Abstract: A sensing arrangement for detecting a body part in a vehicle opening is described. The arrangement includes a flexible sealing member with first and second separate electrically conductive members which are connected by a varicap diode. In operation of the sensing arrangement an electrically oscillating signal is applied to one of the electrically conductive members to generate an electric field in the opening. The control voltage of the varicap diode is modulated by a frequency f₀ and the sensing arrangement includes detecting means for detecting frequency f₀ to verify that there are no breaks and/or defects in said electrically conductive members.
VEHICLE OPENING DEVICE

This invention relates to a sensing arrangement for sensing a body part in an opening, such as a vehicle window opening.

More particularly, the invention relates to verifying the operation of the sensor or sensing arrangement.

US 2004/0172879 discloses an object sensing arrangement with two electrodes in which the electrodes are connected by a control resistor and the system integrity is tested by applying a testing voltage to the electrodes and control resistor. In this citation the control resistor is merely present to ensure continuity between the electrodes. Charging the value of the voltage applied to the electrodes and the control resistor has no effect on the operation of the object sensing assembly.

It is an object of the invention to provide an object sensing arrangement in which continuity of the electrodes is monitored by applying a modulating frequency to a variable capacitance means interconnecting the electrodes and detecting the applied modulating frequency.

The modulating frequency is also used to modulate the electric field used in detecting body parts in the vehicle opening.
According to the invention there is provided a sensing arrangement for sensing a body part in a vehicle opening, said sensing arrangement comprising:

a flexible sealing member adapted to be positioned adjacent to said opening; a first electrically conductive member within said flexible sealing member; a second electrically conductive member within said flexible sealing member separate from said first electrically conductive member; means for applying an electrically oscillating signal to at least one of said first and second electrically conductive members to generate an electric field in said opening; said electrically oscillating signal having a modulation frequency; variable capacitance means interconnecting said first and second electrically conductive members and having a capacitance which varies at said modulation frequency of said electrically oscillating signal, and detecting means for detecting a change in capacitance of said first and second electrically conductive members when a body part is within said electric field and for detecting said modulation frequency to enable electrical continuity of said first and second electrically conductive members to be determined.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying diagrammatic drawings in which:

Figure 1 is a diagrammatic side elevation of a motor vehicle;
Figure 2 is a cross-sectional view along line H-II of Figure 1 of the window frame with a sealing and guiding strip showing an arrangement of the electrically conductive members according to the invention;

Figure 3 is a representative view of the connection between the two electrically conductive members and the variable capacitance means, and the connection of the second electrically conductive member to the control circuitry of figure 4.

Figure 4 is a block circuit diagram for the arrangement shown in Figures 2 and 3.

In the drawings, like elements are generally designated with the same reference numeral.

Figure 1 shows a motor vehicle 5 having a front door 6 with a power-driven window 8 which is shown cross-hatched for clarity. The power-driven window 8 is raised and lowered by means of a suitable motor, normally an electric motor, under the control of switches positioned within the vehicle for use by the driver or passenger. All or some of the other side windows in the vehicle may also be power-driven.

The window frame 10, forming part of the vehicle door, incorporates a window guide channel 12 one form of which is shown in Figure 2. The window guide channel comprises extruded plastics or rubber material which incorporates an embedded metal core or carrier 18.
The carrier 18 may take any suitable form. For example, it may comprise a simple channel of metal. The channel could additionally be formed with apertures to increase its flexibility. Instead, the carrier could be made from U-shaped metal elements arranged side-by-side to define the channel and either connected together by short flexible interconnecting links or entirely disconnected from each other. The metal could be steel or aluminium, for example.

Instead, the carrier could be made of metal wire looped to and fro to define the channel.

The carrier 18 is advantageously incorporated into the extruded material by a known cross-head extrusion process.

In this embodiment the carrier 18 is C-shaped, with an extension piece 28 extending down from one of the arms of the C-shaped channel. Between extension piece 28 and sidewall 44 is a hollow chamber 46. Advantageously, metal carrier 18 within the window guide channel 12 where it runs along the top part 1OC of the window frame (Figure 1) is separated from the metal carrier 18 in those parts of the window guide channel 12 fitted to parts 1OA and 1OB of the window frame.

The extruded material defines a lip 40 projecting outwardly from a sidewall of the window guide channel 12, a lip 62 directed inwardly into the glass receiving channel.
from sidewall 44 of the window guide channel 12 and a similar lip 38 on the opposite side of the window guide channel 12 but of shorter extent.

The area 14 between window 8 and lip 38 of channel 12 is glass receiving channel 14.

The window frame 10 (Figure 1) may take the form of a metal channel which is sized to receive the window guide channel 12 as shown in Figure 2. When the window guide channel 12 is fitted into position within this window frame 10, lips 24 and 26 (Figure 2) overlap and grip the outsides of the window frame 10, specifically lips 24 contact panel 22 of window frame 10.

The window guide channel 12 extends around the sides and top of the window frame 10. Thus, it extends up that part 10A of the frame alongside the "A" pillar of the vehicle, along the top 10C of the frame and down that part 10B of the frame corresponding to the "B" pillar. Where the window glass 8 slides into and out of the lower part 5A of the door 5, a waist-seal (not shown) is provided on each side of the slot.

The surfaces of the window guide channel 12, and of the waist-seal, which contact the sliding glass are advantageously covered in flock or other suitable material to provide a low-friction and substantially weather-proof surface.
The window guide channel 12 also has a portion 30 which is clipped into window frame 1OC and also holds the window guide channel in position. Lips 32 and 31 contact parts of window frame 1OC to hold window guide channel 12 in position.

As shown in Figure 2, window guide channel 12 includes sealing member 52 and sealing lip 50 on the outside of the window frame. Sealing member 52 and sealing lip 50 engage the frame of the door opening when the door 5 is closed, to provide a seal around the edge of the door 5.

Window guide channel 12 also includes flexible seal member 60. This may be formed of the same extruded plastic or rubber material as window guide channel 12 or a different material. It may be formed integrally with window guide channel 12, or as a separate element to be joined to window guide channel 12. Seal member 60 may be joined to window guide channel 12 during the moulding operation which forms window guide channel 12 or they may be joined by applying an adhesive.

The connection between window guide channel 12 and seal member 60 is not an essential feature of the invention. Flexible seal member 60 is located on the underside of window frame 10, inside of the car at a distance from window 8.

Embedded in seal member 60 are an outer electrically conductive member 72 and an inner electrically conductive member 66. The inner and outer electrically conductive members are separated by hollow chamber 70. The outer electrically conductive
member 72 includes wire 74 which is located within and runs the length of outer electrically conductive member 72, and the inner electrically conductive member 66 includes wire 68 which is located within and runs the length of inner electrically conductive member 66. One end of wire 66 is connected to VCO 302 (see figure 4) and one end of wire 74 is connected to ground. Of course, these connections may be the other way round. The other end of wires 74 and 68 are connected together by a varicap diode - (see figure 3).

Preferably, the inner and outer electrically conductive members 72, 66 are made of electrically conductive rubber. The remainder of flexible seal member 60 is preferably made from insulating rubber. Preferably wires 74 and 68 are metal wires.

In this embodiment of the invention outer electrically conductive member 72 has a main body portion 78 and side portions 76 which extend away from main body portion 78 towards the inner electrically conductive member 66. The outer electrically conductive member 72 is thus substantially channel-shaped and the inner electrically conductive member 66 is located on the opposite side of hollow chamber 70 within, and extending lengthwise of, the channel defined by the outer electrically conductive member 72. Other arrangements for the inner and outer electrically conductive members may be contemplated and the invention is not limited to electrically conductive members with the shapes as described above.
It is understood that the extruded plastic or rubber material of flexible seal member 60 electrically insulates the inner and outer electrically conductive members 66 and 72 from the vehicle bodywork.

Flexible seal member 60 also has seal region 80 located between the main body portion 78 and window frame 10C. Seal region 80 contacts window frame 10C. Extending away from seal member 60, on the opposite side of the seal member 60 to window 8 is lip seal 64 which engages with window frame 10C.

Seal member 60 also includes protrusion 82, located on the underside of flexible seal member 60 below inner electrically conductive member 66. The protrusion 82 is separated from inner electrically conductive member 66 by a part of the body of flexible seal member 60.

In the usual way, when a driver or passenger of the vehicle wishes to raise or lower a window they operate an appropriate switch to energise the motor, and the window glass moves either up or down (as desired) within the guide channel 12.

The arrangement now to be described is a sensing arrangement for sensing a body part (e.g. a hand) which may have been placed within a gap between the window glass 8 and the window frame 10. The arrangement will detect such an obstruction when it comes within a predetermined distance of flexible seal member 60. In a preferred embodiment the motor driving the window glass will stop and/or reverse the window
movement to prevent the body part from becoming trapped (and possible injured) in the region between the top of the window glass and the window frame.

Figure 3 shows, in schematic form, the connection between the inner and outer electrically conductive members 66 and 72, and how the members are connected to the detection circuitry of figure 4.

Wire 74 extends through the length of outer electrically conductive member 72. One end of wire 74 is connected to ground by connection 350. The other end of wire 74 is connected to one side of a variable capacitance means, in this example, a varicap diode 90. The other side of the varicap diode 90 is connected to one end of wire 68, which, as mentioned previously runs through inner electrically conductive member 66. The other end of wire 68 is connected to a high frequency supply line 330 (see figure 4) by connection 340.

When a high frequency electrically oscillating signal is applied to the wire 68 in the inner electrically conductive member 66, the two electrically conductive members 66 and 72 act as a capacitor.

Figure 4 shows a detection circuit 300 for energising motor 322 for raising and lowering the window glass.
Motor 322 for driving the window glass up and down is connected to a micro-controller 312 and switches 316 and 318 for moving the window up and down respectively are also connected to the micro-controller 312. Micro-controller 312 also includes A/D converter 324.

The detection circuit 300 has a first oscillator 308, which is quartz stabilised and has an output frequency (in this example) of 4MHz. The output of oscillator 308 passes on line 334 to phase detector 304. Typically, the first oscillator 308 and phase detector 304 are integral parts of an electrical chip such as Motorola MC145155-2 (Motorola CMOS application specific digital-analogue integrated circuits).

The output frequency of voltage controlled oscillator (VCO) 302 is also received at phase detector 304. The output frequency of VCO 302 is compared with output frequency of oscillator 308 in the phase detector 304. As a result of the comparison, a control voltage Uvco for VCO 302 is output from the phase detector 304 along line 358. Phase detector 304 includes a divider (not shown) set by micro-controller 312 so that the initial control voltage, Uvco output from the phase detector 304 is 1 Volt.

The initial value of control voltage Uvco is also supplied to micro-controller 312 over line 336 where it is stored as a reference value.

The control voltage Uvco output from phase detector 304 passes along line 358 to VCO 302 via the junction of a resistor 306 and a capacitor 314.
It will be apparent that phase detector 304 and VCO 302 form a phase locked loop, the control voltage Uvco being supplied to the VCO 302 via a loop filter formed by resistor 306 and capacitor 314.

Line 330 connects the VCO 302 (via another capacitor 342) to one side 340 of the capacitor (shown in Figure 3), formed by outer electrically conductive member 72 and inner electrically conductive member 66. The other side 350 of the capacitor formed by the two electrically conductive members is connected to ground. Preferably VCO 302 is connected to inner electrically conductive member 66 and outer electrically conductive member 72 is connected to ground.

Circuit 300 also includes sine wave generator 360. A DC voltage controlling the varicap diode 90 (see figure 3) is modulated by modulating frequency f_0 output from the sine wave generator 360. Modulating frequency f_0 passes to varicap diode 90 via the junction of resistors 344 and 346. The capacitance of varicap diode 90 will vary at the modulating frequency f_0. Typically the modulating frequency f_0 is less than 200 Hz.

The output frequency f_i of VCO 302 depends on the capacitance of the inner and outer electrically conductive members 66, 72 and also on the variable capacitance of the varicap diode 90. Therefore, the frequency f_i of VCO 302 is frequency modulated at the frequency f_0 of the sine wave generator 360.
Circuit 300 also includes a frequency/voltage converter 362. The converter 362 includes monostable 370, resistor 372 and capacitor 374. The time constant used by converter 362 is smaller than the time constant of the phase locked loop. The frequency modulated output of VCO 302 is input to monostable 370 of converter 362 along line 376.

In response to the input from VCO 302, monostable 370 outputs pulses of fixed duration along line 373. Resistor 372 and capacitor 374 act as a low pass filter to remove high frequencies from the output pulses of monostable 370.

Once the output pulses have been filtered in this way they pass out of converter 362 to band pass filter 364. Band pass filter 366 is arranged to eliminate substantially all frequencies except modulating frequency $f_0$. The output of band pass filter 364 passes via amplifier 365 to switching circuit 366.

Converter 362, filter 364 and switching circuit 366 are used to determine the electrical continuity of the inner and outer electrically conductive members 66, 72 as now described.

If there is electrical continuity of the electrically conductive members 66, 72 and the varicap diode 90, the modulating frequency $f_0$, output from sine wave generator 360 will be continuously supplied to the varicap diode 90. The resultant change of
capacitance of varicap diode 90 causes the output frequency of VCO 302 to be
frequency modulated at the modulating frequency \( f_0 \). As mentioned above, this is
received at monostable 370 in converter 362 along line 376. Whilst there is electrical
continuity of the electrically conductive members 66, 72 then a sine wave with
frequency \( f_0 \) is present at capacitor 374 of converter 362. As mentioned above, \( f_0 \) is
the modulating frequency and can pass through band pass filter 364 to switch 366 via
amplifier 365. The output of the amplifier 365 is supplied to the gate electrode of the
transistor 384 and switches the transistor on. The gate electrode of the transistor 384 is
also connected to ground via resistor 381. The time constant of \( C388* R386 \)
(capacitor 388* resistor 386) is such that no significant signal is present at capacitor
388 when \( f_0 \) has been received in switch 366 and switched transistor 384 on.
Therefore, whilst the transistor 384 is switched on no error signal will be produced.
The absence of an error signal from the switching circuitry indicates that there is
electrically continuity of the inner and outer electrically conductive members 66, 72
and that the operation of the sensing arrangement for sensing a body part in the
window opening can continue. By contrast, if there is an interruption of electrical
continuity due to a break and/or defect in one or both of the electrically conductive
members 66, 72, pulses will continue to be output from monoflop 370 but in this case,
there will only be a DC voltage present at capacitor 374 in converter 362. The
modulating frequency \( f_0 \) will not be present at capacitor 374. The value of the DC
voltage is dependent on the frequency \( f_1 \) of the VCO 302. This DC voltage cannot
pass through band pass filter 364 and so output pulses will no longer be supplied from
amplifier 365 to the gate electrode of transistor 384, the transistor 384 will not be
switched on, and this will generate an error signal from capacitor 388 which is detected by the micro-controller 312.

Micro-controller 312 will respond to the error signal by disabling motor 322 which drives the window glass up and down.

As well as verifying the continuity of the inner and outer electrically conductive members 66, 72 as described above the sensing arrangement is also used to detect a body part in the vicinity of the window opening, as will now be described.

When the wire 68 in inner electrically conductive member 66 is energised by VCO 302 an electric field is radiated by the inner electrically conductive member 66 and is present within the area of the window frame 10. The relationship between the arrangement of the two electrically conductive members 66, 72 in this embodiment is such that electric field lines are concentrated in the vicinity of the window opening. This is because the inner and outer electrically conductive members 66, 72 are significantly differently shaped. More specifically, in this embodiment, side portions 76 of the outer electrically conductive member 72 are directed towards the inner electrically conductive member 66 to define a channel, and the inner electrically conductive member 66, which is relatively flat, extends lengthwise of the channel, in this example wholly within the channel.
Electric field lines generated by this arrangement are represented by arrows $E$ in Figure 2. As depicted in that Figure, the field lines are concentrated in the vicinity of the window opening; elsewhere, for example outside the window opening or within the interior of the vehicle, the field lines are much less dense.

The concentration of field lines in the vicinity of the window opening gives the sensing assembly greater sensitivity to the presence of a body part such as a hand within the opening.

When the window is open, closing switch 316 will cause the motor to be raised automatically by motor 322 if the continuity of the electrically conductive members 66, 72 has been verified and the motor is operational. During the movement of the window upwards, the instantaneous frequency of VCO 302 is continually detected at phase detector 304 and compared with reference output for quartz stabilised oscillator 308. The control voltage $U_{vco}$ resulting from the comparison is output to microcontroller 312 along line 336 to be compared with the stored reference value of the control voltage.

If the difference between the value of the instantaneous voltage $U_{vco}$ and the stored reference value is below a certain preset threshold then the window will continue to move upwards. The threshold is set to be dependent on the position of the window in the window opening and is such that the window will close even if the window is wet,
when there are no obstacles with high dielectric constant within the vicinity of the electric field in the opening.

If an obstacle with a relatively high dielectric constant e.g. a human body part is within the vicinity of the electric field in the window opening, this will cause a change in capacitance of the capacitor formed by the outer and inner electrically conductive members 72 and 66.

This change in capacitance will lead to a change in the frequency of VCO 302. The altered frequency is received along line 332 at phase detector 304 where it is compared with the reference frequency for the quartz oscillator 308.

The control voltage Uvco resulting from the comparison is output to micro-controller 312 and the value of the control voltage is compared with the stored reference value. If the difference between the two voltage values exceeds the same preset threshold, this indicates that the output frequency of VCO 302 has changed sufficiently to indicate the presence of a body part in the vicinity of the electric field in the window opening. In this case, micro-controller 312 will stop and preferable reverse the window to prevent damage to the body part in the window opening.

Of course, whilst the window is being moved up and the circuitry of figure 4 is operating to detect a body part in the vicinity of the window opening, it is also continuing to determine the electrical continuity of the inner and outer electrically
conductive members 66, 72. If a lack of continuity is detected, indicating a break and/or defect in one or other of the electrically conductive members, movement of the window will be halted, even if a body part is not within the vicinity of the window.

Environmental changes e.g. rainfall may also cause a small change in the capacitance of the capacitor formed by inner and outer electrically conductive members 66 and 72. In this case, the small change in capacitance will cause a change in the frequency of VCO 302 which is detected by phase detector 304. As described above, phase detector 304 performs a comparison and outputs an instantaneous value of the control voltage of VCO 302. The instantaneous value of the control voltage is compared with the stored reference value in micro-controller 302. This comparison will be below the preset threshold and movement of the window will not be stopped or disabled as a result of the environmental conditions. The instantaneous control voltage \( U_{VCO} \) will also be provided to VCO 302 along line 358 and will tend to compensate the change in capacitance by appropriately adjusting the frequency of VCO 302.

The system is set so that the rising window is stopped before the hand or other body part actually makes contact with the top 10C of the window frame or the flexible seal member 60. Instead, it can be set so that the window stops when the hand or other body part is in actual contact with the top 10C but before the rising window applies more than a predetermined and non-injurious force to the hand or other body part (e.g. 100 N).
The rising window glass on its own (that is, when no human hand or other body part is present in the gap between the glass and the top 10C of the window frame) does not of itself significantly affect the output of the oscillator 302. This is because the dielectric constant of the window glass is many times less than that of a human hand or other body part.

The system can also be adapted for frameless windows. In this case, there is no separate window frame. The rising and lowering window glass slides with respect to a seal or channel carried by the frame on the vehicle body within which the door is located. This channel or seal (such as a door seal) will normally also incorporate inner and outer electrically conductive members 66, 72 which can thus be connected to receive the output of the oscillator 302 in the manner already explained.

In the system of figure 2, protrusion 82 is located on the underside of flexible seal member 60 such that any body part on the rising edge of window glass 8 will eventually contact protrusion 82 as the window glass rises to its closed position. Contact between a body part and protrusion 82 will cause deformation of flexible seal member 60 and inner electrically conductive member 66 will be moved towards the outer electrically conductive member 72. This movement of inner conductive member 66 will cause a change in capacitance of the capacitor defined by the two electrically conductive members 66 and 72 when they are energised by VCO 302. Like the non-contact detection mode previously described, this change in capacitance will produce a change in the signal on line 330 which causes a change in frequency of VCO 302.
Again, this change in frequency will be detected by the PLL 304 and will cause the motor 322 to be de-energised as described above, thereby immediately stopping the rising window glass.

Also, it is possible that movement of inner electrically conductive member 66 may be so great, that it moves through the hollow chamber 70 and physically contacts outer electrically conductive member 72. In this case, there will be electrical contact between the two electrically conductive members 66 and 72, and when they are energised this will cause a short circuit. Once again, this interruption of the control circuitry will cause motor 322 to be de-energised as described above, thereby immediately stopping the rising glass, if for some reason it has not been stopped already. These two contact modes of detection can also be used to detect objects in the window opening with relatively low dielectric constants.
1. A sensing arrangement for sensing a body part in a vehicle opening, said sensing arrangement comprising:
   a flexible sealing member adapted to be positioned adjacent to said opening;
   a first electrically conductive member within said flexible sealing member;
   a second electrically conductive member within said flexible sealing member separate from said first electrically conductive member;
   means for applying an electrically oscillating signal to at least one of said first and second electrically conductive members to generate an electric field in said opening,
   said electrically oscillating signal having a modulation frequency;
   variable capacitance means interconnecting said first and second electrically conductive members and having a capacitance which varies at said modulation frequency of said electrically oscillating signal, and
   detecting means for detecting a change in capacitance of said first and second electrically conductive members when a body part is within said electric field and for detecting said modulation frequency to enable electrical continuity of said first and second electrically conductive members to be determined.

2. A sensing arrangement according to claim 1 wherein said variable capacitance means is a varicap diode.
3. A sensing arrangement according to claim 2 wherein said means for applying an electrically oscillating signal includes a voltage controlled oscillator and a sine wave generator.

4. A sensing arrangement according to claim 3 wherein said sine wave generator outputs said modulation frequency.

5. A sensing arrangement according to claim 4 wherein said modulation frequency is less than 200Hz.

6. A sensing arrangement according to any preceding claim wherein said detecting means includes means for detecting said modulation frequency and generating output pulses at said modulation frequency.

7. A sensing arrangement according to claim 6 wherein said detecting means further includes a filter and said output pulses at said modulation frequency are output from said filter.

8. A sensing arrangement according to claim 7 wherein said filter is a band pass filter.

9. A sensing arrangement according to claim 7 or claim 8 wherein said output pulses are output from said filter into switching circuitry.
10. A sensing arrangement according to claim 9 wherein said switching circuitry detects if said modulation frequency is received at the circuitry, and outputs an error signal if said modulation frequency is not received, to disable a motor driving a closure member in said opening.

11. A sensing arrangement according to any preceding claim wherein said first and second electrically conductive members are differently shaped whereby to concentrate said electric field in the vicinity of said opening.

12. A sensing arrangement according to any preceding claim wherein said first and second electrically conductive members are made of electrically conductive rubber.

13. A sensing arrangement according to any preceding claim wherein said first and second electrically conductive members include an electrical conductor embedded within said electrically conductive members.

14. A sensing arrangement according to claim 17 wherein said electrical conductor is a metal wire.

15. A sensing arrangement according to any preceding claim wherein said flexible sealing member is made of electrically insulating rubber.
16. A sensing arrangement according to any preceding claim wherein said first and second electrically conductive members are separated from each other by a hollow chamber.

17. A sensing arrangement for sensing a body part in a vehicle opening, substantially as herein described with reference to the accompanying figures.
## A. CLASSIFICATION OF SUBJECT MATTER

**INV. E05F15/00 H01H3/02**

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)

**E05F**

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 practical, search terms used)

**EPO-Internal**

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>EP 1 343 252 A (DELPHI TECH INC [US]) 10 September 2003 (2003-09-10) abstract</td>
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* Additional information:*
- **A**: Special categories of cited documents
  - 'A1' document defining the general state of the art which is not considered to be of particular relevance
  - 'E1' earlier document but published on or after the international filing date
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- **Date of the actual completion of the international search**: 5 June 2007
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