(12) STANDARD PATENT (11) Application No. AU 2015362825 B2
(19) AUSTRALIAN PATENT OFFICE

(54) Title
Autonomous ready vehicle

(51) International Patent Classification(s)
G05D 1/00 (2006.01) ***G07C 9/00*** (2006.01)

(21) Application No: **2015362825** (22) Date of Filing: **2015.12.14**

(87) WIPO No: **WO16/100219**

(30) Priority Data

(31) Number	(32) Date	(33) Country
62/091,946	**2014.12.15**	**US**

(43) Publication Date: **2016.06.23**
(44) Accepted Journal Date: **2020.04.02**

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(56) Related Art
US 20110071718 A1
US 20140156134 A1
US 20140303827 A1
US 20140143839 A1

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 June 2016 (23.06.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/100219 A1

(51) International Patent Classification:
G05D 1/00 (2006.01) *G07C 9/00* (2006.01)

(21) International Application Number:
PCT/US2015/065586

(22) International Filing Date:
14 December 2015 (14.12.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/091,946 15 December 2014 (15.12.2014) US

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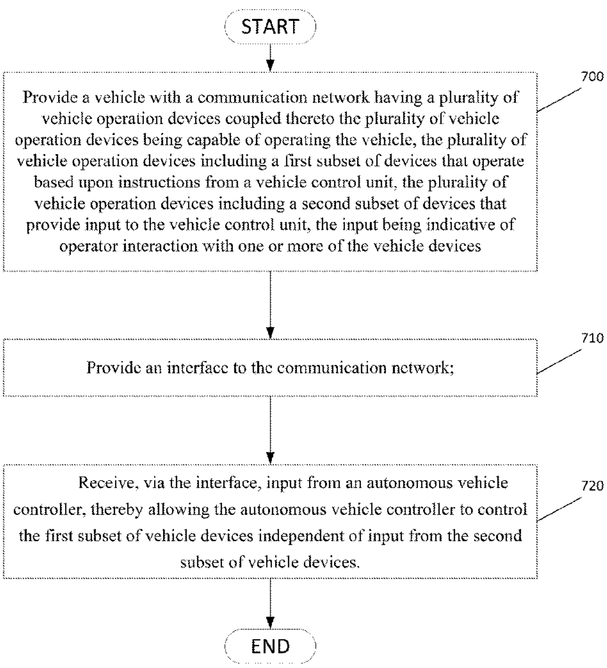
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE,

[Continued on next page]

(54) Title: AUTONOMOUS READY VEHICLE

FIG. 6



(57) Abstract: A system and method for interfacing an autonomous or remote control drive-by-wire controller with a vehicle's control modules. Vehicle functions including steering, braking, starting, etc. are controllable by wire via a control network. A CAN architecture is used as an interface between the remote/autonomous controller and the vehicle's control modules. A CAN module interface provides communication between a vehicle control system and a supervisory, remote, autonomous, or drive-by-wire controller. The interface permits the supervisory control to control vehicle operation within pre-determined bounds and using control algorithms.

WO 2016/100219 A1

DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *with international search report (Art. 21(3))*

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AUTONOMOUS READY VEHICLE

FIELD OF THE INVENTION

[000a] The present invention relates to autonomous ready vehicles, and more particularly to such vehicles configured to receive commands from an autonomous controller on the vehicle or a remote controller to control vehicle functions

INCORPORATION BY CROSSREFERENCE

[0001] The present specification originates in PCT application PCT/US2015/065586 that claims priority from US Provisional Application Serial Number 62/091,946; filed December 15, 2014, titled Autonomous Ready Vehicle, the disclosure of which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] Vehicles configured to receive commands from an autonomous controller or remote controller to control vehicle functions are known in the art. For example, patent publication US2011/0071718 A discloses a vehicle having a communication network having a plurality of vehicle devices coupled thereto, a vehicle control unit coupled to the communication network and able to control a first subset of the plurality of devices via the communication network to effect vehicle operation; the vehicle control unit operable to receive input from a second subset of the vehicle devices via the network and to control the first subset of the plurality of devices responsive to the input received from the second subset of vehicle devices, input from the second subset of vehicle devices being indicative of operator interaction with one or more of the vehicle devices, and a network interface operable to couple to an autonomous vehicle controller such that the autonomous vehicle controller is able to selectively effect vehicle operation via the first subset of vehicle devices independent of input from the second subset of vehicle devices.

[0003] It would be advantageous to further develop autonomous ready vehicles to be operable based on environmental factors encountered during vehicle operation.

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SUMMARY OF THE INVENTION

[0004] In accordance with a first aspect of the present invention, there is provided an autonomous vehicle, including a communication network for transmitting signals:

a plurality of vehicle devices including a first subset arranged to operate the vehicle by one or more of switching on or off of the vehicle, shifting gears of the vehicle, accelerating the vehicle and braking the vehicle, the first subset coupled to the communication network, and a second subset arranged for receiving vehicle operator input commands aimed at controlling movement of the vehicle through one or more of vehicle on-off switching, gear shifting, steering, accelerating and breaking the vehicle:

a vehicle control unit enabled to control the first subset of the plurality of devices via the communication network to effect vehicle operation, the vehicle control unit selectively operable to receive input from the second subset of the vehicle devices via the communications network and to control the first subset of the plurality of devices responsive to the input received from the second subset of vehicle devices, input from the second subset of vehicle devices being indicative of operator interaction with one or more of the vehicle devices; and

an autonomous vehicle controller configured to selectively effect vehicle operation through a network interface via the control module and the first subset of vehicle devices independent of input from the second subset of vehicle devices, wherein the autonomous vehicle controller is further configured for effecting and adapting vehicle operation through implementation of (i) one or both of terrain detection and obstacle detection and avoidance using real-time or near real-time detection using one or more of vehicle sensors, pre-recorded maps and lane structures, trips with the vehicle planned and tracked, collision avoidance systems and adaptive cruise control. The autonomous vehicle controller can be further configured for effecting and adapting vehicle operation through implementation of one or more of (ii) vehicle supervisory control to a level of emulating a human vehicle operator, (iii) vehicle navigation by GPS corrected inertial navigation or precision guidance, (iv) vehicle localization and (v) vehicle lane detection and lane departure.

[0005] In accordance with a second aspect, the present invention provides a method of operating an autonomous-ready vehicle as described above or in preferred embodiments mentioned herein below, including:

receiving, via the interface to the communication network, input signals from the autonomous vehicle controller representative of commands to control movement of the vehicle autonomously; and upon enabling of the autonomous vehicle controller, the vehicle controller operating the vehicle through the first subset of vehicle devices in accordance with the commands received from the autonomous vehicle controller independent of vehicle operator commands inputted through the second subset of vehicle devices.

[0006] The present disclosure also makes available a system and method for interfacing an autonomous or remote control drive-by-wire controller with a vehicle's control modules. Vehicle functions including steering, braking, starting, etc. are controllable by wire via a control network. For example, a CAN architecture available from Polaris Industries, Inc. is used as an interface between the remote/autonomous controller and the vehicle's control modules in an illustrated embodiment of the present disclosure. A CAN module interface illustratively provides communication between a vehicle control system and a supervisory, remote, autonomous, or drive-by-wire controller. The interface permits the supervisory control to control vehicle operation within pre-determined bounds and using control algorithms.

[0007] Also disclosed herein are vehicles which include a communication network having a plurality of vehicle devices coupled thereto; a vehicle control unit coupled to the communication network and able to control a first subset of the plurality of devices via the communication network to effect vehicle operation; the vehicle control unit operable to receive input from a second subset of the vehicle devices via the network and to control the first subset of the plurality of devices responsive to the input received from the second subset of vehicle devices, input from the second subset of vehicle devices being indicative of operator interaction with one or more of the vehicle devices; and a network interface; the network interface operable to couple to an autonomous vehicle controller such that the autonomous vehicle controller is able to effect vehicle operation via the first subset of vehicle devices independent of input from the second subset of vehicle devices.

[0008] Also disclosed herein is a method of providing autonomous vehicle operation, including: providing a vehicle with a communication network having a plurality of vehicle operation devices coupled thereto, the plurality of vehicle operation devices being capable of operating the vehicle, the plurality of vehicle operation devices including a first subset of devices that operate based upon instructions from a vehicle control unit, the plurality of vehicle operation devices including a second subset of devices that provide input to the vehicle control unit, the input being indicative of operator interaction with one or more of the vehicle devices; and providing an interface to the communication network; receiving, via the interface, input from an autonomous vehicle controller, thereby allowing the autonomous vehicle controller to control the first subset of vehicle devices independent of input from the second subset of vehicle devices.

[0009] Also disclosed herein is a computer readable media having non-transitory instructions thereon that when interpreted by a processor cause the processor to: provide instructions to a first subset of vehicle devices capable of operating a vehicle, the first subset of device operate based upon instructions from a vehicle control unit, the instructions being provided via a vehicle communication network; receive input, via the communication network, from a second subset of vehicle devices, the input being indicative of operator interaction with one or more of the vehicle devices; and receive, via an interface to the communication network, input from an autonomous vehicle controller, thereby allowing the autonomous vehicle controller to control the first subset of vehicle devices independent of input from the second subset of vehicle devices.

[0010] Features of the present invention that may be selected and used in specific embodiments of the first and second aspects of the invention will become apparent to those skilled in the art upon consideration of the following detailed description of illustrative embodiments exemplifying the best mode of carrying out the invention as presently perceived.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The detailed description of the drawings particularly refers to the accompanying figures in which:

[0012] Fig. 1 is a block diagram illustrating components of an autonomous ready vehicle of an illustrated embodiment of the present disclosure;

[0013] Fig. 2 is a block diagram illustrating communication between a CAN communication network module of the vehicle and an accessory hardware platform and accessory software;

[0014] Fig. 3 is a flowchart illustrating steps performed during normal operation in an autonomous or remote control mode and during a lockout mode of operation;

[0015] Fig. 4 is an exemplary wiring harness used to provide by-wire override control of the vehicles ignition;

[0016] Fig. 5 is a flowchart showing illustrative steps performed to authenticate a module sending instructions to the vehicle; and

[0017] Fig. 6 is a flowchart showing illustrative steps that permit autonomous operation of the vehicle.

DETAILED DESCRIPTION OF THE DRAWINGS

[0018] For the purposes of promoting an understanding of the principles of the present disclosure, reference will now be made to certain illustrated embodiments and drawings. The embodiments disclosed below are not intended to be exhaustive or limit the invention to the precise form disclosed in the following detailed description. Rather, the embodiments are chosen and described so that others skilled in the art may utilize their teachings. It will be understood that no limitation of the scope of the invention is thereby intended. The invention includes any alterations and further modifications in the illustrated devices and described methods and further applications of the principles of the invention which would normally occur to one skilled in the art to which the invention relates.

[0019] U.S. Patent Application Publication No. 2014/0288763; U.S. Patent No. 8,534,397; PCT International Publication No. WO 2014/134148; and U.S. Patent Application Publication No. 2014/0244110 are all expressly incorporated by reference herein. Features disclosed herein may be used in combination with features disclosed in these patent documents.

[0020] Fig. 1 illustrates components of an autonomous ready vehicle 10 of the present disclosure. Vehicle 10 is configured to be controlled by an autonomous or remote controller 12. The controller 12 may be an autonomous controller for controlling the vehicle 10 without any human interaction. The controller 12 may also be a remote controller where an operator uses an input device such as pedals, a joystick, a computer, or other controller to guide the vehicle 10. Functions of the controller 12 also include obstacle avoidance. The controller 12 sends specific commands to the vehicle 10 to control movement of the vehicle. Controller 12 also receives feedback from the vehicle 10. Communication with the controller 12 is provided through a gateway interface module or communication interface module (CIM) 14 on the vehicle 10. In an illustrated embodiment, the communication interface module is a Controller Area Network (CAN) module. CIM 14 packages information for transport between components.

[0021] A mode switch 16 coupled to module 14 permits a user to select between a manual operation mode and the autonomous or remote control mode. In the manual mode, the vehicle 10 is operated by a driver in a normal manner (via operator action on vehicle devices such as a steering device, (such as handles, wheel, joystick), a brake pedal, a gear shift, an accelerator pedal, and an ignition switch (or a sensor that detects operation of any of the foregoing) that

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respectively cause operation of other vehicle devices, such as a steering device (such as a steering tie arm), a brake actuator, an transmission shifter controller, a throttle, and an ignition relay (generally any vehicle device or actuators for operating such devices). Overall, it should be appreciated that for any operational input device, embodiments are envisioned that utilize physical connections and embodiments are envisioned where sensors are placed on input devices and operation of the devices is communicated via electrical signals. Likewise, embodiments are envisioned where physical connections are used to drive action in actuators and embodiments are envisioned where actuators receive electrical signals that instruct their operation.

[0022] In one embodiment, the mode switch 16 is a physical switch. In other embodiments, the mode switch 16 is actuated in software using one of a manned and autonomous or remote user input. The communication interface module 14 controls a system on/off function 18 and an ignition interrupt function 20. The communication interface module 14 also communicates with a display 22 within the vehicle 10. The display 22 is preferably a high resolution color display. The display 22 may also be provided by a vehicle gauge display.

[0023] Communication interface module 14 further communicates with an electronic power steering control 24. The power steering control 24 controls a steering position function 26 for guiding the vehicle 10.

[0024] Communication interface module 14 further communicates with an engine control module (ECM) 28. The ECM 28 controls and responds to a pedal position function 30. ECM 28 further controls an engine start/stop function 32. The pedal position function 30 receives instruction from the network interface module 14 whether to accept actual position of the foot pedal or an acceleration command received from controller 12 for controlling the vehicle throttle position. For example, in manual mode the pedal position function 30 takes the physical response from the pedal for throttle application, whereas in autonomous or remote mode the controller 12 provides a percentage of throttle that is to be applied in the same manner as the physical application of the throttle.

[0025] Communication interface module 14 further communicates with a vehicle control module 34. The vehicle control module 34 controls a transmission position function 36, a brake position function 38, and a parking brake position function 40. Shifting of the vehicle is controlled by a driver during manual mode or by signals received from the controller 12 through communication interface module (CIM) 14 in the autonomous or remote control mode. The vehicle control module 34 also provides vehicle status and sensor information through communication interface module 14 back to the controller 12. The vehicle status and sensor information includes, for example, vehicle speed, steering angle, requested speeds, requested steering angles, brake status, fuel level, accelerometer data, brake sensors, throttle position sensors, wheel speed sensors, gear selection sensors, temperature sensors, pressure sensors, emissions levels, trouble codes, error messages, or the like. The brake position function 38 is illustratively implemented using an i-Booster intelligent brake control available from Bosch.

[0026] Furthermore, in the event of interaction or conflicting messages between the ECM 28 pedal position function 30 and VCM 34 brake position function 38 the CIM 14 will filter the appropriate communication messages to pass to the external controller 12, thus avoiding interaction issues regarding the input or pedal positions.

[0027] The vehicle control module 34 controls the transmission position function 36 by detecting a request to shift gears and then providing a shifting signal when conditions are right. Brake position function receives inputs from a pedal position detector and brake commands received over the communication interface module 14 to apply the vehicle brakes 38 or the parking brake 40.

[0028] Autonomous or remote controller 12 may also control suspension components through the communication interface module 14. Vehicle sensors outputs are received and processed by controller 12 and signals are then sent from controller 12 through communication interface module 14 to control adjustable springs or adjustable shocks the vehicle suspension. See, for example, U.S. Patent Application Publication No. 2014/0125018 and U.S. Application Serial No. 14/507,355, filed on October 6, 2014, the disclosures of which are expressly incorporated by reference herein for details of adjustable suspension components.

[0029] Fig. 2 illustrates an exemplary accessory integration device 50 having an accessory CAN port 52 which communicates through a CAN bus 54 to an accessory hardware platform 56 of the vehicle 10. Specifically, the CAN bus 54 communicates with a hardware CAN transceiver 58. Transceiver 58 communicates with hardware platform firmware 62 of accessory software 60. The hardware platform firmware 62 communicates with CAN accessory application programming interface (API) software 64. The API software 64 communicates with third party application software 66.

[0030] The CAN accessory API software 64 includes a compiled code library. The library

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provides an interface between a proprietary CAN network and an application programmer's application code. This allows a third party accessory creator to access specific and limited information on the CAN network, therefore enabling the creation of smart accessories, without access to proprietary information of the CAN network, and without the ability to interfere with vehicle communications. Further, this interface does not allow for compromising the vehicles intended operation or network security.

[0031] In one embodiment, the compiled code library includes a set of proprietary, secure, and predefined function calls. The function calls include items such as getEngineRPM( ), getVehicleSpeed( ), or getEngineTemperature( ), for example. The third party application programmer may use these function calls to bring the accessible vehicle information into their application code.

[0032] In one example, the code library may be compatible with large open source electronics platforms. In addition to the software library, a quick start custom accessory includes a durable housing and hardware peripherals that the third party developer may use. The peripherals include, for example, an LED bar and a basic LCD display, etc.

[0033] The present disclosure permits any third party to create software applications for use with the vehicle without interfering with the other functionality of the vehicle. Therefore, third parties can develop smart accessories for use with the vehicle. This enables vehicle users to drive innovation in vehicle accessories.

<u>Conflict Resolution</u>

[0034] In one embodiment, when conflicts arise between individual or multiple manual inputs and input instructions received from the autonomous or remote controller 12 when the vehicle 10 is in the autonomous or remote control mode, the vehicle may respond with a manual override of autonomous control and the CIM 14 may continue to watch the remote input messages without executing the instructions, while continuing to send CAN messages.

[0035] In another embodiment, a user is detected in the vehicle, i.e, via an input torque sensed on the steering wheel, therefore allowing manual operation to override specific or all functions of autonomy.

[0036] Another embodiment includes autonomous or remote controller 12 override of manual control inputs to the vehicle. For example, messages may be detected from the controller 12 allowing for autonomous control to override specific or all functions of manned mode operation.

[0037] Some vehicles implement a switch to transition from autonomous or remote mode to manned mode. In some examples, the switch position will override the conflicting messages. For example, if the switch is in autonomous mode, and messages are received from the vehicle pedals, the vehicle will continue to operate in autonomous mode.

Brake-Throttle interactions in Autonomy

[0038] In some instances inputs may comprise manned and autonomy or remote messages that are conflicting or occur simultaneously. For example, if commands are sensed for brake application and throttle application, the CIM 14 may be calibrated so that the brake application takes precedence. Furthermore, profiles may determine whether the pedal positions were intended actions. If the actions were unintended the vehicle may enter a lockout mode. Otherwise, the responses of the vehicle controls may be calibrated to pre-selected limits.

[0039] In another instance, the vehicle's response may include a blended application of at least one of the manned and autonomous or remote inputs. For example, the CIM 14 may receive messages for throttle application and brake application. A blended response may reduce the throttle to a calibrated level low enough such that the vehicle brakes will overcome the throttle application to the engine. In other situations, alternative calibrations may be desired. These calibrations comprise profiles that pre-select which vehicle features have priority in the event of conflicting messages

[0040] An exemplary vehicle system response of conflicting individual or multiple manual inputs and individual or multiple input instructions received from autonomous or remote controller 12 when the vehicle 10 is in the autonomous or remote control mode, may be as follows:

- Brakes: The vehicle 10 has both mechanical and electrical brake controls. If conflicts occur between the brake pedal input and the brake request command from the controller 12, an override causes the strongest braking request (manned or autonomous/remote) to be implemented. Therefore, an occupant in the vehicle may use the brakes to override remote commands to stop the vehicle 10.
- Steering: the steering will not respond to manual input.
- Transmission: the transmission will not respond to manual input.
- Engine: the accelerator pedal will be non-responsive to manual input.

Lockout Mode

[0041] A lockout function of the present disclosure is implemented in a vehicle 10 which supports both manned and autonomous or remote modes. In manned mode, the vehicle operates normally, receiving inputs from a driver through pedals, a steering wheel, and a shift lever. In remote mode, the vehicle 10 operates by receiving commends from an external controller 12 which communicates through a gateway communication interface module 14 which conditions and translates the commands onto the vehicle's CAN network. The lockout function permits only approved third parties to send commands via the vehicle gateway in remote control or autonomous mode. The vehicle 10 behaves in a known way in the event of the loss of or corruption of communication between the vehicle gateway 14 and the external controller 12.

[0042] The lockout function is illustratively part of the software which allows a third party to communicate with and drive a vehicle via controller 12 and interface module 14. In lockout mode the vehicle operations may comprise coming to a controlled stop, shifting into park, shutting off the engine, locking the steering column/brakes/clutch, shutting off the display/suspending communications, shut off power to the vehicle, inhibit starting of the vehicle. In order to insure only approved third parties are accessing the gateway module 14, the third party's external controller must successfully complete an authentication sequence. In an illustrated embodiment, authentication is based on a J1939 seed key exchange. It is understood that other authentication techniques may also be used. Another embodiment authentication protocol is described below with respect to Fig. 5.

Entering lockout mode

[0043] In order to insure only approved third parties are accessing the gateway module 12 in remote mode the third party's external controller 12 must successfully complete an authentication sequence. In one illustrated example, an authentication sequence is based on the J1939 or other seed key exchange. If an authentication sequence is not initiated and completed successfully at least once every five minutes, for example, then the vehicle enters lockout mode. Additionally, if the integrity of the communication, which may be ensured using checksums, message counters, or other communication errors, in any message coming from the external module to the vehicle gateway is compromised the vehicle enters the lockout mode.

Controlling the vehicle to execute lockout mode

[0044] The gateway control module 14 executes lockout mode by ignoring any incoming

CAN message from the external controller 12. Then module 14 sends a throttle command of zero over the vehicles internal CAN network and begins to command breaks to stop the vehicle 10. The braking force used is determined by a calibratable map which is dependent on vehicle speed and steering angle. Once the vehicle has stopped moving the transmission is commanded to shift into park and the engine is turned off. The gateway module 14 ignores incoming messages from external controllers 12, keeps the engine off, the transmission in park, and the brakes depressed until lockout mode is exited.

Exiting lockout mode

[0045] Exiting the lockout mode may occur by reauthentication, reestablishing communication, by a manual key cycle, etc. In one embodiment, the lockout mode is exited once the vehicle 10 has come to a complete controlled stop, the engine is shut off, and the transmission is shifted into park. In another embodiment, the lockout mode may be exited during the shutdown sequence (i.e. before a complete controlled stop has occurred, before the engine is shut off, or before the transmission is shifted into park) if reauthentication or reestablished communication occurs during the shutdown sequence. If the lockout was caused by loss of or corrupt communication, then lockout mode is exited once communication has been reestablished. If lockout mode was caused by a failure to authenticate, lockout mode is exited once an authentication sequence completes successfully. If the conditions to exit lockout mode are satisfied while the vehicle is in the process of stopping, shutting down the engine, and parking, the lockout mode is exited once the vehicle has come to a complete stop, shutdown the engine, and shifted into park.

[0046] Further details of the normal operation in the autonomous or remote control mode and the lockout mode are illustrated in Fig. 3. During normal operation, as illustrated at block 70, autonomous or remote controller 12 sends drive requests to the communication interface module or gateway interface module 14. The interface module 14 sends vehicle status information to controller 12. Module 14 also sends drive commands to vehicle communication nodes (such as CAN, Ethernet, etc.) based on the drive requests received from controller 12 as discussed above. Vehicle nodes send status information to the interface module 14.

[0047] Next, the communication interface module 14 determines whether the autonomous or remote controller 12 has initiated and successfully completed an authentication, such as, for

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example, a seed key exchange as illustrated at block 72. If authentication was successfully completed at block 72, module 14 resets an authentication timer at block 74 and continues with normal operation at block 70. If authentication was not successfully completed at block 72, module 14 determines whether a predetermined period of time, such as 5 minutes, has elapsed since the last successful authentication, as illustrated at block 76. If the predetermined amount of time has not elapsed at block 76, normal operation continues at block 70. If the predetermined amount of time has elapsed at block 76, module 14 enters a lockout mode at block 78.

[0048] Module 14 sends drive commands to the vehicle modes to bring the vehicle to a lockout state in a controlled manner as illustrated at block 78. Module 14 controls braking of the vehicle based upon speed and steering angle of the vehicle to bring the vehicle to a controlled stop. Engine control module 28 then shuts off the engine function at block 32. In the lockout mode, controller 12 may continue sending drive requests to the communication interface module 14. The interface module 14 continues to send vehicle status information to the controller 12. Interface module 14 sends drive commands to the vehicle nodes in order to maintain lockout of the vehicle. The vehicle nodes send status information back to the interface module 14.

[0049] In another illustrated embodiment, communications form controller 12 to the vehicle CIM 14 still occurs regardless of the vehicle being in lockout mode. After a predetermined number of failed authentication attempts or a failure in communication, the CIM 14 stops executing commands to the vehicle. Vehicle CIM 14 will still be receive communications from controller 12, but will no longer send communications to controller 12.

[0050] In yet another illustrated embodiment, when the vehicle 10 enters lockout mode, the entire vehicle communication network is still functional while the external communication network between controller 12 and CIM 14 is shut down.

[0051] In still another illustrated embodiment, active control is provided for individual vehicle nodes of the vehicle communications network. Lockout authentication is applied between any two vehicle nodes or vehicle communications networks to implement lockout functionality. This technique is also be used to prevent an unauthorized vehicle node from being added to the CAN network.

[0052] Next, the interface module 14 determines whether the controller 12 has initiated and successfully completed an authentication, such as by a seed key exchange, as illustrated at block 82. If not, interface module 14 maintains the lockout mode at block 80. If the authentication was successful at block 82, interface module 14 resets the authentication timer at block 74 and resumes normal operation in which the vehicle is again controlled by the autonomous or remote controller 12.

[0053] When the vehicle 10 is in autonomous or remote control mode, communications failures may occur. In the event of a communications failure, including problems with a message counter and checksum as well as if any J1939 defined "error" messages, the communication interface module 14 enter the lockout mode discussed above. If the remote module commands the brakes at greater than 0% and the throttle at greater than 0%, the communication interface module 14 obeys the brake command, ignores the throttle command, and broadcasts a diagnostic trouble code over the external CAN network. The following are exemplary actions taken by the communication interface module 14 in the event a J1939 "not available" message is received for each subsystem controlled in remote mode. In one example:

- Brakes: brake command interpreted as 0%
- Steering: steering angle maintained at last valid requested angle
- Transmission: requested gear maintained at last valid requested gear
- Engine: pedal command interpreted as 0%, engine on/off command interpreted as engine off

[0054] In one illustrated example, if the CIM 14 receives a brake command and the data says the command is not available, the CIM 14 determines that the command is invalid and waits to see if it receives another message. Limit the number of messages, before a lockout or alternative operation takes place. If multiple input commands (brakes, steering, etc.) are not valid, this could signal a problem and the CIM 14 enters lockout mode to stop these commands from continuing. The CIM 14 may enable options for any pedal commands, any steering commands, pre-set "limp-home" commands, etc. If problems occur with check sum or data errors, then the CIM 14 uses use last valid commands, however, if the conditions are still not valid vehicle will eventually enter a lockout mode or limp home/degrade mode condition.

<u>Remote Vehicle Power Up and Remote Mode Selection</u>

[0055] In another embodiment, the system permits remote mode selection and vehicle power up remotely. The communication interface module 14 has a low power mode which wakes when a CAN message is received from controller 12. The mode selection is controlled by

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a CAN message from the remote controller 12 (if not present default to manual mode). Once woken up, the communication interface module 14 controls the circuit in Fig. 4 in order to bypass the key switch if in remote mode. A conventional wiring harness is modified by adding an inline connector behind the key switch connector as shown in Fig. 4. An auto start control line for the ECM 28 is routed to a 5 pin connector with existing key switch lines. Fig. 4 also shows both sides of a new pass through connector with an auto/manual bypass circuit in-between.

[0056] If communication is lost in autonomous or remote control mode while the vehicle 10 is in motion, a "stop procedure" is implemented. The system monitors ground based vehicle speed and steering angle then applies the brakes based on these two inputs to bring the vehicle to a stop. Applications based on a 3D map calibrated to the vehicle (speed, steering angle and brakes percentage) may be used to provide feedback of the surrounding terrain.

[0057] In illustrative embodiments, the controller 12 implements one or more of the following features:

- Vehicle supervisory control to the level of emulating a human driver
- Sensory fusion
- Navigation by GPS corrected inertial navigation or other system capable of required precision in determining position
- Localization
- Lane detection and lane departure
- Extensive terrain and obstacle detection, avoidance and database characterization using real-time or near real-time detection, pre-recorded maps and lane structures, trips planned and tracked, collision avoidance system (LIDAR, Video, sensors), and adaptive cruise control.
- In the absence of communications from a controller 12, the vehicle has the ability to operate in a full autonomous mode.

[0058] The communication interface module 14 may provide:

- Run/Auto Start, Speed /Acceleration Control, Steering, Braking, Gear select, and other chassis functions such as lighting
- Yaw rate models vs. steering command are used at the vehicle control level
- Command modes include target condition and rate with standard and maximum rate of change profiles

- Remote dashboard messages.
- Creating drive profiles from vehicle sensors
- Black out mode
- Infrared (IR) mode
- Automating driveline control, by executing drive modes including 2 wheel drive, 4 wheel drive and turf mode, etc.
- Status messages sent over the CAN include controller conflicting commands, vehicle health data, and state and conditions of vehicle lockout mode.

[0059] Still further, embodiments are envisioned where the vehicle 10 (and controller 34) is provided with information regarding the terrain being traversed (via GPS or otherwise, alone or in combination with other sources). This information can include the type of terrain, changes in terrain, or otherwise to inform the vehicle 10 about conditions expected to impact operation thereof. Vehicle 10 then uses this information to impact the operation of the vehicle. In one example, vehicle 10 is determined to be travelling in a cross-hill direction. Vehicle 10 uses this information to impact the stiffness settings of the electrically adjustable shocks to increase vehicle stability. Similarly, other examples include adjusting shock settings by determining whether an on-road or off-road setting is being traversed.

[0060] With reference to Fig. 5, another embodiment authentication protocol is described to ensure only authorized entities are able to access the CAN network to direct operation of the vehicle. Upon enabling autonomous mode, the CIM 14 sends an authentication request to the remote module 12, block 500. The request contains a seed value. The seed value is illustratively a 7-byte long key that is generated to approximate a random number. Remote module 12 receives the request and calculates a key based on the seed value (a private key) and an algorithm, block 510. Module 12 then sends back a public key value to CIM 14, block 520. CIM 14 then compares the returned value to a value it calculated internally and therefore expects to match the returned value to indicate an authentic module 12. Upon receiving the public key value, CIM 14 determines if the response was received within a defined timing window, block 530. This timing requirement limits the ability of a third party to have unlimited time to attempt any number of responses (i.e. a “brute force” hack attempt). If the public key response was received within the required timing window and the public key matches the expected response, block 540, then the module is authenticated and module 12 is permitted to transmit control signals, block 550.

[0061] If the public key received within the timing window does not match or if the public key response was received outside of the required window, CIM 14 locks out module 12 and enters a lockout mode (which either disables the vehicle or returns it to manual user control), block 560.

[0062] CIM 14 then waits for another authentication request from module 12 (which may be the same or different module 12 that provided the failed public key response), block 570. Upon receiving another authentication request, CIM 14 enforces a delay to again reduce the likelihood of success for a brute-force type attack, block 580. If the delay time has not elapsed, CIM 14 again locks out module 12 and then waits for another authentication request, block 590. If the delay time has elapsed, then CIM 14 returns to block 510 to again attempt to authenticate module 12.

[0063] As noted, once a module 12 is authenticated, it is permitted to transmit commands to CIM module 14 for instructing operation of vehicle 10. As part of this, CIM 14 receives an input command from module 12, block 600. Each received message has a checksum and message counter value attached thereto. CIM 14 compares the checksum and counter within the message to what is internally calculated (and therefore expected from the message), blocks 610, 620, 630. If either the counter or checksum do not match, CIM 14 locks out module 12, block 560. If the counter and checksum match, then the received command input is accepted and distributed within vehicle 10 to achieve invocation thereof, block 640.

[0064] Overall, with reference to Fig. 6, it should be appreciated that a method allowing ready connection of a vehicle with an autonomous controller disclosed. A vehicle is provided with a communication network having a plurality of vehicle operation devices coupled thereto, the plurality of vehicle operation devices being capable of operating the vehicle, the plurality of vehicle operation devices including a first subset of devices that operate based upon instructions from a vehicle control unit, the plurality of vehicle operation devices including a second subset of devices that provide input to the vehicle control unit, the input being indicative of operator interaction with one or more of the vehicle devices, block 700. An interface to the communication network is provided, block 710. Input is received via the interface from an autonomous vehicle controller, thereby allowing the autonomous vehicle controller to control the

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first subset of vehicle devices independent of input from the second subset of vehicle devices, block 720.

[0065] The logical operations of the various embodiments of the disclosure described herein are implemented as: (1) a sequence of computer implemented steps, operations, or procedures running on a programmable circuit within a computer, and/or (2) a sequence of computer implemented steps, operations, or procedures running on a programmable circuit within a directory system, database, or compiler.

[0066] Embodiments of the disclosure may be practiced using various types of electrical circuits comprising discrete electronic elements, packaged or integrated electronic chips containing logic gates, a circuit utilizing a microprocessor, or on a single chip containing electronic elements or microprocessors. Embodiments of the disclosure may also be practiced using other technologies capable of performing logical operations such as, for example, AND, OR, and NOT, including but not limited to mechanical, optical, fluidic, and quantum technologies. In addition, aspects of the methods described herein can be practiced within a general purpose computer or in any other circuits or systems.

[0067] Embodiments of the present disclosure are implemented as a computer process (method), a computing system, or as an article of manufacture, such as a computer program product or computer readable media. The computer program product may be a computer storage media readable by a computer system and encoding a computer program of instructions for executing a computer process. Accordingly, embodiments of the present disclosure may be embodied in hardware and/or in software (including firmware, resident software, micro-code, etc.). In other words, embodiments of the present disclosure may take the form of a computer program product on a computer-usable or computer-readable storage medium having computer-usable or computer-readable program code embodied in the medium for use by or in connection with an instruction execution system. A computer-usable or computer-readable medium includes any medium that includes media capable of containing or storing the program for use by or in connection with the instruction execution system, apparatus, or device.

[0068] Embodiments of the present disclosure, for example, are described above with reference to block diagrams and/or operational illustrations of methods, systems, and computer program products according to embodiments of the disclosure. The functions/acts noted in the blocks may occur out of the order as shown in any flowchart. For example, two blocks shown in succession may in fact be executed substantially concurrently or the blocks may sometimes be executed in the reverse order, depending upon the functionality/acts involved.

[0069] While this invention has been described as having an exemplary design, the present invention may be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention pertains.

Claims

1. An autonomous-ready vehicle, including:

a communication network for transmitting signals:

a plurality of vehicle devices including a first subset arranged to operate the vehicle by one or more of switching on or off of the vehicle, shifting gears of the vehicle, accelerating the vehicle and braking the vehicle, and a second subset arranged for receiving vehicle operator input commands aimed at controlling movement of the vehicle through one or more of vehicle on-off switching, gear shifting, steering, accelerating and breaking the vehicle, the first and second subset coupled to the communication network:

a vehicle control unit configured to control the first subset of the plurality of devices via the communication network to effect vehicle operation, the vehicle control unit selectively operable to receive input from the second subset of the vehicle devices via the communications network and to control the first subset of the plurality of devices responsive to the input received from the second subset of vehicle devices, input from the second subset of vehicle devices being indicative of operator interaction with one or more of the vehicle devices; and

an autonomous vehicle controller configured to selectively effect vehicle operation through a network interface via the vehicle control module and the first subset of vehicle devices independent of input from the second subset of vehicle devices, wherein the autonomous vehicle controller is further configured for effecting and adapting vehicle operation through implementation of one or both of terrain detection and obstacle detection and avoidance using real-time or near real-time detection using one or more of vehicle sensors, pre-recorded maps and lane structures, trips with the vehicle planned and tracked, collision avoidance systems and adaptive cruise control.

2. The vehicle of claim 1, wherein the first subset of vehicle devices include one or more of a steering controller, a brake controller, a transmission shift controller, a vehicle speed controller and a vehicle on/off controller.

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3. The vehicle of claim 1 or 2, wherein the second subset of vehicle devices include one or more of a brake pedal, a steering device, a shift lever, a shift button, an accelerator pedal and a vehicle on/off mode selector.

4. The vehicle of any one of claims 1 to 3, wherein the vehicle control unit is configured to review commands received via the network interface for controlling the first subset of vehicle devices, the review comparing the commands to a set of allowable conditions to block implementation of the commands when doing so would cause the vehicle to assume a non-allowable state.

5. The vehicle of any one of claims 1 to 4, further including a mode switch, the mode switch having a first state in which the first subset of vehicle devices is controlled responsive to the second subset of vehicle devices, the mode switch having a second state in which the first subset of vehicle devices is controlled responsive to commands received via the network interface from the autonomous vehicle controller.

6. The vehicle of claim 5, wherein the switch is one of a software switch enabled to change states without physical manipulation and a physical switch operable via physical manipulation.

7. The vehicle of any one of claims 1 to 6, wherein the vehicle control unit receives input from the second subset of the plurality of devices and receives input from the network interface via the communication network, and wherein the vehicle control unit is further configured to determine which input to use to control the first subset of the plurality of devices.

8. The vehicle of claim 7, wherein the vehicle control unit determines which input to use responsive to determining a state of a or the mode switch.

9. The vehicle of claim 7, wherein the second subset of vehicle devices includes a brake actuator and the vehicle control unit is further configured to determine which input to use based upon which input indicates a greatest actuation of the brake actuator.

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10. The vehicle of any one of claims 1 to 9, wherein the plurality of vehicle devices further include a plurality of sensors, the vehicle control unit configured and operable to receive input from the plurality of sensors to determine one or more operational error states of the vehicle, the control unit further configured and operable to determine conflicting commands between those received from at least one of the plurality of sensors and the first subset of vehicle devices and those received via the network interface, the detection of conflicting commands being used to determine one or more error states, the control unit responding to determining one or more error states by entering a degraded operational mode.

11. The vehicle of any one of claims 1 to 10, wherein the vehicle control unit is further configured to invoke an authentication protocol to determine whether commands received via the network interface are being sent from an authorized source.

12. The vehicle of claim 11, wherein the vehicle control unit is further configured to instruct operation of the vehicle as one of operation as instructed via the second subset of vehicle devices and operation via a shut-down mode upon a determination that commands received via the network interface are not from an authorized source.

13. The vehicle of claim 12, wherein the shut-down mode causes the vehicle to come to a stop when the vehicle is in motion and refuses instructions via the network interface until such time as the authentication protocol is successfully completed.

14. The vehicle of any one of claims 1 to 13, wherein autonomous vehicle controller is further configured for effecting and adapting vehicle operation through implementation of one or more of (i) vehicle supervisory control to a level of emulating a human vehicle operator, (ii) vehicle navigation by GPS corrected inertial navigation or precision guidance, (iii) vehicle localization and (iv) vehicle lane detection and lane departure.

15. The vehicle of any one of claims 1 to 14, wherein the autonomous vehicle controller is a remote controller associated with operator input devices to guide movement of the vehicle remotely from the vehicle.

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16. A method of operating an autonomous-ready vehicle according to any one of claims 1 to 15, including the following steps:

receiving, via the network interface to the communication network, input signals from the autonomous vehicle controller representative of commands to control movement of the vehicle; and

upon enabling of the autonomous vehicle controller, the vehicle controller operating the first subset of vehicle devices in accordance with the commands received from the autonomous vehicle controller independent of input of vehicle operator commands inputted through the second subset of vehicle devices.

17. The method of claim 16, wherein the autonomous vehicle controller is enabled through operator selection.

18. The method of claim 16 or 17, further including reviewing commands received via the network interface for controlling the first subset of vehicle devices, the reviewing including comparing the commands to a set of allowable conditions to block implementation of the commands when doing so would cause the vehicle to assume a non-allowable state.

19. The method of claim 16, further including detecting a state of a mode switch, the mode switch having a first state in which the first subset of vehicle devices is controlled responsive to the second subset of vehicle devices, the mode switch having a second state in which the first subset of vehicle devices is controlled responsive to commands received via the network interface from the autonomous vehicle controller.

20. The method of claim 19, wherein the mode switch is a software switch for changing states without physical manipulation.

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21. The method of any one of claims 16 to 20, further including:

receiving, by the vehicle control unit, vehicle operator inputs from the second subset of the plurality of devices;

receiving, by the vehicle control unit, via the network interface, signals indicative of vehicle operation commands provided by or through the autonomous vehicle controller; and

determining, by the vehicle control unit, which input to use to control the first subset of the plurality of devices.

22. The method of claim 21, wherein the determining is performed by the vehicle control unit responsive to determining a state of a or the mode switch.

23. The method of claim 22, wherein the second subset of vehicle devices includes a brake actuator and wherein the vehicle control unit determines which input to use based upon which input indicates a greatest actuation of the brake actuator.

24. The method of any one of claims 16 to 23, wherein the plurality of vehicle devices include a plurality of sensors, and further including the steps of:

receiving input by the vehicle control unit from the plurality of sensors and determine one or more operational error states of the vehicle responsive to the input,

determining, by the vehicle control unit, conflicting commands between those received from at least one of the plurality of sensors and the first subset of vehicle devices and those received via the network interface,

determining, by the vehicle control unit, one or more error states responsive to the detection of conflicting commands, and

the vehicle control unit entering a degraded vehicle operational mode in response to determining existence of the one or more error states.

25. The method of any one of claims 16 to 24, further including the vehicle control unit invoking an authentication protocol to determine whether commands received via the network interface are being sent from an authorized source.

26. The method of claim 25, further including, upon determining that commands received via the network interface are not from an authorized source, the vehicle control unit instructing operation of the vehicle as one of operation as instructed via the second subset of vehicle devices and operation via a shut-down mode.

27. The method of claim 26, wherein operating via the shut-down mode causes the vehicle to come to a stop when the vehicle is in motion, and including the further step of the vehicle control unit refusing commands received via the network interface until such time as the authentication protocol is successfully completed.

28. A computer readable media having non-transitory instructions thereon that when carried out by a processor of an autonomous-ready vehicle in accordance with any one of claims 1 to 15 cause the processor to perform a method of operation of the vehicle in accordance with any one of claims 16 to 27.

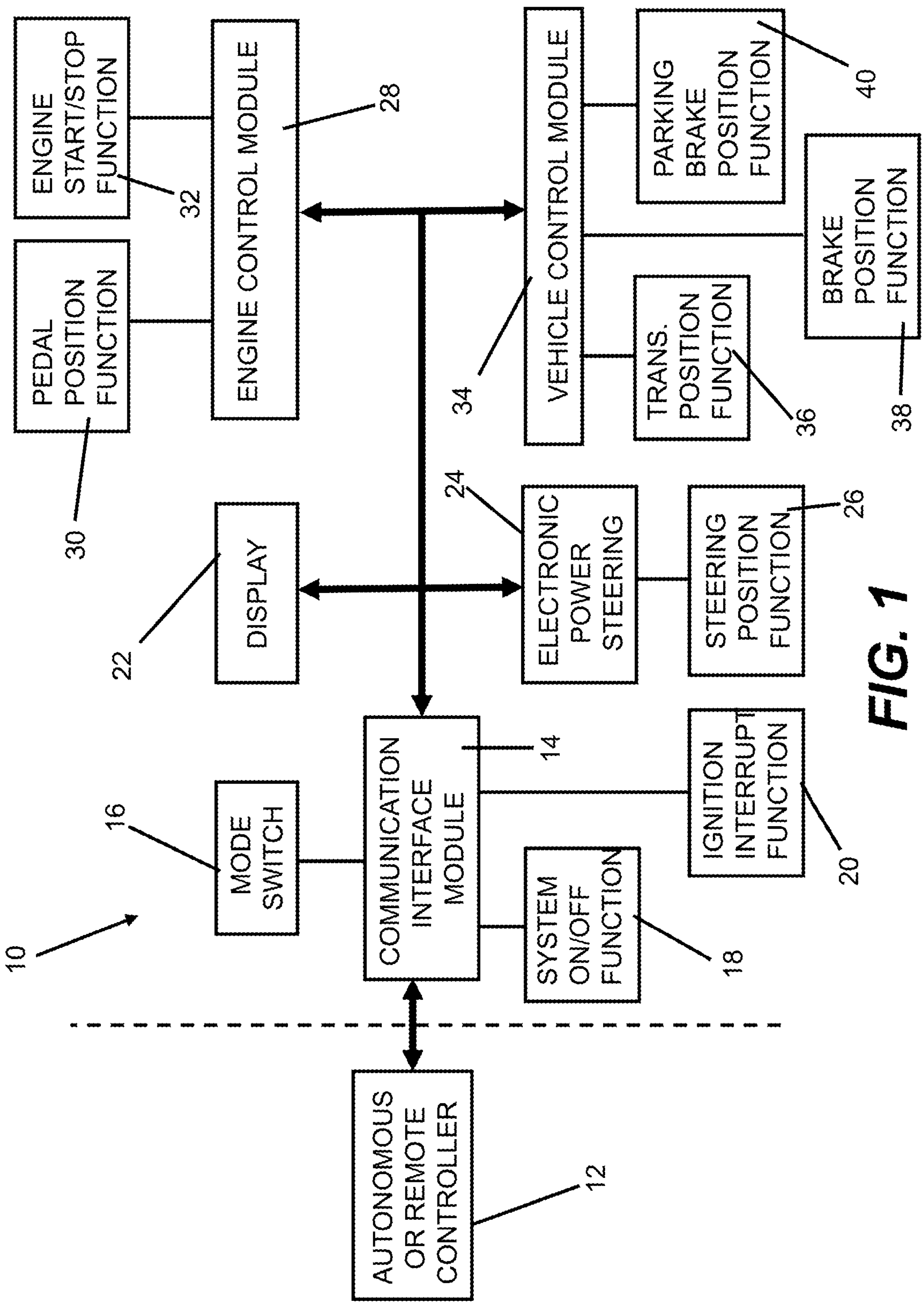
AUTONOMOUS OR REMOTE CONTROLLER
12
COMMUNICATION INTERFACE MODULE
14
MODE SWITCH
16
SYSTEM ON/OFF FUNCTION
18
IGNITION INTERRUPT FUNCTION
20
10
DISPLAY
22
ELECTRONIC POWER STEERING
24
STEERING POSITION FUNCTION
26
PEDAL POSITION FUNCTION
30
ENGINE START/STOP FUNCTION
32
ENGINE CONTROL MODULE
28
VEHICLE CONTROL MODULE
34
TRANS. POSITION FUNCTION
36
BRAKE POSITION FUNCTION
38
PARKING BRAKE POSITION FUNCTION
40

FIG. 1

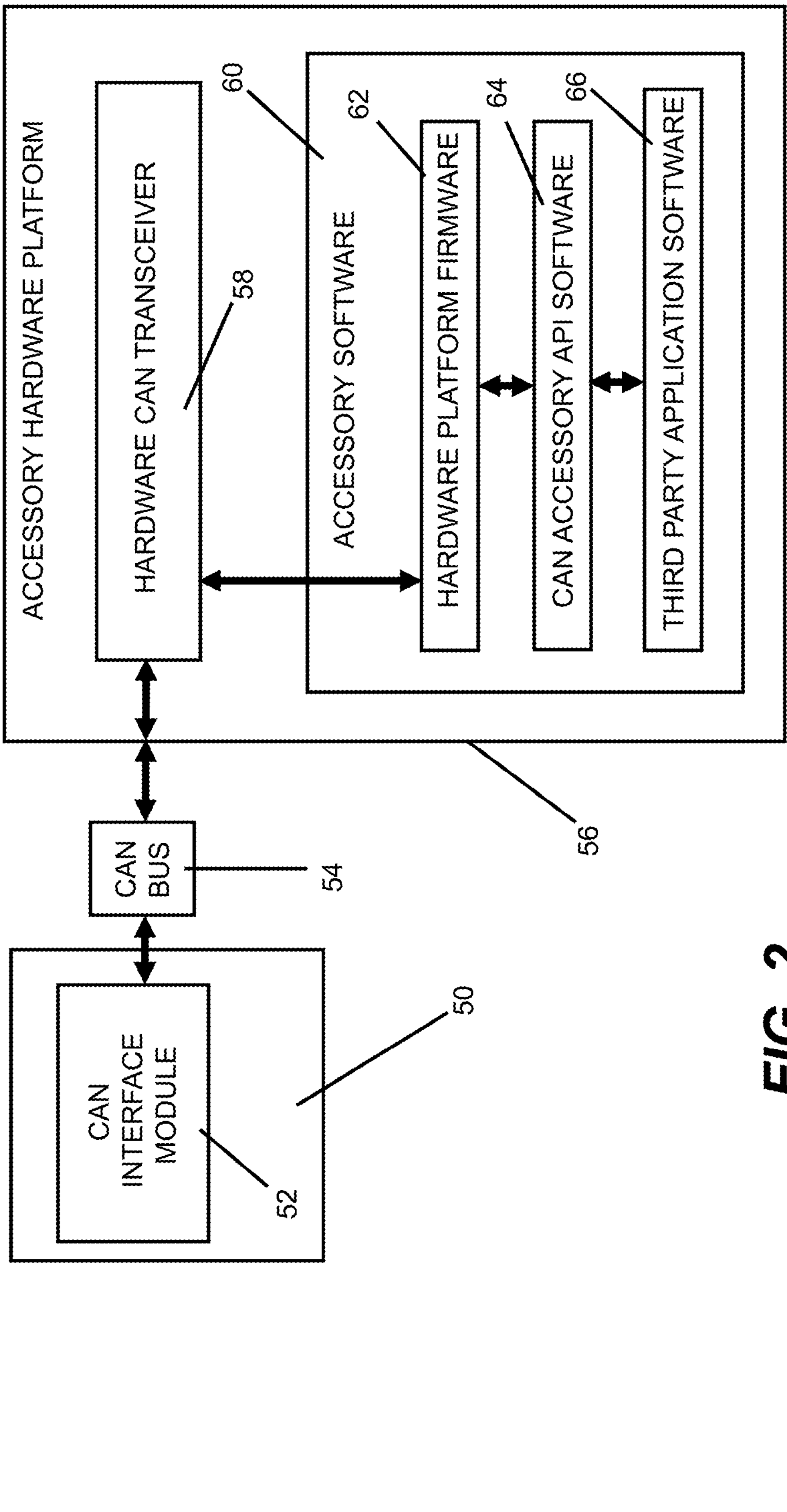
ACCESSORY HARDWARE PLATFORM
HARDWARE CAN TRANSCEIVER
58
60
ACCESSORY SOFTWARE
62
HARDWARE PLATFORM FIRMWARE
64
CAN ACCESSORY API SOFTWARE
66
THIRD PARTY APPLICATION SOFTWARE
56
CAN BUS
54
CAN INTERFACE MODULE
50
52

FIG. 2

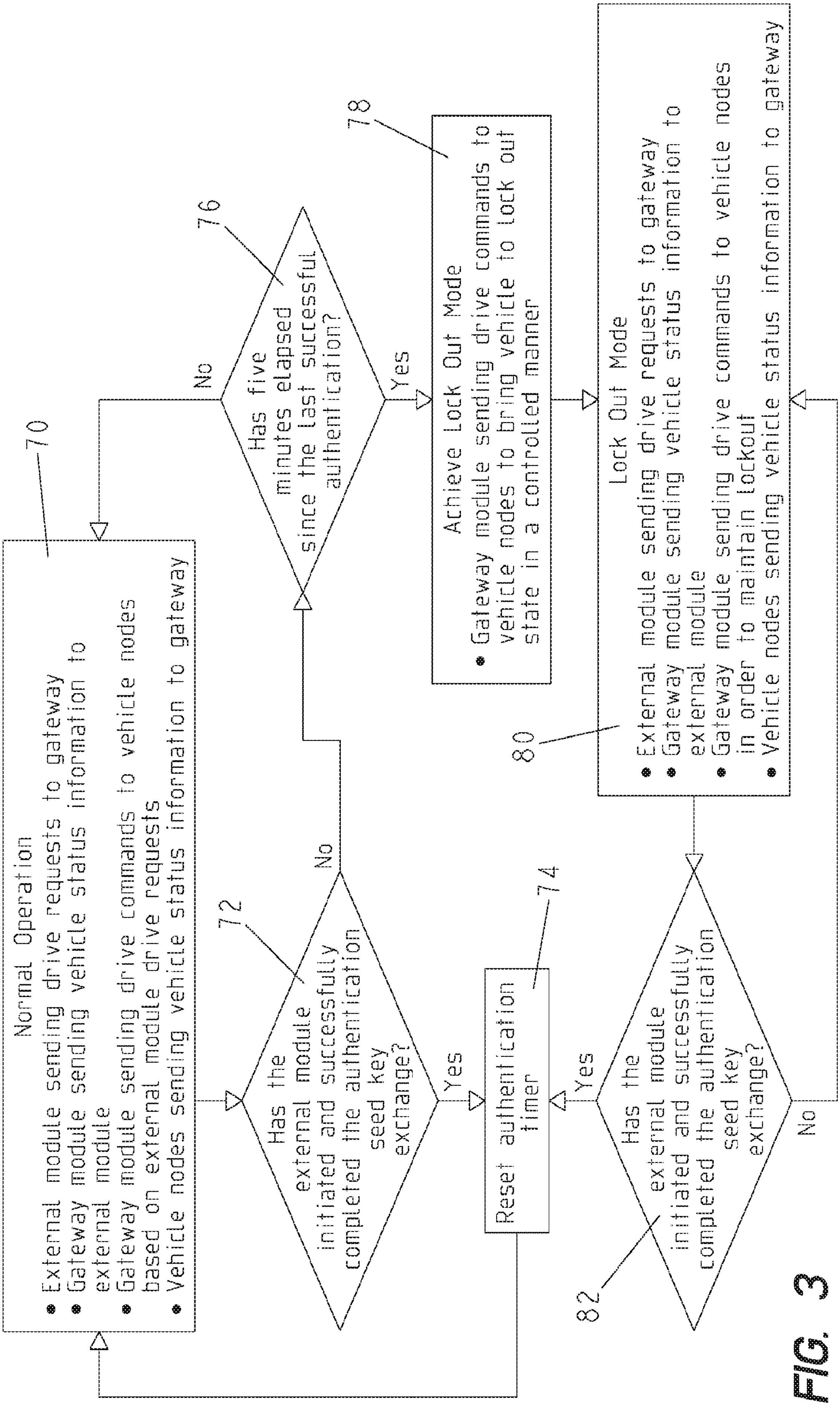
70
Normal Operation
• External module sending drive requests to gateway
• Gateway module sending vehicle status information to external module
• Gateway module sending drive commands to vehicle nodes based on external module drive requests
• Vehicle nodes sending vehicle status information to gateway
72
Has the external module initiated and successfully completed the authentication seed key exchange?
Yes
No
74
Reset authentication timer
76
Has five minutes elapsed since the last successful authentication?
No
Yes
78
Achieve Lock Out Mode
• Gateway module sending drive commands to vehicle nodes to bring vehicle to lock out state in a controlled manner
80
Lock Out Mode
• External module sending drive requests to gateway
• Gateway module sending vehicle status information to external module
• Gateway module sending drive commands to vehicle nodes in order to maintain lockout
• Vehicle nodes sending vehicle status information to gateway
82
Has the external module initiated and successfully completed the authentication seed key exchange?
Yes
No

FIG. 3

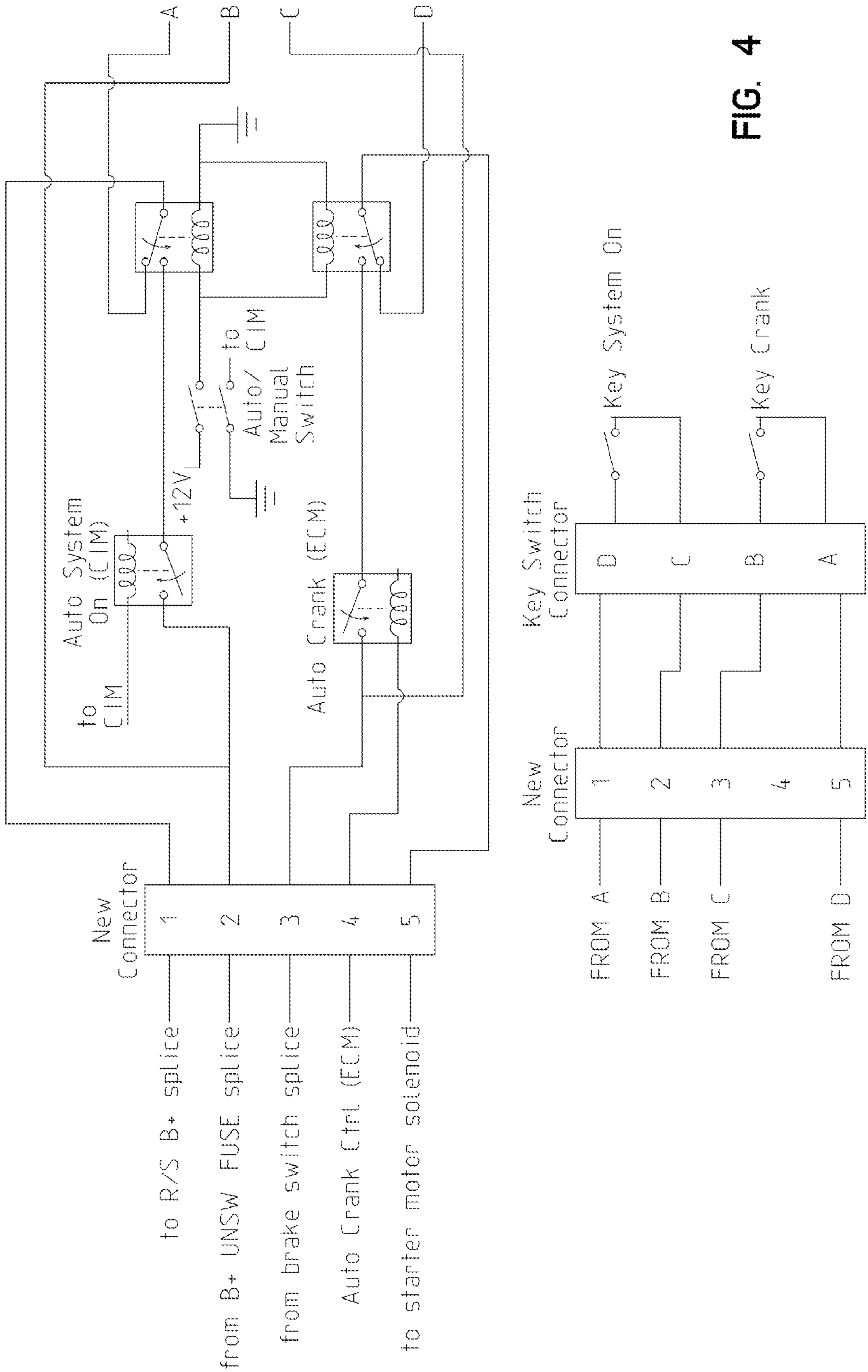
A
B
C
D
to CIM
Auto System On (CIM)
+12V
Auto/ Manual Switch
to CIM
Auto Crank (ECM)
New Connector
1
2
3
4
5
to R/S B+ splice
from B+ UNSW FUSE splice
from brake switch splice
Auto Crank Ctrl (ECM)
to starter motor solenoid
Key Switch Connector
D
C
B
A
Key System On
Key Crank
New Connector
1
2
3
4
5
FROM A
FROM B
FROM C
FROM D

FIG. 4

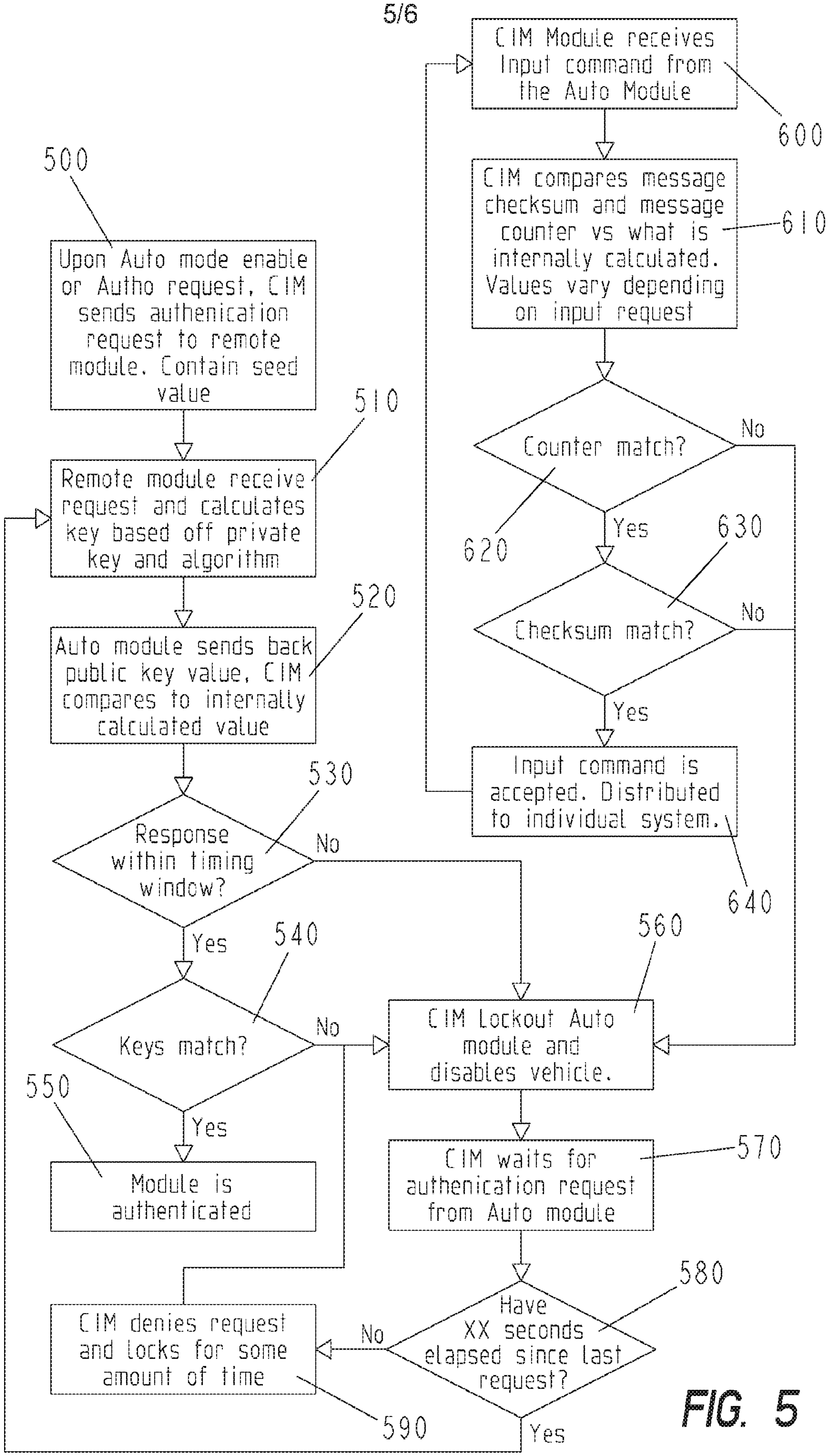
500
Upon Auto mode enable or Autho request, CIM sends authenication request to remote module. Contain seed value
510
Remote module receive request and calculates key based off private key and algorithm
520
Auto module sends back public key value, CIM compares to internally calculated value
530
Response within timing window?
No
Yes
540
Keys match?
No
Yes
550
Module is authenticated
560
CIM Lockout Auto module and disables vehicle.
570
CIM waits for authenication request from Auto module
580
Have XX seconds elapsed since last request?
No
Yes
CIM denies request and locks for some amount of time
590
600
CIM Module receives Input command from the Auto Module
610
CIM compares message checksum and message counter vs what is internally calculated. Values vary depending on input request
Counter match?
620
No
Yes
630
Checksum match?
No
Yes
Input command is accepted. Distributed to individual system.
640

FIG. 5

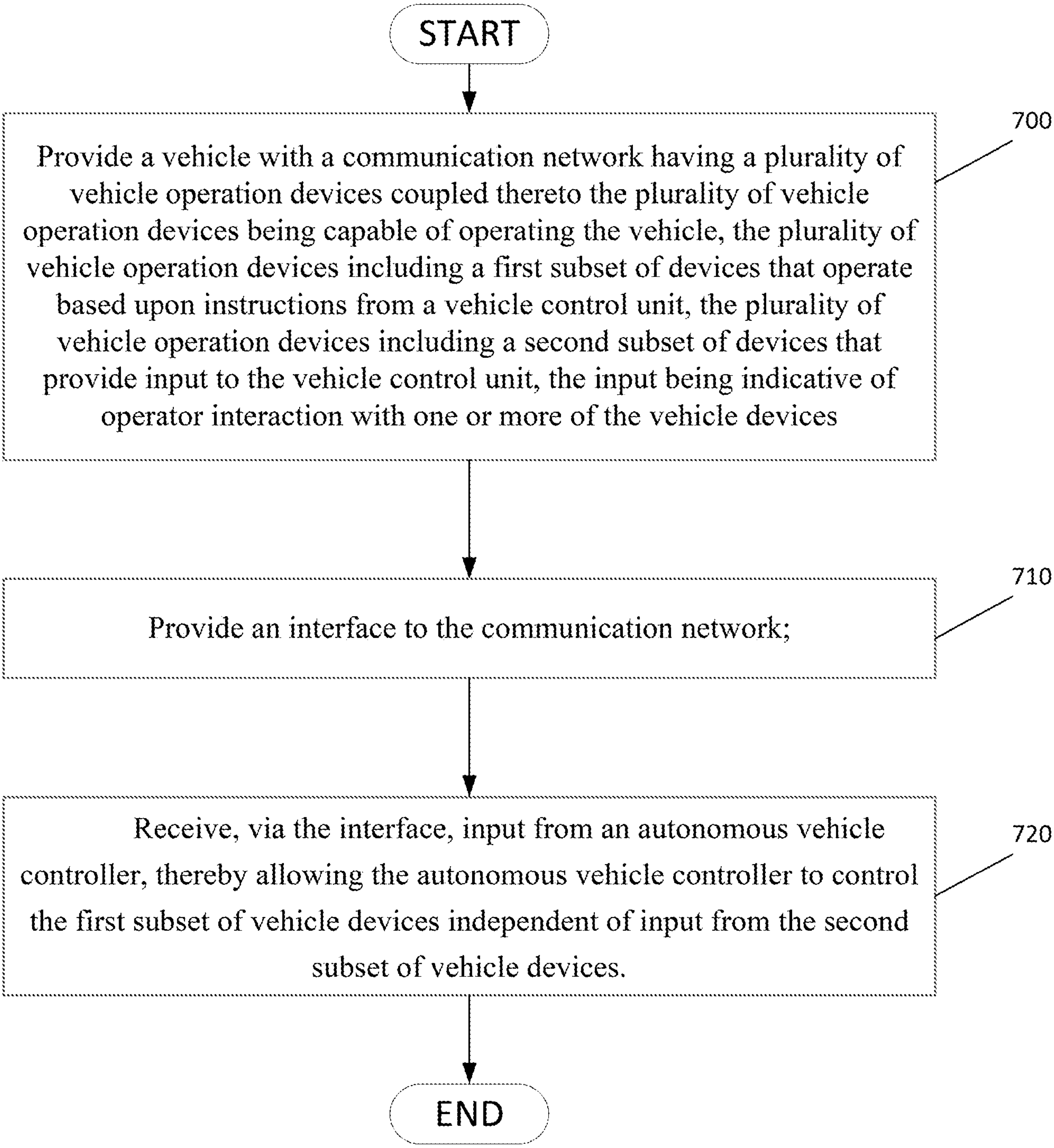
START
Provide a vehicle with a communication network having a plurality of vehicle operation devices coupled thereto the plurality of vehicle operation devices being capable of operating the vehicle, the plurality of vehicle operation devices including a first subset of devices that operate based upon instructions from a vehicle control unit, the plurality of vehicle operation devices including a second subset of devices that provide input to the vehicle control unit, the input being indicative of operator interaction with one or more of the vehicle devices
700
Provide an interface to the communication network;
710
Receive, via the interface, input from an autonomous vehicle controller, thereby allowing the autonomous vehicle controller to control the first subset of vehicle devices independent of input from the second subset of vehicle devices.
720
END

FIG. 6