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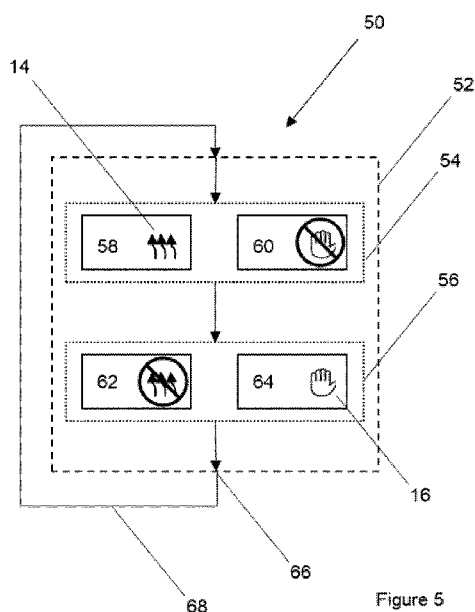


Figure 5

(57) Abstract: A method (50) of controlling a heating element (14) for a vehicle steering wheel and a hands on detection (HoD) sensor (16) for determining when a user is touching the steering wheel, wherein the method (50) comprises controlling each of the heating element and the HoD sensor through one or more cycles (52), each cycle comprising a heating period (54) and a sensing period (56), wherein: during the heating period (54) the heating element (14) is activated (58) and the HoD sensor (16) is deactivated (60); and during the sensing period (56) the heating element (14) is deactivated (62) and the HoD sensor



## Control of functions of a vehicle steering wheel

### TECHNICAL FIELD

The present invention relates to control of functions of a steering wheel. In particular, but not exclusively, the present invention relates to a method of controlling a heating element for a vehicle steering wheel and a hands on detection (HoD) sensor for determining when a user is touching the steering wheel. Aspects of the invention relate to a controller, a vehicle steering wheel and a vehicle.

### BACKGROUND

As vehicles such as cars are provided with increasing levels of autonomous driving functionality, it is becoming increasingly important to be able to monitor the attentiveness of the driver. One way of determining driver attentiveness is to sense when the driver is touching the steering wheel.

There are several technologies that may be implemented to detect when the driver is touching the steering wheel, one such technology employs sensors comprising capacitive zones placed around the steering wheel rim. Such sensors are typically referred to as Hands on Detection or HoD sensors. With capacitive HoD sensors, the behaviour of an electrical charge in a given HoD sensor is affected when a user touches the zone of the steering wheel associated with that sensor. This charge is periodically or continually monitored by a HoD sensor control module, calibrated to determine when the user is touching the steering wheel with one or both hands. With multiple detection zones arranged around the steering wheel rim, an autonomous driving system may be able to determine the level of attentiveness of the driver.

Generally, this capacitive zone technology works well, but false positive readings can be introduced in certain situations, these can either result in the system reading that the driver is holding the steering wheel when they are not, or give rise to a fault code being created, which can lead to the autonomous driving mode being deactivated until the fault code is cleared. It is an aim of the present invention to mitigate the problems associated with the prior art.

### SUMMARY OF THE INVENTION

According to an aspect of the present invention for which protection is sought there is provided, a method of controlling a heating element for a vehicle steering wheel and a hands on detection (HoD) sensor for determining when a user is touching the steering wheel, wherein the method comprises controlling each of the heating element and the HoD sensor through one or more cycles, each cycle comprising a heating period and a sensing period, wherein: during the heating period the heating element is activated and the HoD sensor is deactivated; and during the sensing period the heating element is deactivated and the HoD sensor is activated.

Advantageously, power supplied to the heating element can be interrupted periodically and the HoD sensors can operate during those periods of interruption without being affected by the current that would otherwise be passing through the heating element. The method advantageously coordinates the operation of the HoD sensors and the heating element such that, when they are both required to be active, they are operated out of phase with one another, so that the operation of the heating element does not adversely affect the performance of the HoD sensor. In an example, the duration of the interruptions in the heating element operation may be in the order of a second or less, which is not readily perceived by the user and which gives sufficient time for the HoD sensor to perform its intended function.

In an example, the method further comprises a delay period between the heating period and the sensing period wherein, during the delay period, the heating element is deactivated and the HoD sensor is deactivated. Advantageously, adding a delay between the deactivation of the heating element by means of the controlled interruption of its power supply and the activation of the HoD sensors can add further robustness against any latencies that may be involved with control of multiple components and functions in the steering wheel and gives time for the capacitive sensing zones of the HoD sensors to settle once the power supply to the heating element has been interrupted.

In an example, during the heating period, the heating element is controlled using a duty cycle comprising one or more ON regions and/or one or more OFF regions. In an example, the heating element power is controlled using pulse width modulation (PWM) control and, during the heating period, when the heating element is activated, the method further comprises selectively supplying a pulse width modulated voltage to the heating element in the form of one or more ON and OFF regions of a PWM duty cycle. Advantageously, controlling the heating element using PWM control allows for finer control and adjustment of the steering wheel temperature and power consumption of the heating element, to better balance heating performance with cost and energy consumption. Using PWM control further provides the advantage that by introducing relatively brief OFF regions between the ON regions, that is to say deliberately providing repeated brief interruptions in the power supply for the heating element, it is possible to create controlled windows of opportunity in which the HoD sensor may be operated without risk of interference from the heating element operation. These controlled interruptions may be in the order of 5:1 or even 10:1 ON duration versus OFF duration, which has only a limited effect on the warm-up time for the steering wheel and is generally not perceivable to the user. In this way, the control of the HoD sensors and the heating element may be perceived as concurrent, but are actually operated sequentially, interlacing their activation to avoid potential conflict between the heating element and the HoD sensors. It will be appreciated that other ratios of ON duration versus OFF duration may be useful.

In an example, the method of controlling the heating element further comprises: a warm-up mode, wherein a total duration of the one or more ON regions is greater than a total duration of the one or more OFF regions; and a temperature sustain mode, wherein the total duration of the one or more ON regions is less than or equal to the total duration of the one or more OFF regions. In an embodiment, the mode of operation is selected in response to a measured temperature signal indicative of at least one of: a steering wheel rim temperature; an ambient temperature; and a vehicle occupant compartment temperature. Advantageously, different heating element operation modes may be selected in dependence on a measured temperature signal, in this way, power consumption and heating performance can be matched to prevailing operating conditions. Depending on measured temperature signal, the heating element may be prioritized during a heater ramp up period as long as the HoD sensors are not required to be active.

In an example, the method comprises averaging a signal from the HoD sensor during the sensing period. In an embodiment, the method comprises averaging the signal from the HoD sensor over more than one cycle. Advantageously, using a calculated average from the HoD sensor output tends to mitigate against the unwanted effect of momentary transients. In some circumstances, transients can be caused by unwanted electrical noise on a vehicle voltage supply.

In another aspect for which protection is sought, there is provided a steering wheel function controller for a vehicle steering wheel having a heating element and a hands on detection (HoD) sensor for determining when a user is touching the steering wheel, the steering wheel function controller comprises control means arranged to control each of the heating element and the HoD sensor through one or more cycles, each cycle comprising a heating period and a sensing period, wherein: during

the heating period the control means activates the heating element and deactivates the HoD sensor; during the sensing period the control means deactivates the heating element and activates the HoD sensor.

In an example, the cycle comprises a delay period between the heating period and the sensing period, and during the delay period the control means deactivates the heating element and deactivates the HoD sensor. In an embodiment, the control means is arranged to control the heating element using PWM control and, when the heating element is activated, the control means is configured to control power supplied to the heating element in the form of one or more ON region and one or more OFF region of a duty cycle, the ratio of duration between ON and OFF being controlled by the control means. In an embodiment, the ratio of duration between ON and OFF controlled by the control means is arranged to operate the heating element in different modes of operation, the modes of operation comprising a warm-up mode and a temperature-sustain mode, whereby the ratio of ON duration to OFF duration is greater in the warm-up mode than in the temperature-sustain mode. In an example, where HoD sensors are not active, the control means may operate the heating element in one of the following modes: a rapid warm-up mode with a duty cycle of at least 90%; an interlaced warm-up mode with a duty cycle of between 75-95%; a temperature sustain mode with a duty cycle of between 10-50%; and a stand-by mode with a duty cycle of around 0%.

In an embodiment, the steering wheel function controller comprises a temperature signal input, wherein the control means is arranged to control the heating element mode of operation in dependence on the temperature signal and, wherein the temperature signal is indicative of at least one of: a steering wheel rim temperature; an ambient temperature; and a vehicle occupant compartment temperature.

In an example, the control means is configured to implement a time delay between the start of the OFF region of the power supplied to the heating element and activating the HoD sensor and between deactivating the HoD sensor and the start of the ON region of the power supplied to the heating element. Advantageously, a delay between the interruption in the power supplied to the heating element and the commencement of the activation of the HoD sensor by the control means, serves to ensure any unwanted disturbance in the charge applied to the sensor caused by current flowing in the heating element is mitigated or removed completely. In an embodiment, the duration of the time delay is arranged to accommodate latency between the response of the heating element to the control means; the response of the HoD sensor to the heating element and the control means; and latency within or between control means. Advantageously, the duration of the delay period is selected to be greater than or equal to a latency measured between components in communication via a network such as a local interconnected network (LIN) or controller area network (CAN) bus.

In an example, upon activation of the HoD sensor, the control means applies a rolling average calculation of an output from the HoD sensor, the result of the rolling average is stored in a memory of the control means when the HoD sensor is deactivated and the stored rolling average result is used by the control means as the starting point of the rolling average calculation upon subsequent activation of the HoD sensor.

In an example, the control means comprises a heating element controller arranged to control operation of the heating element and a HoD sensor controller arranged to control operation of the HoD sensor, wherein the heating element controller and the HoD sensor controller are each arranged to issue status signals indicative of their respective statuses over a shared data bus, and wherein the activities of the heating element controller and the HoD sensor controller are synchronized with a communication cadence communicated by the data bus.

Advantageously, the provision of separate HoD sensor and heating element controllers may be useful where they are to be packaged within the hub and/or spokes of a vehicle steering wheel and may allow the communication between the HoD sensor and the HoD sensor controller to be more robust against adverse effects of external influences such as electrical noise, if the electrical connection between sensor and controller is kept as short as possible. The separation of the HoD sensor controller and the heating element controller may necessitate a synchronizing signal, to ensure that the timing of ON and OFF commands from the heating element controller coincide with the activation and deactivation of the HoD sensor as desired. Electrically coupling the HoD sensor controller with the heating element controller via a shared data bus or communication network such as a local interconnected network (LIN) or controller area network (CAN) bus may be particularly useful in this regard.

10 In another aspect for which protection is sought there is provided a vehicle steering wheel comprising a steering wheel function controller as hereinbefore defined.

In a further aspect for which protection is sought there is provided a vehicle comprising a steering wheel function controller or a vehicle steering wheel as hereinbefore defined.

15 Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner.

## 20 BRIEF DESCRIPTION OF THE DRAWINGS

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

- Fig. 1a shows a vehicle steering wheel in accordance with an embodiment of the invention;
- 25 Fig. 1b shows a section through a rim of the steering wheel of Fig. 1a;
- Fig. 2 shows a vehicle steering wheel in accordance with an embodiment of the invention;
- Fig. 3 shows a vehicle steering wheel in accordance with an embodiment of the invention;
- Fig. 4 shows a systematic representation of a steering wheel function controller in accordance with an embodiment of the invention;
- 30 Fig. 5 shows a method in accordance with an embodiment of the invention;
- Fig. 6 shows a method in accordance with an embodiment of the invention;
- Fig. 7 shows a schematic timeline operation of a steering wheel function controller and method in accordance with an embodiment of the invention;
- Fig. 8 shows systematic representation of a method in accordance with an embodiment of the invention;
- 35 Fig. 9 shows systematic representation of a variation of the method shown in Fig. 5;
- Fig. 10 shows examples of different operating modes of the steering wheel function controller controlling both the heating element and the HoD sensor of a steering wheel in accordance with an embodiment of the invention; and
- Fig. 11 shows a vehicle in accordance with an embodiment of the invention.

**DETAILED DESCRIPTION**

Fig. 1a shows an example of a steering wheel 1 for a vehicle 2000 (as shown in Fig. 11) according to an embodiment of the present invention. The steering wheel 1 comprises a substantially central hub 4 and, in the example shown, radiating out from the hub 4 are three spokes 3 connecting the hub 4 to a steering wheel rim 2, which is arranged to be grasped by a user, for example a driver of the vehicle. In the example shown, the steering wheel 1 comprises a pair of user operable electrical switchpacks 6, each accommodated within a respective spoke 3 and positioned to the left hand and right hand side of the central hub 4. The switchpacks 6 are configured to control a number of vehicle features and functions. For example, the left hand switchpack can be arranged to control a vehicle cruise control system and an infotainment system having audio controls for a radio, hands-free phone calls and the like, while the right hand side switchpack can be arranged to control a number of vehicle features such as autonomous driving modes and a steering wheel related function, namely, a heated steering wheel function. Other arrangements may be useful.

The steering wheel 1 may be selectively heated by means of a heating element 14 substantially surrounding the rim 2 as is shown in Fig. 1b taken as a cross-sectional view through the line x-x shown in Fig. 1a. The switchpacks 6 and the heating element 14 are supplied with power via a clockspring electrical connector 5, arranged to provide an electrical connection between the steering wheel 1 and the rest of the vehicle throughout the full range of motion of the steering wheel, which may typically be between 2-4 full turns. In the example shown, some of the features controlled by the switchpacks 6 are not operated directly, but are instead managed by a steering wheel function controller 10, which is shown accommodated within the central spoke 3. In this example, the steering wheel function controller 10 is electrically connected to the vehicle via the clockspring 5 and to the right hand switchpack 6, and is arranged to control the operation of the heating element 14 and a hands on detection (HOD) sensor 16, as will be described in detail below. It will be appreciated that other arrangements to electrically connect the steering wheel function controller 10 to the vehicle 2000 are within the scope of the invention.

Fig. 1b shows the construction of the steering wheel rim 2. The structure of the rim 2 is provided by a metal steering wheel armature, in this case cast from a magnesium alloy. This armature comprises an armature hub, three armature spokes and an armature rim 7, only the armature rim 7 is shown for clarity. Overmoulded around the armature rim 7 is an inner layer 2a of dense foam, in this example, PU foam is used. Surrounding this inner layer 2a of foam is the heating element 14, which substantially surrounds the steering wheel rim 2. The heating element 14 is then covered with a shield layer 9, arranged to electrically insulate the heating element 14 from the HOD sensor 16. It will be appreciated that the shield layer 9 may be a separate component or may be integrally formed with the heating element 14 or the HoD sensor 16. The HoD sensor 16 may be a single part or divided into sections as per the example shown in Fig. 2 and as will be described below. In the example shown, there is an outer layer 2b of foam covering the HoD sensor 16 and covering this outer layer 2b of foam is the outermost layer of the steering wheel rim 2, which in this case is a layer of leather 2c, which is stitched into place around the rim to form the outer covering. It will be appreciated that the layer of leather 2c may be substituted with another material such as wood veneer, vinyl, or other plastics material as may be desired. The outer layer 2b of foam provides a uniform texture around which to wrap the outer covering and serves to make the presence of components around the rim such as electrical connectors or wires less perceivable in the user's hands.

Turning now to Fig. 2, which shows an example of how the HoD sensors may be arranged around the rim of the steering wheel. The example of Fig. 2 illustrates an example arrangement of HoD sensors in which the rim is divided into sections so as to allow for the determination as to whether the user is touching the steering with one or both hands. Other arrangements of HoD sensors may be useful. The determination that the user is touching the steering wheel may be used

to permit operation of the vehicle in semi-autonomous driving modes. With the ability to monitor the steering wheel to determine whether the driver is touching the steering wheel, autonomous driving systems can take appropriate action in the event system determines that the driver has taken their hands off the steering wheel for extended periods of time whilst the vehicle is driving in a semi-autonomous mode. This may take the form of an audible and/or visual alert to the driver requesting they place at least one hand back onto the steering wheel, or, if necessary, cancel the driving mode.

In the example shown, the HoD sensor 16 is divided into three zones, with zone 1 arranged around the left side of the steering wheel rim 2 when the steering wheel is in the position typically used when driving straight ahead. In the example shown, zone 1 is arranged to come into contact with the user's left hand in normal highway driving. Zone 1 is arranged to cover a region of the rim 2 from approximately the 8'o clock position to the 12'o clock position. Zone 2 is arranged around the right hand side of the rim 2, from approximately the 12'o clock position to the 4'o clock position and is arranged to come into contact with the user's right hand when using a typical 10'o clock and 2'o clock grip on the rim 2, or, as in the example shown, when the user is gripping the rim 2 adjacent to the spokes 3, and as such, is adopting a 9'o clock and 3'o clock grip. Zone 3 occupies the lower third of the steering wheel rim. Zone 3 covers rim 2 from the 4'o clock position to the 8'o clock position. This arrangement of providing the HoD sensor 16 into three zones enables an autonomous driving feature using the output from the HoD sensor 16 to determine whether the user is touching the rim of the steering wheel and whether they are gripping the wheel with one or both hands. It will be appreciated that, for the HoD sensors, there may be more than three zones and that the zones may be arranged in other configurations around the rim or the steering wheel as may be desired.

Fig.s 3 & 4 show two examples of a steering wheel function controller according to an embodiment of the present invention. In the arrangement shown in Fig. 3, a steering wheel function controller is indicated generally at 10 and uses a separate HoD sensor controller 26 and heating element controller 24 to form a distributed architecture steering wheel function controller 20, whereas in the example shown in Fig. 4, the functions of the HoD sensor controller 36 and heating element controller 34 are performed in a shared steering wheel function controller or control module 30 using a centralized architecture.

Turning first to the example shown in Fig. 3, a request to activate the HoD sensors 16 (with only zone 2 shown by way of example) is received via the clockspring 5 from a controller located in the vehicle 2000. The clockspring 5, the heating element controller 24 and the HoD sensor controller 26 are all interconnected via a wiring harness and communicate via a shared network or data bus such as a local interconnected network (LIN) 23. When the steering wheel function controller 10 employs a distributed architecture with separate control modules for the HoD sensor controller 26 and the heating element controller 24, in order for the steering wheel function controller 20 to control the operation of the heating element 14 and the HoD sensor 16 according to the method described below in reference to Fig.s 5 to 8, it is important to synchronize the timing of their activities. As such, linking the HoD sensor controller 26 and the heating element controller 24 together via LIN 23 is advantageously employed to synchronize their operation, to send activity requests to the controllers and to transmit HoD sensor output data pertaining to the hands-on status of the steering wheel to other controllers located elsewhere in the vehicle.

From Fig. 3 it may be seen that the HoD sensor controller 26 is in communication with the clockspring 5, and thus the rest of the vehicle network, via a HoD controller I/O line 25s. Similarly, the heating element controller 24 is in communication with the clockspring 5, and thus the rest of the vehicle network, via a heating element controller I/O line 25h. The heating

element controller I/O line 25h and the HoD controller I/O line 25s supply their respective controllers with supply voltage from the vehicle via the clockspring 5. In this example, the right hand switchpack 6 is electrically coupled to the heating element controller 24 via a heating element controller input line 24i. The user may select whether to turn on or turn off the heated steering wheel function via a switch on the right hand switchpack 6 and this request is sent to the heating element controller 24 via the heating element controller input line 24i. The heating element controller 24 and the switchpack 6 having the heated steering wheel function switch on it, may be formed as two separate components or may be formed as a single electrical component.

The heating element controller 24 draws a supply voltage from the clockspring 5 via the heating element controller I/O line 25s. When the heating element controller 24 receives a request to activate the heating element 14 from the switchpack 6 via the heating element controller input line 24i, the heating element controller 24 sends a supply voltage to power the heating element 14 via a heating element controller output line 24o. The heating element controller 24 then monitors the heating element controller input line 24i for a change in request from the switchpack 6 and also monitors an output from a rim temperature sensor 24r integrated into the heating element. This rim temperature sensor 24r is in electrical communication with the heating element controller 24. The heating element controller 24 also monitors temperature signals transmitted from the vehicle via the LIN 23 indicative of ambient temperature and/or a temperature measured inside an occupant compartment of the vehicle 2000 in which the steering wheel 1 is located.

The heating element controller 24 is configured to select a mode of operation in dependence on all of the information it has available, for example, if the ambient temperature is below a threshold, for example, 0°C, then it will check the temperature measurement output signal from the rim temperature sensor 24r, and as long as the rim temperature is below a pre-set threshold value, for example 43°C, a warm-up mode is selected, where the heating element is driven by the heating element controller 24 at full, or near full capacity. Once the temperature of the steering wheel rim 2 has reached the prescribed value, for example 43°C, then the heating element controller 24 will switch over from the warm-up mode to a temperature sustain mode, which consumes less electrical energy and prevents the steering wheel rim 2 from becoming uncomfortably hot.

The heating element controller 24 can interrupt or otherwise suspend the heating element supply voltage at any time as may be desired. In the examples shown, the heating element controller 24 controls the heating element 14 by means of a pulse width modulation (PWM) power supply, switching between 0V for an OFF region and a nominal 13.5V ( $V_{\text{batt}}$ ) for an ON region. The ratio in the duration of the ON region to the OFF region defines a duty cycle for the heating element, from a duty cycle of 100%, where the heating element 14 is continuously supplied with the nominal 13.5V supply voltage as may be used during a warm-up mode operation used during a heater ramp up phase, to 20-50% duty cycle in a temperature sustain mode, where the supply voltage is at 0V for at least half of the time the heating element 14 is active. The heating element controller 24 is arranged to adjust the duty cycle of the heating element supply voltage in order to control the power consumption and achieve different modes of operation such as the warm-up mode and the temperature sustain mode as has been described above and also in an synchronized or interlaced mode, as will be described in detail below, when both the HoD sensors are required to be active when the heated steering wheel function is also active.

The heating element controller may apply a temperature control feedback loop in the form of a PI controller to regulate the electrical current sent to the heating element by way of adjusting the PWM duty cycle of the heating element supply voltage. The PI controller takes the rim temperature sensor output as a feedback loop to determine an error signal indicative of the

difference between the measured rim temperature and a target temperature, the further away from the target rim temperature, the greater the duty cycle generated by the heating element controller, and thus the power supplied to the heating element. This phase of operation is referred to as the heater ramp-up phase. As the temperature of the rim 2 approaches the target temperature, the duty cycle is reduced proportional to the error signal until the target temperature is met. In the event of a temperature overshoot, where the rim temperature exceeds the target, the heating element controller will interrupt the supply voltage to the heating element until the rim temperature falls below the target temperature. If at any time, the heating element controller 24 receives a request to deactivate the heated steering wheel function from the switchpack 6 via the heating element controller input line 24i, the heating element controller 24 will deactivate the heating element 14 by cutting its power supply. By using this feedback loop approach, the heating element controller may reduce the PWM duty cycle linearly, such that the duty cycle is directly proportionate to the magnitude of the error between measured rim temperature and target rim temperature. Alternatively, the heating element controller may reduce the PWM duty cycle in set increments or steps as the steering wheel rim approaches the target temperature.

In the arrangement shown in Fig. 3, when the heating element controller 24 is active, it is in communication with the HoD sensor controller 26 via the LIN 23 bus. In the example shown, the heating element controller 24 is active when the vehicle is turned on, but only supplies power to the heating element 14 as required.

In the case of the arrangement shown in Fig. 4, the steering wheel function controller 10 uses a centralized controller architecture and as such an integrated steering wheel function controller 30 is arranged to control both the HoD sensors and the heating element. In this example, the heating element controller 34 and the HoD sensor controller 36 communicate their respective status information to one another via internal communication means integrated into the steering wheel function controller 30.

As hereinbefore mentioned, the performance of the HoD sensors 16 can be affected in some conditions. For example, the HoD sensor controller may detect false positive readings when both the HoD sensors and the heating element are operating together if there is unwanted electrical interference on the voltage supply. Typically, such interference only arises when there is a significant amount of electrical noise in the supply voltage, as can occur if there is a worn or damaged electrical component, such as an alternator or voltage regulator associated with the supply voltage. When a relatively high current device like the heating element is on next to the HoD sensor, this can lead to some electrical voltage disturbances at the HoD sensor, which in turn can lead to unwanted oscillations in the HoD sensor voltage output. This scenario is uncommon, but can give rise to false positives being detected by the HoD sensor controller 26 when the driver is not touching the steering wheel 1. In these cases, it will typically cause semi-autonomous systems to generate a fault code and temporarily suspend the availability of some autonomous driving functionality. This can be a source of inconvenience for the user and so the following method (as described below and illustrated in Figs 5 & 6) has been developed specifically to overcome these situations.

Fig. 5 shows a method 50 of controlling a heating element for a vehicle steering wheel and a hands on detection sensor for determining when a user is touching the steering wheel, according to an embodiment of the invention. In some embodiments of the invention, the vehicle steering wheel, HoD sensor and heating element are as hereinbefore mentioned. The method comprises controlling each of the heating element and the HoD sensor through one or more cycles 52, each cycle comprising a heating period 54 and a sensing period 56. During the heating period 54 the heating element is activated 58 and the HoD sensor is deactivated 60 and during the sensing period 56 the heating element is deactivated 62 and the HoD

sensor is activated 64. At the end 66 of each cycle 52 the method returns 68 to the beginning of the cycle. Through this method the functions of the steering wheel are controlled so that the heating element and HoD sensor are not simultaneously activated. Advantageously this reduces interference for the HoD sensor. An embodiment of the invention as shown in Fig. 6 comprises a delay period 70 between the heating period 54 and the sensing period 56. During the delay period 70, the heating element 14 is deactivated 72 and the HoD sensor 16 is deactivated 74. Advantageously the delay period reduces interference to the HoD sensor.

In either of the embodiments shown in Fig. 5 or Fig. 6, during the heating period, the heating element is, in embodiments of the invention, controlled using a duty cycle as hereinbefore described. The duty cycle comprises one or more ON regions and one or more OFF regions. In a warm-up mode a total duration of the one or more ON regions is greater than a total duration of the one or more OFF regions. In a temperature sustain mode the total duration of the one or more ON regions is less than or equal to the total duration of the one or more OFF regions. In some embodiments of the invention the mode of operation is selected in response to a measured temperature signal indicative of at least one of a steering wheel rim temperature; a vehicle occupant compartment temperature within the vehicle 2000; and/or an ambient temperature. In example embodiments the method comprises averaging a signal from the HoD sensor during the sensing period. Optionally the method comprises averaging the signal from the HoD sensor over more than one cycle.

The method 50 may be carried out by a steering wheel function controller 10 comprising some or all of the features of the steering wheel function controller as hereinbefore described. Features of the steering wheel controller and its operation are therefore described with reference to Figs. 1a to 4 and with additional reference where mentioned. For clarity the following description relates to the steering wheel function controller only. It will be appreciated, however, that the method steps performed by the controller may form optional steps of the method as described in relation to Figs. 5 and 6.

The steering wheel function controller comprises control means 10, for example one or more controller, arranged to control each of the heating element and the HoD sensor through one or more cycles, each cycle comprising a heating period and a sensing period. In an embodiment, the one or more controller 10 is a single centralised controller 30 as shown and described in relation to Fig. 4. In another embodiment the one or more controller 10 comprises a HoD sensor controller 26 and heating element controller 24 as shown and described in relation to Fig. 3. In each embodiment, during the heating period the control means activates the heating element and deactivates the HoD sensor, while during the sensing period the control means deactivates the heating element and activates the HoD sensor.

In some embodiments of the invention the cycle comprises a delay period between the heating period and the sensing period, and during the delay period the control means 10 deactivates the heating element and deactivates the HoD sensor. The control means is arranged to control the heating element using PWM control and, when the heating element is activated, the control means is configured to control power supplied to the heating element in the form of an ON region and an OFF region of a duty cycle, the ratio between ON region duration and OFF region duration being controlled by the control means. The ratio between ON and OFF controlled by the control means is arranged to operate the heating element in different modes of operation, the modes of operation comprising a warm-up mode and a temperature-sustain mode, whereby the ratio of ON duration to OFF duration is greater in the warm-up mode than in the temperature-sustain mode.

As shown in Fig. 3, the steering wheel function controller can be arranged to take an input signal from a temperature sensor 24r. In this embodiment the control means is arranged to control the heating element mode of operation in dependence on

the temperature signal. Other arrangements, for example where the steering wheel function controller is arranged to take an input from an ambient temperature sensor and/or vehicle occupant compartment temperature sensor may be useful.

The delay period may be provided by control means being configured to implement a time delay between the start of the OFF region of the power supplied to the heating element and activating the HoD sensor and/or between deactivating the HoD sensor and the start of the ON region of the power supplied to the heating element. Advantageously the duration of the time delay is arranged to accommodate latency between: the response of the heating element to the control means; the response of the HoD sensor to the heating element and the control means; and the latency within or between the one or more controller 10.

In an example, upon activation of the HoD sensor, the control means applies a rolling average calculation of an output from the HoD sensor, the result of the rolling average is stored in a memory 31 of the control means 10 when the HoD sensor is deactivated and the stored rolling average result is used by the control means as the starting point of the rolling average calculation upon subsequent activation of the HoD sensor.

In some embodiments of the invention the heating period and sensing period, and optionally the delay period are provided by the PWM control or similar as described above. For example, the duration of the heating period would be provided by the ON region of the power supplied to the heating element while the delay period and the sensing period are provided in the OFF region of the power supplied to the heating element. Put another way, the HoD sensor is activated during the OFF region of the heating element, optionally the HoD sensor is activated after a period following the switch from ON to OFF of the heating element, the period being termed the delay period.

Fig. 7 illustrates a timeline 80 showing the operation of the heating element 14 alongside the operation of the HoD sensor 16. The heating element and sensor are shown schematically to operate between 1 and 0 in which they are activated and deactivated respectively. The timeline shown begins with a sensing period 56. At the end of the sensing period a heating period 54 begins. A delay period 70 is then provided before repeating the periods 56, 54, 70. In embodiments of the invention the sensing period is in the range 0.1-0.5s, the heating period is in the range 1-5s, and the delay period is in the range 0.01-0.3s. Other ranges may be useful. As mentioned above, in an embodiment of the invention the heating period comprises PWM control or similar of the heating element so that within the heating period the heater is both ON 82 and OFF 84 for periods of time. This is illustrated in the heating period 54' shown in Fig. 7. In other embodiments as described the heating period as a whole comprises the ON region of the PWM or similar duty cycle while the sensing period, and optionally the delay period are within the OFF region of the PWM or similar duty cycle. For convenience this is also illustrated in Fig. 7.

By way of further examples of the foregoing, the following description describes elements of the method 50 and the operation of the steering wheel function controller. In an example scenario, the heating element 14 is active when the HoD sensors 16 need to be activated. The steering wheel function controller accordingly coordinates the heating period and the sensing period so as to interlace the heating and sensing functions.

During a warm-up operation, the heating element controller 24, 34 switches from a 100% duty cycle to a slightly reduced value, for example 90% duty cycle. This mode is referred to as the interlaced warm-up mode, and when operating in this mode, the HoD sensors 16 are active only during the OFF regions of the heating element duty cycle, that is to say when the power supply to the heating element 14 is interrupted. The HoD sensors 16 are then deactivated during the next ON region of the heating element duty cycle and then the process is repeated.

In an example, the HoD sensor controller 26, 36 may then implement a time delay between the start of the OFF region of the power supplied to the heating element 14 and activating the HoD sensor 16 and between deactivating the HoD sensor 16 and the start of the ON region of the power supplied to the heating element 14. Advantageously, a delay between the interruption in the power supplied to the heating element 14 and the commencement of the activation of the HoD sensor 16 by the HoD sensor controller 26, 36, serves to ensure any unwanted disturbance in the charge applied to the sensor caused by current flowing in the heating element is mitigated or removed completely. The duration of the time delay is arranged to accommodate latency between the response of the heating element to the heating element controller 24, 34 and the response of the HoD sensor 16 to the heating element 14 and the HoD sensor controller 26, 36. The duration of the delay period is selected to be greater than or equal to a latency measured between components in communication via the data network such as a local interconnected network (LIN) 23, or the like.

The arrangement of Fig. 4 operates in the same manner as that described for Fig. 3, but rather than a distributed architecture with discrete control modules for the HoD sensors 16 and the heating element 14, in this example, the function of both controllers is provided by a single, centralized steering wheel function controller or control module 30. The key difference between the steering wheel function controller 20 and control module 30 is that HoD controller 36 and heating element controller 34 of control module 30 are able to communicate internally and not rely on LIN 23 to enable the synchronizing the activities of the HoD controller 36 and the heating element controller 34 when heated steering wheel function and HoD sensors are required to work together. In this way, internal communication between the HoD sensor controller and the heating element controller may reduce, or remove completely, a source of latency, thus the duration of the delay period may be less for a centralized architecture than for a distributed architecture steering wheel function controller 10.

In an example, the ON region during this interlaced warm-up mode has a duration of 3.4s, the OFF region then has a duration of 0.5s before the next 3.4s ON region as this cycle is repeated. In an enhanced variant of the interlaced warm-up mode, referred to as the time-delayed the interlaced warm-up mode, the HoD sensor controller 26 waits for confirmation from the heating element controller 24, 34 that the OFF region has started and then adds a short time delay before activating the HoD sensors 16. In an example of this time-delayed interlaced warm-up mode, the ON region of the heating element 14 has a duration of 3.4s, a time delay of 200ms is then used by the HoD sensor controller 26 before it activates the HoD sensors 16 for 300ms. The HoD sensors 16 are then deactivated at a time to coincide with the start of the next ON region for the heating element duty cycle.

In an example, a further delay period may be applied before the commencement of the next ON region of the heating element, the duration of this delay period may be in the order of 10-100ms. It will be appreciated that other duration values for ON and OFF regions for the heating element and for the activation period of the HoD sensor and for the duration of the one or more delay periods may be used, as may be required to best suit a given application and may be adjusted in response to operating modes and or measured temperature values. This process is repeated for as long as both the HoD sensors 16 and the heating element 14 are both required to operate together. Short interruptions of the power supplied to the heating element 14 have only a limited impact on the warm-up time for the steering wheel 1 and do not give rise to temperature fluctuations at the rim 2 perceivable by the user. However, operating the HoD sensors 16 only once any source of potential interference from the heating element 14 has diminished, greatly enhancing HoD sensor performance, allowing for some autonomous or semi-autonomous driving modes to be available to the user even when the heated steering wheel function is active, which greatly enhances perceived quality of the vehicle.

Once the steering wheel rim 2 has reached the prescribed temperature, in this example, 43°C, the heating element controller 24, 34 can switch over to a temperature sustain mode with a greatly reduced duty cycle of 50% or less. However, by virtue of the communication between the HoD sensor controller 26, 36 and the heating element controller 24, 34, this reduction in duty cycle may still be coordinated with the operational state of the HoD sensor controller 26, 36. The cadence and duration of the HoD sensor activation pulses may remain unchanged from that used in this time-delayed interlaced warm-up mode. For example, a 200ms delay may be applied by the HoD sensor controller 26, 36 after the start of the OFF region of the heating element 14 followed by the HoD sensor activation period of 300ms, regardless of whether the heating element controller 24, 34 is operating in an interlaced warm-up mode or a temperature sustain mode. Depending on other vehicle conditions such as vehicle speed and steering angle, the HoD sensor controller 26, 36 may extend the duration of the HoD activation period above 300ms, or may follow the 300ms activation period with another delay period before reactivating the HoD sensors and repeating this as a cycle for as long as the OFF region of the heating element duty cycle lasts. Advantageously, this maintains the cadence of the HoD sensor output data for any systems that rely on this data for their function and can even greatly increase the duration of the HoD sensing periods in some driving conditions without having to completely deactivate the steering wheel heating function.

It will be appreciated that the duty cycle of the heating element 14 may be controlled by the heating element controller 24, 34 in a variety of different modes to suit the conditions and the given application. For example, depending on whether the HoD sensors are active, the control means may operate the heating element in one of the following modes: a rapid warm-up mode with a duty cycle of at least 90%, where the HoD sensors are not active; an interlaced warm-up mode with a duty cycle of between 75-95%, when the HoD sensors are active; a temperature sustain mode with a duty cycle of between 10-50%, where, regardless of the HoD sensors being active, this mode is arranged to be compatible with interlaced or coordinated operation with the HoD sensors as may be desired; and a stand-by mode with a duty cycle of around 0%.

Fig. 8 shows a flowchart explaining the method 100 of controlling functions associated with a vehicle steering wheel 1 having both a heating element 14 and a hands on detection (HoD) sensor 16 for determining when a user is touching the steering wheel. The method 100 starts at 102, typically this will be at an initialisation of the HoD sensor controller 26, 36 and the heating element controller 24, 34 at or shortly after vehicle start. From start 102, the HoD sensor controller 26, 36 initialises and a determination is made as to whether HoD sensing is required at step 110, if it is determined that HoD sensing is not required at initialisation 110, the HoD sensor controller 26, 36 will return to the start at 102 and continue to monitor its input for a change in HoD function status.

If, at initialisation step 110, it is determined that HoD sensing is required, then the method moves to step 112 where a function check is performed to confirm that the HoD sensors 16 are operational. Before activating the HoD sensors 16, the HoD sensor controller 26, 36 will communicate with the heating element controller 24, 34 at step 114 and determine whether the steering wheel heating function is active at step 116. If the steering wheel heating function is not active then the HoD sensor controller 26, 36 will proceed to step 117 and select a standard HoD sensor operating mode. If the steering wheel heating function is active then the HoD sensor controller 26, 36 will proceed at step 119 to select an interlaced HoD sensor operating mode, synchronizing HoD sensor activity with the heating element controller 24, 34. In this way, the HoD sensor controller 26, 36 and the heating element controller 24, 34 coordinate their activities and adopt a modified mode of operation, providing regular opportunities for the HoD sensor 16 to operate by periodically interrupting the voltage supply to the heating element 14.

Going back to the start at 102, in addition to the process by which the HoD sensor controller 26, 36 determines which operating mode to apply, the heating element controller 24, 34 is also initiated at 120 when the vehicle is switched on or otherwise activated. Upon initializing, the heating element controller 24, 34 will determine, based on received input signals, whether the heating element 14 needs to be active. If the steering wheel heating is not required by the user, then the method will return to the start at 102 and continue to monitor for a change in status. If the heating element 14 is required to be active, the method proceeds to initiating the heating element at step 122, which is a function check to confirm that the heating element 14 is operational.

Before activating the heating element 14, the heating element controller 24, 34 will communicate with the HoD sensor controller 26, 36 at step 124 and determine if the HoD sensors 16 are active. In addition to checking the activity status of the HoD sensors 16, the heating element controller 24, 34 will also check, at step 125, the value of any measured temperature values available to it, these values may include a steering rim temperature, an ambient temperature and an occupant compartment temperature and with the information pertaining to the measured temperature values and the HoD sensor status, the heating element controller at step 128 will determine a suitable operating mode for the heating element, the operating mode may be chosen from a list including a warm-up mode and a temperature sustain mode. If a warm-up mode is appropriate then, at step 130 a confirmation is made regarding the HoD sensor activity is made, if the HoD sensor are not active then a maximum duty cycle warm-up mode is selected at step 131, if the HoD sensors are active then an interlaced warm-up mode is selected at step 133. If a temperature sustain mode is appropriate then, at step 140 a confirmation is made regarding the HoD sensor activity is made and if the HoD sensor are not active then a temperature sustain duty cycle mode is selected at step 141, if the HoD sensors are active then an interlaced temperature sustain mode is selected at step 143.

Fig. 9 shows a flowchart explaining the operating of method 200, which is substantially the same as method 100 and like reference numerals are used for like steps. However, the notable difference with method 200 when compared to method 100 is in the way the heating element controller handles a decision to operate the heating element in a temperature sustain mode made at step 228. When the decision is made to operate in a temperature sustain mode at step 228, there is no subsequent confirmation as to the activity status of the HoD sensor controller, rather, the heating element controller automatically selects at step 235, a temperature sustain mode that is capable of interlaced operation with the HoD sensors 16. In this mode, at any point the HoD sensors 16 are required during a journey, the HoD sensor controller 26, 36 will automatically synchronize operation of the HoD sensors 16 with the OFF regions of the temperature sustain duty cycle. In this way, the heating element controller 24, 34 need not change its mode of operation until either the rim temperature drops below a threshold, or the user deactivates the heated steering wheel function via the switchpack 6. In this way, step 235 effectively replaces and combines the steps of 141, 143 in method 100 above to provide a simplified control strategy.

Fig. 10 shows examples of different operating modes of the steering wheel function controller controlling both the heating element 14 and the HoD sensor 16 of a steering wheel in a series of status against time graphs. These graphs are split into two categories, the top two graphs show state changes of the input requests for the HoD sensor 16 and the heated steering wheel feature, whereas the bottom two graphs show the heating element controller and HoD sensor controller status outputs in response to the inputs shown in the top two graphs.

Starting with the first graph at the top of the Fig., this shows the status of the request for the heated steering wheel function changing between being OFF and ON. The graphs all start, as they typically would when the user first starts the vehicle,

with both the HoD sensors 16 and the heating element 14 being off. When the vehicle is switched on or otherwise active, both the HoD sensor controller 26, 36 and the heating element controller 24, 34 are active and capable of controlling the HoD sensors and the heating element respectively, providing power thereto as required.

Following the start and after a short interval, it can be seen from the top graph that the user requests the heating steering wheel function be activated. In region a), only the heated steering wheel function is requested. Upon receipt of the request to activate the heated steering wheel function, the heating element controller 24, 34 checks the temperature signal data provided to the heating element controller 24, 34 via the steering wheel rim temperature sensor 24r and other measured temperature signals provided to the heating element controller 24, 34. In this example, measured temperatures from an occupant compartment temperature sensor and an ambient temperature sensor all indicate that the vehicle occupant compartment and ambient temperature are below a predetermined threshold. In addition, the heating element controller 24, 34 also confirms that the HoD sensors 16 are not active, so, in response, the heating element controller 24, 34 selects a warm-up mode to quickly bring the steering wheel 1 up to the desired temperature by providing the heating element 14 with power at the maximum available duty cycle as can be seen in the response in the output sent to the heating element as shown in region f) in the graph below.

As the graphs progress in time, we can see at region b) that the heated steering wheel function is still required, but now the HoD sensors 16 are also required to be active. In response to this change, the heating element controller 24, 34, switches operating mode, from a warm-up mode to an interlaced warm-up mode. This mode has a slightly reduced duty cycle than the non-interlaced warm-up mode, but the OFF regions of the duty cycle are arranged to provide the HoD sensor controller opportunities to activate the HoD sensors without risk of electrical interference from the heating element. The heating element controller switched at time interval b) to the interlaced warm-up mode because the temperature signal data provided to the heating element controller indicated that steering wheel rim temperature is still below a predetermined threshold. The effect of switching from the warm-up mode to the interlaced warm-up mode may be seen the heating element controller output graph for the heating element during interval g) and corresponding activity of the HoD sensors from the bottom graph at interval h). It can clearly be seen during interval h) that the HoD sensors are only being activated during the OFF periods of the heating element duty cycles, the activities of the heating element supply voltage and the HoD sensors are thus synchronised so as to be out of phase with each other, effectively interlacing their activity cycles.

At time interval c), the user operates the heated steering wheel function control on the steering wheel switchpack 6 to deactivate the heating element 14, so that now, only the HoD sensors 16 remain active. The response to this change may be seen in the heating element controller 24, 34 output drop to 0 for the heating element, resulting in a duty cycle of 0%. The HoD sensor controller is able to take advantage of this change in activity for the heating element, and may be seen in interval i) to activate the HoD sensors more frequently, or in the example shown, the HoD sensor activity is set to 1 for as long as the HoD sensors are required active and the heating element is switched off. In the example shown, it may be seen that the HoD sensor controller 26, 36 applies a short delay following confirmation that the heating element 14 has been deactivated before activating the HoD sensors 16. The mode of HoD sensor operation described above is given by way of example, alternatively, the HOD controller 26, 36 may continue to operate as it did during time interval h) as may be desired.

In the interval between c) and d), neither the HoD sensors nor the heating element are active, so in response, whilst the respective controllers remain active, the heating element 14 and the HoD sensors 16 are deactivated. In time interval d), the HoD sensors 16 are not required to be active, but the heated steering wheel function is reactivated. Here the heating

element controller 24, 34 checks the measured temperature data and determines that the rim 2 is still below the prescribed temperature value. As a result, the heating element controller 24, 34 selects the warm-up mode during the interval of d) as may be seen by the heating element controller output in interval j), which shows the heating element 14 is being driven with a 100% duty cycle as the HoD sensors 16 are not active at this time.

5 At time interval e), the measured temperature output from the rim temperature sensor indicated that the steering wheel rim, thanks to the effect of the heating element 14, is up to the target temperature. In response to this, the heating element controller 24, 34 switches from the warm-up mode to a temperature sustain mode, with a reduced duty cycle as compared to the warm-up mode as may be seen in interval k). The timing of the ON regions of the temperature sustain duty cycle are arranged such that they may be used in an interlaced manner with the HoD sensor controller using the OFF regions of the  
10 heating element duty cycle if the HoD sensors are required to reactivate whilst the heating element is still active in this mode.

At time interval l), the HoD sensors are reactivated whilst the heating element is operating in a temperature sustain mode. In response to the change in activity status, the HoD sensor controller 26, 36 operates the HoD sensors in an interlaced mode, activating the HoD sensors only during the OFF regions of the heating element duty cycle, it may be seen when  
15 comparing the activity of the heating element in interval k) with the activity of the HoD sensors in interval l) that they are out of phase with one another.

Finally, in interval m), the user has deactivated the heated steering wheel function, and in response to this status change, the heating element controller switches to a 0% duty cycle. During this time, only the HoD sensors 16 remain active and so, reacting to the deactivation of the heating element 14, at interval m), the HoD sensor controller switches to a continuous  
20 mode of HoD sensor activity, indicated by the HoD sensor controller output of 1 throughout the remaining period where the HoD sensors are required active. Again, it may be seen that the HoD sensor controller 26, 36 applies a short delay following confirmation that the heating element 14 has been deactivated before activating the HoD sensors 16. This may be done to provide additional confidence to another system in the vehicle, to perform a momentary self-diagnosis or self-calibration test.

25 In another example, not shown in Fig. 7, once the heated steering wheel is up to the target temperature, the HoD sensor controller 26, 36 and the heating element controller 24, 34 may switch to a mode of operation no-longer driven by the priority to achieve the target temperature. In this mode, the HoD sensors 16 and the heating element 14 may be activated alternately with approximately equal durations of activity, operating effectively with a 50:50 split in activation time, adjusted as necessary to ensure the temperature of the steering wheel rim is maintained. In this way, the 50:50 split may be, for  
30 example, alternating periods of 0.5-1 second, cycling continuously between HoD sensor activity and heating element activity, the duration of the activation period may be varied depending on factors such as the rate of steering rim cooling and vehicle driving modes, some of which may require more frequent HoD sensor readings depending on more of operation or driving conditions etc.

It will be appreciated that various changes and modifications may be made to the apparatus and method described herein  
35 without departing from the scope of the present invention.

**Claims**

1. A method of controlling a heating element for a vehicle steering wheel and a hands on detection sensor for determining when a user is touching the steering wheel,

wherein the method comprises controlling each of the heating element and the HoD sensor through one or more  
5 cycles, each cycle comprising a heating period and a sensing period, wherein:

during the heating period the heating element is activated and the HoD sensor is deactivated; and

during the sensing period the heating element is deactivated and the HoD sensor is activated.

2. The method according to claim 1, comprising a delay period between the heating period and the sensing period wherein, during the delay period, the heating element is deactivated and the HoD sensor is deactivated.

10 3. The method according to claim 1 or claim 2, wherein during the heating period the heating element is controlled using a duty cycle comprising one or more ON regions and one or more OFF regions;

optionally, the duty cycle comprises a pulse width modulation signal.

4. The method of claim 3, comprising a warm-up mode wherein a total duration of the one or more ON regions is greater than a total duration of the one or more OFF regions, and a sustain mode wherein the total duration of the one or  
15 more ON regions is less than or equal to the total duration of the one or more OFF regions.

5. The method according to claim 4, wherein the mode of operation is selected in response to a measured temperature signal indicative of at least one of an ambient temperature; a vehicle occupant compartment temperature; and/or a steering wheel rim temperature.

6. The method according to any preceding claim, comprising averaging a signal from the HoD sensor during the  
20 sensing period;

optionally, comprising averaging the signal from the HoD sensor over more than one cycle.

7. A steering wheel function controller for a vehicle steering wheel having a heating element and a hands on detection (HoD) sensor for determining when a user is touching the steering wheel,

the steering wheel function controller comprises control means arranged to control each of the heating element and the  
25 HoD sensor through one or more cycles, each cycle comprising a heating period and a sensing period, wherein:

during the heating period the control means activates the heating element and deactivates the HoD sensor;

during the sensing period the control means deactivates the heating element and activates the HoD sensor.

8. The steering wheel function controller according to claim 9, wherein the cycle comprises a delay period between the heating period and the sensing period, and during the delay period the control means deactivates the heating element  
30 and deactivates the HoD sensor.

9. The steering wheel function controller according to claim 10, wherein the control means is arranged to control the heating element using PWM control and, when the heating element is activated, the control means is configured to control power supplied to the heating element in the form of an ON region and on OFF region of a duty cycle, the ratio between ON region duration and OFF region duration being controlled by the control means.

5 10. The steering wheel function controller according to claim 11, wherein the ratio between ON and OFF controlled by the control means is arranged to operate the heating element in different modes of operation, the modes of operation comprising a warm-up mode and a temperature-sustain mode, whereby the ratio of ON duration to OFF duration is greater in the warm-up mode than in the temperature-sustain mode.

10 11. The steering wheel function controller according to claim 12, comprising a temperature signal input, wherein the control means is arranged to control the heating element mode of operation in dependence on the temperature signal and, wherein the measured temperature signal is indicative of at least one of: a steering wheel rim temperature; an ambient temperature and; a vehicle occupant compartment temperature.

12. The steering wheel function controller according to any one of claims 11 to 13, wherein the control means is configured to implement a time delay between the start of the OFF region of the power supplied to the heating element and  
15 activating the HoD sensor and between deactivating the HoD sensor and the start of the ON region of the power supplied to the heating element;

optionally, the duration of the time delay is arranged to accommodate latency between the response of the heating element to the control means and the response of the HoD sensor to the heating element and the control means.

13. The steering wheel function controller according to any one of claim 9 to 15, wherein upon activation of the HoD  
20 sensor, the control means applies a rolling average calculation of an output from the HoD sensor, the result of the rolling average being stored in a memory of the control means when the HoD sensor is deactivated and the stored rolling average result is used by the control means as the starting point of the rolling average calculation upon subsequent activation of the HoD sensor.

14. The steering wheel function controller according to any one of claim 9 to 16, wherein the control means comprises  
25 a heating element controller arranged to control operation of the heating element and a HoD sensor controller arranged to control operation of the HoD sensor, wherein the heating element controller and the HoD sensor controller are each arranged to issue status signals indicative of their respective statuses over a shared data bus and, wherein the activities of the heating element controller and the HoD sensor controller are synchronized with a communication cadence communicated by the data bus.

30 15. A vehicle comprising a steering wheel function controller according to claims 7 to 14.

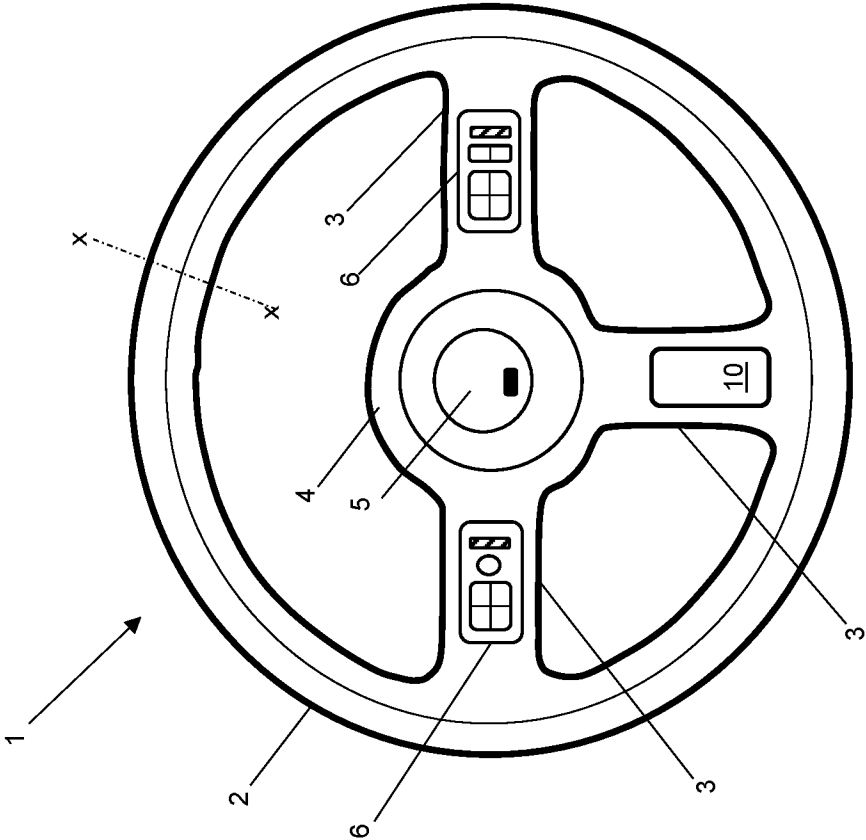


Figure 1a

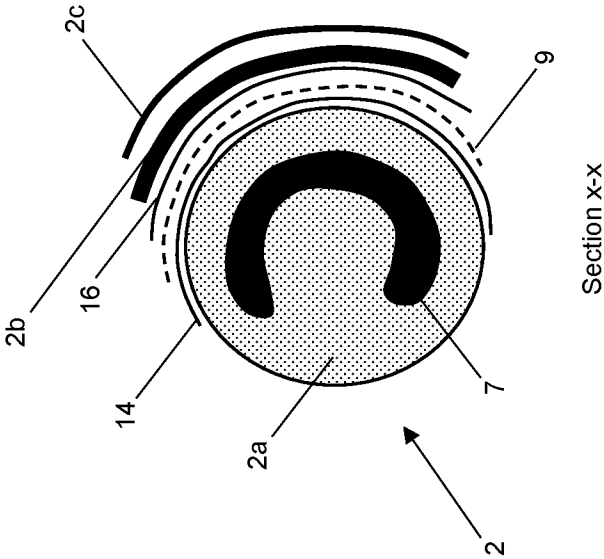


Figure 1b

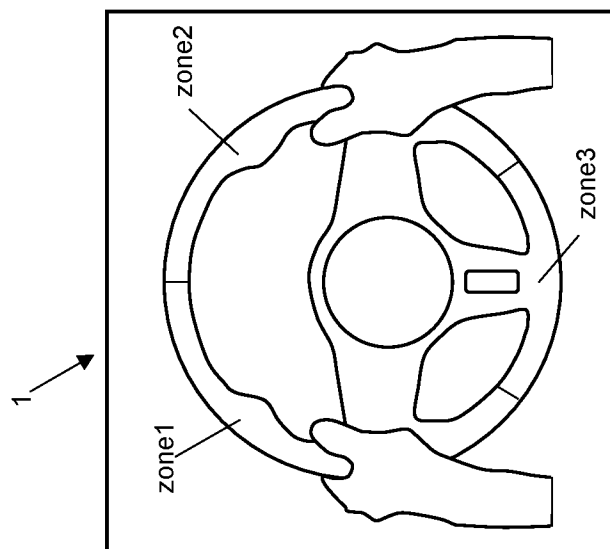
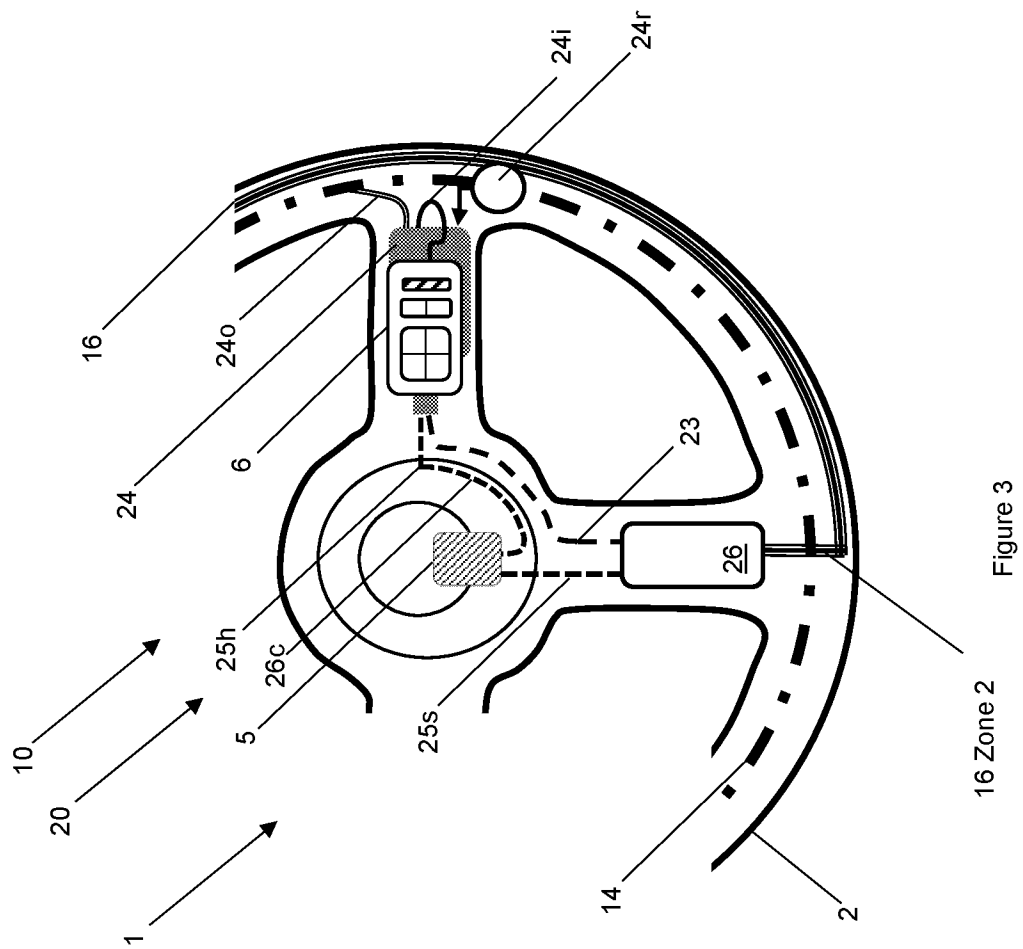


Figure 2

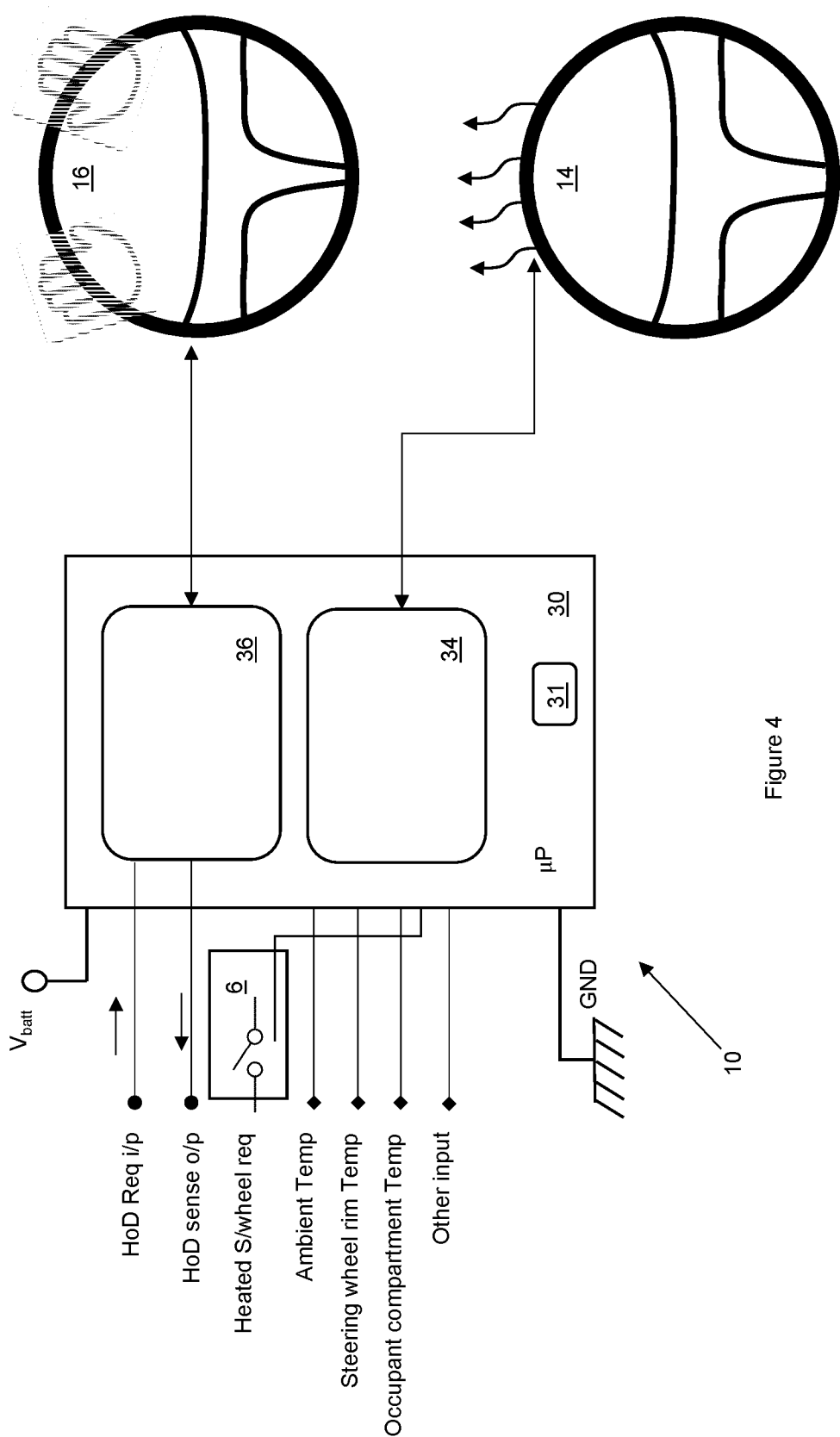


Figure 4

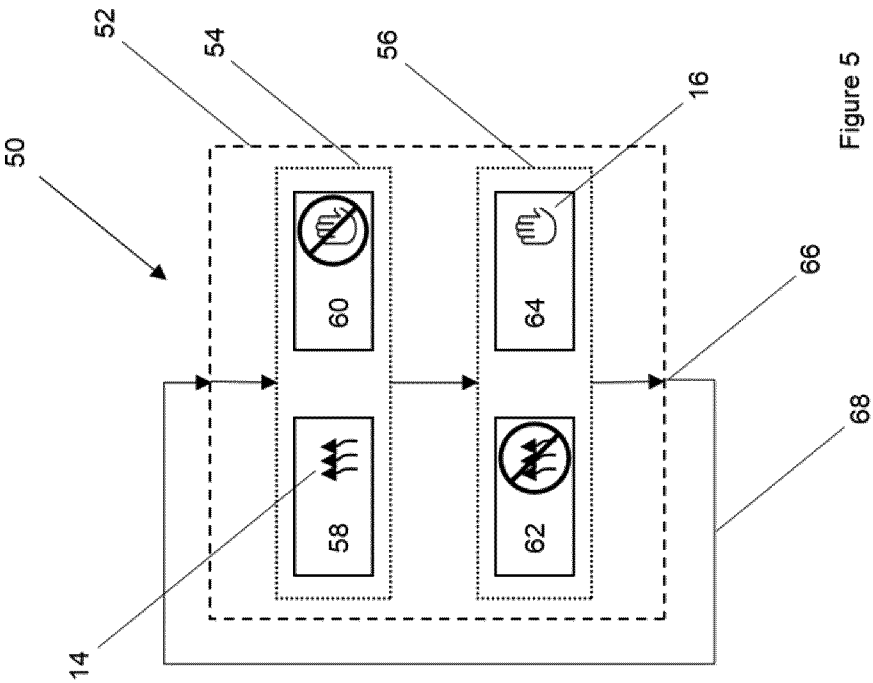


Figure 5

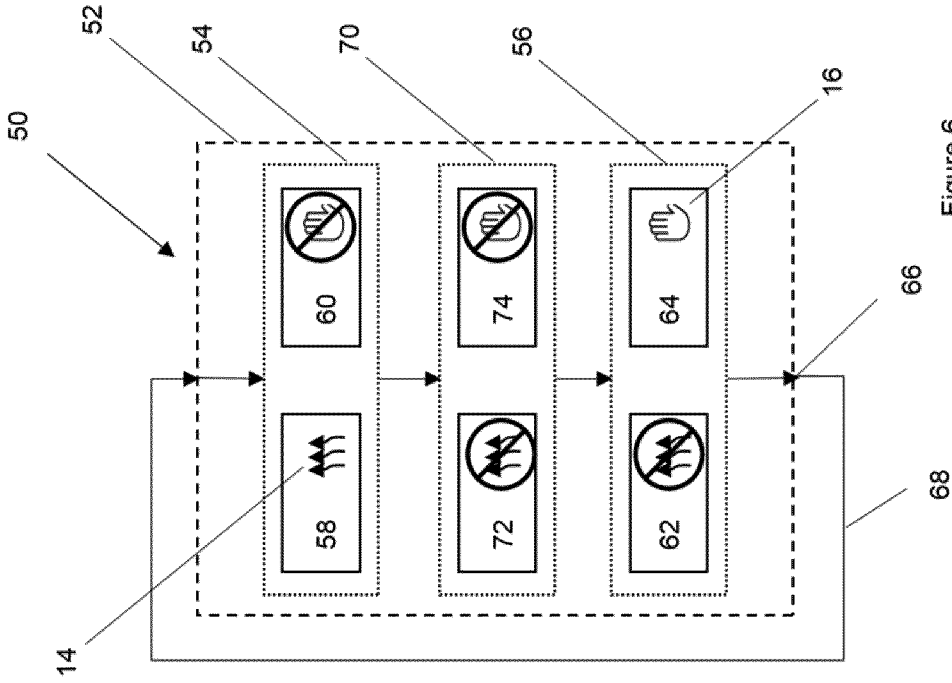


Figure 6

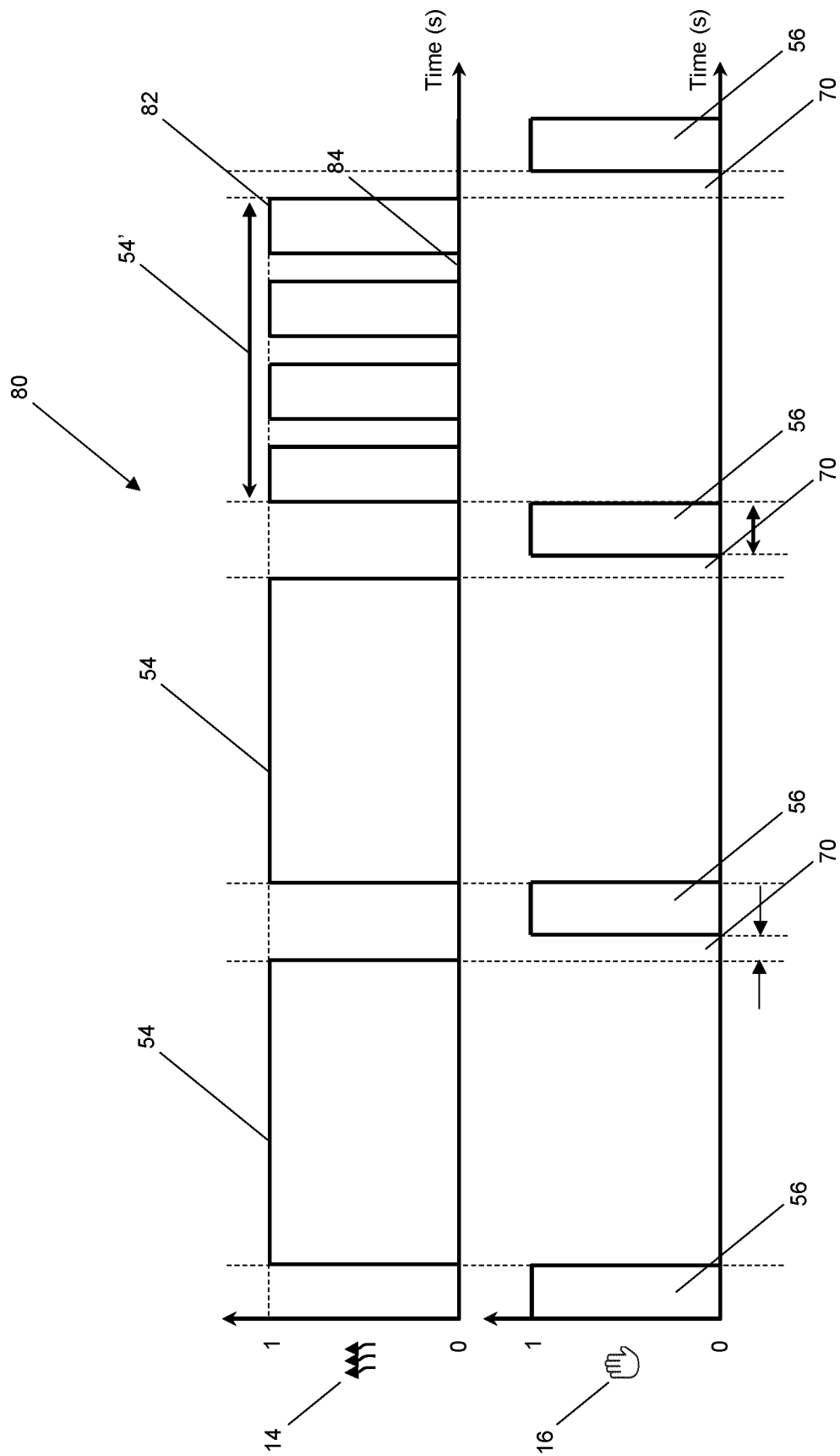


Figure 7

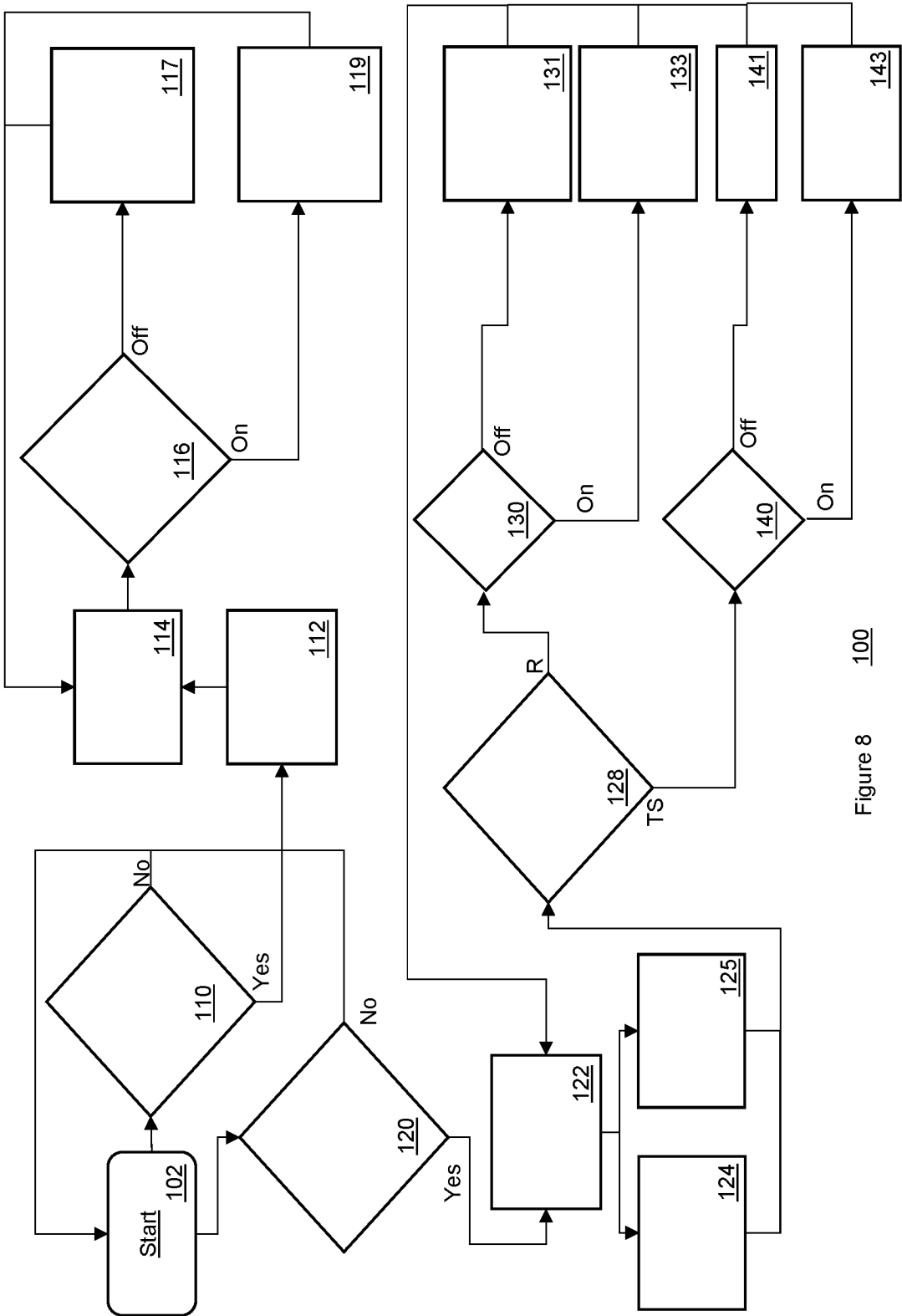


Figure 8 100

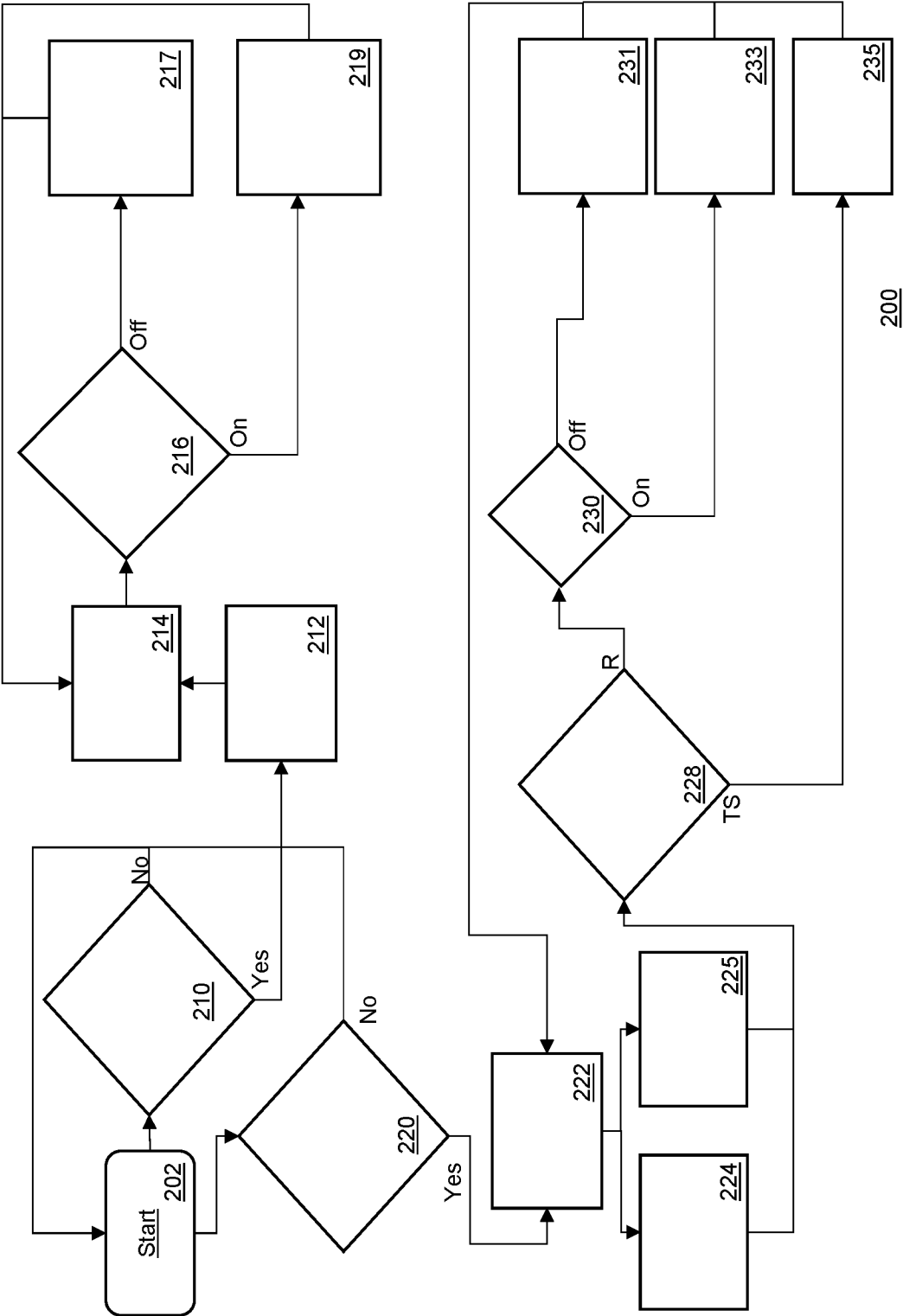


Figure 9

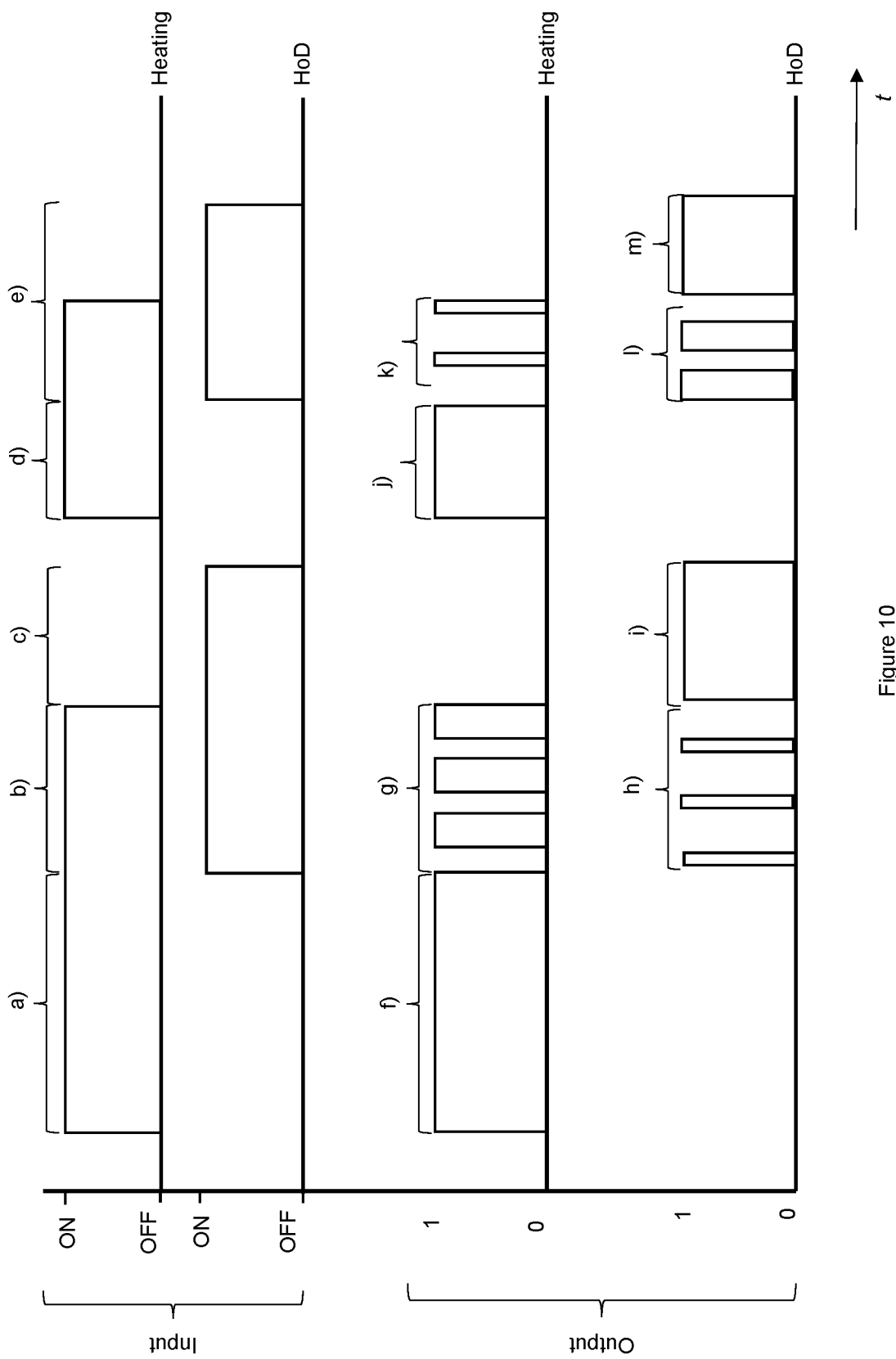


Figure 10

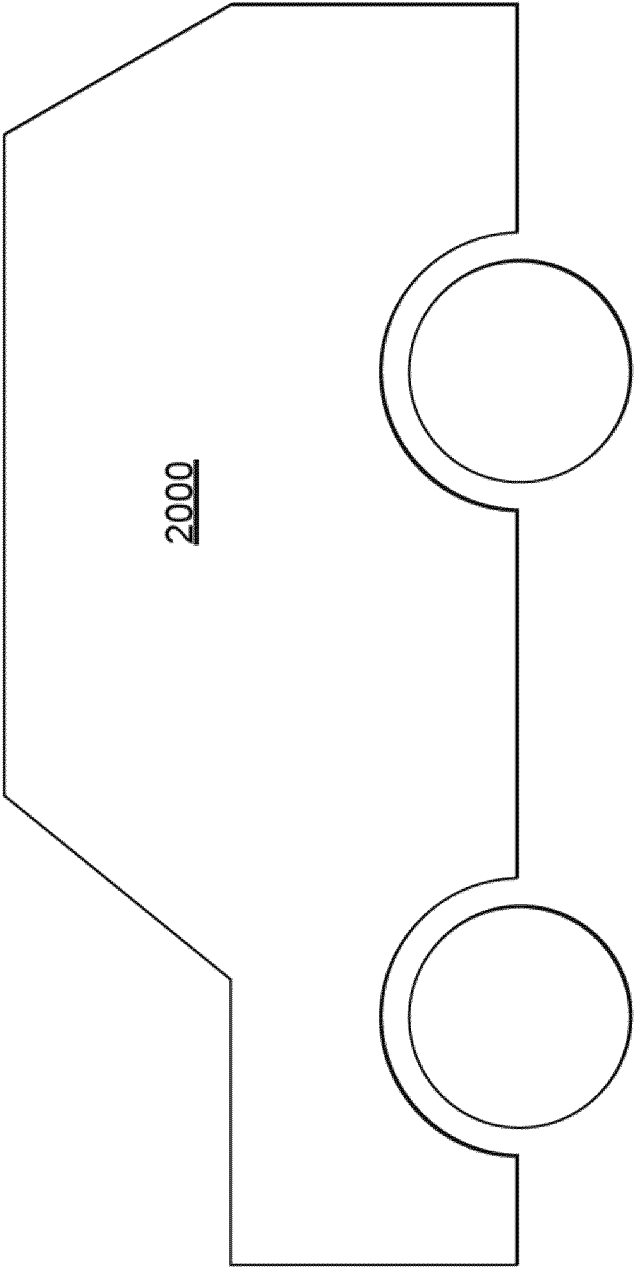


Figure 11