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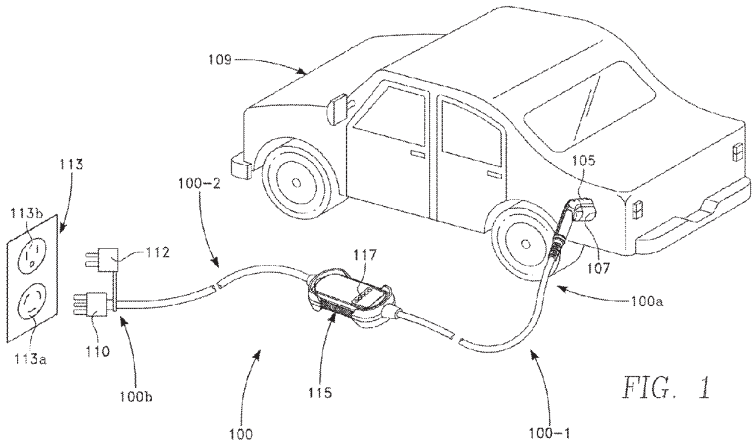

FIG. 1

(57) **Abstract**: A portable electric vehicle support equipment (EVSE) unit is formed as a cord of plural insulated conductors and a flexible outer sheath enclosing said plural insulated conductors. The cord includes an EVSE docking connector on a docking end of the cord and a utility plug on a utility end of the cord, said cord being divided into a docking section terminated at said docking connector and a utility section terminated at said utility connector. The cord further includes an in-line EVSE controller and a housing enclosing said controller, said housing sealed with said flexible outer sheath and disposed at an intermediate section of said cord between said docking and utility sections.

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PORTABLE CHARGING CABLE WITH IN-LINE CONTROLLER

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CROSS-REFERENCE TO RELATED APPLICATIONS

[1] This application claims priority of U.S. Provisional Application Serial No. 61/322,807 filed April 9, 2010 entitled L1/L2 CORD SET & POWER DANGLE, by Albert Joseph Flack, et al.; U.S. Provisional Application Serial No. 61/434,282 filed January 19, 2011 entitled LEVEL 1-2 PORTABLE EV CHARGER CABLE, by David Paul Soden, et al.; U.S. Provisional Application Serial No. 61/437,001 filed January 27, 2011 entitled PORTABLE ELECTRIC VEHICLE CHARGING CABLE WITH IN-LINE CONTROLLER, by David Paul Soden, et al.; and U.S. Provisional Application Serial No. 61/467,068 filed March 24, 2011 entitled PORTABLE CHARGING CABLE WITH IN-LINE CONTROLLER, by David Paul Soden, et al. All of the above applications are hereby incorporated by reference in their entirety.

TECHNICAL FIELD

[2] The invention concerns electric supply equipment such as home-charging devices for electric vehicles.

BACKGROUND

[3] Electric vehicle supply equipment (EVSE) for residential charging of an electric vehicle (EV) is implemented at present as stationary units connected to the electric utility grid through a household electric

utility panel, and are not readily portable. The possibility of a loss of battery power when the EV is far from a commercial recharging station or personal home charging equipment is a problem that has not been solved.

SUMMARY OF THE INVENTION

[4] A portable electric vehicle support equipment (EVSE) unit is formed as a cord of plural insulated conductors and a flexible outer sheath enclosing said plural insulated conductors. The cord includes an EVSE docking connector on a docking end of the cord and a utility plug on a utility end of the cord, said cord being divided into a docking section terminated at said docking connector and a utility section terminated at said utility connector. The cord further includes an in-line EVSE controller and a housing enclosing said controller, said housing sealed with said flexible outer sheath and disposed at an intermediate section of said cord between said docking and utility sections. The in-line EVSE controller is connected in series between conductors of said docking section and conductors of said utility section. In one embodiment, the sheath and said housing form a continuous outer seal. The housing is sealed with a portion of said sheath enclosing said docking section or it is sealed with portions of said sheath enclosing both said docking and utility sections.

[5] In embodiments, the housing is joined with said utility and docking sections at opposing ends of the housing, said housing being suspended between said docking and utility sections of said cord so as to be freely movable with the cord. In one embodiment, the housing has as length of about 5-6 inches, a width of about 3-4 inches and a height of about 0.5-2 inches and

has a mass less than the mass of said docking section of said cord.

[6] In embodiments, said housing includes a pair of congruent upper and lower half shells having respective outer side walls, each of said half shells having a pair of half openings at opposite ends of the respective half shell, annular portions of said docking and utility sections being compressed between edges of facing ones of said half openings. The in-line controller may include a circuit board having electrical components connected to conductors of said docking and utility sections of said cord, and a potting compound encapsulating said circuit board between said half shells.

[7] In embodiments, the housing further includes a bumper formed of an elastically deformable material and surrounding the outer side walls of said half shells. The bumper has holes in registration with said half openings. The bumper may be integrally formed and may include an annular outer case and an annular interior belt surrounded by said outer case, said annular interior belt comprising an upward facing lip and a downward facing lip, an upper bumper groove being defined between said outer case and said upper facing lip and a lower bumper groove being defined between said outer case and said downward facing lip. The upper and lower half shells may comprise respective interior walls parallel with the respective ones of said outer side walls and forming respective upper and lower shell grooves. The upward facing lip is compressed in said upper shell groove, and said downward facing lip is compressed in said lower shell groove. The edge portions of the

respective outer side walls are pressed inside respective ones of said upper and lower bumper grooves.

[8] In embodiments, the outer case comprises a pair of opposing arcuate end skirts and a pair of straight gripping saddles joining said end skirts, each of said end skirts having a first height extending above a ceiling of said upper half shell and below a floor of said lower half shell, said gripping saddles having a second height less than said first height, to provide free air flow around the housing as its rests on a surface. The outer case of said bumper forms a bumper side wall, said bumper side wall comprising an annular convex apex, that promotes rotation of the housing whenever it is placed on one of its side edges.

[9] In embodiments, there is a control pilot conductor in said docking section of said cord, and said in-line EVSE controller comprises a microprocessor comprising a serial port, an analog buffer coupled between said microprocessor and said control pilot conductor, and a conductor connected between said serial port and said control pilot conductor. In further embodiments, the in-line controller further includes a pulse generator coupled to said control pilot conductor and having a duty cycle controlled by said microprocessor, signifying a maximum current limit, and a temperature sensor having a temperature output coupled to said microprocessor, said temperature output representing a present temperature. In embodiments, said microprocessor is programmed to reduce charging current flow through said EVSE cord whenever said present temperature exceeds a predetermined limit, by adjusting said duty cycle in response to said

present temperature approaching a predetermined temperature limit.

[10] In further embodiments, a method is provided for communicating digital data between said in-line controller of the EVSE cord and an external digital device, said method comprising coupling a serial port of a microprocessor of said in-line controller to a conductor of said cord that runs between said in-line controller and said docking connector, and coupling a serial port of an external digital device to said conductor by connection to said docking connector. The external digital device may be any one of a personal computer, a notebook computer, a cell phone, a personal digital assistant, or an interface tool dedicated to external connection with said docking conductor.

[11] In embodiments, the method may further include downloading from said microprocessor to said digital device via said serial port an identification of firmware stored in said in-line controller, determining whether said firmware has been superseded, and uploading from said digital device to said microprocessor via said serial port and via said conductor a current version of said firmware.

[12] In related embodiments, the method may include downloading from said microprocessor to said digital device status data representative of conditions in or status of said EVSE cord, interpreting said status data and generating an image representing a meaning of said status data on a display of said digital device. The data may be downloaded on a request-only basis or as a constant stream.

[13] In an alternative embodiment, the EVSE cord is connected to the EV, and the method includes downloading from said microprocessor via said serial port to the EV digital device status data representative of conditions in or status of said EVSE cord, interpreting said status data and generating an image representing a meaning of said status data on a display of said EV.

[14] In another embodiment, the utility connector may be adapted to connect to different outlets of different voltages (e.g., 120 VAC and 240 VAC), and the method further includes sensing at a sensor in said in-line controller a utility voltage received through said utility connector, determining in said processor which one of plural predetermined voltage ranges said utility voltage is closest to, and setting said one predetermined voltage range as the allowed voltage range. The processor may issue a fault alarm whenever an output of said sensor indicates said utility voltage is outside of said one predetermined range. In a related embodiment, the system designer may have previously correlated the different possible utility voltages to different maximum allowable current levels. The method controls the pulse duty cycle imposed on the control pilot conductor to signify a maximum current level, and sets said duty cycle to a current level previously correlated to said one predetermined voltage range.

[15] In another embodiment, an EVSE kit is provided consisting of the EVSE cord and an interface tool providing external access to the serial port through the control pilot conductor. The interface tool includes (1) a tool enclosure, (2) an EV connector mounted on said

tool enclosure for connection with said control pilot conductor, and (3) a serial port connector mounted on said tool enclosure and adapted to receive a serial port connector from an external digital device. The EVSE docking connector can be connected to the charging port of an EV whenever the EV is to be charged and can be connected to said interface tool whenever digital communication with said in-line controller is to be performed.

[16] In an alternative embodiment, the interface tool may be a stand-alone handheld device that includes a processor in said tool enclosure, a display disposed on said tool enclosure, said display controlled by said processor, said processor comprising a serial port coupled to the control pilot conductor whenever the EVSE cord and the interface tool are connected to one another. The interface tool may also include a key pad on said interface tool enclosure. Alternatively, or in addition, the display of said interface tool is a touch screen for user communication with said processor.

BRIEF DESCRIPTION OF THE DRAWINGS

[17] So that the manner in which the exemplary embodiments of the present invention are attained and can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings. It is to be appreciated that certain well known processes are not discussed herein in order to not obscure the invention.

[18] FIG. 1 depicts the portable charging cable of one embodiment.

[19] FIG. 2 is a simplified block diagram depicting internal elements of the portable cable of FIG. 1.

[20] FIG. 3 is a simplified block diagram depicting elements in the charging interface of an EV connected to the portable charging cable of FIG. 1.

[21] FIG. 4 is a flow diagram depicting a method performed in the embodiment of FIG. 1 for automatically adjusting to different utility supply voltages.

[22] FIG. 5 is a simplified block diagram depicting an embodiment in which the portable cable facilitates file uploading from an external computer through a special interface tool.

[23] FIG. 5A is an orthographic view of a robust handheld embodiment of the special interface tool of FIG. 5.

[24] FIG. 5B is a simplified schematic block diagram of the special interface tool of FIG. 5A.

[25] FIGS. 6A and 6B together constitute a flow diagram depicting methods of operation in the embodiment of FIG. 5.

[26] FIG. 7 is a block diagram depicting the contents of a memory used in the methods of FIGS. 6A and 6B.

[27] FIG. 8 is a flow diagram depicting methods of operating the embodiments of FIGS. 1-3 for prevention of

overheating in the in-line controller of FIG. 1 during EV charging.

[28] FIG. 9 is an orthographic view of one embodiment.

[29] FIG. 10 is an enlarged view corresponding to FIG. 9.

[30] FIG. 11 is an exploded orthographic view of the embodiment of FIG. 10.

[31] FIG. 12 is an enlarged detailed view of a bumper depicted in FIG. 11.

[32] FIG. 13 is a cut-away end view corresponding to FIG. 10.

[33] FIG. 14 is an elevational side view corresponding to FIG. 10.

[34] FIG. 15 includes elevational end views corresponding to FIG. 10 at different rotational positions.

[35] FIG. 16 is a cross-sectional elevational side view corresponding to FIG. 10.

[36] FIG. 17 is a cut-away end view of an exploded assembly corresponding to FIG. 10.

[37] FIGS. 18A, 18B and 18C are orthographic views of different fasteners employed in the embodiment of FIG. 17.

[38] FIG. 19 is a cut-away elevational side view corresponding to FIG. 10 depicting a first embodiment of cable strain relief.

[39] FIG. 20 is a cut-away elevational side view corresponding to FIG. 10 depicting a second embodiment of cable strain relief.

[40] FIG. 21 is an orthographic view corresponding to a portion of FIG. 10 and depicting a third embodiment of cable strain relief.

[41] FIGS. 22A, 22B and 22C are cut-away end views corresponding to FIG. 21 depicting sequential compression of a cable fitting.

[42] FIGS. 23A, 23B and 23C depict alternative shapes of cable openings providing strain relief, including a hexagonal opening (FIG. 23A), an octagonal opening (FIG. 23B) and a square or diamond-shaped opening (FIG. 23C).

[43] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation. It is to be noted, however, that the appended drawings illustrate only exemplary embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

DETAILED DESCRIPTION

[44] Embodiments of the present invention facilitate charging an EV using commonly available electricity outlets with a cable that functions as a light transportable EVSE unit. The light transportable EVSE unit can be easily carried in an EV and independently used at remote locations to charge the EV from standard electric power outlets. Electrical and electronic components required to perform the functions of an EVSE are integrated into the cable that constitutes the light transportable EVSE unit, in one embodiment.

[45] Referring to FIG. 1, the light transportable EVSE unit, in one embodiment, is an intelligent portable charging cable 100. The exterior surface of the cable 100 is formed by a a cylindrical flexible sleeve of an insulating material such as rubber or flexible plastic, for example. The cable 100 contains multiple insulated conductors described below with reference to FIG. 2. In FIG. 1, a docking end 100a of the portable charging cable 100 has a docking connector 105 connectable to an EV charging port 107 of an EV 109. A utility end 100b of the portable charging cable 100 has a 240 Volt AC plug 110 connectable to a standard 240 Volt AC power outlet 113a. Optionally, a 120 Volt-to-240 Volt plug adapter 112 connectable to a standard 120 Volt AC power outlet 113b may be tethered to the utility end 100b of the cable 100. The portable charging cable 100 further includes a programmable in-line controller 115 situated at an intermediate location between the docking end 100a and the utility end 100b and interrupting the conductor paths within the portable charging cable 100. The in-line controller 115 thus divides the portable charging cable 100 into a docking cable section 100-1 and a utility cable section 100-2. The in-line controller 115 provides

the portable charging cable 100 with the complete functionality of a conventional EVSE unit, including the capability to perform charging of an EV and to perform the communication protocols required by the EV on-board systems. For this purpose, the in-line controller 115 includes circuit elements and programmable controller elements adapted to implement the required functionality, as will now be described.

[46] Referring to FIGS. 1 and 2, the cable docking section 100-1 contains a pair of insulated power conductors 202a, 204a extending from the docking connector 105 to and into one side of the in-line controller 115. The cable utility section 100-2 contains a pair of insulated power conductors 202b, 204b extending from the plug 110 to and into an opposite side of the in-line controller 115. Within the in-line controller 115, a pair of contactors 206, 208 provide interruptable connection between the power conductors 202a, 202b and between the power conductors 204a, 204b, respectively. The contactors 206, 208 are actuated by an actuator 207 which may be a solenoid or other suitable device, and will be referred to herein as a solenoid.

[47] Communication between in-line controller 115 and the EV 109 is carried over a control pilot conductor 209 of the docking section 100-1 of the cable 100. Such communication may be implemented in accordance with the communication protocols defined in Section 5.3 of the Society of Automotive Engineers Specification SAE J1772. A neutral grounded conductor 211 extends through the entire length of the portable charging cable 100. The neutral grounded conductor 211 may correspond to utility ground at the connector 110. Each of the conductors

202a, 204a, 209 and 211 is connected to a corresponding conductive pin (not shown) inside the docking connector 105.

[48] The in-line controller 115 may include various sensors, such as a ground-fault coil sensor 210, a sensor 212 connected to the power conductors 202b, 204b and adapted to sense voltage (and/or phase and/or frequency) of the power from the power outlet 113, and a temperature sensor 214 to monitor temperature inside the in-line controller 115. Operation of the in-line controller 115 is governed by a computer or processor 216. Each of the sensors 210, 212 and 214 has an output connected to an input of the processor 216. The processor 216 has a central processing unit (CPU) or microprocessor 217 and a memory 218 storing a set of program instructions in the form of firmware. The microprocessor 217 executes the program instructions to perform various functions including implementing the required communication protocols with the on-board systems of the EV. If the communication protocols are those defined in Society of Automotive Engineers Specification SAE J1772, they are implemented by the EVSE and the EV imposing a sequence of voltage changes on the control pilot conductor 209. For this purpose, analog circuitry 220 is coupled between the microprocessor 217 and the control pilot conductor 209 that enables the microprocessor 217 to impose the required voltage changes on the control pilot conductor 209 (and to sense voltage changes imposed on the control pilot conductor 209 by the internal systems of the EV 109). Pulse modulation of the voltage on the control pilot conductor 209 is performed by a pulse generator 222 whose pulse duty cycle is controlled by the microprocessor 217. The pulse duty cycle signifies to

the EV the maximum allowable charging current that may be drawn from the EVSE.

[49] If the microprocessor 217 determines from the sensor 212 that the utility cord section 100-2 is connected to a voltage of 120 volts, then the microprocessor 217 sets the pulse duty cycle to a value signifying a particular current level (e.g., a Level 1 current level defined by SAE J1772). If the microprocessor 217 determines that the utility cord section 100-2 is connected to a voltage of 240 volts, then the microprocessor 217 may set the pulse duty cycle to a value signifying another current level (e.g., a Level 2 current defined by SAE J1772). Such current levels may be predetermined in accordance with the current ratings of the components of the portable charging cable 100, particularly the current ratings of the 220 Volt plug 110 and the 120 Volt adapter 112 of FIG. 1.

[50] The D.C. voltage on the control pilot conductor 209 is controlled and sensed through the analog circuitry 220 by the microprocessor 217 in accordance with the required communication protocol. The microprocessor 217 controls the solenoid 207 to open or close the contactors 206, 208. The microprocessor 217 monitors the outputs of the ground fault interrupt sensor 210, the voltage/frequency/phase sensor 212 and the temperature sensor 214 to determine whether any conditions arise that are outside of a prescribed set of conditions (e.g., voltage beyond a prescribed range, temperature outside of a prescribed range, ground fault occurrence, etc.), and if so, opens the contactors 206 and 208. Such an occurrence may be indicated under control of the

microprocessor 217 on a user interface or by external lights or light emitting diodes (LEDs) 117 provided on the in-line controller 115 as shown in FIG. 1. The light patterns for different conditions may be specified for the user.

[51] FIG. 3 is a simplified diagram depicting certain components of the EV 109 of FIG. 1 and their connection through the EV charging port 107 to the EVSE 100 of FIG. 1. These components include a battery pack 352 and a charge controller or battery management unit 354. In addition, analog circuitry 356 may be provided to enable the charge controller 354 to respond to and impose changes in voltage on the control pilot conductor 209 through the EV connector 107. This feature enables the charge controller 354 to respond appropriately to changes in voltage on the control pilot conductor 209 in accordance with the required communication protocol referred to above.

[52] As described above with reference to FIG. 1, the plug 110 may be configured for insertion into a standard 240 volt A.C. outlet, and an optional 240 volt/120 volt adapter 112 may be tethered to the cable utility end 100b to permit connection to a standard 120 volt A.C. outlet. Thus, the source voltage may be either 120 VAC or 220 VAC.

[53] The in-line controller 115, in one embodiment described below herein, automatically detects (through the sensor 212) the voltage input through the cable utility end 100-2, and ascertains the appropriate voltage range, which is either Level 1 (i.e., 120 VAC $\pm$10%) or Level 2 (i.e., 240 VAC $\pm$10%). Once the appropriate range has been ascertained, the microprocessor 217 constantly

compares the actual voltage measured by the sensor 212 with the appropriate voltage range, and issues an alarm or halts charging whenever (for example) an over-voltage condition occurs. Therefore the portable charging cable 100 can be operated as a Level 1 or Level 2 EVSE depending upon the attached plug connector.

[54] FIG. 4 depicts one method for automatically adapting to the voltage range. In this method, the microprocessor continually monitors the utility supply voltage using the sensor 212 (block 240 of FIG. 4). The microprocessor 217 determines whether the sensed voltage is closer to 120 VAC - "Level 1", or 240 VAC - "Level 2" (block 242). If the sensed voltage is closer to 120 VAC (YES branch of block 242), then the microprocessor 217 establishes the allowable voltage range as 120 VAC $\pm$ 10% (block 244a). If the sensed voltage is closer to 240 VAC (NO branch of block 242), then the microprocessor 217 establishes the allowable voltage range as 240 VAC $\pm$ 10% (block 244b).

[55] In a further aspect, the designer may have established a maximum allowable current level, which may be the same for both possible voltage ranges (i.e., Level 1 and Level 2) or may be different for the two ranges. For example, the maximum allowable current level may be higher for the Level 2 voltage range than for the Level 1 voltage range, to take advantage of the higher current levels allowed by the specification SAE J1772 for Level 2 voltages, and to account for any difference in current ratings between the 240 Volt plug 110 and the tethered 120 Volt adapter 112 of FIG. 1. The microprocessor 217 sets the maximum allowable current level (block 248 of FIG. 4), which may depend upon whether the allowable

voltage range is a Level 1 voltage or a Level 2 voltage. The microprocessor 217 sets the pulse generator 222 to a duty cycle corresponding to the maximum allowable current level (block 250).

[56] The microprocessor 217 monitors the current using the output of the sensor 212 (block 252) and produces an alarm and a trouble code if the current exceeds the limit (block 254). The microprocessor 217 continues to monitor the utility supply voltage, and if the sensed voltage deviates outside of the allowable voltage range, the microprocessor 217 generates a fault alarm to the user and stores a corresponding trouble code in the memory 218 (block 255).

[57] In an alternative embodiment, the portable charging cable 100 may be configured to accept only 120 volt A.C. power, and can be provided as a combination of the in-line controller 115 and the docking cable section 100-1 without the utility cable section 100-2. In this alternative embodiment, in place of the utility cable section 100-2 is a socket on the in-line controller 115 for attaching a conventional 120 volt extension cord. In this simplified configuration, a user would be able to charge the EV from commonly available electrical outlets using readily available equipment. In a further configuration of the above embodiment, the extension cord may include GFI (ground fault interrupter) circuitry.

[58] A housing or enclosure 230 provides a permanent water-proof seal around the exterior of the in-line controller 115, as indicated in FIG. 2. The housing 230 may have flat and/or curved exterior surfaces (not shown in FIG. 2). The in-line controller 115 may be an

integral part of the cable 100. The housing occupies an intermediate zone of the cable 100 between the docking section 100-1 and the utility section 100-2. Alternatively, each cable section 100-1 and 100-2 may be detachably connected to optional ports 115-1, 115-2, respectively, on opposite ends of the housing 230. In one embodiment, the housing 230 may be integrated with (or sealed with) the exterior surfaces of the cable docking section 100-1 and the cable utility section 100-2. The housing 230 may comprise a plastic or metal enclosure. The interior of the housing 230 may contain the electronic and electrical components of the type depicted in FIG. 2. In addition, a potting compound may fill the empty spaces inside the housing 230 and thereby provide thermal conduction from the interior components to the exterior of the housing 230. In one embodiment, the housing 230 may be formed by potting the components of the in-line controller 115 with a potting compound. The embodiments of the housing 230 are described later in this specification.

[59] The housing 230 is an integral part of the cable 100 and is freely suspended between the cord docking and utility sections 100-1, 100-2 whenever cord is lifted or moved, so that the entire cord 100 including the housing 230 behaves mechanically as a single integrated cord during handling or moving. The housing 230 is sufficiently small and light to behave as an integral part of cord during handling. In embodiments, the housing 230 may have length in the range of 5-6 inches, a width in the range of 3-4 inches and a height in the range of 1.0-2.5 inches. The cord docking section 100-1 may be about 15-25 feet long. The cord docking and utility sections 100-1, 100-2 have circular cross-

sections of diameter between 0.25 and 1.0 inch, while the housing 230 has a rectangular cross-section.

File Uploading/Downloading via Control Pilot Serial Port:

[60] One advantage of permanently sealing the components of the in-line controller components within the housing 230 is that the in-line controller 115 is protected from moisture, mechanical shock, electrical shock and tampering. However, this feature prevents accessing the electronic components of the in-line controller 115. This would prevent, for example, conducting simple tests or fetching information from the memory 218 to determine, for example, whether the firmware or computer programs stored in the memory 218 are the latest version. Such encapsulation also prevents uploading new software into the memory 218 or replacing existing software.

[61] This limitation is overcome by providing for serial data transfer from and to the microprocessor 217 over the control pilot conductor 209. Referring now to FIG. 5, the microprocessor 217 has a serial port 400 that provides serial data transfer in accordance with a suitable serial data transfer protocol such as Universal Serial Bus (USB) or RS232. The appropriate driver firmware may be stored in the memory 218 to enable the microprocessor 217 to implement data transfer via the control pilot conductor 209 in both directions. A serial bus or conductor 410 connects the serial port 400 with the control pilot conductor 209. The control pilot conductor 209 thus functions as (A) a communication channel for the analog D.C. voltage level changes by which the EVSE and the EV communicate with each other and (B) a two-way serial bus for digital communication.

[62] External access to the serial port 400 via the control pilot conductor 209 is provided through a stand-alone interface tool 415 shown in FIG. 5. The interface tool 415 has an interface tool connector port 420 able to mate with the EVSE connector 105 whenever the EVSE connector 105 is not mated to the EV charging port 107. Whenever the EVSE connector 105 is mated with the interface tool connector port 420, one pin 420a of the interface tool connector port 420 is coupled to the control pilot conductor 209, while a second pin 420b is coupled to the neutral conductor 211. A user-accessible serial port 425, such as a USB port, is provided on the interface tool 415 and is connected to the pins 420a and 420b through internal conductors inside the interface tool 415.

[63] Whenever it is desired to communicate with the microprocessor 217 or verify contents of the memory 218 or to perform file transfers (e.g., to upload a latest revision of firmware) to the microprocessor 217 and/or memory 218, the EVSE connector 105 is disconnected from the EV charging port 107 and connected instead to the interface tool connector port 420. The interface tool connector port 420 provides for connection between the control pilot conductor 209 and the user-accessible serial port 425. The serial port 425 may be implemented as a USB connector which may be connected to a computer 430 (e.g., a personal computer or a notebook computer) or to a handheld programmable communication device 435, such as a PDA (personal digital assistant) or a smart phone or equivalent device. Both the processor 216 and the computer 430 (or PDA 435) contain respective firmware program instructions that enable a user to perform

various tasks, such as downloading and interpreting EVSE trouble codes, verifying the software version of programs stored in the memory 218, deleting obsolete software stored in the memory 218 and uploading updated versions of the software from the computer 430 or PDA 435 to the memory 218. The character representation of each EVSE trouble code and the conditions under which it is to be issued by the microprocessor 217 are predetermined by the system designer.

[64] In some cases, provision may be made for the EV 109 to transmit diagnostic trouble codes to the EVSE. In this case, if the EVSE is the portable charging cable 100 of FIG. 1, these trouble codes may be stored in the memory 218 of the in-line controller 115, and later (when the EV 109 and EVSE 100 are no longer connected) downloaded through the interface tool 415 for evaluation or diagnosis by a technician.

[65] The interface tool 415 may be provided as a portable tool that the user may store at home. The interface tool 415 may be provided as standard equipment stored in the EV along with the portable charging cable 100. The interface tool 415 may be provided in a kiosk at a vehicle dealer for example, that can be visited by the user. The interface tool 415 may be provided as a professional technician's tool for use by repair facilities or dealers. In this latter case, the interface tool 415 may include most or all of the functionality of a computer 430 (including a microprocessor and memory, a display, and program firmware for downloading and interpreting trouble codes), so as to be a self-contained hand-held diagnostic tool. Software updates may be obtained by the computer 430, the

handheld communication device 435, or by the interface tool 415 itself, via a communication channel such as a dedicated radio link, a local area network or via the internet.

[66] FIGS. 5A and 5B depict a versatile handheld embodiment of the interface tool 415. FIG. 5A depicts how the interface tool may be shaped while FIG. 5B depicts its internal architecture. In FIG. 5A, the interface tool 415 includes the connector port 420. The connector port 420 may be compatible with the type specified by the Society of Automotive Engineers Specification SAE J1772, for connection to the docking connector 105 of the EVSE 100 of FIGS. 1-3 and 5. The interface tool of FIGS. 5A and 5B further includes a microprocessor 436, a memory 437 and a display or video monitor screen 438. The microprocessor 436 includes a serial port 436a that is connected to the connector port pins 420a, 420b to facilitate communication with the EVSE's microprocessor 217. The microprocessor 436 controls the display 438 and is coupled to the memory 437. The memory 437 stores firmware including an operating system 437a, a USB driver 437b for communication with the EVSE's microprocessor 217 and a video driver 437c for controlling the display 438. In addition, the memory 437 may store diagnostic firmware 437d enabling the microprocessor 436 to interpret trouble codes and status data received from the EVSE microprocessor 217 and to generate representative images on the display 438 that enable the user to understand the status of the EVSE 100 and to understand the trouble codes. A communication module 439 coupled to the microprocessor 436 enables the microprocessor 436 to access new information via a communication network such

as the internet or a local area network (e.g., within a facility such as a vehicle dealership). For example, the communication module 439 may include conventional wireless local area networking hardware. A keypad 440 may be provided on the interface tool 415 to enable the user (e.g., a technician) to enter commands to the EVSE microprocessor 217 (e.g., requesting a particular data transfer or information) and/or to respond to prompts on the display 438 generated by the diagnostic firmware. The display 438 may be a touch screen, enabling the user to communicate to the microprocessor 436. In this case, the key pad 440 may not be required.

[67] The information obtained from the EVSE 100 by the interface tool 415 may include the current status of the EVSE 100 (e.g., temperature within range, supply voltage within range, frequency within range, no GFE faults, etc.). This information may be displayed on a monitor of the computer 430 or on a display screen of the PDA 435, for example. Or, if the interface tool 415 is the versatile embodiment of FIGS. 5A and 5B, then the information may be displayed on the screen or display 438 of the interface tool 415.

[68] In an alternative embodiment, the information obtained from the microprocessor 217 via serial data communication on the control pilot conductor 209 may be displayed on the driver's display of the EV 109. This would be possible whenever the EVSE docking connector 105 is connected to the EV charging port 107, not to the interface tool 415. In such a case, an on-board computer of the EV 109 may be programmed to obtain the information through the EV battery management system. With regard to such a feature, the EV 109 of FIG. 3 includes a serial

port 358 that is coupled to the control pilot conductor 209 of the EVSE 100 whenever the EVSE 100 is connected to the EV 109. In addition, FIG. 3 depicts further elements of the EV 109, including an on-board computer 360 and an EV driver display 362 controlled by the on-board computer 360. The on-board computer 360 may access firmware 364 that enables it to communicate with the battery management system 354 to obtain information via the serial port 358 (or the on-board computer 360 may communicate directly with the serial port 358). In this way, during the time that the EV 109 is being charged by the EVSE 100, information concerning the status of the EVSE 100 may be displayed on the EV driver display 362. As noted above, the displayed information may include current status of the EVSE 100, a history of past trouble codes, identification of the firmware version stored in the EVSE memory 218, and related information.

[69] FIGS. 6A and 6B depict methods using the control pilot conductor as a serial bus to communicate digital information to and from the EVSE memory 218 and microprocessor 217 using the interface tool 415 of FIG. 5A with the computer 430 or using the interface tool of FIGS. 5A and 5B. The operations depicted in FIGS. 6A and 6B rely upon the EVSE memory 218 containing certain components as depicted in FIG. 7.

[70] Referring to FIG. 7, the components stored in the memory 218 may include an operating system 400, and a set of instructions 402 that may be used control the microprocessor 217 to perform particular data transfer operations. These operations may include downloading specified information in the memory 218, erasing specified locations in the memory 218, and uploading new

files to specified locations in the memory 218. The components stored in the memory 218 may further include a firmware package or program 404 that enables the microprocessor 217 to perform the required communication protocols and charge the EV 109 in accordance with the required procedures. The memory 218 may further contain a program 406 that enables the microprocessor 217 to generate appropriate trouble codes whenever a fault (or condition violating the requirements of a controlling specification) is detected. The memory 218 may also contain a list of allowed voltage ranges 408, current limits 410, temperature limits 412 and a may contain a USB driver 414.

[71] Referring again to FIGS. 6A and 6B, a first operation (block 500) is to download data or information files from the memory 218 to the computer 430 via the control pilot conductor 209 serial port 400 using the interface tool 415. There are various tasks this operation can perform. A first task may be for the computer 430 to download the data transfer instruction set of the microprocessor 217 via the serial port 400 (block 502). This would enable the user to select the proper instruction to command the microprocessor 217 to perform specific data transfer tasks. One such task may be to download current trouble codes (block 504), which may be used, for example, in testing the EVSE 100 in the absence of the EV 109. Another task may be to download the present EVSE status (block 506). This task may be performed in one of three modes, depending upon the command asserted by the computer 430: (1) manually, upon request (block 508), (2) continuously, in streaming mode (block 510), and (3) an automatic dump of information upon status change (block 512).

[72] A further download task may be to download the entire history of trouble codes stored in the memory 218 (block 514). Another download task may be to download from the memory 218 the identity (or date) of the firmware currently stored in the memory 218 (block 516) to determine whether it has been superseded or needs updating.

[73] A next operation using the control pilot conductor 209 as a serial data bus is to display the downloaded information (block 520). This operation may use the display on a screen of the computer 430 or on a display or screen of the PDA 435 (block 522). The downloaded information may be displayed on the interface tool display screen 438 of FIG. 5A (block 524). In an alternative embodiment, the downloaded information is displayed on the EV driver display 362 of FIG. 3 (block 526 of FIG. 6). In this embodiment, the EVSE docking connector 105 is connected to the EV charging port 107, not to the interface tool 415. The information to be displayed is communicated to the EV on-board computer 360 via the control pilot conductor 209 (block 528).

[74] A third type of operation is to upload program files to the memory 218 via the control pilot conductor 209 (block 530). The uploaded files may be furnished from a computer 430 or PDA 435 connected to the interface tool 415. Alternatively, the uploaded program files may be furnished by the interface tool 415 itself, using its communication module 439, for example. A first step is to connect the docking connector 105 to the interface tool 415. If necessary, the interface tool 415 is connected to the computer 430 or PDA 435, in the manner

illustrated in FIG. 5 (block 532). The next step is for the computer 430 (or PDA 435) to obtain the latest firmware files from a source, for example over the internet (block 534). The memory 218 may be cleared by erasing selected (or all) firmware files previously loaded into the memory 218 (block 536). The operation is completed by writing the new files to the memory 218 (block 538).

[75] Because of the compact size and insulation of the in-line controller 115, it may operate at fairly high internal temperatures, which need to be controlled in order to avoid overheating. In accordance with a further aspect, the microprocessor 217 may be programmed to prevent shutdown of the charging operation due to overheating of the in-line controller 115 of FIG. 1. It does this by reducing the charging current before the temperature reaches the maximum allowed limit. Specifically, the EVSE microprocessor 217 (FIG. 2) may be programmed to override the nominal setting of the pulse duty cycle and reduce the duty cycle of the pulse generator 222, in response to the output of the temperature sensor 214 exceeding a predetermined threshold temperature (e.g., 70 degrees C) that is 10%-30% below the maximum operating temperature of the microprocessor 217 (e.g., 85 degrees C). It does this so as to reduce the charging current (set by the pulse duty cycle) by an amount proportional to the approach of the measured temperature to the maximum operating temperature of the microprocessor 217 (e.g., 85 degrees C). The nominal pulse duty cycle is stored in the memory 218 at one location, the predetermined threshold temperature is stored in the memory 218 at another location and the maximum operating temperature is stored in the memory 218

at third location. The reduction in charging current may be by an amount proportional to the rise of the measured temperature above the predetermined threshold temperature. The operation is represented as a series of program instructions stored in the memory 218 and executed by the microprocessor 217, and is illustrated in FIG. 8.

[76] Referring now to FIG. 8, the EVSE cable 100 and the EV 109 perform the prescribed handshake protocol via the control pilot conductor 209 after the docking connector 105 has been inserted into the EV charging port 107 (block 710 of FIG. 8). The duty cycle of the pulse generator 222 is set to the maximum allowable current draw that was previously determined by the system designer (block 715). The output of the temperature sensor 214 is sampled to obtain a present temperature of inside the EVSE 100 (block 720). A comparison of the present temperature to the predetermined threshold temperature (e.g., 70 degrees C) is performed (block 725). If the present temperature is below the predetermined threshold temperature (YES branch of block 725), then the operation returns to the step of block 715. Otherwise (NO branch of block 725), the present temperature is compared with the maximum operating temperature (e.g., 85 degrees C) in block 730. If the present temperature is less than the maximum operating temperature (YES branch of block 730), then the microprocessor 217 overrides the previously set nominal duty cycle value and reduces the duty cycle from the nominal value by a factor proportional to either the ratio between the measured present temperature and the maximum operating temperature or the difference between them (block 735). In the unlikely event that the measured temperature exceeds the maximum operating

temperature (NO branch of block 730), charging is halted (block 740), and the operation returns to the step of block 720. The occurrence of such an event is unlikely because the onset of charging current reduction (block 735) occurs at the predetermined threshold temperature, which is 10% to 30% below the maximum operating temperature. Thus, in the examples provided herein, the predetermined threshold temperature may be 70 degrees C for a maximum operating temperature of 85 degrees C.

[77] In an exemplary embodiment, the step of block 735 may be performed by reducing the control pilot pulse duty cycle by a factor F, so that the duty cycle is changed from the current duty cycle D by multiplying D by (1-F), so that the new duty cycle is (1-F)D. F depends upon the present temperature sensed by the sensor 214. One example of how to define F is as follows:

F = (present temp - 70 deg C)/(85 deg C - 70 deg C),

where "present temp" is the measured temperature from the sensor 214 in degrees C, 85 deg C is the maximum operating temperature, and 70 deg C is the predetermined threshold temperature. The skilled worker may use suitable definitions of F other than the foregoing.

SEALED ENCAPSULATING HOUSING:

[78] In an embodiment, the in-line controller 115 is permanently sealed within the housing 230 from any external moisture or gas. The housing 230 may include elastically deformable materials, such as rubber, that insulate the in-line controller 115 from shock and vibration. In one embodiment, the housing 230 may be filled with a potting compound that provides a thermal

path from the electrical and electronic components of the in-line controller 115 to the external surfaces of the housing 230. In another embodiment, the housing 230 itself is formed as a solid volume of potting compound that encapsulates the components of the in-line controller 115.

[79] One embodiment of the housing 230 is illustrated in FIGS. 9-16. FIG. 9 is an orthographic view of the EVSE cable 100 including the housing 230, while FIG. 10 is an enlarged view corresponding to FIG. 9. FIG. 11 is an exploded orthographic view corresponding to FIG. 10. FIG. 12 is an enlarged detailed view of a bumper depicted in FIG. 11. FIG. 13 is a cut-away end view corresponding to FIG. 10. FIG. 14 is an elevational side view corresponding to FIG. 10. FIG. 15 includes elevational end views corresponding to FIG. 10 showing the housing 230 at different rotational orientations. FIG. 16 is a cut-away elevational side view of a completed assembly corresponding to FIG. 11.

[80] In the embodiment illustrated in FIGS. 9-16, the housing 230 includes a shell 600 as indicated in FIG. 9. As shown in FIG. 11, the shell 600 is formed as two matching halves, namely a top half shell 602 and a bottom half shell 604, both preferably formed of a hard high-impact material, which may be plastic, metal, alloy, carbon fiber or other synthetic material. The top half shell 602 has a ceiling 602a and a side wall 602b, while the bottom half shell 604 has a floor 604a and a side wall 604b. There are exposed edges 602c, 604c of the side walls 602b and 604b that are generally congruent with one another. The ceiling 602a and floor 604a are generally flat while the side walls 602b and 604b follow

a "racetrack shape" defined by long straight edges 602c-1, 604c-1, respectively, and short curved edges 602c-2, 604c-2, respectively. The top half shell 602 has half-circle openings 606a, 606b at respective ends of the side wall 602b. Similarly, the bottom half shell 604 has half-circle openings 608a, 608b at respective ends of the side wall 604b. The half circle openings form circular openings 607, 609 (shown in FIG. 16) at the respective ends of the shell 600 when the two half shells 602, 604 are mated. The top and bottom half shells 602, 604 have structurally reinforcing interior ribs 610, 611, respectively, extending in transverse direction to opposite sides. The ribs 610 of the bottom half shell 604 are visible in the view of FIG. 11, and there are corresponding ribs 611 in the top half shell 602 visible in FIG. 16. Interior reinforcing posts 612 extend from the floor 604a to the ceiling 602a are each divided into separate half posts, of which the bottom half posts 612b extending from the floor 604a are visible in the view of FIG. 11, while the top half posts 612a are shown in FIG. 16 and in hidden line in FIG. 11.

[81] A circuit board 614 supports the electrical and electronic components of the in-line controller 115 previously described herein with reference to FIGS. 2 and 3. The circuit board 614 is held within the interior volume formed between the two half shells 602, 604, as shown in FIG. 11. The circuit board 614 has a pair of holes 616a, 616b through which the reinforcing posts 612 extend. The components mounted on the circuit board 614 are the components of the in-line controller 115 of FIGS. 1 and 2, and include the light emitting diodes 117 previously referred to herein, and transparent covers 118. LED holes 622 in the ceiling 602a are in

registration with the LEDs 117 and are sealed by respective O-rings 119. Permanent fasteners 620a through 620d provide permanent attachment between the top and bottom half shells 602, 604, as is described below in greater detail.

[82] As best seen in the view of FIG. 13, the top half shell 602 has an interior side wall 626 parallel to the side wall 602b and forming an upper groove 628 between the two side walls 602b and 626. In like manner, the bottom half shell 604 has an interior side wall 630 parallel to the side wall 604b and forming a lower groove 632 between the two side walls 604b and 630.

[83] A bumper 634 formed of an elastically deformable material, such as rubber, surrounds the side walls 602b, 604b. As shown in FIGS. 11-13, the bumper 634 consists of an outer case 634a and an interior belt 634b generally parallel with the outer case 634a. The interior belt 634b forms upper and lower lips 634b-1 and 634b-2 that fit within the upper and lower grooves 628, 632, respectively. The outer case 634a and the upper lip 634b-1 form an upper bumper groove 636 between them, while the outer case 634a and the lower lip 634b-2 form a lower bumper groove 638 between them. A lip of the upper side wall 602b is held in the upper bumper groove 636, with some elastic deformation of the upper bumper groove 636, while a lip of the lower side wall 604b is held in the lower bumper groove 638, with some elastic deformation of the lower bumper groove 638.

[84] The outer case 634 has a pair of arcuate end skirts 640, 642 covering the short curved edges 602c-2, 604c-2, respectively, of the side walls 602c, 604c. The

outer case 634 further includes gripping saddles 644, 646 covering the long straight edges 602c-1, 604c-1, respectively, of the side walls 602c, 604c. The arcuate end skirts 640, 642 have a major height, H (FIG. 12), extending above the plane of the ceiling 602a and below the plane of the floor 604a, while the gripping saddles 644, 646 have a minor height, h (FIG. 12) that is less than H. As shown in FIGS. 13 and 14, this feature enables air to flow freely around and underneath the shell 600 whenever the unit is resting on a surface, for improved cooling, because the end skirts 640, 642 hold the shell 600 above the surface. A hole 648 in the end skirt 640 is in registration with the hole 607 formed by the half circle openings 606b, 608b in the half shells 602, 604, respectively. A hole 649 in the end skirt 642 is in registration with the hole 609 formed by the half circle openings 606a, 608a in the half shells 602, 604, respectively. The end skirts 640, 642 have arcuate convex crests 640a, 642a. The effect of this feature is illustrated in FIG. 15, in which the in-line controller 115 tends to rotate until it rests on one of its major faces after being placed on its edge. This rotation places the in-line controller 115 in the strongest orientation to resist compression if stepped on or run over by a vehicle.

[85] FIG. 17 illustrates how the permanent fasteners 620a through 620d are tightly received into holes 656 in the upper half shell 602 and holes 658 in the lower half shell 604. FIGS. 18A, 18B and 18C illustrate different embodiments of the permanent fasteners 620 that may be inserted into the holes 656, 658, including an expandable insert (FIG. 18A), a barbed insert (FIG. 18B), and a press-fit insert (FIG. 18C). With the foregoing

features, the two half shells 602, 604 are permanently attached by pressing them together, and the fastening cannot be undone.

[86] FIG. 19 depicts one type of cable strain relief that may be employed to isolate the electrical connections (between the conductors in each cable 100-1, 100-2 and components on the circuit board 614) from tension on the cables 100-1, 100-2. FIG. 19 is a view of one of the two circular openings 607, 609 at each end of the shell 600 depicting a structure that is common to both. An interior end of a hollow cylinder 660 is threadably engaged inside the circular opening 607. At its exterior end, the hollow cylinder 660 protrudes outwardly from the shell 600 and is divided into plural compressible leaves 662. The cable (100-1 or 100-2) extends through the hollow cylinder 660. A nut 664 is threadably engaged around the exterior end of the hollow cylinder 660 and compresses the plural leaves 662 together against the outside surface of the cable 100-1 or 100-2 as the nut is tightened onto the hollow cylinder. In compressing the outer surface of the cable 100 in this manner provides an integral seal between each cable section 100-1, 100-2 and the housing 230, so that the housing 230 and the cable sections 100-1, 100-2 form an integral cable.

[87] FIG. 20 depicts another cable strain relief feature that may be used alone or in combination with the cable strain relief feature of FIG. 19. FIG. 20 is a view of one of the two circular openings 607, 609, and depicts a structure that is common to both. In FIG. 20, the upper half shell 602 has a downwardly extending post 670 near the circular opening 607, while the lower half

shell 604 has an upwardly opening socket 672 in registration with the post 670. The post 670 deflects the cable (100-1 or 100-2) into the socket 672, bending the cable by a predetermined amount that is compatible with the flexibility of the cable. Optionally, a hollow cylinder or bushing 674 may surround the cable and be threaded or bonded into the hole 607 (or 609).

[88] In one alternative embodiment, only the cable (100-1 or 100-2) is inserted through the hole (607 or 609), and the hole is sized so that its edge compresses the outer insulator of the cable, thereby providing cable strain relief.

[89] In another alternative embodiment depicted in FIG. 21, an elastic or plastic hollow fitting 680 fits around the exterior of the cable 100-1 (100-2). The fitting 680 has a circular groove 682 that receives the edges of the two half circular openings 606, 608. The fitting 680 may include a flexible conical section 684 that provides relief from lateral bending of the cable. In a further aspect, the two half circular openings 606, 608 may not be circular, but instead may be non-circular, to enhance compression of the cable 100-1 (in one embodiment) or of the fitting 680 (in another embodiment). One shape of a non-circular opening is depicted in FIG. 22A, at a point in time before the two half shells 602, 604 are brought together. As the two half shells 602, 604 are moved toward one another (FIG. 22B), the fitting 680 begins to deform until it conforms to the non-circular shape of the opening when the two half shells 602, 604 are mated (FIG. 22C). In compressing the outer surface of the cable 100 in this manner provides an integral seal between each cable section 100-1, 100-2 and the housing 230, so that

the housing 230 and the cable sections 100-1, 100-2 form an integral cable.

[90] FIGS. 23A, 23B and 23C depict alternative shapes of cable openings 606, 608 providing strain relief, including a hexagonal opening (FIG. 23A), an octagonal opening (FIG. 23B) and a square or diamond-shaped opening (FIG. 23C).

[91] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. An EVSE cord comprising:

plural insulated conductors and a flexible outer sheath enclosing said plural insulated conductors,

an EVSE docking connector on a docking end of the cord and a utility plug on a utility end of the cord,

said cord being divided into a docking section terminated at said docking connector and a utility section terminated at said utility connector,

an in-line EVSE controller and a housing enclosing said controller, said housing sealed with said flexible outer sheath and disposed at an intermediate section of said cord between said docking and utility sections.

2. The EVSE cord of Claim 1 wherein said in-line EVSE controller is connected in series between conductors of said docking section and conductors of said utility section.

3. The EVSE cord of Claim 1 wherein said sheath and said housing comprising a continuous outer seal.

4. The EVSE cord of Claim 1 wherein said housing is sealed only with a portion of said sheath enclosing said docking section.

5. The EVSE cord of Claim 1 wherein said housing is sealed with portions of said sheath enclosing both said docking and utility sections.

6. The EVSE cord of Claim 1 wherein said housing is joined with said utility and docking sections at

opposing ends of the housing, said housing being suspended between said docking and utility sections of said cord so as to be freely movable with the cord.

7. The EVSE cord of Claim 1 wherein said housing comprises an outer surface of an elastic sealing material.

8. The EVSE cord of Claim 1 wherein said housing has as length of about 5-6 inches, a width of about 3-4 inches and a height of about 0.5-2 inches.

9. The EVSE cord of Claim 1 wherein said housing comprises a rubber material.

10. The EVSE cord of Claim 1 wherein said housing comprises a pair of congruent upper and lower half shells having respective outer side walls, each of said half shells having a pair of half openings at opposite ends of the respective half shell, annular portions of said docking and utility sections being compressed between edges of facing ones of said half openings.

11. The EVSE cord of Claim 10 further comprising:

a circuit board having electrical components connected to conductors of said docking and utility sections of said cord;

a potting compound encapsulating said circuit board between said half shells.

12. The EVSE cord of Claim 10 wherein said housing further comprises a bumper formed of an elastically deformable material and surrounding the outer side walls of said half shells.

13. The EVSE cord of Claim 12 wherein said bumper comprises holes in registration with said half openings.

14. The EVSE cord of Claim 12 wherein said bumper is integrally formed and comprises:

an annular outer case and an annular interior belt surrounded by said outer case, said annular interior belt comprising an upward facing lip and a downward facing lip, an upper bumper groove being defined between said outer case and said upper facing lip and a lower bumper groove being defined between said outer case and said downward facing lip.

15. The EVSE cord of Claim 14 wherein:

said upper and lower half shells comprise respective interior walls parallel with the respective ones of said outer side walls and forming respective upper and lower shell grooves;

said upward facing lip being compressed in said upper shell groove, and said downward facing lip being compressed in said lower shell groove.

16. The EVSE cord of Claim 15 wherein edge portions of the respective outer side walls are pressed inside respective ones of said upper and lower bumper grooves.

17. The EVSE cord of Claim 14 wherein said outer case comprises a pair of opposing arcuate end skirts and a pair of straight gripping saddles joining said end skirts, each of said end skirts having a first height extending above a ceiling of said upper half shell and below a floor of said lower half shell, said gripping

saddles having a second height less than said first height.

18. The EVSE cord of Claim 14 wherein said outer case of said bumper comprises a bumper side wall, said bumper side wall comprising an annular convex apex.

19. The EVSE cord of Claim 1 further comprising a control pilot conductor in said docking section of said cord, wherein said in-line EVSE controller comprises:

a microprocessor comprising a serial port;

an analog buffer coupled between said microprocessor and said control pilot conductor;

a serial bus connected between said serial port and said control pilot conductor.

20. The EVSE cord of Claim 1 further comprising a control pilot conductor in said docking section of said cord, wherein said in-line EVSE controller comprises:

a microprocessor comprising a serial port;

an analog buffer coupled between said microprocessor and said control pilot conductor;

a pulse generator coupled to said control pilot conductor and having a duty cycle controlled by said microprocessor; and

a temperature sensor having a temperature output coupled to said microprocessor, said temperature output representing a present temperature.

21. The EVSE cord of Claim 20 wherein said duty cycle signifies a maximum current draw by an EV coupled to said EVSE cord.

22. The EVSE cord of Claim 20 wherein said microprocessor is programmed to halt charging current flow through said EVSE cord whenever said present temperature exceeds a predetermined limit.

23. The EVSE cord of Claim 20 wherein said microprocessor is programmed to adjust said duty cycle in response to said present temperature approaching a predetermined temperature limit.

24. The EVSE cord of Claim 20 further comprising a memory coupled to said microprocessor, said memory storing: (a) a nominal pulse duty cycle corresponding to a nominal value of maximum allowable current, (b) a maximum operating temperature, and a (c) set of program instructions executable by said microprocessor to reduce the pulse duty cycle of said pulse generator from said nominal pulse duty cycle to an adjusted pulse duty cycle by a reduction factor that is a function of the closeness of said present temperature to said maximum operating temperature.

25. The EVSE cord of Claim 24 wherein said function is a proportional function.

26. The EVSE of Claim 24 wherein said predetermined threshold temperature is in a range of 10% to 30% of said maximum operating temperature.

27. An EVSE cord comprising a utility connector at one end and an EVSE docking connector at an opposite end, and an in-line EVSE controller in said cord.

28. In an EVSE cord comprising a utility connector at one end, an EVSE docking connector at an opposite end, and an in-line EVSE controller sealed with said cord, a method of communicating digital data between said in-line controller and an external digital device, said method comprising:

coupling a serial port of a microprocessor of said in-line controller to a conductor of said cord that runs between said in-line controller and said docking connector;

coupling a serial port of an external digital device to said conductor by connection to said docking connector.

29. The method of Claim 28 wherein said external digital device comprises any one of a personal computer, a notebook computer, a cell phone, a personal digital assistant, or an interface tool dedicated to external connection with said docking conductor.

30. The method of Claim 28 further comprising:

downloading from said microprocessor to said digital device via said serial port an identification of firmware stored in said in-line controller;

determining whether said firmware has been superseded;

uploading from said digital device to said microprocessor via said serial port and via said conductor a current version of said firmware.

31. The method of Claim 28 further comprising:

downloading from said microprocessor to said digital device status data representative of conditions in or status of said EVSE cord;

interpreting said status data and generating an image representing a meaning of said status data on a display of said digital device.

32. The method of Claim 31 further comprising downloading said status data on a request-only basis.

33. The method of Claim 31 further comprising downloading said status data as a constant stream.

34. The method of Claim 28 further comprising:

downloading from said microprocessor via said serial port to an electric vehicle currently connected to said docking connector, digital device status data representative of conditions in or status of said EVSE cord;

interpreting said status data and generating an image representing a meaning of said status data on a display of said EV.

35. The method of Claim 28 further comprising:

sensing at a sensor in said in-line controller a utility voltage received through said utility connector;

determining in said processor which one of plural predetermined voltage ranges said utility voltage is closest to;

setting said one predetermined voltage range as the allowed voltage range;

issuing a fault alarm whenever an output of said sensor indicates said utility voltage is outside of said one predetermined range.

36. The method of Claim 35 further comprising:

imposing a pulse signal on a control pilot conductor of said docking connector, wherein a duty cycle of said pulse signal is representative of a maximum current level;

setting said duty cycle to a current level previously correlated to said one predetermined voltage range.

37. An EVSE kit, comprising:

(A) an EVSE cord, comprising:

(1) an EVSE docking connector on a docking end of the cord and a utility plug on a utility end of the cord, said cord being divided into a docking section enclosed by a first outer sheath and terminated at said docking connector and a utility section enclosed by a second outer sheath and terminated at said utility connector, said docking section containing a control pilot conductor,

(2) an in-line EVSE controller and a housing enclosing said controller, said housing sealed with at least one of said first and second outer sheaths and disposed at an intermediate section of said cord between said docking and utility sections, said controller comprising a microprocessor having a serial port, said serial port coupled to said control pilot conductor;

(B) an interface tool, comprising:

(1) a tool enclosure,

(2) an EV connector mounted on said tool enclosure, said EV connector adapted to receive said EVSE docking connector and comprising a conductor pin that is connected to said control pilot conductor whenever said EV connector of said tool enclosure is mated with said EVSE docking connector of said EVSE cord,

(3) a serial port connector mounted on said tool enclosure and adapted to receive a serial port connector from an external digital device, said interface tool further comprising a serial data path between said conductor pin and said serial port connector of said tool enclosure.

38. The EVSE kit of Claim 37 wherein said EVSE docking connector is adapted to be connected to the EV charging port of an EV whenever the EV is to be charged and to said interface tool whenever digital communication with said in-line controller is to be performed.

39. The EVSE kit of Claim 37 wherein said serial port connector comprises a USB connector.

40. An EVSE kit, comprising:

(A) an EVSE cord, comprising:

(1) an EVSE docking connector on a docking end of the cord and a utility plug on a utility end of the cord, said cord being divided into a docking section enclosed by a first outer sheath and terminated at said docking connector and a utility section enclosed by a second outer sheath and terminated at said utility connector, said docking section containing a control pilot conductor,

(2) an in-line EVSE controller and a housing enclosing said in-line EVSE controller, said

housing sealed with at least one of said first and second outer sheaths and disposed at an intermediate section of said cord between said docking and utility sections, said controller comprising a microprocessor having a serial port, said serial port coupled to said control pilot conductor;

(B) an interface tool, comprising:

(1) a tool enclosure,

(2) an EV connector mounted on said tool enclosure, said EV connector adapted to receive said EVSE docking connector and comprising a conductor pin that is connected to said control pilot conductor whenever said EV connector of said tool enclosure is mated with said EVSE docking connector of said EVSE cord,

(3) a processor in said tool enclosure, a display disposed on said tool enclosure, said display controlled by said processor, said processor comprising a serial port coupled to said conductor pin.

41. The EVSE kit of Claim 40 wherein said interface tool further comprises a key pad on said interface tool enclosure, said key pad coupled to said processor.

42. The EVSE kit of Claim 40 wherein said display of said interface tool comprises a touch screen for user communication with said processor.

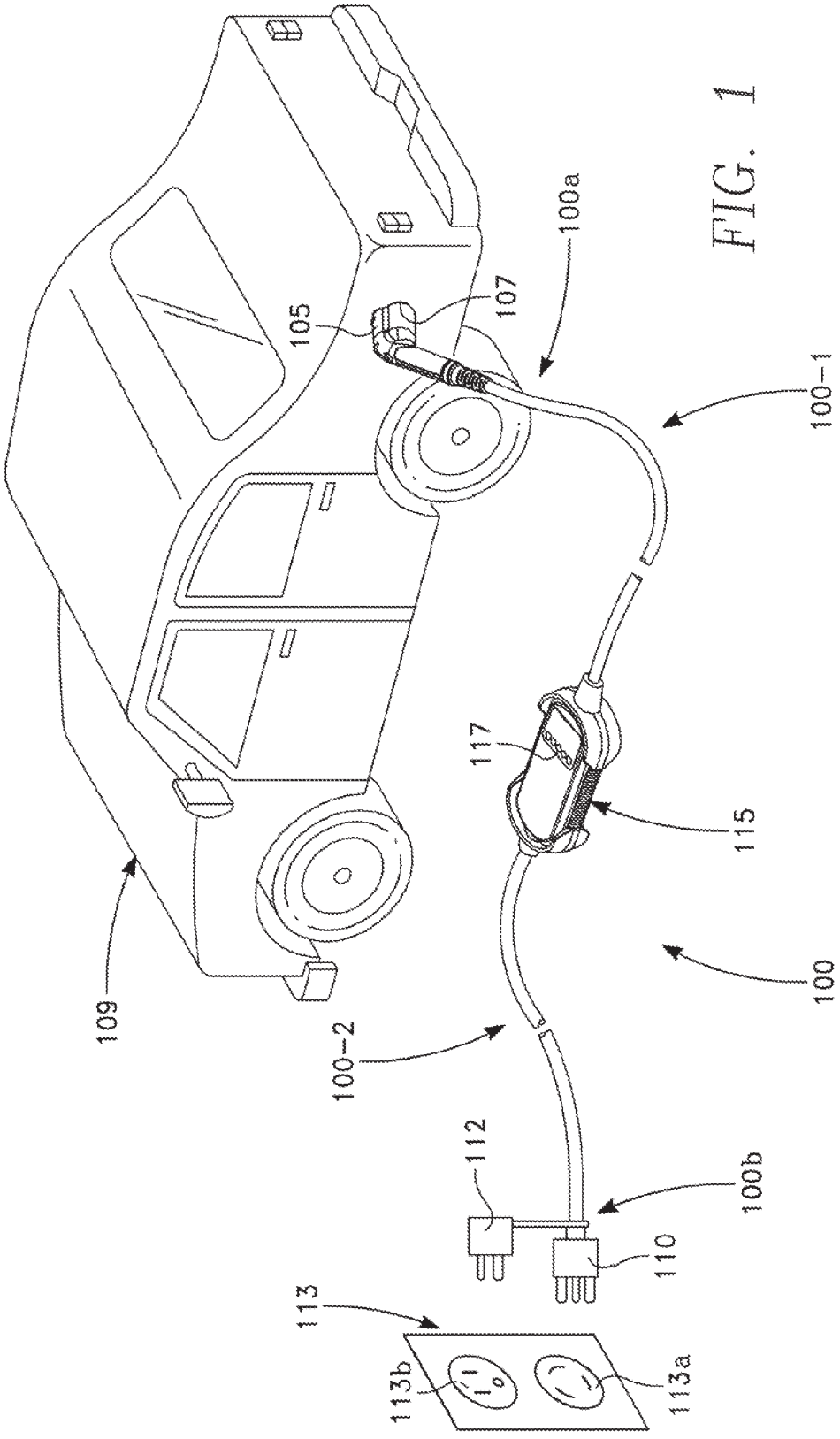
105
107
100a
100–1
117
115
109
100
100–2
112
100b
110
113
113b
113a

FIG. 1

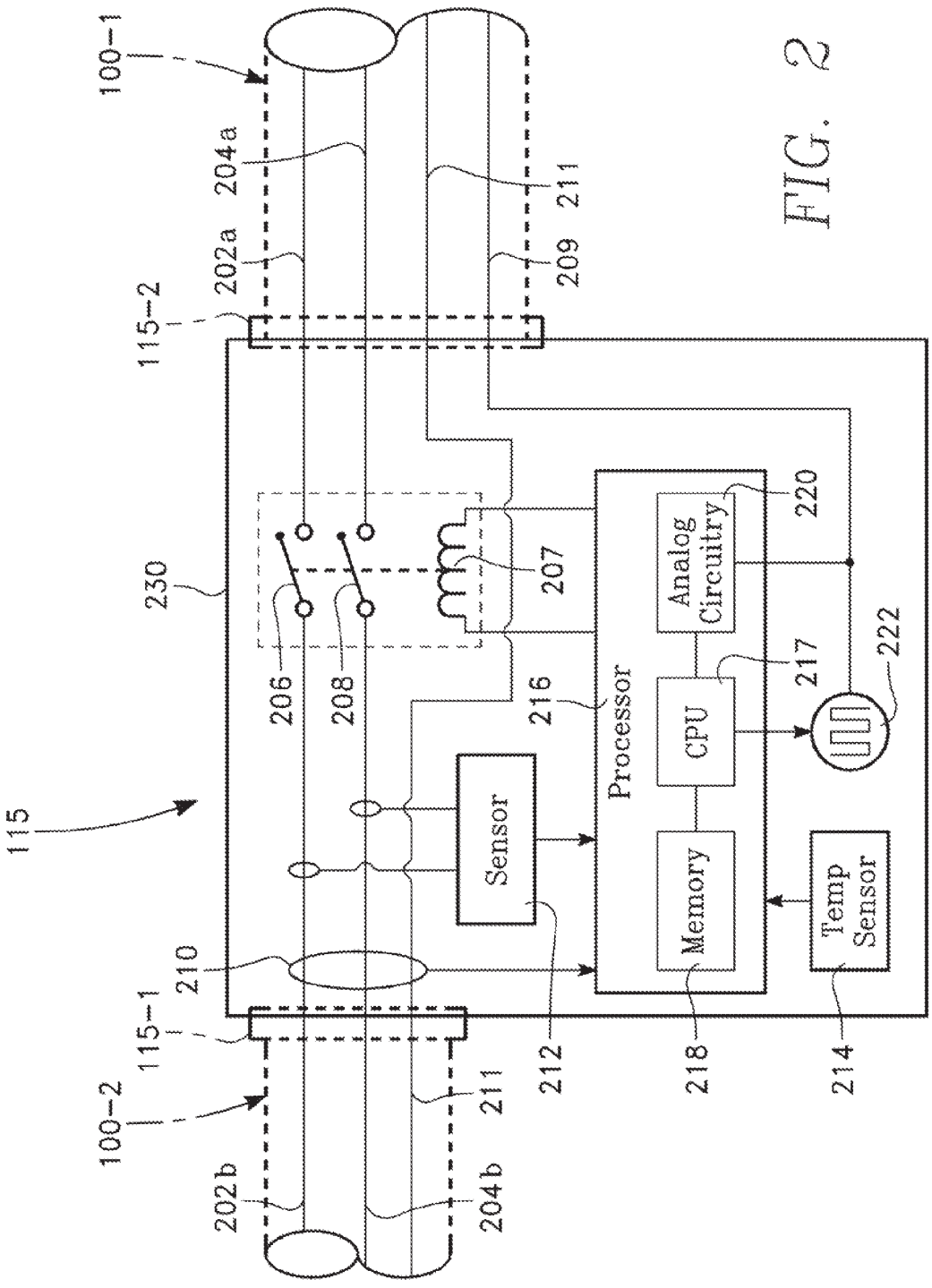
100-1
204a
211
202a
209
115-2
230
207
206
208
216
Processor
Analog Circuitry
220
CPU
217
222
115
Sensor
Memory
Temp Sensor
210
115-1
212
218
214
100-2
211
202b
204b

FIG. 2

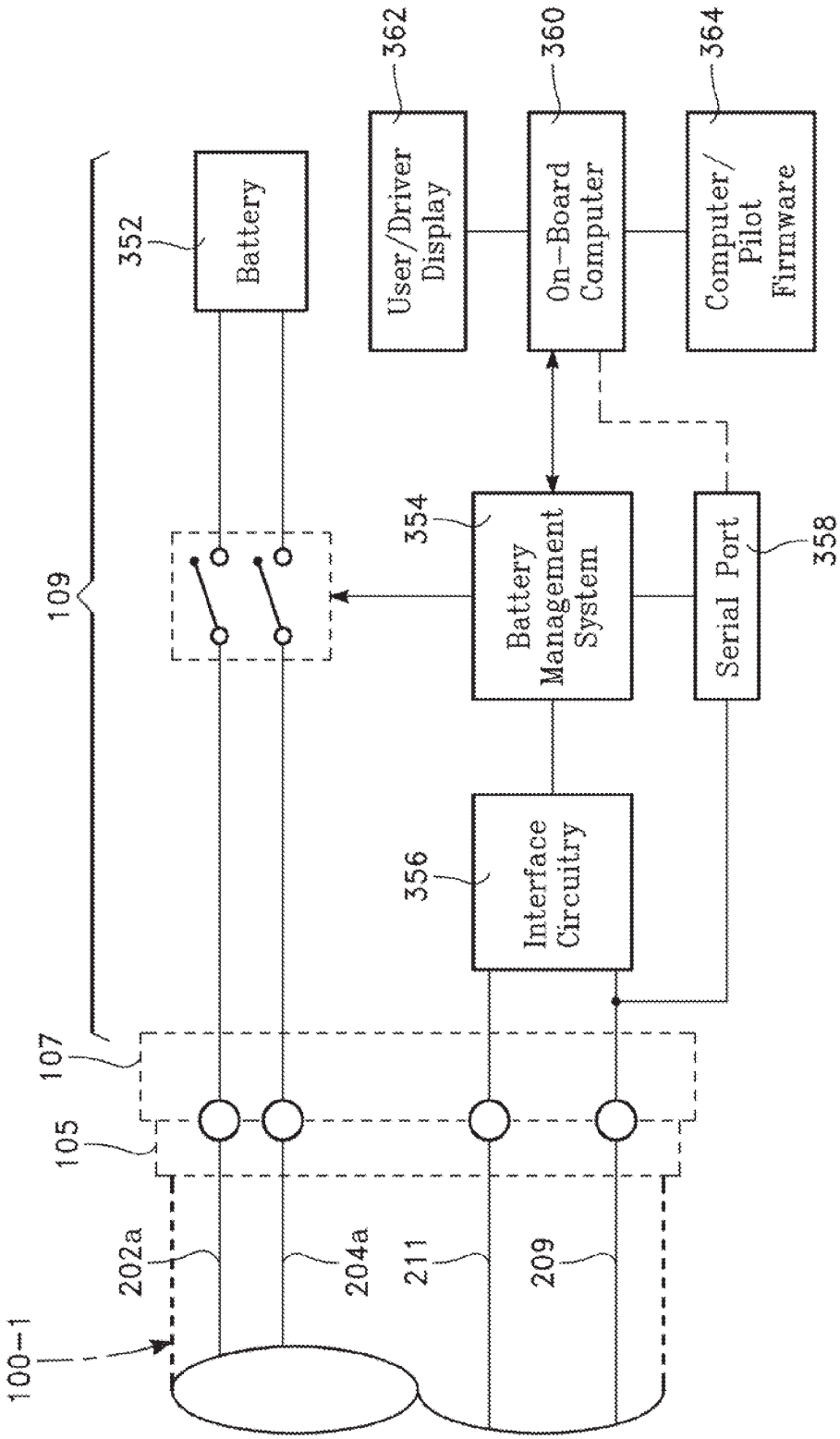
100-1
202a
204a
211
209
105
107
109
352
Battery
354
Battery Management System
356
Interface Circuitry
358
Serial Port
360
On-Board Computer
362
User/Driver Display
364
Computer/ Pilot Firmware

FIG. 3

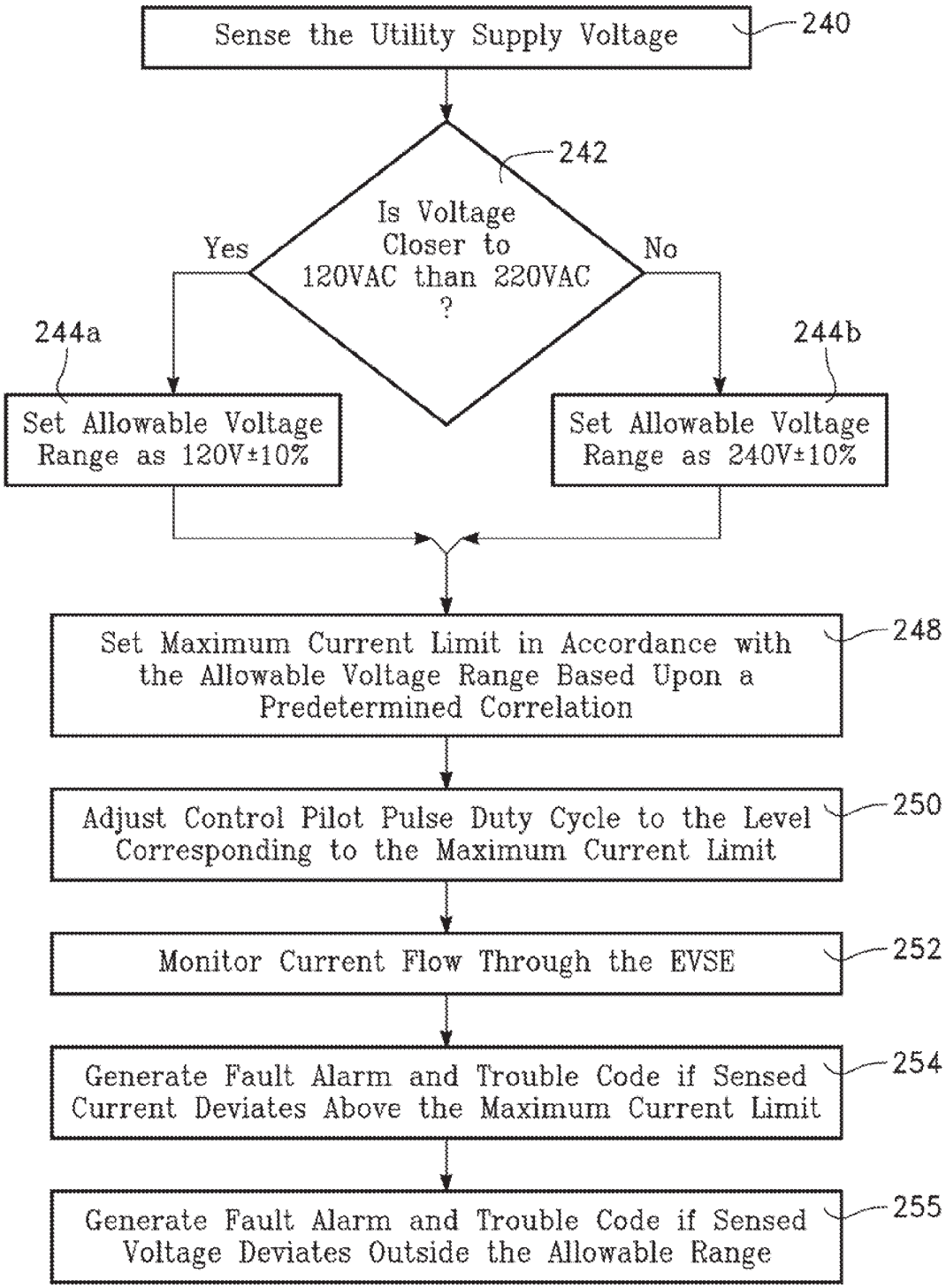
Sense the Utility Supply Voltage
240
242
Is Voltage Closer to 120VAC than 220VAC ?
Yes
No
244a
Set Allowable Voltage Range as 120V±10%
244b
Set Allowable Voltage Range as 240V±10%
Set Maximum Current Limit in Accordance with the Allowable Voltage Range Based Upon a Predetermined Correlation
248
Adjust Control Pilot Pulse Duty Cycle to the Level Corresponding to the Maximum Current Limit
250
Monitor Current Flow Through the EVSE
252
Generate Fault Alarm and Trouble Code if Sensed Current Deviates Above the Maximum Current Limit
254
Generate Fault Alarm and Trouble Code if Sensed Voltage Deviates Outside the Allowable Range
255

FIG. 4

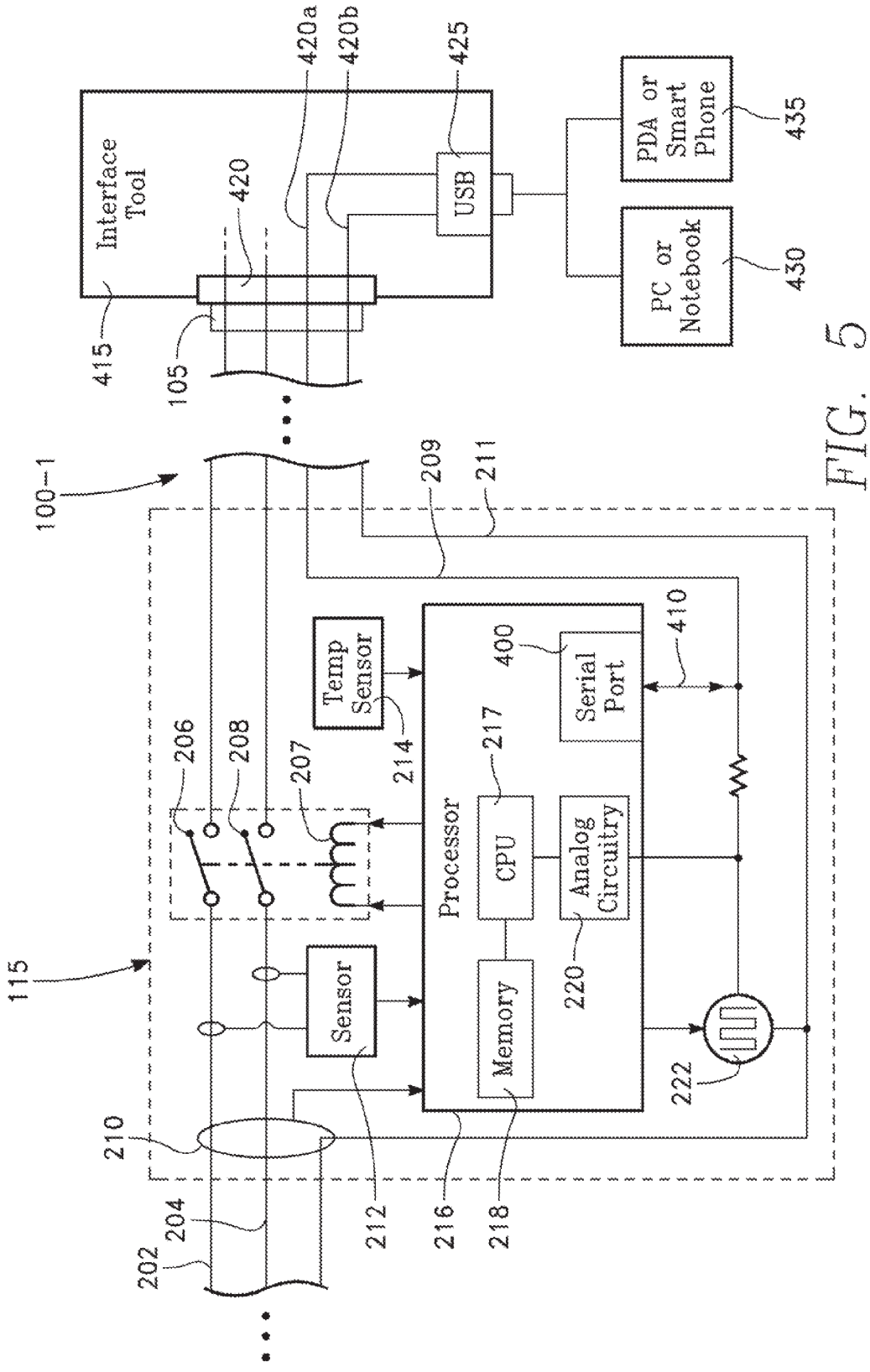
Interface Tool
415
105
420
420a
420b
425
USB
PDA or Smart Phone
435
PC or Notebook
430
100-1
209
211
115
206
208
207
214
Temp Sensor
Sensor
212
Processor
CPU
217
Memory
216
Analog Circuitry
220
400
Serial Port
410
222
218
210
204
202

FIG. 5

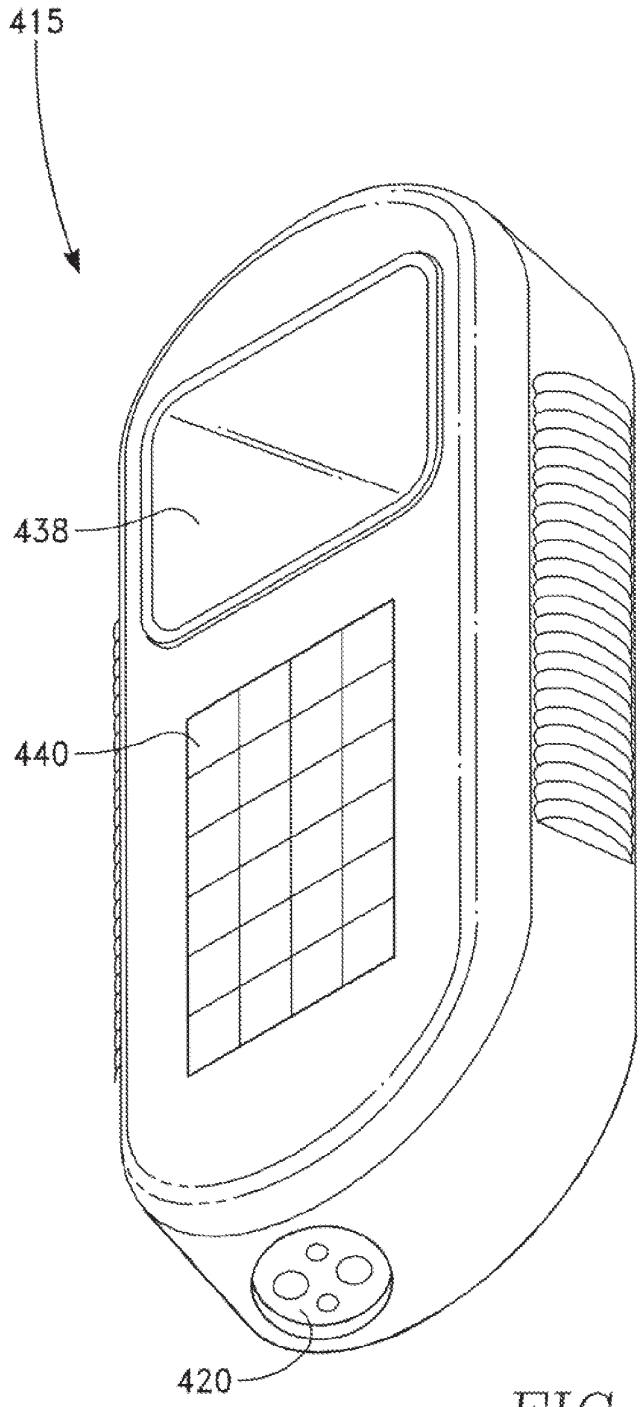

FIG. 5A

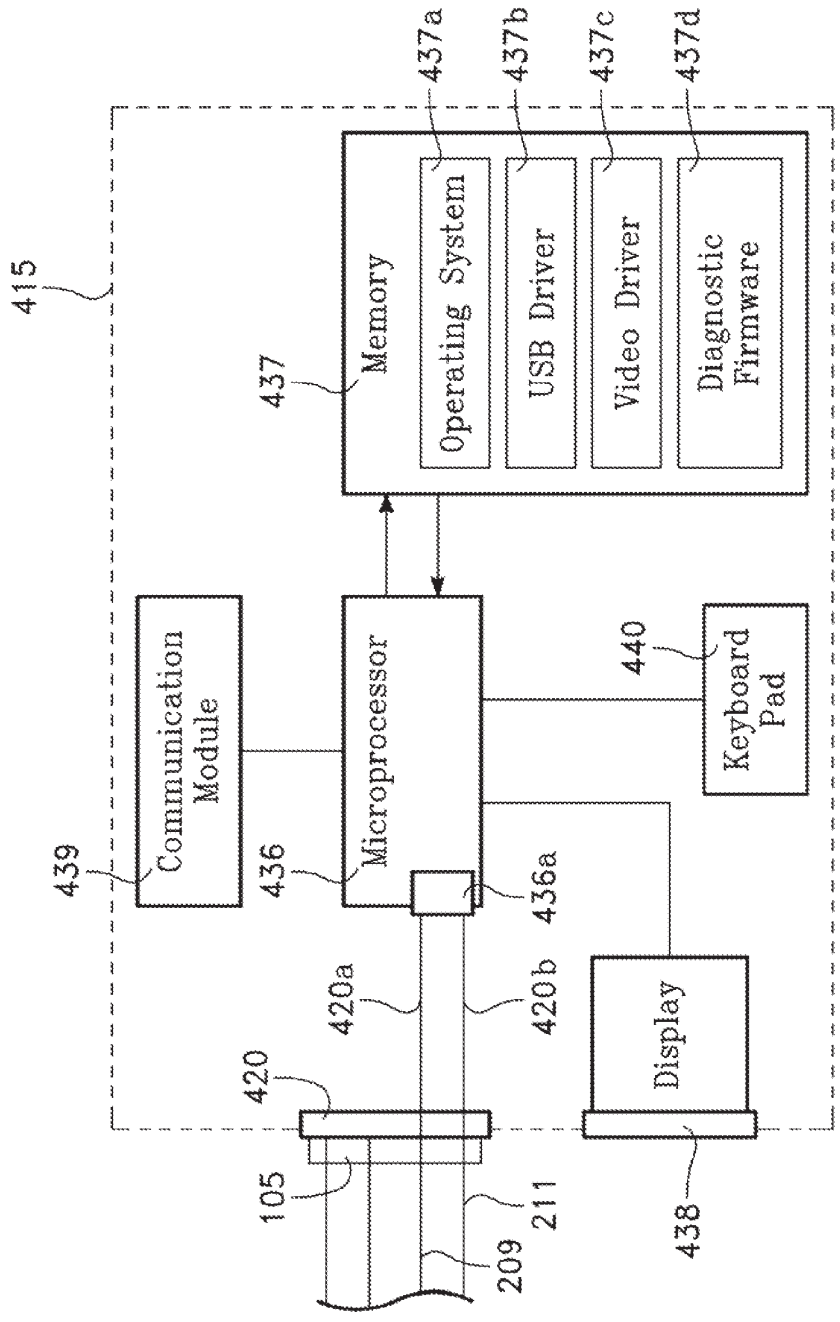
415
437
Memory
437a
Operating System
437b
USB Driver
437c
Video Driver
437d
Diagnostic Firmware
439
Communication Module
436
Microprocessor
436a
440
Keyboard Pad
420a
420b
Display
420
105
211
209
438

FIG. 5B

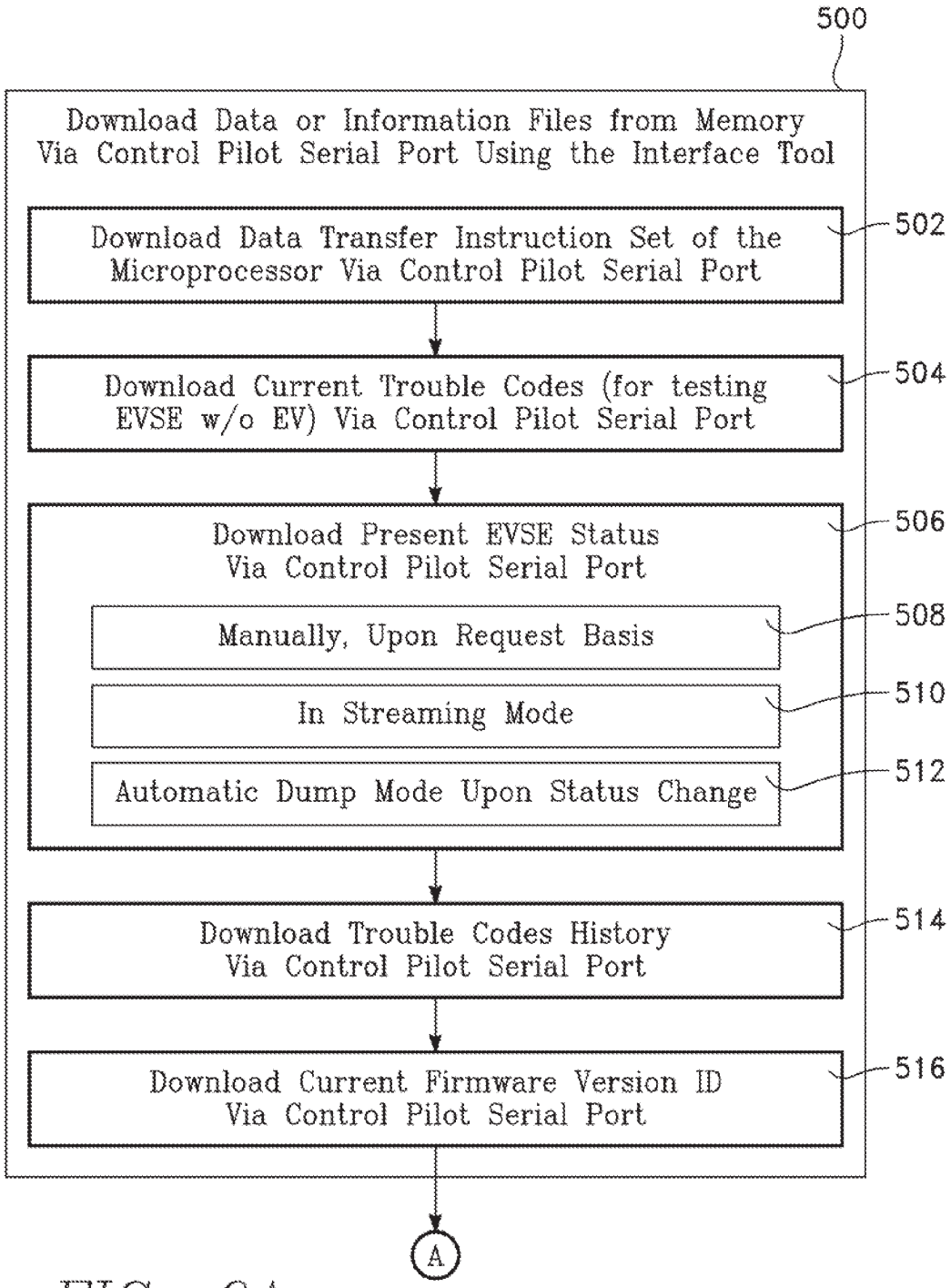
500
Download Data or Information Files from Memory Via Control Pilot Serial Port Using the Interface Tool
Download Data Transfer Instruction Set of the Microprocessor Via Control Pilot Serial Port
502
Download Current Trouble Codes (for testing EVSE w/o EV) Via Control Pilot Serial Port
504
Download Present EVSE Status Via Control Pilot Serial Port
506
Manually, Upon Request Basis
508
In Streaming Mode
510
Automatic Dump Mode Upon Status Change
512
Download Trouble Codes History Via Control Pilot Serial Port
514
Download Current Firmware Version ID Via Control Pilot Serial Port
516
A

FIG. 6A

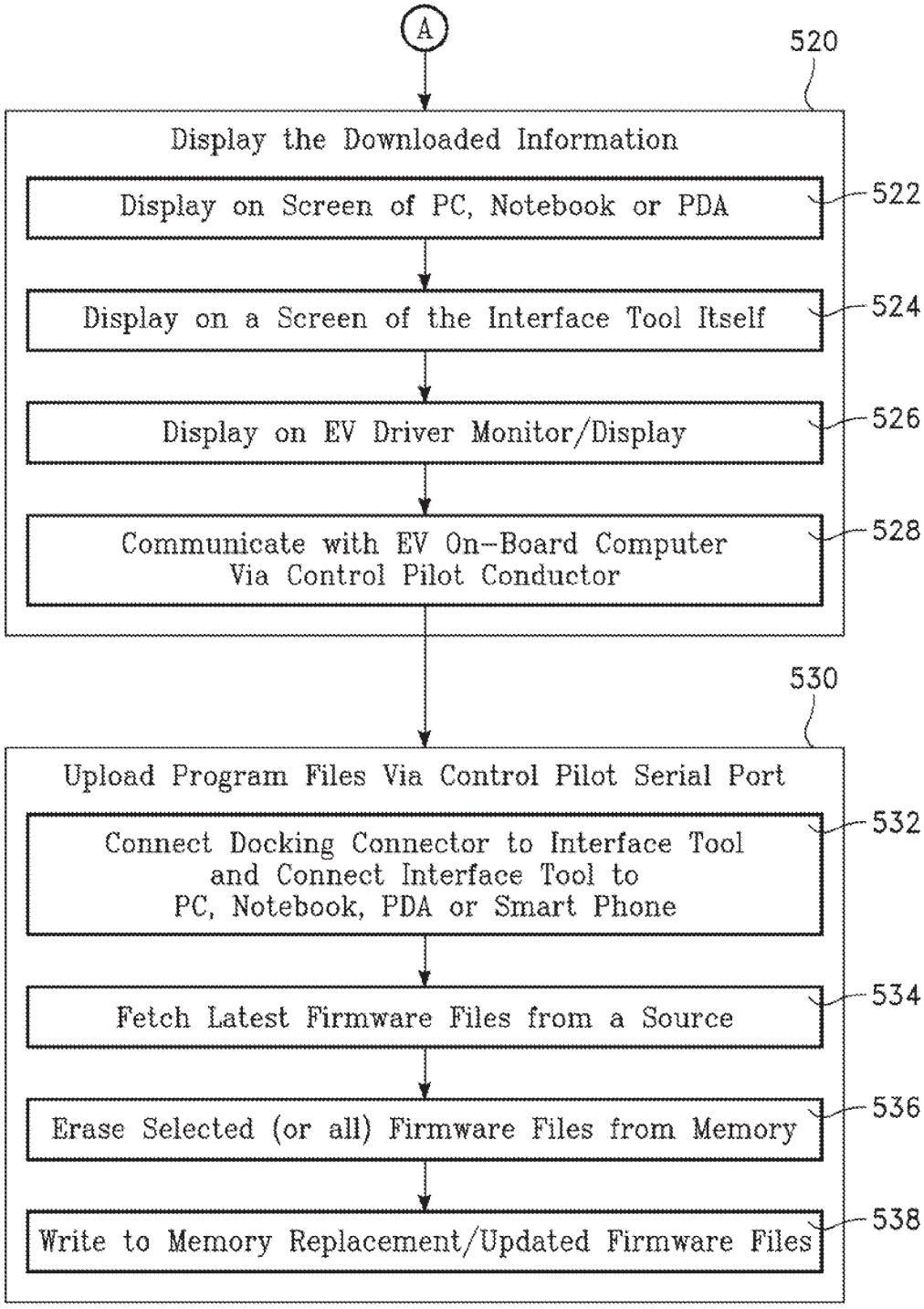
A
520
Display the Downloaded Information
Display on Screen of PC, Notebook or PDA
522
Display on a Screen of the Interface Tool Itself
524
Display on EV Driver Monitor/Display
526
Communicate with EV On-Board Computer Via Control Pilot Conductor
528
530
Upload Program Files Via Control Pilot Serial Port
Connect Docking Connector to Interface Tool and Connect Interface Tool to PC, Notebook, PDA or Smart Phone
532
Fetch Latest Firmware Files from a Source
534
Erase Selected (or all) Firmware Files from Memory
536
Write to Memory Replacement/Updated Firmware Files
538

FIG. 6B

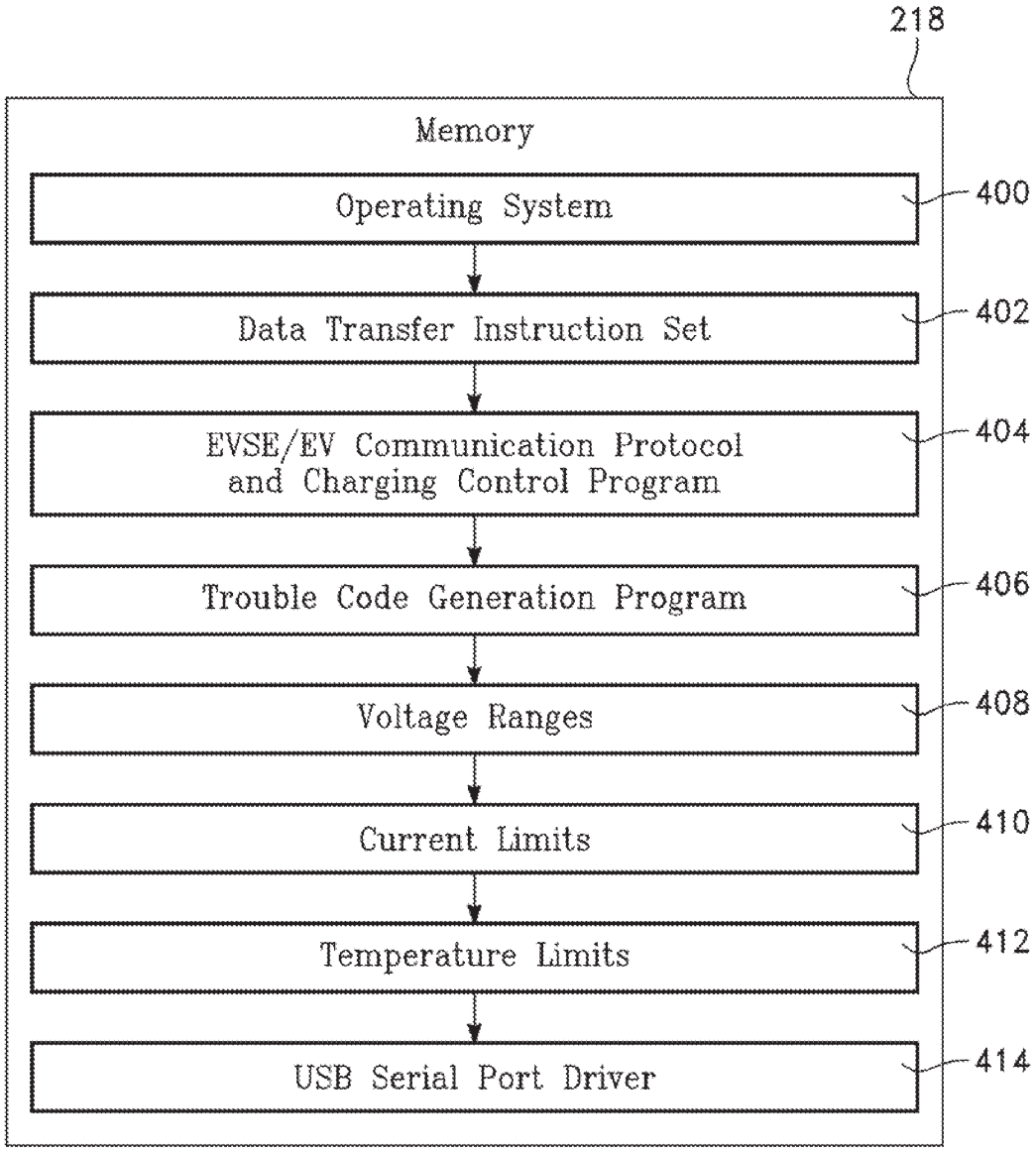
218
Memory
Operating System
400
Data Transfer Instruction Set
402
EVSE/EV Communication Protocol and Charging Control Program
404
Trouble Code Generation Program
406
Voltage Ranges
408
Current Limits
410
Temperature Limits
412
USB Serial Port Driver
414

FIG. 7

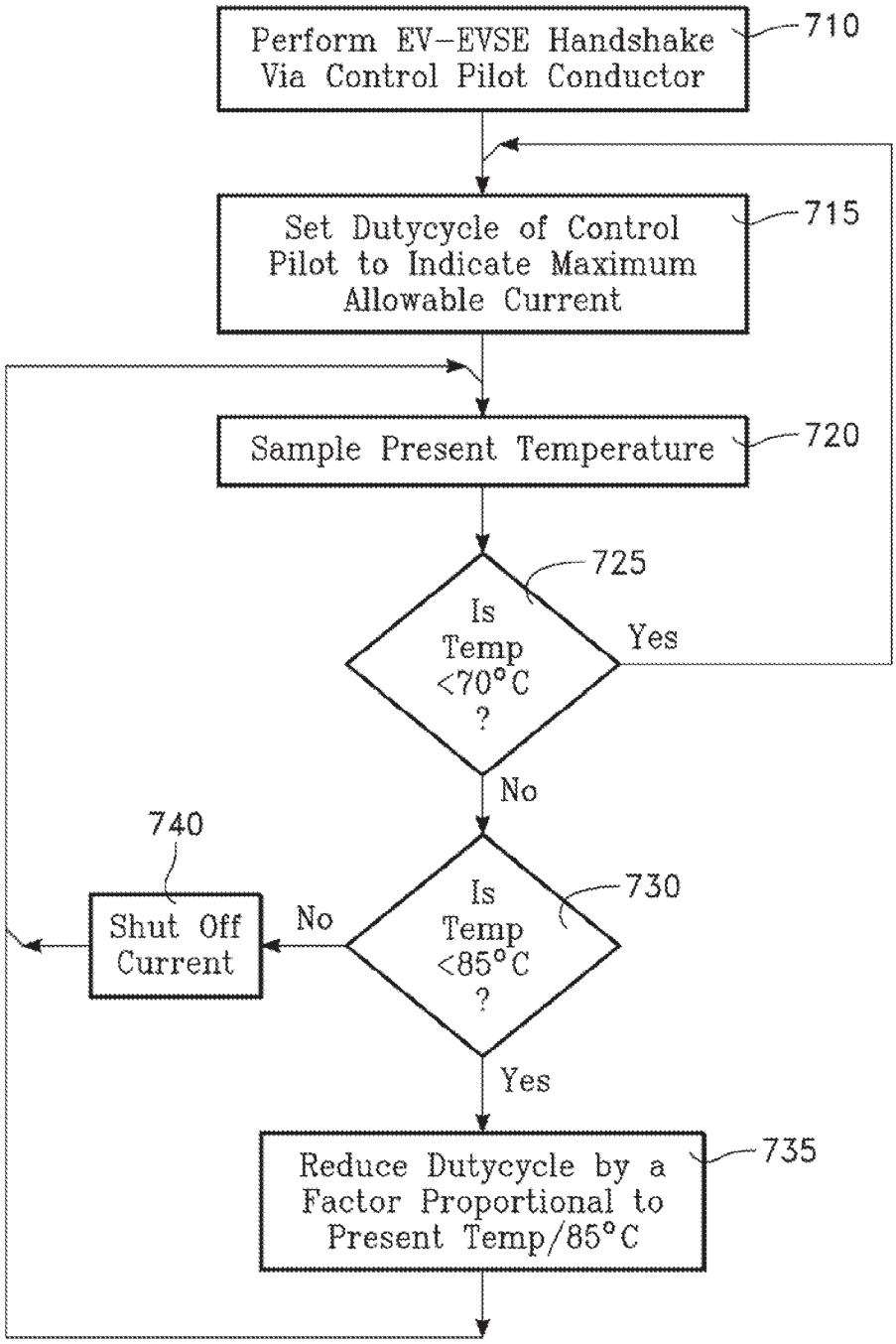
Perform EV-EVSE Handshake Via Control Pilot Conductor
710
Set Dutycycle of Control Pilot to Indicate Maximum Allowable Current
715
Sample Present Temperature
720
725
Is Temp <70°C ?
Yes
No
740
Shut Off Current
No
Is Temp <85°C ?
730
Yes
Reduce Dutycycle by a Factor Proportional to Present Temp/85°C
735

FIG. 8

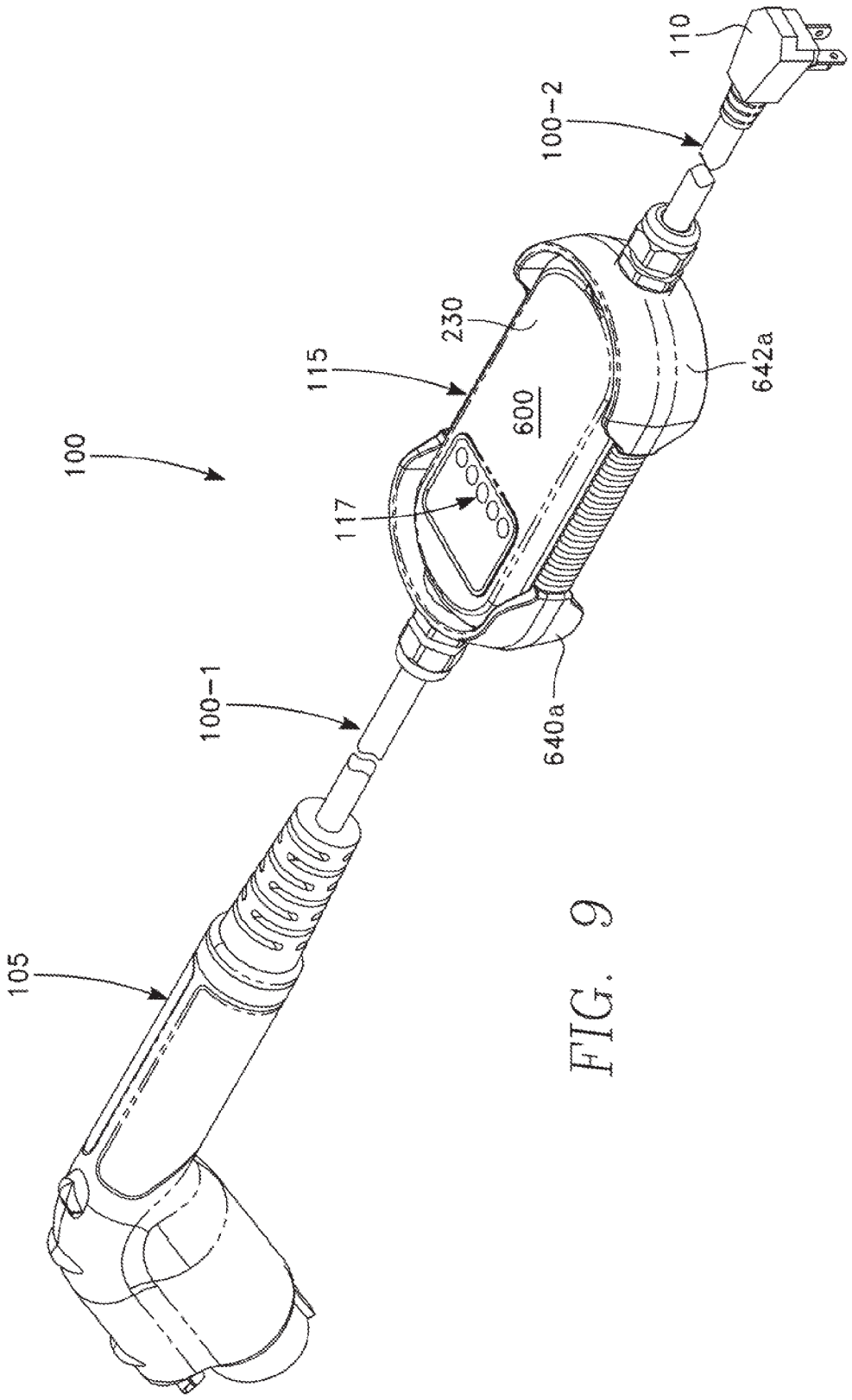

FIG. 9

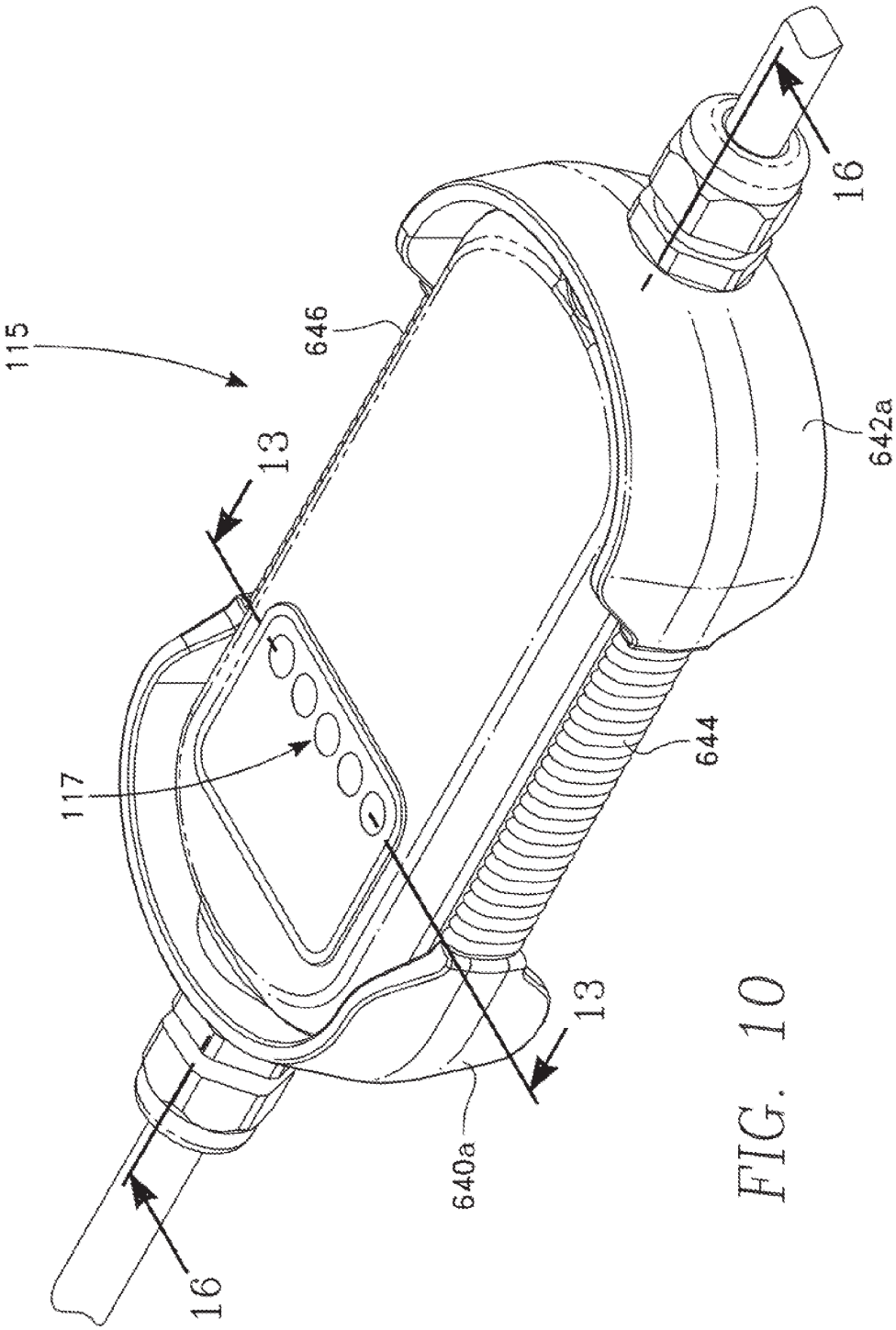

FIG. 10

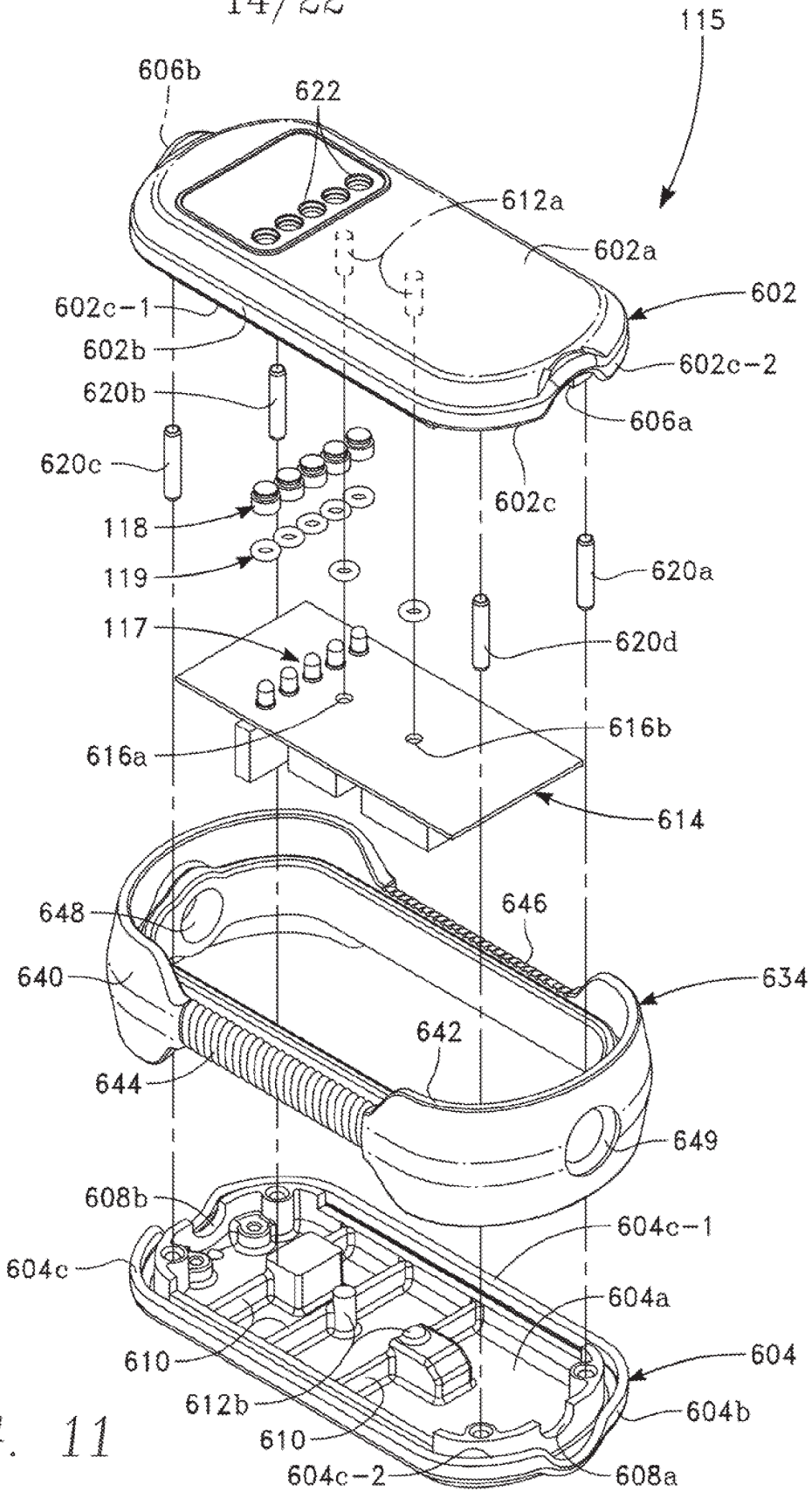
115
606b
622
612a
602a
602
602c-1
602b
602c-2
620b
606a
620c
602c
118
620a
119
117
620d
616b
616a
614
648
646
640
634
642
644
649
608b
604c-1
604c
604a
610
604
612b
604b
610
604c-2
608a

FIG. 11

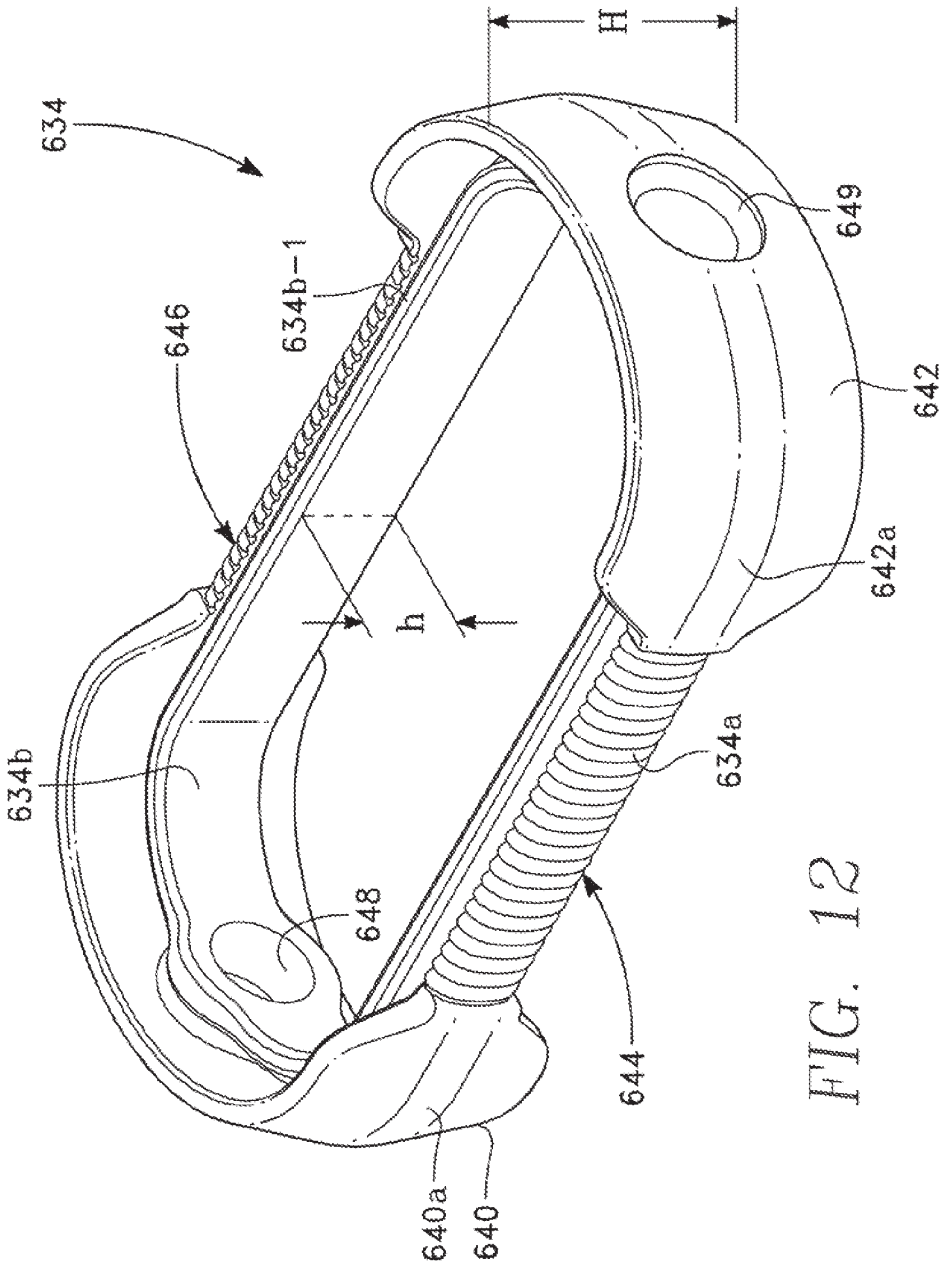

FIG. 12

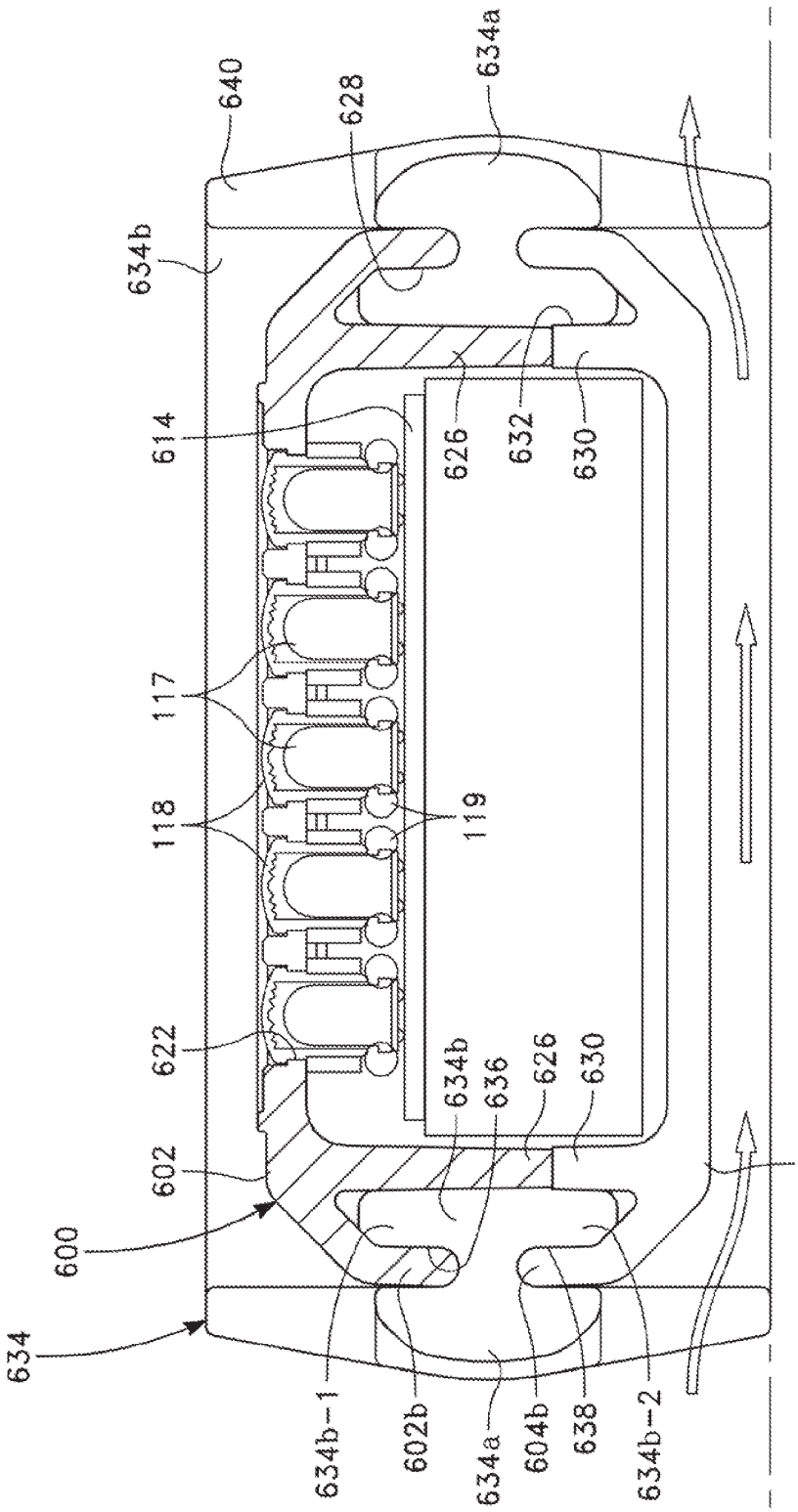
640
628
634a
634b
614
626
632
630
117
118
119
622
634b
636
626
630
602
604
600
634
634b-1
602b
634a
604b
638
634b-2

FIG. 13

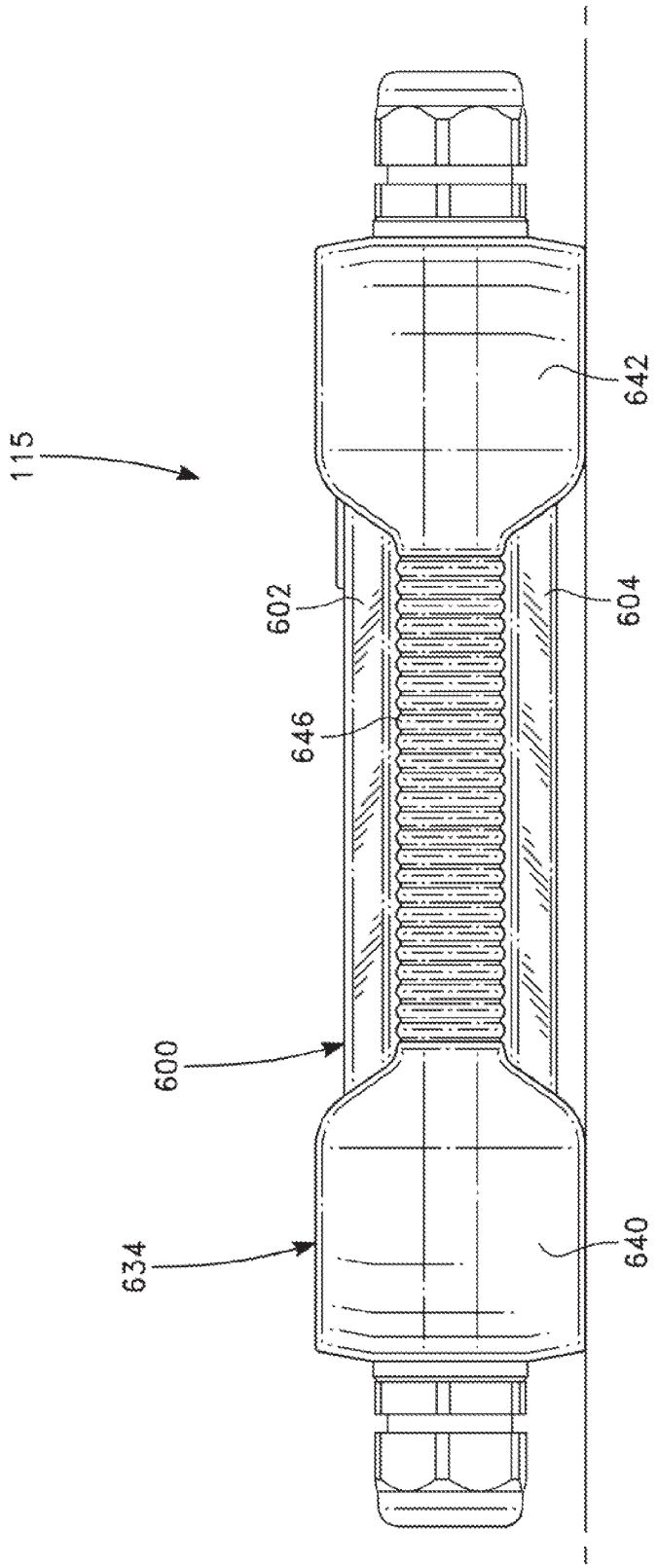

FIG. 14

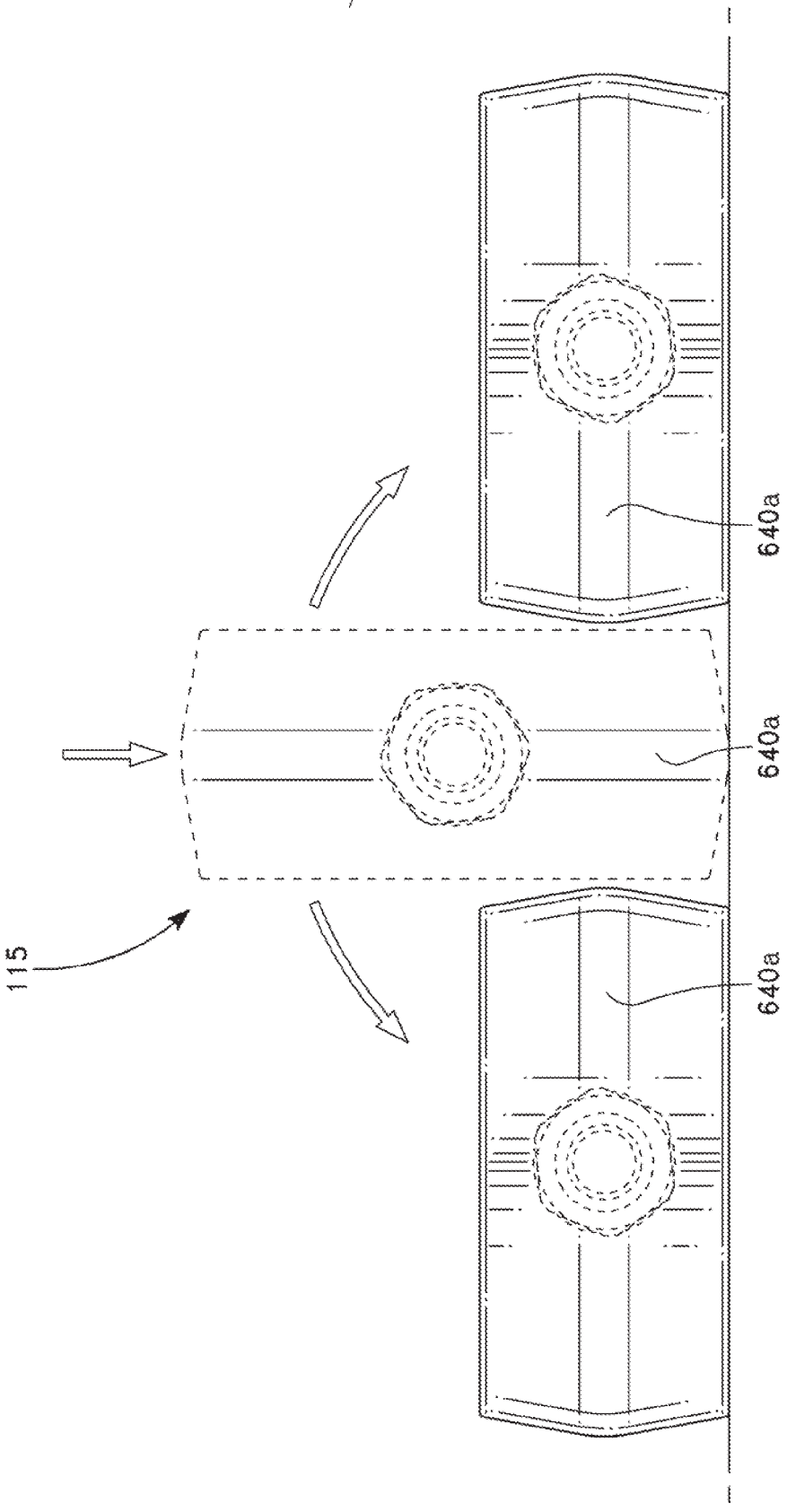

FIG. 15

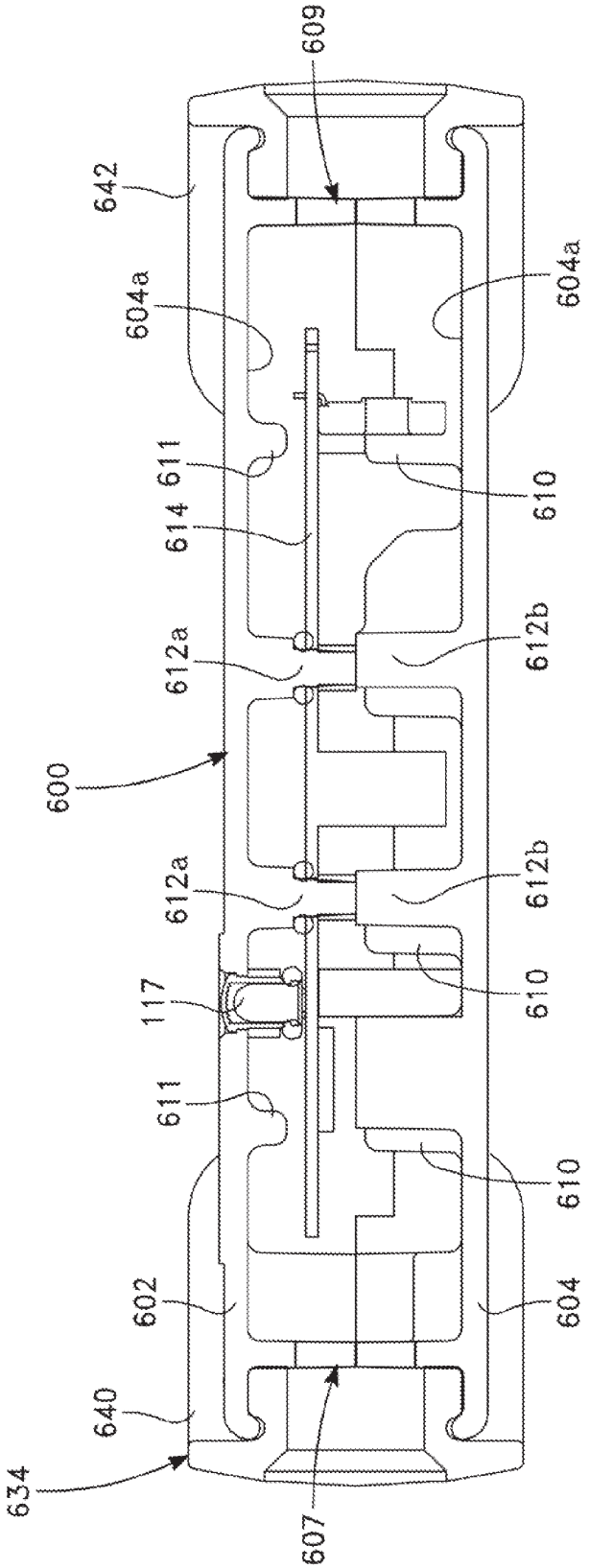
609
642
604a
604a
611
614
610
612a
612b
600
612a
612b
117
610
611
610
602
604
640
634
607

FIG. 16

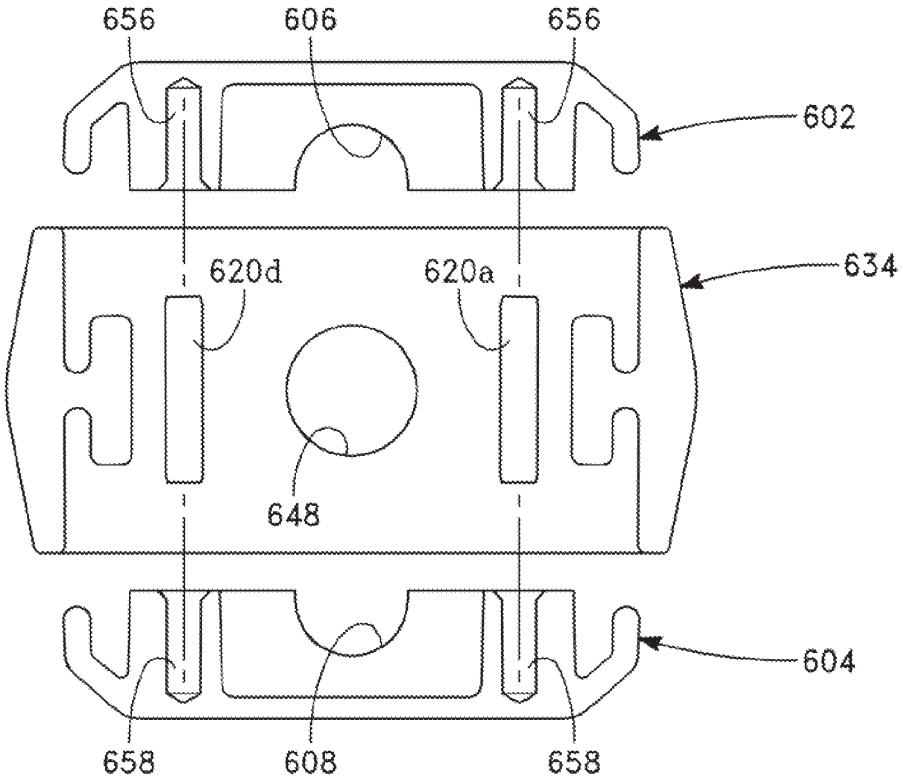

FIG. 17

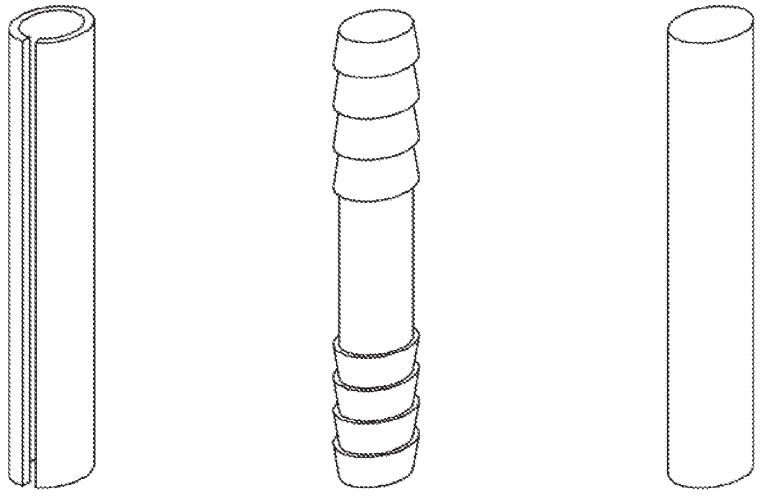

FIG. 18A FIG. 18B FIG. 18C

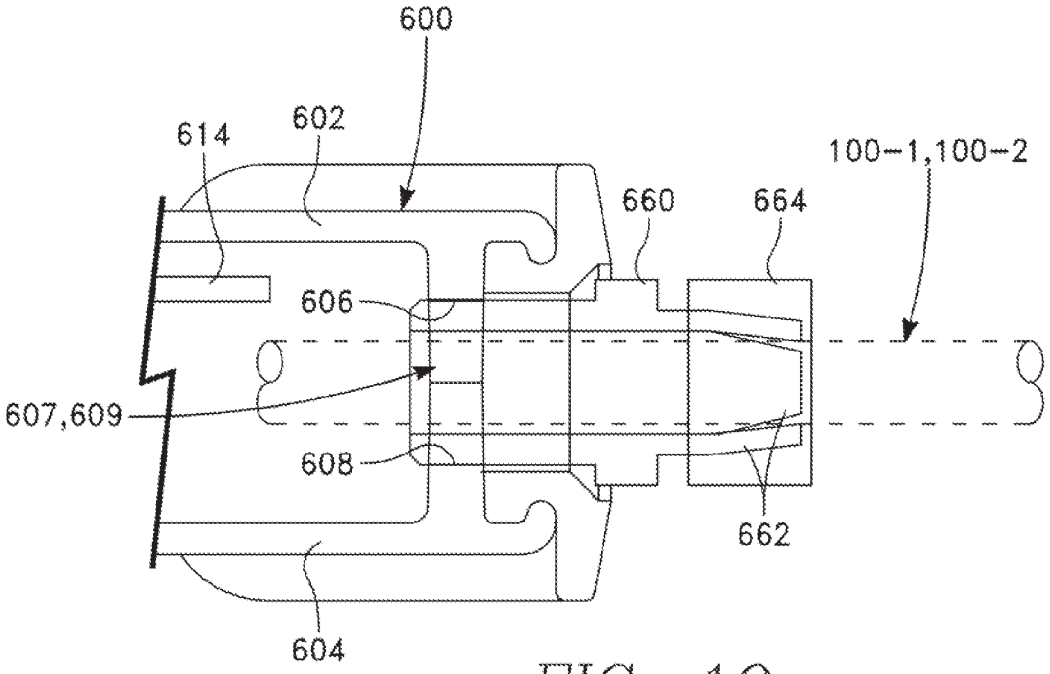
600
614
602
100-1,100-2
660
664
606
607,609
608
662
604

FIG. 19

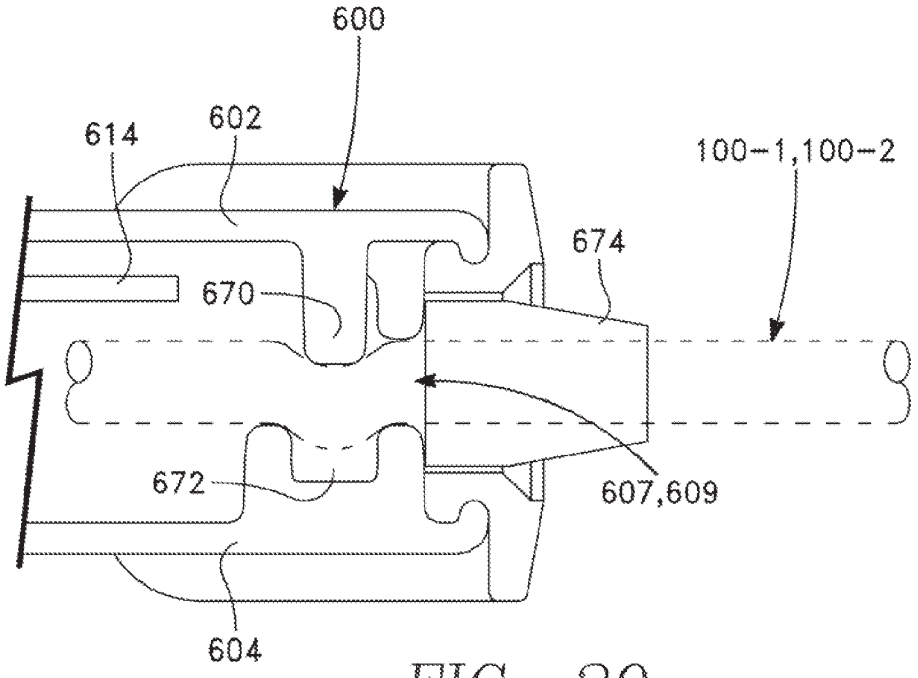
600
614
602
100-1,100-2
674
670
672
607,609
604

FIG. 20

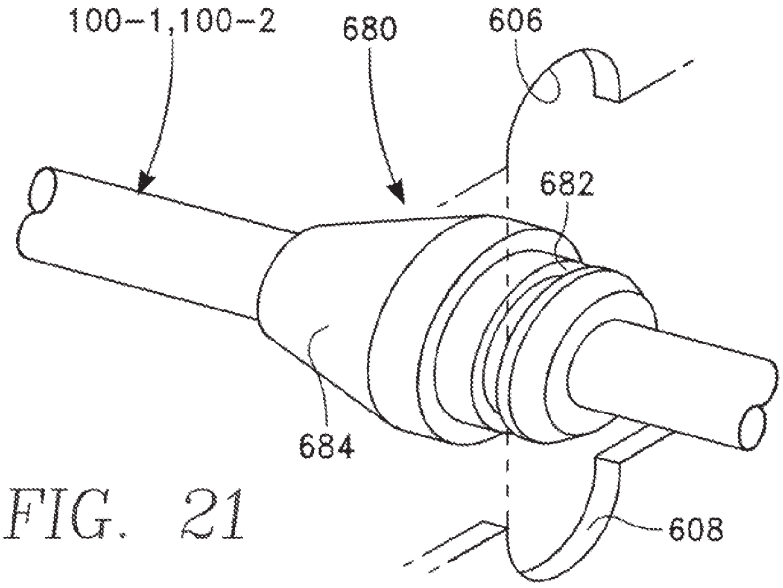

FIG. 21

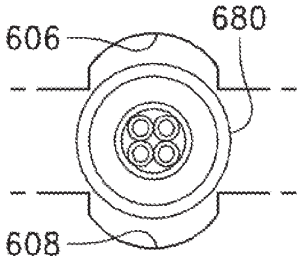

FIG. 22A

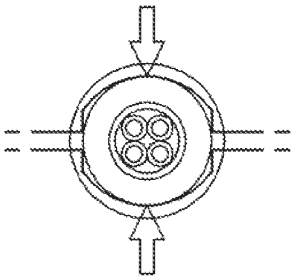

FIG. 22B

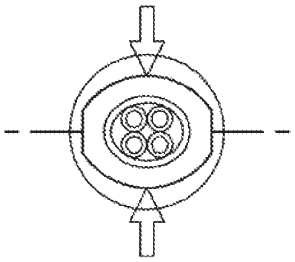

FIG. 22C

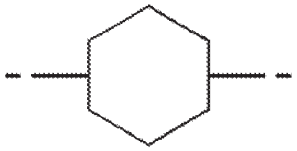

FIG. 23A

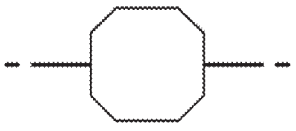

FIG. 23B

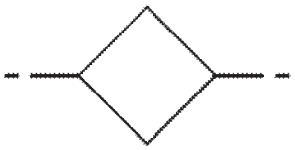

FIG. 23C