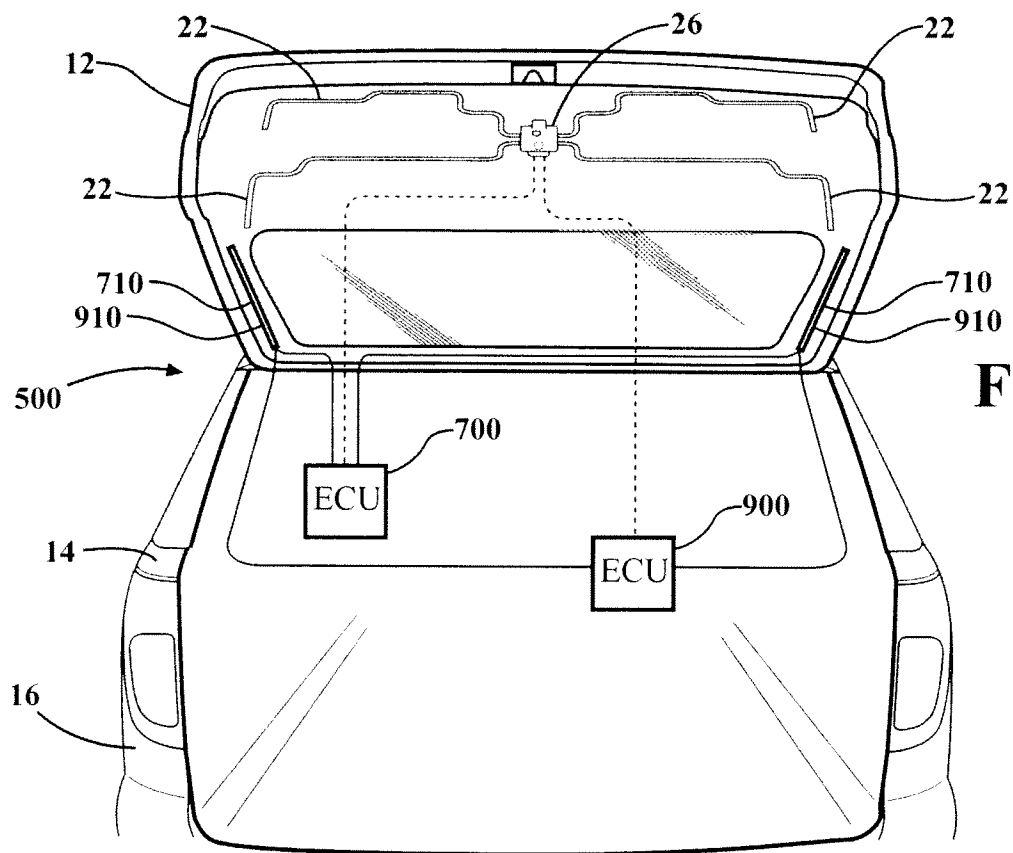


FIG. 8



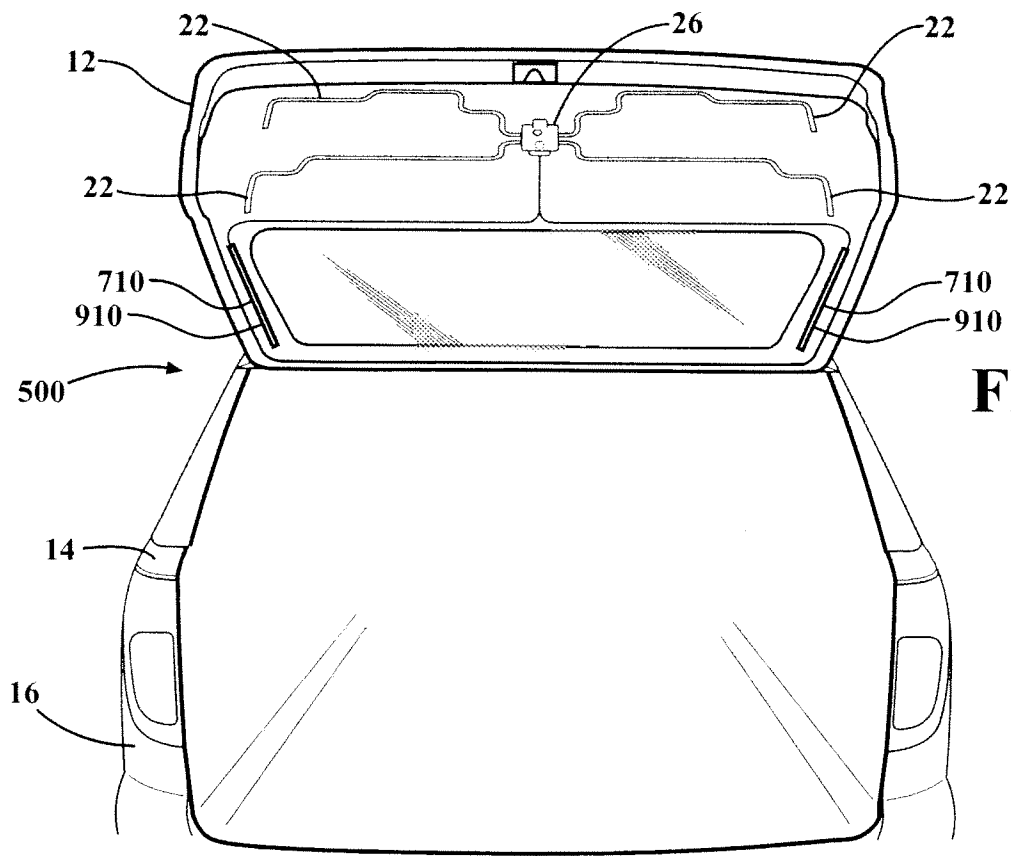


FIG. 11