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(54) **SYSTEMS AND METHODS FOR POWERING A VEHICLE, AND GENERATING AND DISTRIBUTING ENERGY**

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See application file for complete search history.

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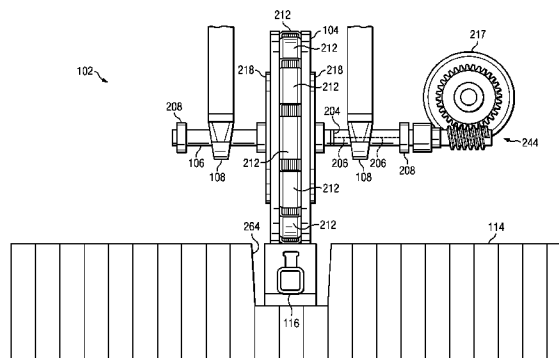
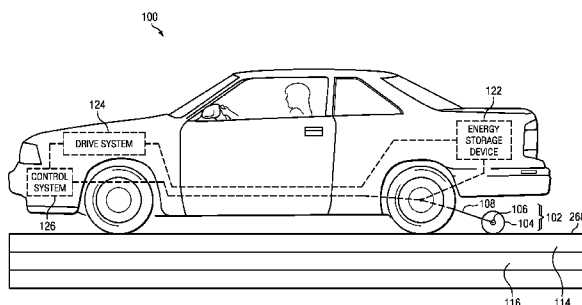
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(57) **ABSTRACT**

A system and method for powering of a vehicle is disclosed. In accordance with embodiments of the present disclosure, a powering assembly may include an axle, a wheel coupled to the axle, and at least one secondary coil winding affixed to the wheel. The wheel may be configured to rotate about the axle in a plane substantially perpendicular to an axis of the axle. The at least one secondary coil may be configured such that when the wheel is proximate to an embedded conductor embedded in a roadway and carrying a first electrical current, a magnetic field induced by the first electrical current induces a second electrical current in the at least one secondary coil winding.

**11 Claims, 7 Drawing Sheets**



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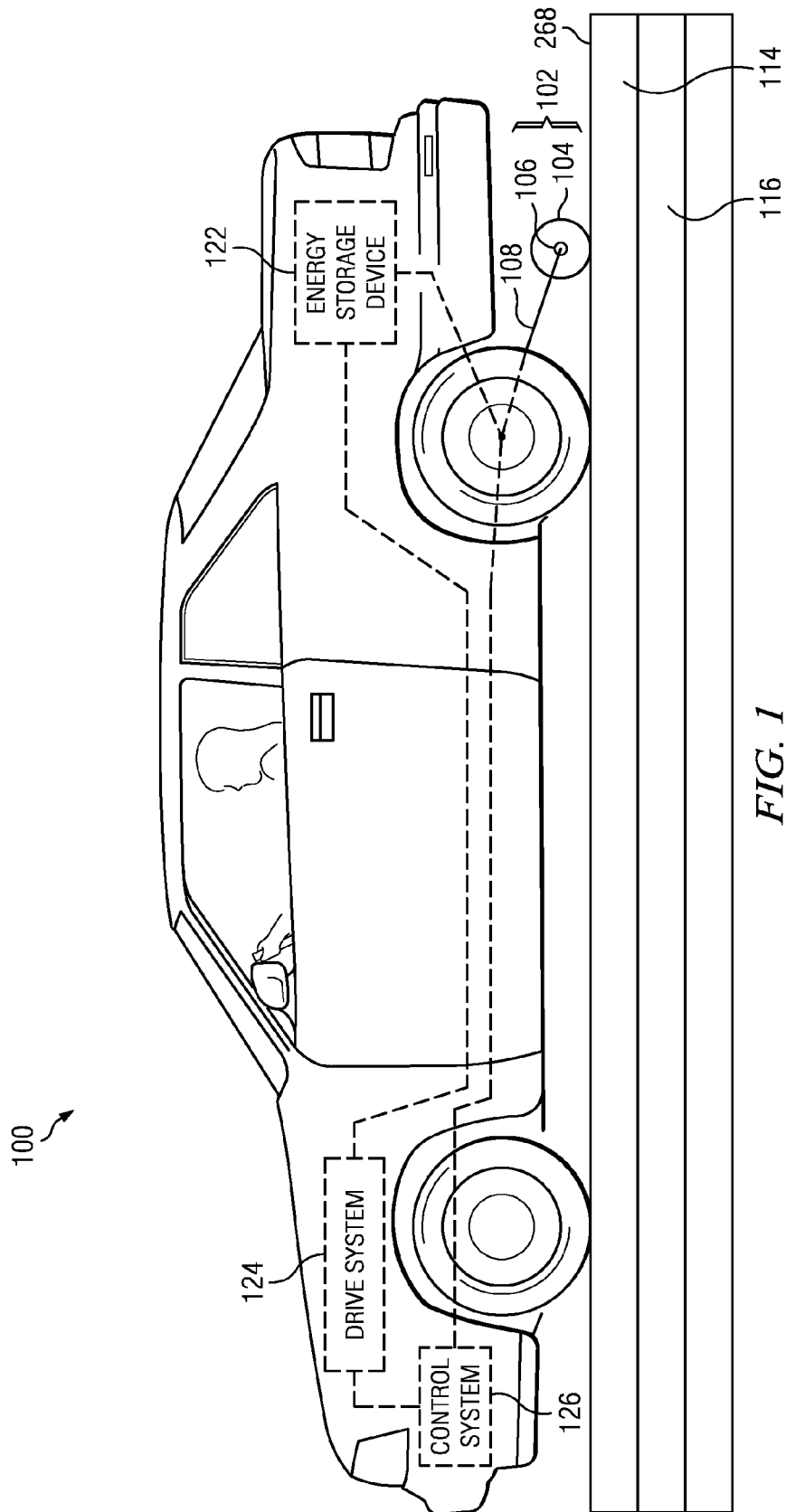
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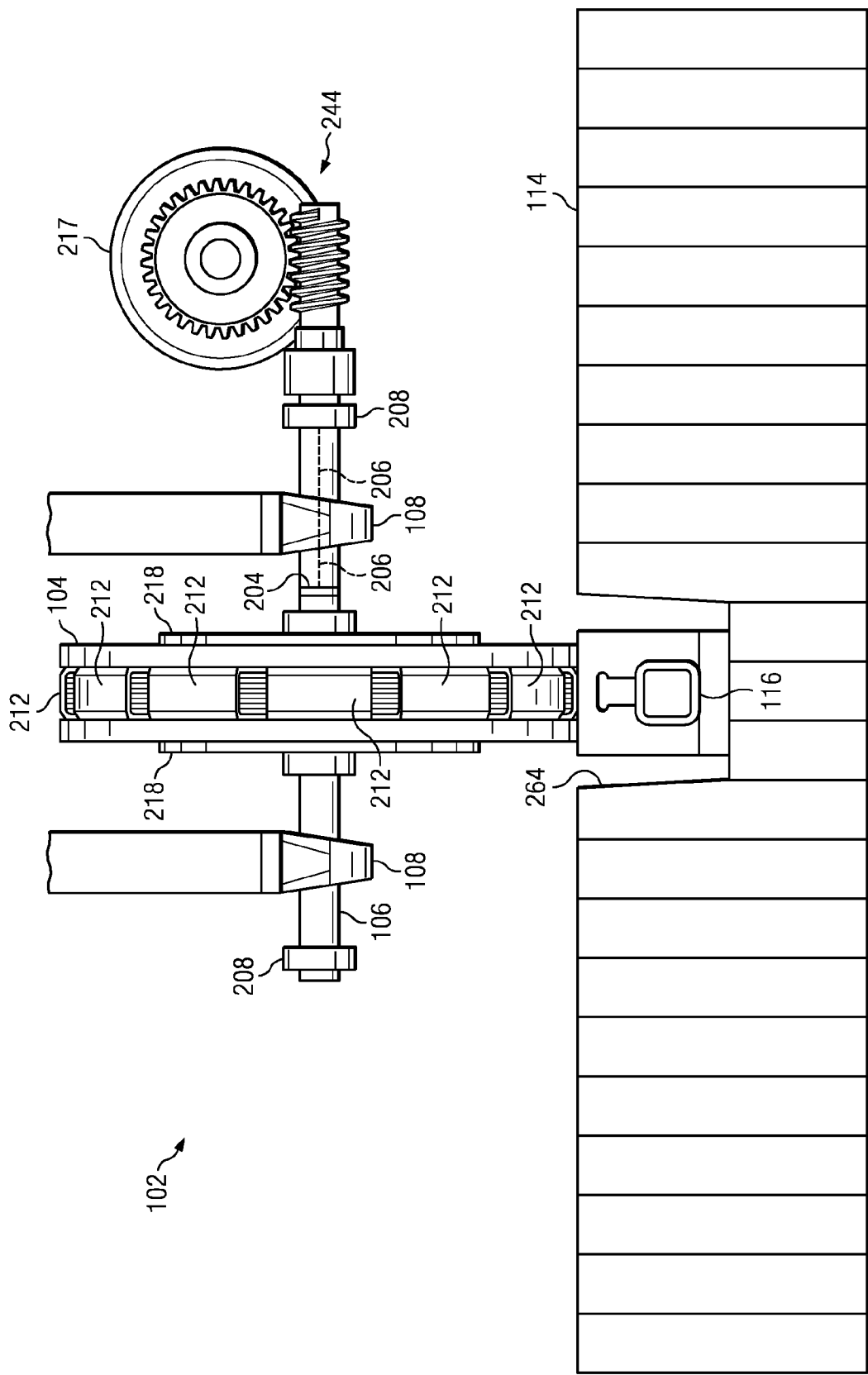


FIG. 2A

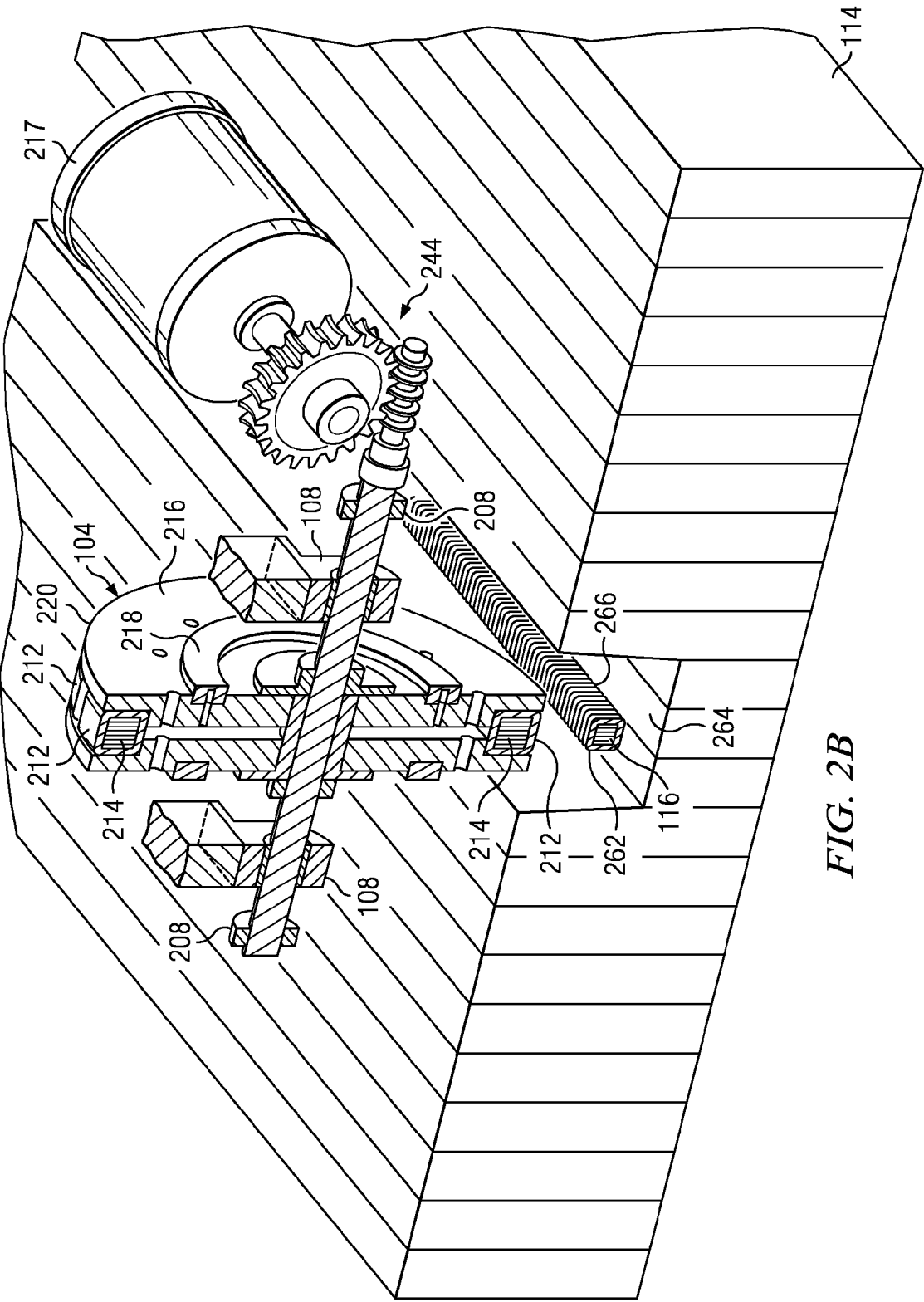


FIG. 2B

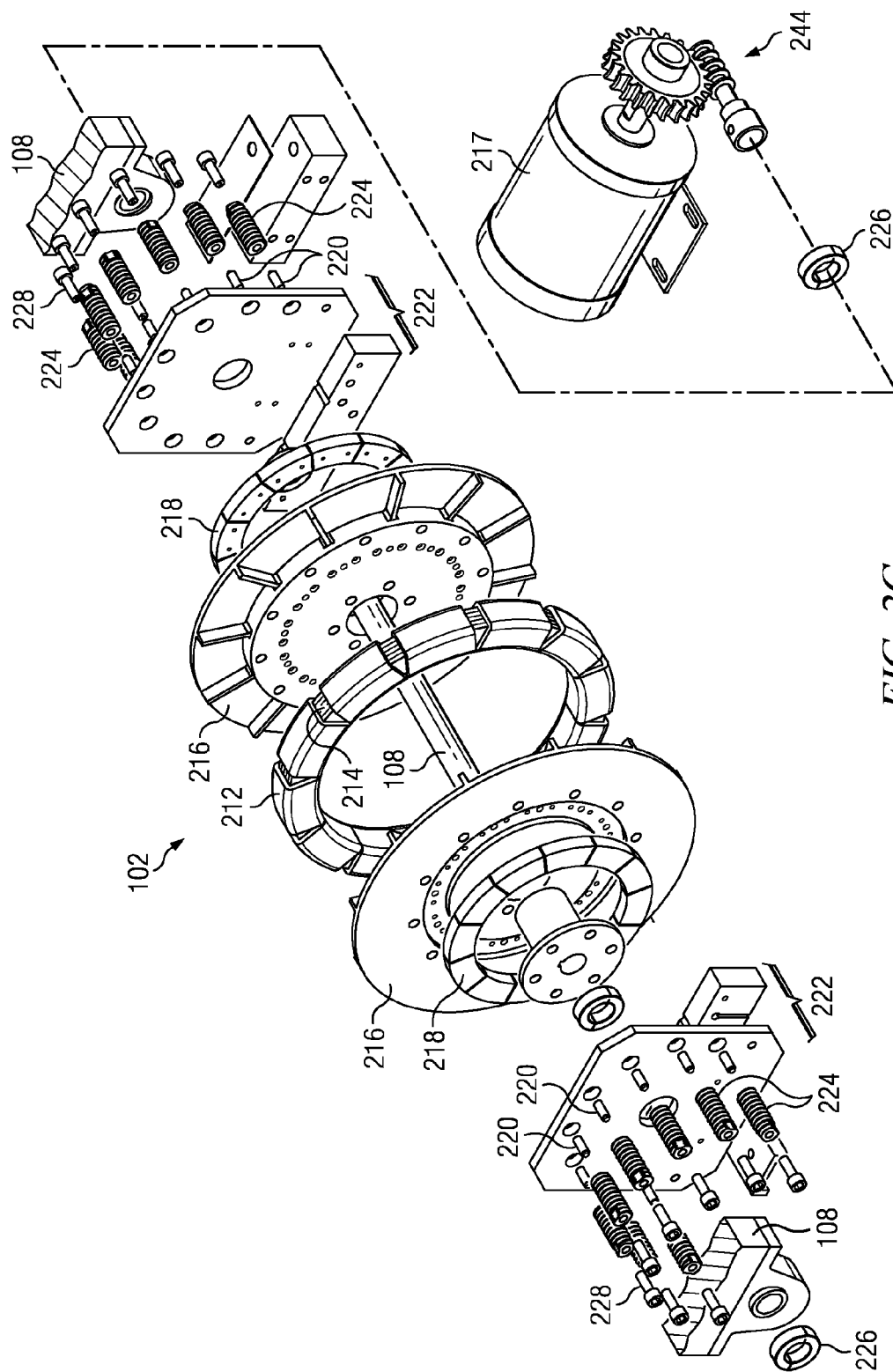


FIG. 2C

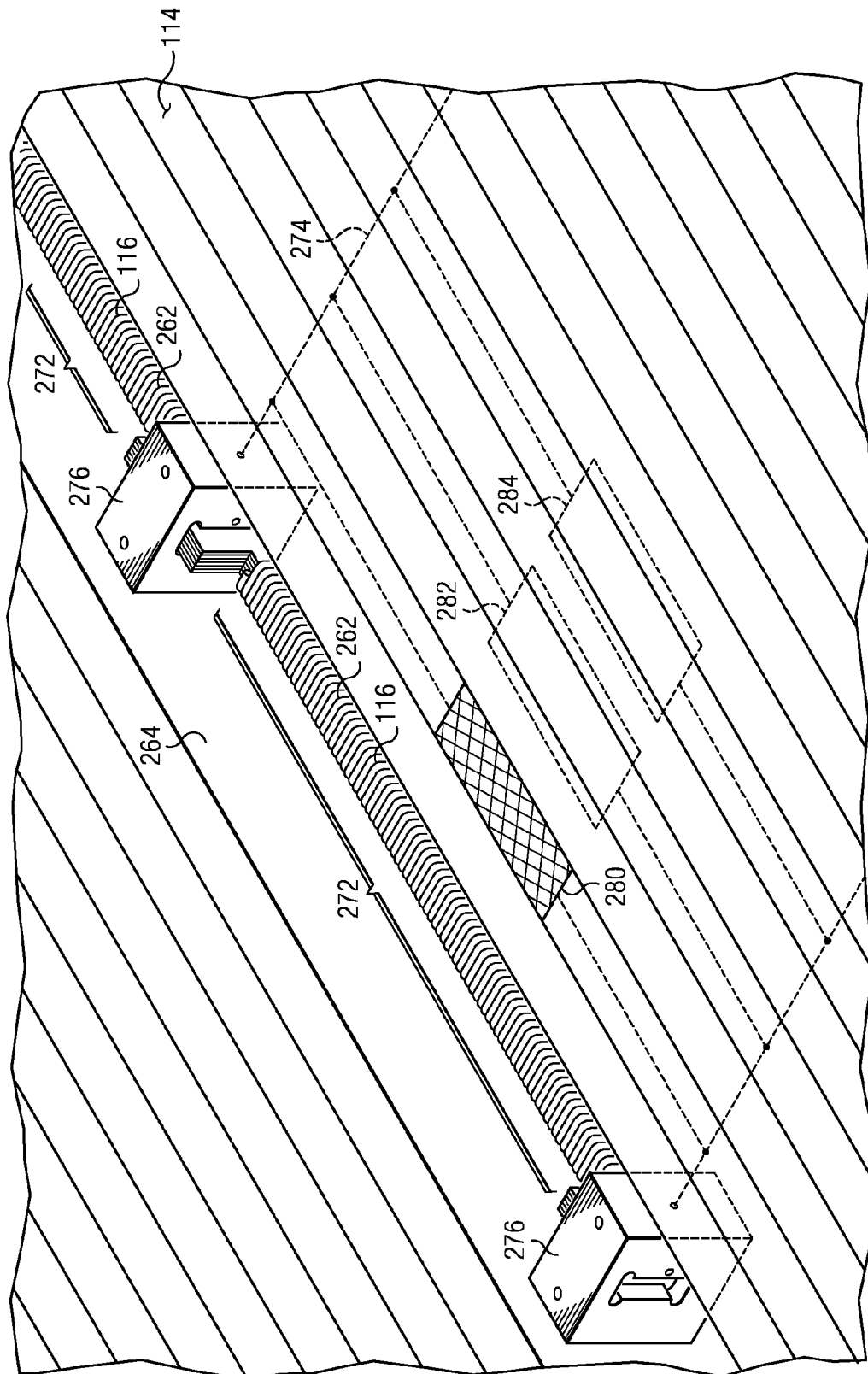


FIG. 2D

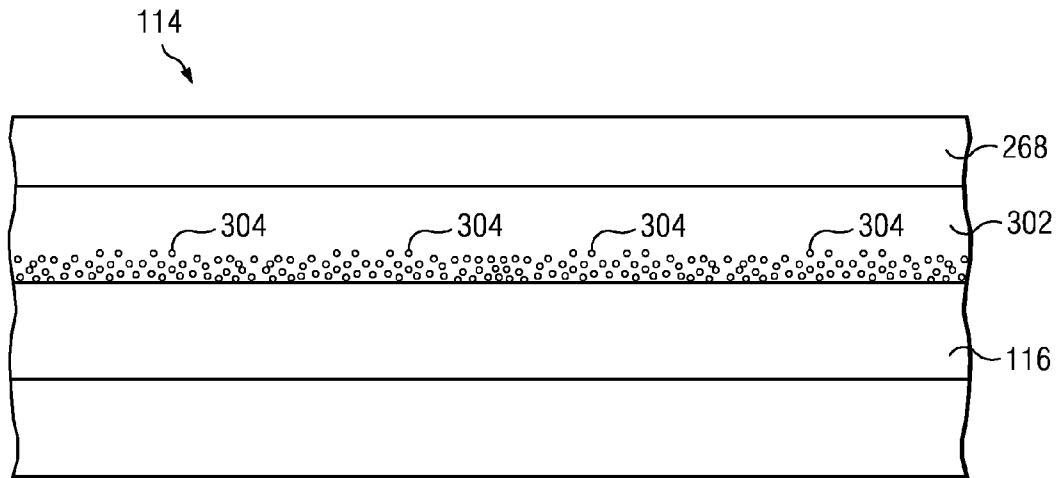


FIG. 3A

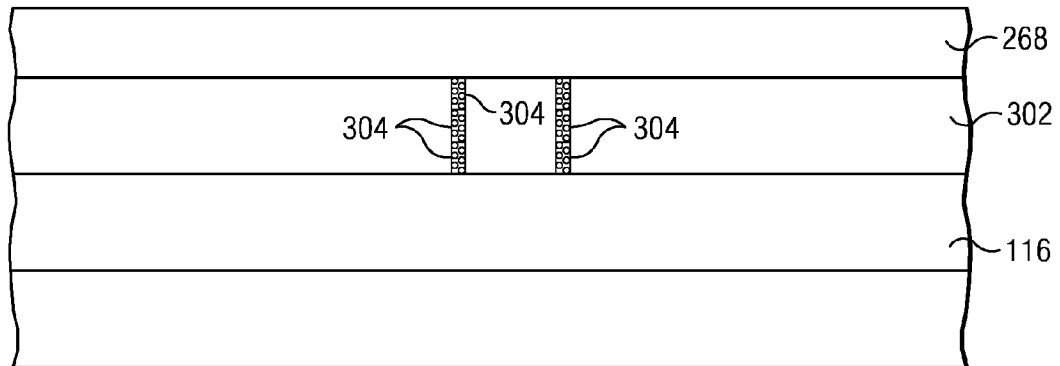


FIG. 3B

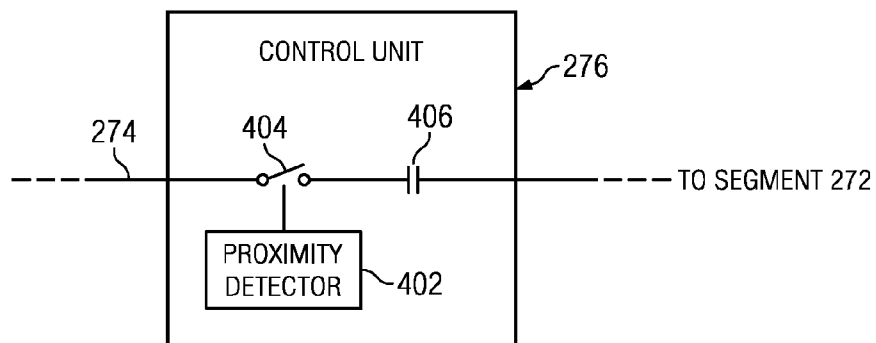
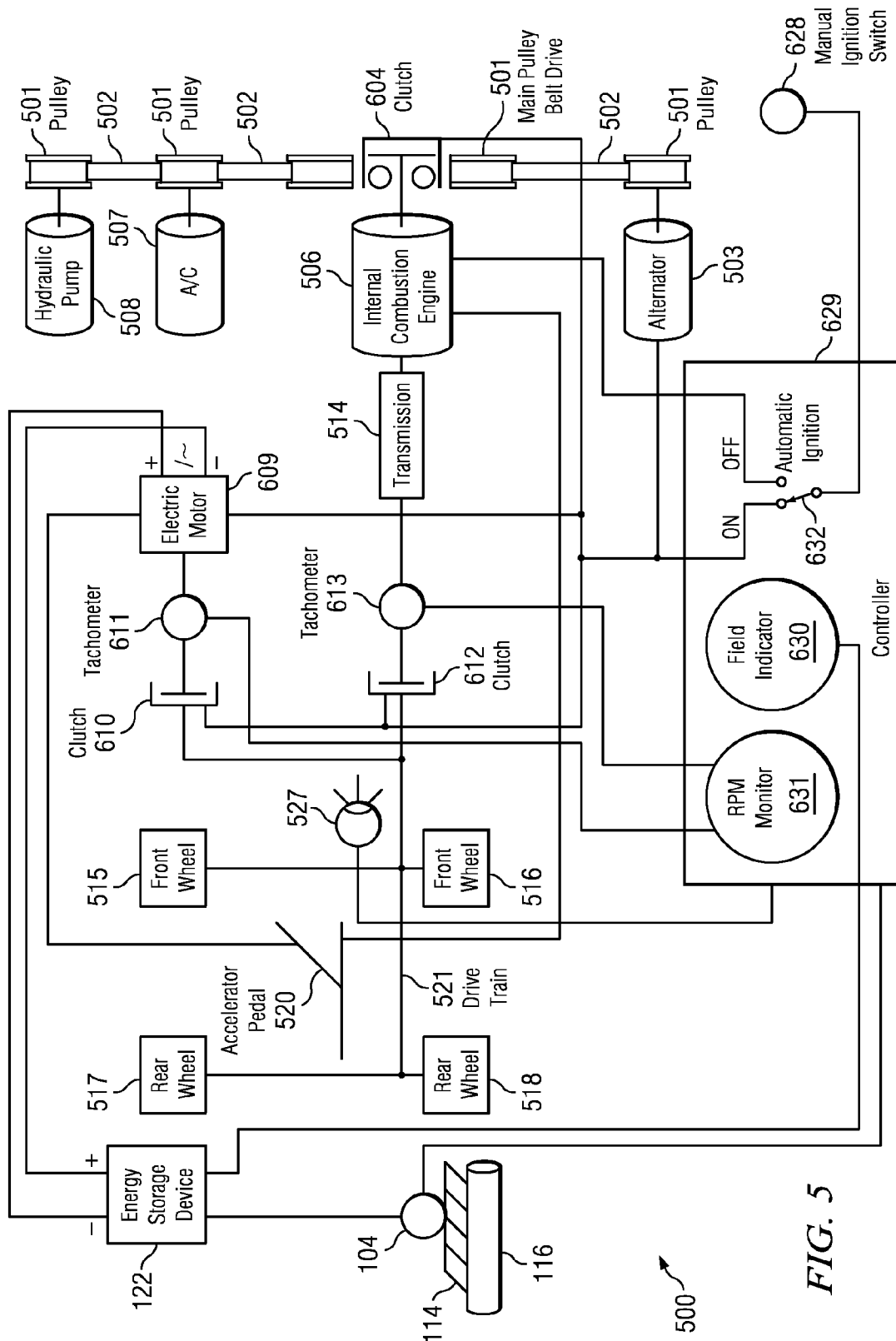


FIG. 4





**FIG. 5**

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# SYSTEMS AND METHODS FOR POWERING A VEHICLE, AND GENERATING AND DISTRIBUTING ENERGY

## RELATED APPLICATIONS

This application is a continuation application of International Application Number PCT/US11/43933 filed Jul. 14, 2011; which claims the benefit of U.S. provisional application No. 61/399,665 filed Jul. 15, 2010, and also claims the benefit of U.S. provisional application No. 61/488,048 filed May 19, 2011, the contents of which are hereby incorporated by reference in its entirety.

This application is also copending with U.S. patent application Ser. No. 13/188,110, filed Jul. 21, 2011, entitled "Systems and Methods for Converting a Gasoline-Fueled Vehicle to a Dual-Mode Powered Vehicle."

## TECHNICAL FIELD

The present invention relates generally to powering of motor vehicles, and more particularly to powering of a vehicle from a roadway-embedded conductor using magnetic induction and electric conduction.

## BACKGROUND

Due to increased environmental consciousness and political and economic concerns associated with the importation of foreign petroleum products, electric vehicles have been considered as alternatives to traditional internal combustion engine vehicles. However, significant transition from use of internal combustion engine vehicles to electric vehicles or hybrid electric/combustion engine vehicles has not been realized due to numerous challenges and disadvantages.

For example, an existing challenge is the relatively short range of electric vehicles utilizing batteries coupled with battery recharge times that may be significantly larger than the usage time of the battery. This shortcoming has been addressed by various approaches employing magnetic induction (also known as inductive coupling) to power vehicles and/or charge vehicle batteries.

To achieve inductive coupling of energy between physically separate elements, a primary coil may be electrically coupled to a current source such that the flow of current through the primary coil induces a magnetic field surrounding the primary coil. Current may be induced in a secondary coil when turns of the secondary coil cut through imaginary lines of flux of the magnetic field. The turns of the secondary coil may be caused to cut through magnetic lines of flux by producing relative motion between the primary and secondary coils and/or by causing the magnetic field to fluctuate using an alternating current source coupled to the primary coil.

In vehicles, magnetic induction powering has been proposed by providing a primary coil that is embedded in or near a roadway or path of vehicle travel and by affixing a secondary coil to the vehicle, such that the secondary coil moves with the vehicle, thereby producing relative motion between the primary and secondary coils. Presently, induction powering systems have been deployed only for charging stationary vehicles ((e.g., in parking areas). However, such traditional approaches of applying magnetic induction powering are not without shortcomings.

As an example, one shortcoming is the distance between the primary coil and the secondary coil in traditional approaches. To provide clearance of the secondary coil from debris and other roadway hazards, traditional approaches pro-

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vide an air gap between the roadway (having the primary coil) and a pick-up unit carrying the secondary coil. Such an air gap may reduce the effectiveness of magnetic induction, as inductive coupling between two coils decreases as the distance between the coils increases. A similar shortcoming is that traditional approaches do not ensure lateral alignment between the primary coil and the secondary coil. Due to such shortcoming, some vehicles, particularly those vehicles steered by a person, may stray from a centerline of a roadway, thereby reducing the inductive coupling between the primary and secondary coils. Additionally, another shortcoming of approaches pre-dating this disclosure is that the distance between the pavement and the secondary may continuously vary on a vehicle in motion due to horizontal motion of a vehicle in motion generated by the non-uniformity of pavement and the response of vehicle shock and struts.

As another example, the relative motion between a primary coil embedded in a roadway and a secondary coil mounted to a vehicle may not be sufficient to induce a sufficient amount of current in the secondary coil. While the current induced in the secondary coil may be increased by utilizing high-frequency alternating current in the primary coil, the resulting induced current may still remain insufficient to provide the necessary power or charging.

In addition, proposed methods to providing powering to a vehicle from a roadway may expose humans and other animals to high-frequency currents which may pose health and safety concerns.

## SUMMARY

In accordance with the present disclosure, the disadvantages and problems associated with prior systems and methods for powering a vehicle have been substantially reduced or eliminated.

In accordance with embodiments of the present disclosure, a powering assembly may include an axle, a wheel coupled to the axle, and at least one secondary coil winding affixed to the wheel. The wheel may be configured to rotate about the axle in a plane substantially perpendicular to an axis of the axle. The at least one secondary coil may be configured such that when the wheel is proximate to an embedded conductor embedded in a roadway and carrying a first electrical current, a magnetic field induced by the first electrical current induces a second electrical current in the at least one secondary coil winding.

In accordance with further embodiments of the present disclosure, a vehicle may include a chassis and a powering assembly mechanically coupled to the chassis. The powering assembly may include an axle, a wheel coupled to the axle, and at least one secondary coil winding affixed to the wheel. The wheel may be configured to rotate about the axle in a plane substantially perpendicular to an axis of the axle. The at least one secondary coil may be configured such that when the wheel is proximate to an embedded conductor embedded in a roadway and carrying a first electrical current, a magnetic field induced by the first electrical current induces a second electrical current in the at least one secondary coil winding.

In accordance with additional embodiments of the present disclosure, a method for powering a vehicle may include coupling a wheel to an axle such that the wheel rotates about the axle in a plane substantially perpendicular to an axis of the axle. The method may also include affixing at least one secondary coil winding to the wheel such that when the wheel is proximate to an embedded conductor embedded in a roadway and carrying a first electrical current, a magnetic field induced

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by the first electrical current induces a second electrical current in the at least one secondary coil winding.

In accordance with other embodiments of the present disclosure, a method for adapting a conventional gasoline-powered vehicle to permit the vehicle to be powered via a roadway-embedded conductor may include mechanically coupling a first clutch between an internal combustion engine transmission of the vehicle and a drive train of the vehicle, the first clutch configured to engage the internal combustion engine with the drive train during a first mode of operation and disengage the internal combustion engine from the drive train during a second mode of operation. The method may also include mechanically coupling a second clutch to the drive train and mechanically coupling an electric motor to a second clutch, the second clutch configured to engage the electric motor with the drive train during the second mode of operation and disengage the electric motor from the drive train during the first mode of operation. The method may further comprise electrically coupling the electric motor to at least one of: (i) a powering assembly configured to transfer at least a portion of electrical energy from a roadway-embedded conductor, the electrical energy in the form of at least one of a magnetically-induced electric current and an electrically-conducted current; and (ii) an energy storage device configured to convert at least a portion of the electrical energy transferred by the powering assembly into stored potential energy.

In accordance with other embodiments of the present disclosure, a system for adapting a conventional gasoline-powered vehicle to permit the vehicle to be powered via a roadway-embedded conductor may include a powering assembly, an electric motor, a first clutch, and a second clutch. The powering assembly may be configured to transfer electrical energy from a roadway-embedded conductor, the electrical energy in the form of at least one of a magnetically-induced electric current and an electrically-conducted current. The electric motor may be configured to be powered by at least one of a portion of the electrical energy transferred by the powering assembly and stored potential energy converted from at least a portion of the electrical energy transferred by the powering assembly. The first clutch may be configured to be mechanically coupled to an internal combustion engine transmission of the vehicle and a drive train of the vehicle, the first clutch further configured to engage the internal combustion engine with the drive train during a first mode of operation and disengage the internal combustion engine from the drive train during a second mode of operation. The second clutch may be configured to be mechanically coupled to the electric motor, the second clutch further configured to engage the electric motor with the drive train during the second mode of operation and disengage the electric motor from the drive train during the first mode of operation.

#### BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and its advantages, reference is now made to the following description taken in conjunction with the accompanying drawings, in which:

FIG. 1 illustrates a vehicle with a powering assembly and a roadway for providing an electric current for induction powering, in accordance with embodiments of the present disclosure;

FIGS. 2A-2D illustrate selected components of a powering assembly and a roadway, in accordance with embodiments of the present disclosure;

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FIGS. 3A and 3B depict a cross-sectional elevation view of an example of one embodiment for providing dual-mode electrical characteristics for a surface of roadway;

FIG. 4 depicts a block diagram of an example control unit, in accordance with embodiments of the present disclosure; and

FIG. 5 depicts a block diagram of a conventional gasoline-powered vehicle adapted with a conversion kit to allow for powering of the vehicle via a roadway-embedded conductor, in accordance with embodiments of the present disclosure.

#### DETAILED DESCRIPTION

FIG. 1 illustrates a vehicle 100 with a powering assembly 102, in accordance with particular embodiments of the present disclosure. Although vehicle 100 depicted in FIG. 1 is a passenger automobile, vehicle 100 may broadly represent any system, device, or apparatus configured or used to transport persons and/or cargo in whole or in part on land, including without limitation a passenger automobile (e.g., a car, truck, sport utility vehicle, van, bus, motorcycle, coach, etc.), a train, a trolley, an aircraft, a spacecraft, an amphibious watercraft, industrial equipment (e.g., a forklift, cart, etc.), and/or any other suitable vehicle. As depicted in FIG. 1, vehicle 100 may include powering assembly 102. Powering assembly 102 may comprise a system, device, or apparatus configured to generate electrical energy via magnetic induction, and transmit such generated energy to one or more energy storage devices 122 (e.g., one or more rechargeable batteries and/or super-capacitors) disposed in and/or affixed to vehicle 100, and/or transmit such generated energy to a drive system 124 of vehicle 100 (e.g., one or more components, including without limitation an engine, a motor, a drive train, axles, pulleys, and wheels, configured to convert electrical and/or chemical energy into mechanical energy to propel vehicle 100). Example structure, function, and selected components of powering assembly 102 are described in greater detail below with respect to FIGS. 2A-2C and 3.

To generate electric energy via magnetic induction, powering assembly 102 may be configured to travel upon a roadway 114 having an embedded conductor 116. Although roadway 114 is depicted in FIG. 1 as a roadway adapted for use by passenger automobiles, roadway 114 may broadly represent any roadway configured for use by any vehicle, including without limitation a road, street, freeway, highway, bridge, runway, tarmac, rail, dock, warehouse floor, building hallway floor, and/or any other suitable surface upon which a vehicle 100 may travel. Embedded conductor 116 may be embedded beneath the surface of roadway 114 and may include any material suitable for conducting an electric current. In addition, embedded conductor 116 may be electrically coupled to a power source configured to generate an electric current in embedded conductor 116. Example structure, function, and selected components of roadway 114 are described in greater detail below with respect to FIGS. 2A-2D.

As shown in FIG. 1, and in greater detail in FIGS. 2A-2C, powering assembly 102 may include wheel assembly 104, axle 106, and one or more arms 108. As described in greater detail below with respect to FIGS. 2A-2C, wheel assembly 104 may include one or more coil windings (e.g., coils 212 depicted in FIGS. 2A-2C) electrically coupled to energy storage device 122, drive system 124, and/or other components of vehicle 100 and may be configured to rotate about axle 106 and proximate to embedded conductor 116 such that the one or more of the coil windings cut through a magnetic field generated by an electrical current in embedded conductor 116, thus inducing an electrical current in the one or more coil

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windings which may recharge energy storage device **122** and/or provide energy to drive system **124** for operation of vehicle **100**. In addition or alternatively, such coil windings may be configured to receive electrical energy from embedded conductor **116** via electric conduction via roadway **114**, as described in greater detail below.

Axle **106** may comprise any suitable shaft for wheel assembly **104**. Axle **106** may be configured with appropriate bearings, bushings, and mounting points for wheel assembly **104** such that, during rotation of wheel assembly **104**, axle **106** may remain in a substantially fixed position relative to wheel assembly **104**.

An arm **108** may include any suitable structural member configured to mechanically couple powering assembly **102** to the remainder of vehicle **100** (e.g., the frame or chassis of the vehicle). For example, in the embodiment depicted in FIG. 1, an arm **108** may be coupled to a rear axle of vehicle **100** via a bearing, bolt, fastener, and/or other suitable manner. In other embodiments, arm **108** may be coupled at one end to the undercarriage or other appropriate point of vehicle **100** via a bearing, bolt, fastener, weld, and/or other suitable manner. In addition, arm **108** may be coupled at another end to axle **106** via a bearing, bolt, fastener, weld, and/or other suitable manner thus mechanically coupling powering assembly **102** to the remainder of vehicle **100** in a desired manner.

Energy storage device **122** may be electrically coupled to powering assembly **102** and one or more other components of vehicle **100** and may include any device that may store potential energy which may be utilized to operate vehicle **100** and is capable of receiving and storing energy generated via magnetic induction by powering assembly **102**. For example, energy storage device **122** may include a rechargeable electrochemical battery, a fuel cell, a flywheel, hydraulic accumulator, mechanical spring, supercapacitor, and/or any other element operable to store potential energy.

Drive system **124** may be electrically coupled to energy storage device **122** and/or powering assembly **102**, and may include any collection of components and devices that, in the aggregate, convert electrical energy provided by energy storage device **122** and/or powering assembly **102**, and/or chemical energy provided by a fuel (e.g., gasoline, ethanol, etc.) into mechanical energy for propelling vehicle **100**. For example, drive system **124** may include one or more engines, motors, pulleys, belts, drivetrains, axles, wheels, and/or other suitable devices. In addition, although drive system **124** is generically depicted as being present in a particular part of vehicle **100** for purposes of clarity and simplicity of exposition, it is noted that components of drive system **124** may be located throughout vehicle **100**.

Control system **126** may be electrically and/or communicatively coupled to drive system **124**, energy storage device **122**, powering assembly **102** (or components thereof), and/or one or more other components of vehicle **100** and may generally be operable to based on signals received from one or more components of vehicle **100**, communicate control signals to one or more components of vehicle **100** to control operation of such one or more components and/or communicate signals to an operator of vehicle **100** (e.g., via a user interface in a cabin of vehicle **100**).

As shown in FIG. 1, roadway **114** may include embedded conductor **116**. Embedded conductor **116** may comprise any material suitable for conducting an electrical current, including without limitation copper, aluminum, superconductor material (e.g., doped copper oxide), and/or other suitable material. In some embodiments, embedded conductor **116** may include a one or more coil windings of conductive material (e.g., coil windings **266** depicted in FIGS. 2A and 2B)

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oriented in any suitable fashion such that embedded conductor **116** generates a magnetic field above the surface of roadway **114**. In some embodiments, the one or more coil windings may be wound around a ferromagnetic material (e.g., iron) to improve magnetic flux of the generated magnetic field. In some embodiments, embedded conductor **116** may be embedded below the surface of roadway **114** such that the surface of roadway **114** may provide dielectric insulation from embedded conductor **116** in order to reduce or eliminate hazard created if embedded conductor **116** were otherwise exposed. In these and other embodiments, the protective layer the surface of roadway **114** above embedded conductor may have electrically conductive, or dual-mode electrically insulative/electrically conductive properties, so as to, in addition or alternative to creating a magnetic flux for inductive powering of a vehicle **100** upon roadway **114**, embedded conductor **116** may also conduct electrical energy to vehicle **100** through roadway **114**, as described in greater detail below.

In order to carry an electrical current embedded conductor **116** may be electrically coupled to a source of electromagnetic energy (e.g., a power plant, a generating station, and/or other suitable source). The electric current driven to embedded conductor **116** may be direct current or alternating current. In some embodiments, in order to increase the magnetic flux generated by embedded conductor **116** (and thus, the magnetically-induced current in windings of wheel assembly **104**), the electric current driven in embedded conductor **116** may be an alternating current operating at a high frequency (e.g., 240 Hz-400 Hz, compared to 60 Hz commonly available from power plants and generating stations for residential and commercial use). Accordingly, in such embodiments, a frequency converter may be inserted between publically-available source of energy and embedded conductor **116** in order to provide for such increased frequency, as described in greater detail below.

In some embodiments, embedded conductor **116** may include or be part of an electromagnetic strip comprising a series of inductive coils, as described in greater detail below. Such series of inductive coils may be wound around a ferromagnetic material (e.g., iron) and/or encased in an electrically insulated material (e.g., plastic or rubber) that may be embedded into roadway **114**. In these and other embodiments, the electromagnetic strip may be constructed to be flexible, so as to permit handling and transportation on cable spools or a similar package. During application, the electromagnetic strip may be laid into a slot or channel created in roadway **114**.

FIGS. 2A-2D illustrate selected components of powering assembly **102** and roadway **114**, in accordance with particular embodiments of the present disclosure. FIG. 2A depicts an elevation view of powering assembly **102** and roadway **114**, FIG. 2B depicts a cut-away perspective view of powering assembly **102** and roadway **114**, FIG. 2C depicts an exploded view of powering assembly **102**, and FIG. 2D depicts a cut-away perspective view of roadway **114**.

As shown in FIGS. 2A and 2B, a channel **264** may be created in roadway **114**, and embedded conductor **116** may be laid in such channel **264**. Embedded conductor **116** may comprise a flexible electromagnetic strip, including a coil of conductive material **266** (e.g., wire constructed from copper, aluminum, or other conductive material) wrapped (e.g., in loops or turns) about a magnetic core **262** of ferromagnetic or ferrimagnetic material (e.g., iron, ferrite, iron silicide, etc.). In certain embodiments, flexibility of the flexible electromagnetic strip may be sufficient to permit handling and transportation by and on standard cable spools. As described below, segments **272** of embedded conductor **116** may be coupled to one or more switches (e.g., switch **404**) to allow for individual

powering of portions of embedded conductor **116**. During construction of roadway **114**, the electromagnetic strip of embedded conductor **116** may be laid into channel **264**. After the strip is laid into channel **264**, coil **266** may be electrically coupled to a source of electrical energy, such that embedded conductor **116** conducts electrical energy and generates a magnetic flux. A layer of protective asphalt or pavement may be applied on top of the electromagnetic strip, such as layer **268** depicted in FIG. 1. In the case of resurfacing of roadway **114**, the electromagnetic strip may be extracted and reburied at the desired distance from the new surface. In some embodiments, the protective layer (e.g., layer **268**) may have ferromagnetic properties (e.g., the asphalt or pavement comprising layer **268** may include particles of ferromagnetic material such as iron, for example). The presence of ferromagnetic properties in the protective layer may serve to increase magnetic flux generated above roadway **114** by electric current flowing in embedded conductor **116**. In the same or alternative embodiments, channel **264** may be configured to optimize magnetic flux generated above roadway **114** by embedded conductor **116**. For example, in some embodiments, channel **264** may be lined with a metallic material (e.g., aluminum, specially-designed materials with a wavelength corresponding to that of an electromagnetic wave present in embedded conductor **116**, a Halbach array for creating a one-sided flux distribution, etc.). As so configured, such metallic material may serve to direct magnetic flux from channel **264** to above the surface of roadway **114**. Alternatively or in addition, geometry of channel **264** may be configured to optimize magnetic flux. For example, channel **264** may have a parabolic shape which may also serve to direct magnetic flux from channel **264** to above the surface of roadway **114**.

In some embodiments, a surface of roadway **114** substantially above embedded conductor **116** (e.g., layer **268**), may include or be coated with one or materials to further guide magnetic flux lines and/or reduce random dispersion of the magnetic flux lines. For example, in such embodiments, a paint or other covering having ferromagnetic or ferrimagnetic properties may be applied to the surface of roadway **114** in the form of a strip substantially immediately above embedded conductor **116**.

As described above, energy may be transferred from embedded conductor **116** to wheel assembly **104** via magnetic induction. However, in other embodiments, wheel assembly **104** and roadway **114** may be adapted to transfer energy via electric conduction. In such embodiments, the protective layer (e.g., layer **268**) may have electrically insulative, electrically conductive, or dual-mode electrically insulative/electrically conductive properties. In many instances, it may be desirable that protective layer be electrically insulative, such that embedded conductor **116** does not become an electrical shock hazard to people and animals present on the surface of roadway **114**. However, on the other hand, it may be beneficial that the protective later have conductive properties allowing electrical energy to be conducted from embedded conductor **116** to vehicle **100**, to increase transfer of energy between embedded conductor **116** and vehicle **100**. In order to provide desired safety, while allowing for conduction of electrical energy between embedded conductor **116** and vehicle **100**, layer **268** may be formed with a system and/or material allowing it to have dual-mode electrical characteristics such that a portion of it may conduct electrical energy from embedded conductor **116** when a vehicle **100** is proximate to such portion, and may not conduct electrical energy from embedded conductor **116** when a vehicle **100** is not proximate to such portion. Any suitable implementation of

such dual-mode electrical characteristics may be employed. An example of a roadway **114** with such dual-mode characteristics is depicted in FIGS. 3A and 3B.

FIGS. 3A and 3B depict a cross-sectional elevation view of an example of one embodiment for providing dual-mode electrical characteristics for a surface of roadway **114**, in accordance with embodiments of the present disclosure. As shown in FIGS. 3A and 3B, layer **268** may comprise a strip of electrically conductive material (e.g., aluminum, copper, etc.) placed upon a layer of electrically insulative material **302** (e.g., air), wherein such layer of electrically insulative layer is placed upon embedded conductor **116**. In some embodiments, electrically insulative layer **302** may have magnetic properties and thus may include within it include particles of magnetic and electrically conductive material **304** (e.g., iron, iron silicide, and/or another ferromagnetic or ferrimagnetic material), such that in the presence of a magnetic field, particles **304** may form an electrically conductive path, as shown in FIG. 3B. FIGS. 3A and 3B depicts a cross-sectional elevation view of an example of such embodiments. Accordingly, in the absence of a magnetic field, particles **304** may collect (e.g., due to gravity) the bottom of electrically insulative layer **302**, as shown in FIG. 3A. On the other hand, in the presence of a magnetic field, particles **304** may form one or more conductive paths between embedded conductor **116** and layer **268**. The magnetic field inducing alignment of particles **104** in a particular portion of roadway **114** to form one or more conductive paths may be present when a vehicle **100** is proximate to such particular portion. For example, wheel assembly **104** of a vehicle may include a permanent magnet and/or electrical components for producing an induced electromagnetic field capable of aligning particles **304** to complete a path between embedded conductor and layer **268** in portions of roadway **114**, so that the surface of roadway **114** conducts electricity as wheel assembly **104** passes over or near such sections. As another example, as described below, each of individual segments of embedded conductor **116** may be configured to conduct electrical energy when a vehicle **100** is proximate (as determined by sensors present in roadway **114**), and interrupt the flow of current when a vehicle **100** is not proximate to the segment. In such embodiments, the magnetic field induced by embedded conductor **116** while enabled in response to vehicle proximity may align particles **304** to complete a path between embedded conductor and layer **268**.

In addition or alternatively to the embodiment depicted in FIGS. 3A and 3B, layer **268** may include one or more materials that have dual-mode properties in which they may behave as an electrical insulator, but experience a reduction in electrical resistance or behave as an electrical conductor in the present of magnetic and/or electrical fields. Examples of such dual-mode materials may include, without limitation, topological insulator nano-ribbon and cross-correlated manganese oxide exhibiting a magnetoresistance effect. Layer **268** comprising such dual-mode material may be placed over embedded conductor **116**. In embodiments in which energy is transferred between roadway **114** and wheel assembly via electric conduction, wheel assembly **104** may, as described above, provide a magnetic field such that portions of layer **268** may change from insulative to conductive in presence of the magnetic field, thus allowing such portions to conduct electrical energy to wheel assembly **104** as wheel assembly **104** passes over or near such portions of layer **268**.

In some embodiments, embedded conductor **116** may be divided into multiple, individually powered segments **272**, as depicted in FIG. 2D. Also as shown in FIG. 2D, roadway **114** may also have installed therein control units **276** associated

with each segment 272, and conductors 274 coupled from a source of electrical energy (e.g., a publicly available power source) to corresponding segments 272 and control units 276. Conductors 274 may be disposed under the surface of roadway 114 and may comprise any suitable wire, cable, or strip of conductive material configured to conduct electrical energy from a source of electrical energy (e.g., a publicly available power source in the form of overhead or underground transmission lines) to a corresponding segment 272 and control unit 276.

A control unit 276 may be electrically coupled to one or more corresponding conductors 274 and one or more corresponding segments 272, and may include any system, device, or apparatus configured to switch one or more corresponding segments 272 between powered states (e.g., powered or unpowered). FIG. 4 depicts a block diagram of an example control unit 276, in accordance with embodiments of the present disclosure. As shown in FIG. 4, control unit 276 may include a proximity detector 402, a switch 404, and a tuning capacitor 406. Proximity detector 402 may include any system, device, or apparatus configured to detect proximity of a vehicle 100 enabled to receive inductive or conductive electrical energy from embedded conductor 116. For example, in some embodiments, proximity detector 402 may include a radio frequency identification (RFID) receiver configured to receive one or more signals from one or more RFID transmitters disposed in a vehicle 100. As a specific example, in one embodiment a single RFID transmitter may be disposed in certain vehicles 100, and proximity detector 402 may detect the presence of a vehicle 100 by receiving appropriate signals from the single RFID transmitter. As another specific example, in another embodiment, two RFID transmitters may be disposed at opposite ends (e.g., front and rear) of certain vehicles 100, and proximity detector 402 may detect signals from the first RFID transmitter to indicate a vehicle 100 becoming proximate to a segment 272, and detect signals from the second RFID transmitter to indicate the same vehicle leaving proximity of the segment 272. In addition to RFID proximity sensing, proximity sensor 402 may utilize any other suitable detection approach, including optical, electrical, magnetic, acoustical (e.g., Doppler effect), and/or others.

Switch 404 may include any system, device, or apparatus configured to alternatively break an electrical circuit (thus interrupting the current flowing in the circuit) and complete an electrical circuit (thus allowing for current to flow in the circuit), based on a control signal received from proximity detector 402. In some embodiments, switch 404 may be implemented by one or more transistors in a transmission gate configuration. Accordingly, during operation, when a vehicle 100 is proximate to control unit 276, proximity detector 402 may detect such proximity and cause switch 404 to close, such that electrical current flows into a segment 272 corresponding to the control unit. Conversely, when proximity detector 402 does not detect proximity of a vehicle 100, it may cause switch 404 to open, such that flow of electrical current is interrupted to the corresponding segment. Thus, to conserve energy, segments 272 of embedded conductor 116 may each remain in an unpowered state until such time as proximity sensor 402 within a control unit 272 corresponding to a particular segment 272 detects a vehicle 100, at which point the particular segment 272 may power on to provide energy to vehicle 100 in the form of induction and/or conduction.

Control unit 276 may also include one or more tuning capacitors 406 configured to be, when switch 404 is closed, in series with a coil 262 of a segment 272 corresponding to control unit 276. Accordingly, tuning capacitor 406 may provide tuning such that the capacitance of tuning capacitor 406

and the inductance of the corresponding coil 262 generate an inductive-capacitance resonance. Such resonance may be beneficial for inductive powering of a vehicle 100, as the presence of tuning capacitor 406 may tune the frequency of an electromagnetic wave in coil 262 to a desired frequency and/or minimizing an impedance at a particular frequency (e.g., a resonance frequency).

Turning again to FIG. 2D, roadway 114 may also include one or more solar power generators 280, thermoelectric power generators 282, piezoelectric power generators 284, and/or other “alternative” energy power generators. As shown in FIG. 2D, one or more of solar power generator 280, thermoelectric power generator 282, and piezoelectric power generator 284 may be electrically coupled to one or more segments 272 of embedded conductor 116 (e.g., via conductors 274) such that electrical energy generated by one or more of solar power generator 280, thermoelectric power generator 282, and piezoelectric power generator 284 may be transferred to embedded conductor 116, so as to provide electrical energy for induction and/or conduction of electrical energy from embedded conductor to vehicle 100. A solar power generator 280 may include any system, device, or apparatus configured to convert photonic energy (e.g., from the sun and/or vehicle headlights) received by or otherwise impinging solar power generator 280 into electrical energy in the form of an electrical current. For example, in some embodiments solar power generator 280 may include a photovoltaic panel, film, and/or paint placed upon the surface of roadway 114. For example, in the case of a film and/or paint, a two-layer solar cell made of light-absorbing nanoparticles known as quantum dots may be applied to roadway 114 in order to produce solar power generator 280. Such quantum dots may be tuned to absorb different parts of the solar spectrum by varying their size. In these and other embodiments, solar power generator 280 may also include any system, device, or apparatus configured to convert a magnetic field present in photonic energy into electrical energy using optically-induced charge separation and terahertz emission in unbiased dielectrics. In such embodiments, the magnetic field of photonic energy may, in certain materials, affect electron motion in certain materials such that a magnetic dipole is created in the material. By suitably aligning the dipoles in a substantially long fiber, strip, or strand of material, and placing such fiber, strip, or strand on a surface of roadway 114, the fiber, strip, or strand of material may generate a substantial electrical potential to provide electrical energy to embedded conductor 116.

A thermoelectric power generator 282 may be embedded within roadway 114 as shown in FIG. 2D, and may include any system, device, or apparatus configured to convert, using the thermoelectric effect known in the art, thermal energy present in portions roadway 114 proximate to thermoelectric power generator 282 into electrical energy in the form of an electrical current. Thermoelectric power generator 282 may include any suitable material capable of generating electrical current in accordance with the thermoelectric effect, including, without limitation: materials composed of tellurium, antimony, germanium, and silver (TAGS) (including TAGS doped with cerium or ytterbium); skutterudites; and/or lead telluride having nanocrystals of rock salt (SeTe) placed therein.

A piezoelectric power generator 284 may be embedded within roadway 114 as shown in FIG. 2D, and may include any system, device, or apparatus configured to convert vibrational energy present in roadway 114 (e.g., caused by motion of vehicles on roadway 114) into electrical energy in the form of current.

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Electrical energy generated by solar power generator **280**, thermoelectric power generator **282**, and/or piezoelectric power generator **284** may be, in some embodiments, delivered to embedded conductor **116** in the form of an electrical current, such that the electrical current may transfer energy to a vehicle **100** via induction or conduction. In addition or alternatively, electrical energy generated by solar power generator **280**, thermoelectric power generator **282**, and/or piezoelectric power generator **284** may be, in some embodiments, delivered to a public provider of electrical energy (e.g., via a publicly available electrical energy distribution grid) and/or one or more other destinations such that such electrical energy is ultimately consumed by an entity other than vehicles **100** traveling on roadway **114**.

As shown in FIGS. 2A-2C, wheel assembly **104** may include one or more coils **212** of conductive material (e.g., wire constructed from copper, aluminum, or other conductive material) each wrapped (e.g., in loops or turns) about a magnetic core **214** of ferromagnetic or ferrimagnetic material (e.g., iron, ferrite, iron silicide, etc.). For example, in the example embodiment shown in FIGS. 2A-2C, wheel assembly **104** includes 12 coils **212** each wrapped about magnetic core **214**. Each end of each coil **212** may be electrically coupled to a segment of a segmented-ring commutator **218**. In the embodiment depicted in FIGS. 2A-2C, one end of each coil **212** may be in contact with a segment **219** of a first commutator **218** while the other end of each coil is in contact with a segment **219** of second commutator placed opposite to the first commutator **218** within wheel assembly **104**. Wheel assembly **104** may include a holder **216** configured to mechanically and electrically coupled coils to commutator **218** using appropriate bolts, screws, and/or other fasteners.

Wheel assembly **104** may also include tire **220**. Tire **220** may comprise any circular-shaped covering (e.g., a rubber tire) that fits around other components of wheel assembly **104** (e.g., coils **212**) protect other components of wheel assembly **104** and provide a flexible cushion that absorbs shock while maintaining contact with a roadway (e.g., roadway **114**). In embodiments in which energy is transferred from roadway **114** to wheel assembly **104** via electric conduction, tire **220** may be formed of one or more materials having electrically conductive properties, while still having mechanical elasticity (e.g., an elastic polymer having electrically conductive properties), thus allowing tire **220** to conduct electrical energy from a surface of roadway **114** to energy storage device **122** and/or drive system **124** (as described in greater detail below) while maintaining elasticity comparable to that of a traditional rubber tire.

In some embodiments (not explicitly shown), wheel assembly **104** may, instead of being implemented as a wheel separate from those wheels of vehicle **100** intended to provide drive and/or steering to the vehicle (e.g., the standard, traditional four tires of a conventional highway vehicle), wheel assembly **104** may be implemented as or part of one or more wheels of vehicle **100** that provide drive and/or steering to vehicle **100**.

In addition to other components described above, powering assembly **102** may include one or more brushes **220**, brush holders **224**, brush holder brackets **222**, fasteners **226**, **228**, magnetic sensors **204**, worm gears **244**, and bearings **208**. Brushes **220** may comprise electrically conductive material (e.g., copper, aluminum, carbon, etc.) and may be configured to permit conduction of magnetically-induced current and electrically conducted current in coils **212** from segments of commutator **218** to other components of vehicle **100** (e.g., energy storage device **122** and/or drive system **124**). During operation of powering assembly **102**, it may be desirable that

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brushes **220** remain in physical contact with commutator **218**, to ensure electrical conductivity between coils **212** and other components of vehicle **100**. Accordingly, each brush **220** may be mechanically coupled to a brush holder **224** configured to cause its corresponding brush **220** to maintain in contact with commutator **218**. Brush holders **224** may be maintained in place by one or more brush holder brackets **222** and fasteners **226** and **228**. A fastener **226**, **228** may include any suitable bearing, bolt, and/or other fastener. A bracket **222** may be any structural member configured to, in connection with fasteners **226**, **228** maintain brush holders **224** and/or brushes **220** at a desired position relative to other components of powering assembly **102**.

Magnetic sensor **204** may be mechanically mounted to axle **106** or any other suitable component of powering assembly **102** and may include any system, device, or apparatus configured to sense the presence and intensity of a magnetic field (e.g., a magnetic field generated by embedded conductor **116**). Magnetic sensor **204** may be implemented as a Hall effect sensor or any other suitable type of sensor. Magnetic sensor **204** may be electrically coupled to motor **217**, such that magnetic sensor **204** may communicate a signal to motor **217** indicative of the intensity of a detected magnetic field.

Motor **217** may be mechanically coupled to wheel assembly **104** via worm gear **244** and, based on signals received from magnetic sensor **204** indicative of a magnetic field intensity, motor **217** may engage with worm gear **244** so as to cause wheel assembly **104** to move in a lateral direction along axle **106** (e.g., in a direction parallel to the axis of axle **106**). Such movement may be performed in order to align wheel assembly **104** with embedded conductor **116**, in order to cause wheel assembly **104** to rotate in a position where magnetic field strength produced by embedded conductor **116** is the greatest. In some embodiments, lateral translation of wheel assembly **104** by motor **217** and worm gear **244** may be limited by bearings **208** mechanically coupled to axle **108**.

In these and other embodiments, magnetic sensor **204** may also sense the presence of intensity of a magnetic field so as to determine whether vehicle **100** is on or near a roadway (e.g., roadway **114**) having an embedded conductor **116** capable of generating inductive or conductive electrical energy. Accordingly, in such embodiments, one or more arms **108** and/or other components of vehicle **100** may be configured to, after detecting a magnetic field of minimum intensity by magnetic sensor **204**, lower wheel assembly **104** so that tire **220** of wheel assembly makes frictional contact with roadway **114**. In addition or alternatively, after detecting a magnetic field of minimum intensity by magnetic sensor **204**, magnetic sensor **204** may communicate a signal to an operator of vehicle **100** (e.g., via control system **126**) indicating proximity to an energized roadway **114**, and such operator may (e.g., via a user interface in the cabin of vehicle **100**) cause wheel assembly **104** to lower. Once lowered, magnetic sensor **204**, in connection with motor **217** and worm gear **244**, laterally translate wheel assembly **104** such that wheel assembly **104** remains proximate to embedded conductor **116**. Upon leaving an energized roadway **114**, one or more arms **108** and/or other components of vehicle **100** may be configured to, after detecting a magnetic field intensity below a minimum intensity by magnetic sensor **204**, raise wheel assembly **104** from the surface roadway **114**. In addition or alternatively, after detecting a magnetic field below a minimum intensity by magnetic sensor **204**, magnetic sensor **204** may communicate a signal to an operator of vehicle **100** (e.g., via control system **126**) indicating vehicle is no longer in proximity to an energized

roadway 114, and such operator may (e.g., via a user interface in the cabin of vehicle 100) cause wheel assembly 104 to raise.

In some embodiments, magnetic sensor 204 may also communicate one or more signals to control system 126 and/or an operator of vehicle 100 indicating that, based on the position of magnetic sensor 204 relative to embedded conductor 116, vehicle 100 may be in danger of leaving roadway 114 and/or a current lane of travel of vehicle 100. Such a situation may occur is an operator is falling asleep, has his/her attention diverted from the road, and/or is otherwise failing to maintain a vehicle 100 on roadway 114 or the present lane of travel. Thus, in response, an operator may manually respond to the alert by correcting (e.g., via a steering wheel in the cabin of vehicle 100) the detected deviation and/or control system 126 may automatically communicate signals to drive system 124 and/or other components of vehicle 100 to steer and/or alter the velocity of vehicle 100 in order to correct the detected deviation. Thus, magnetic sensor 204, control system 126, and/or other components of vehicle 100 may operate in concert to reduce the occurrence of vehicular accidents.

In operation, wheel assembly 104 may rotate about axle 108 due to friction of tire 220 against roadway 114 while vehicle 100 is in motion. As wheel assembly 114 passes across the surface of roadway 114, coils 212 may intersect perpendicularly with imaginary field lines of magnetic flux generated by embedded conductor 116, thereby inducing an electrical current at each end of coils 212. The induced electric current in coils 212 may be conducted to other components of vehicle 100 (e.g., via commutator 218, brushes 220, etc.) in order to recharge energy storage device 122, power drive system 124 of vehicle 100, and/or power other components of vehicle 100.

Although FIGS. 1 and 2A-2D depict only a single induction wheel assembly 104 for inductive powering of vehicle 100, in some embodiments, a vehicle 100 may include more than one induction wheel assembly 104. Although FIGS. 2A-2D depict inductive powering of a vehicle via induction wheel assembly 104, in some embodiments induction powering assembly 102 may include other components for inductive transfer of energy from embedded conductor 116 to vehicle 100. For example, induction powering assembly 102 may include a rod of ferromagnetic material wound with conductive material and configured to act as a secondary coil for transferring electrical energy from embedded conductor 116 via induction. Such rod of conductive material may be carried by an induction wheel assembly or other suitable mode of carriage.

In addition or alternatively to receiving energy via induction from embedded conductor 116, wheel assembly 104 may receive energy via conduction from embedded conductor 116. In embodiments supporting conduction from embedded conductor 116 via wheel assembly 104, wheel assembly 104 may include a tire 220 or covering having electrically conductive properties, thereby allowing conduction of electrical energy from a surface of the tire 220 or other covering to conductive components of wheel assembly 104 (e.g., commutator 218, brushes 220). Also as described above, layer 268 above embedded conductor 116 may, in some embodiments, be configured such that portions of layer 268 conduct electrical energy from embedded conductor 116 to wheel assembly 104 as wheel assembly 104 passes over or near such sections. Thus, electrical energy may be conducted from embedded conductor 116 to wheel assembly 104 and conducted from wheel assembly 104 to other components of vehicle 100 (e.g., via commutator 218, brushes 220, etc.) in order to recharge

energy storage device 122, power drive system 124 of vehicle 100, and/or power other components of vehicle 100.

In certain embodiments, conductive materials present in vehicle 100 and roadway 114 (e.g., coils 212, tires 220, embedded conductor 116, conductors 272, etc.), may be configured to transmit communication signals, in addition to transmission of electrical energy for powering of vehicles 100. For example, communications packets or frames (generally referred to herein as "datagrams") of any suitable communication standard or protocol may be multiplexed into conductors 272 in accordance with any approach that may be presently or in the future known. Thus, a control system 126 of a first vehicle 100 may be capable of generating and transmitting (e.g., via tire 220 and/or other electrically conductive components) signals to embedded conductor 116. Embedded conductor 116 may further communicate such signals to a second vehicle 100 (e.g., via tire 220 and/or other conductive components of the second vehicle 100) and/or another destination (e.g., via conductors 272). In addition or alternatively, vehicles 100 may also receive signals communicated from a source other than another vehicle 100 (e.g., via conductors 272). Such communication of signals may have many numerous applications. For example, signals communicated between vehicles 100 may serve to alert control systems 126 of vehicles as to the proximity of vehicles 100 to each other, so as to avoid collisions or permit the introduction of autonomous or "driverless" cars that are able to safely travel over roadways without collisions based on signals communicated between vehicles 100 indicative of the proximity of vehicles to each other. As another example, vehicles 100 may transmit information to a remote computing device, which may record such information in order to meter use of a roadway 114 (e.g., for the purposes of collecting tolls or use-based taxes for use of roadway 114), study traffic density and/or congestion, and/or for other suitable uses. As a further example, vehicles may receive information from a remote computing device which may be displayed to an operator via a user interface in the cabin of vehicle 100, wherein the user interface may display information regarding traffic congestion, roadway construction, detours, navigation and/or map information (e.g., similar to that displayed in traditional GPS navigation devices), and/or other suitable information.

FIG. 5 depicts a block diagram of a conventional gasoline-powered vehicle 500 adapted with a conversion kit to allow for powering of the vehicle via a roadway-embedded conductor, in accordance with embodiments of the present disclosure. As is known in the art, a conventional gasoline-powered vehicle may include a number of components, including without limitation, one or more pulleys 501, one or more belts 502, an alternator 503, one or more belt drives 505, an internal combustion engine 506, an air conditioning system 507, a hydraulic pump 508, a transmission 514, wheels 515-518, an accelerator pedal 520, a drive train 521, and one or more lights 527. Because the characteristics and functionality of such components are well known in the art, their characteristics and functionality are not set forth in detail in this disclosure. For purposes of clarity and exposition, components in FIG. 5 traditionally found in a conventional combustion engine vehicle have been assigned reference numerals beginning with the numeral 5.

A conversion kit may include any system, device, or apparatus configured to convert an existing conventional combustion engine vehicle into a gas-electrical hybrid vehicle in which electrical energy used to power the vehicle is received, at least in part, by induction and/or conduction from a roadway-embedded conductor (e.g., embedded conductor 116 in roadway 114) via a powering assembly having a wheel



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assembly (e.g., wheel assembly 104 of powering assembly 102). As shown in FIG. 5, the conversion kit may include wheel assembly 104, energy storage device 122, clutches 604, 610, 612, electric motor 609, tachometers 611, 613, manual ignition switch 628, and controller 629. For purposes of clarity and exposition, components in FIG. 5 comprising the conversion kit (other than wheel assembly 104 and energy storage device 122) have been assigned reference numerals beginning with the numeral 6.

Electric motor 609 may be coupled to energy storage device 122, accelerator pedal 520, controller 529, tachometer 611, clutch 610, and/or one or more other components of vehicle 500. Electric motor 609 may be any system, device, or apparatus configured to convert electrical energy (e.g., stored in energy storage device 122) to mechanical energy for driving drive train 521, wheels 515-518 and/or other components of vehicle 500. In some embodiments, electric motor 609 may be installed proximate to drive train 521, parallel to the existing transmission 514.

Clutches 604, 610, and 612 may each include any system, device, or apparatus configured to transmit mechanical power from one component (e.g., a motor) to another (e.g., a drive train). In some embodiments, one or more of clutches 604, 610, and 612 may comprise an electromagnetic clutch. As shown in FIG. 5, electromagnetic clutch 610 may be coupled between electric motor 609 and drive train 521, and electromagnetic clutch 612 may be coupled between transmission 514 and drive train 521. Clutches 610 and 612 may be configured to operate in tandem such that when clutch 610 is engaged, clutch 612 is disengaged, and vice versa. Accordingly, when electric motor 609 is engaged in fraction of vehicle 500 via drive train 521 and wheels 515-518, clutch 612 may disengage internal combustion engine 506, and vice versa.

Clutch 604 may be mounted on or near a main pulley shaft of internal combustion engine 506, and may be configured to disengage pulley drive 505 from internal combustion engine 506 when electric motor 609 is engaged with and internal combustion engine 506 is disengaged from drive train 521, rendering pulley drive 505 in a free motion state. In addition, clutch 604 may be configured to engage pulley drive 505 when combustion engine 506 is engaged with drive train 521. Substantially contemporaneously with the engaging of electric motor 609 with and disengaging of internal combustion engine 506 from drive train 521, alternator 503 may assume the function of an electric motor (e.g., powered from energy storage device 122 and/or induction powering assembly 102) to drive belt 502 to generate functionality of auxiliary equipment including air conditioning system 507, hydraulic pump 508, and/or other components.

As shown in FIG. 5, accelerator pedal 520 may be communicatively coupled to electric motor 609, such that depression of accelerator pedal 520 may regulate the speed of electric motor 609, and accordingly, speed of vehicle 500.

In addition, as shown in FIG. 5, electric motor 609 may be coupled to and may receive electrical energy in the form of an electric current from energy storage device 122. As described in greater detail above, energy storage device 122 may be charged via electrical energy received by conduction and/or induction via wheel assembly 104 from embedded conductor 116. Although not explicitly shown in FIG. 5, in some embodiments electric motor 609 may receive electrical energy directly from wheel assembly 104.

Tachometers 611 and 613 may be mounted respectively to the shaft of internal combustion engine 506 and the shaft of electric motor 609. Tachometer 611 may be configured to monitor the angular speed of electric motor 609 such that,

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when vehicle 500 is switched from electric-powered to gasoline-powered mode, internal combustion engine 506 may adjust its angular speed based on the angular speed measured by tachometer 611. Similarly, tachometer 613 may be configured to monitor the angular speed of internal combustion engine 506 such that, when vehicle 500 is switched from gasoline-powered to electric-powered mode, electric motor 609 may adjust its angular speed based on the angular speed measured by tachometer 613.

Controller 629 may be any system, device, or apparatus generally configured to receive information from one or more sensors (e.g., tachometers 611, 613, magnetic sensor 204, etc.) and/or control operation of one or more components of vehicle 500. For example, controller 629 may include an RPM monitor 631 configured to receive signals from tachometers 611, 613 indicative of motor speed of electric motor 609 and/or internal combustion engine 506 in order to properly adjust angular speeds of either when switching from one mode of operation to another (e.g., gasoline-powered to electric-powered mode, or vice versa). As another example, controller 629 may include a field indicator 630 configured to receive a signal from magnetic sensor 204 indicative of proximity of induction wheel assembly 104 to an embedded conductor 116 and based on the signal, switch between gasoline-powered mode and electric-powered mode (or vice versa) by actuating automatic ignition switch 632, and/or control alignment of induction wheel assembly with embedded conductor 116 by communicating appropriate control signals to a motor (e.g., motor 217) or induction wheel assembly 104. As further example, controller 629 may monitor vital parameters of energy storage device 122 or other components of vehicle 500.

A conversion kit may also include manual ignition switch 628, allowing an operator of vehicle 500 to select between gasoline-powered mode and electric-powered mode.

While a particular arrangement of components is depicted in FIG. 5, various components of vehicle 500, including the conversion kit, may be arranged in any suitable manner. For example, in some embodiments, despite that electric motor 609 is shown as coupled to drive train 521 via clutch 610, electric motor 609 may in some embodiments (e.g., those in which electric motor 609 is a multi-speed motor) be placed "before" transmission 514, with clutches or other control mechanisms configured to select between electric motor 609 and internal combustion engine 506 for engaging transmission 514.

Based on the foregoing, powering assembly 102 may provide improved systems and methods for electrical powering of vehicles. Modifications, additions, or omissions may be made to vehicle 100 and powering assembly 102 without departing from the scope of the present disclosure.

What is claimed is:

1. A powering assembly comprising:

an axle;

a wheel coupled to the axle and configured to rotate about the axle in a plane substantially perpendicular to an axis of the axle;

at least one secondary coil winding affixed to the wheel and configured such that when the wheel is proximate to an embedded conductor embedded in a roadway and carrying a first electrical current, a magnetic field induced by the first electrical current induces a second electrical current in the at least one secondary coil winding;

a magnetic sensor configured to determine an intensity of a magnetic field; and

an actuator communicatively coupled to the magnetic sensor and configured to, based on at least the intensity,

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- laterally move the wheel in a direction substantially parallel to the axis, the actuator comprising:  
a worm gear mechanically coupled to the axle; and  
a motor mechanically coupled to the worm gear.
2. A powering assembly according to claim 1, further comprising: 5  
at least one commutator electrically coupled to the at least one secondary coil; and  
one or more brushes configured to:  
electrically couple to the at least one commutator; and 10  
electrically couple to at least one of a drive system of a vehicle and energy storage device of a vehicle such that the second electrical current in the at least one secondary winding is conducted to at least one of the drive system and the energy storage device. 15
3. A powering assembly according to claim 1, further comprising an arm mechanically coupled to the axle and configured to mechanically couple the powering assembly to a vehicle.
4. A vehicle comprising: 20  
a chassis; and  
powering assembly mechanically coupled to the chassis, the powering assembly comprising:  
an axle;  
a wheel coupled to the axle and configured to rotate 25  
about the axle in a plane substantially perpendicular to an axis of the axle;  
at least one secondary coil winding affixed to the wheel and configured such that when the wheel is proximate to an embedded conductor embedded in a roadway and carrying a first electrical current, a magnetic field induced by the first electrical current induces a second electrical current in the at least one secondary coil winding; 30  
a magnetic sensor configured to determine an intensity of a magnetic field; and  
an actuator communicatively coupled to the magnetic sensor and configured to, based on at least the intensity, laterally move the wheel in a direction substantially parallel to the axis, the actuator comprising: 40  
a worm gear mechanically coupled to the axle; and  
a motor mechanically coupled to the worm gear.
5. A vehicle according to claim 4, the powering assembly further comprising:  
at least one commutator electrically coupled to the at least 45  
one secondary coil; and  
one or more brushes configured to:  
electrically couple to the at least one commutator; and  
electrically couple to at least one of a drive system of a vehicle and energy storage device of a vehicle such 50  
that the second electrical current in the at least one secondary winding is conducted to at least one of the drive system and the energy storage device.

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6. A vehicle according to claim 4, further comprising an arm mechanically coupling to the axle to the chassis.
7. A method for powering a vehicle comprising:  
coupling a wheel to an axle such that the wheel rotates about the axle in a plane substantially perpendicular to an axis of the axle;  
affixing at least one secondary coil winding to the wheel such that when the wheel is proximate to an embedded conductor embedded in a roadway and carrying a first electrical current, a magnetic field induced by the first electrical current induces a second electrical current in the at least one secondary coil winding; and  
mechanically coupling an actuator to the axle such that, based on an intensity of a magnetic field detected by a magnetic sensor communicatively coupled to the actuator, the actuator causes the wheel to laterally move in a direction substantially parallel to the axis, the actuator comprising:  
a worm gear mechanically coupled to the axle; and  
a motor mechanically coupled to the worm gear.
8. A method according to claim 7, further comprising:  
electrically coupling at least one commutator to the at least one secondary coil;  
electrically coupling one or more brushes to the at least one commutator; and  
electrically coupling the one or more brushes to at least one of a drive system of a vehicle and energy storage device of a vehicle such that the second electrical current in the at least one secondary winding is conducted to at least one of the drive system and the energy storage device.
9. A method according to claim 7, further comprising mechanically coupling an arm to the axle, the arm configured to mechanically couple to a vehicle.
10. An assembly for a vehicle comprising:  
an axle;  
a wheel coupled to the axle and configured to rotate about the axle in a plane substantially perpendicular to an axis of the axle;  
a magnetic sensor mechanically coupled to at least one of the axle and the wheel and configured to determine an intensity of a magnetic field; and  
an actuator communicatively coupled to the magnetic sensor and mechanically coupled to at least one of the axle and the wheel and configured to, based on at least the intensity, laterally move the wheel in a direction substantially parallel to the axis, the actuator comprising:  
a worm gear mechanically coupled to the axle; and  
a motor mechanically coupled to the worm gear.
11. An assembly according to claim 10, further comprising an arm mechanically coupled to the axle and configured to mechanically couple the powering assembly to a vehicle.

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