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(54) Title: VEHICLE ENERGY MEASUREMENT SYSTEM

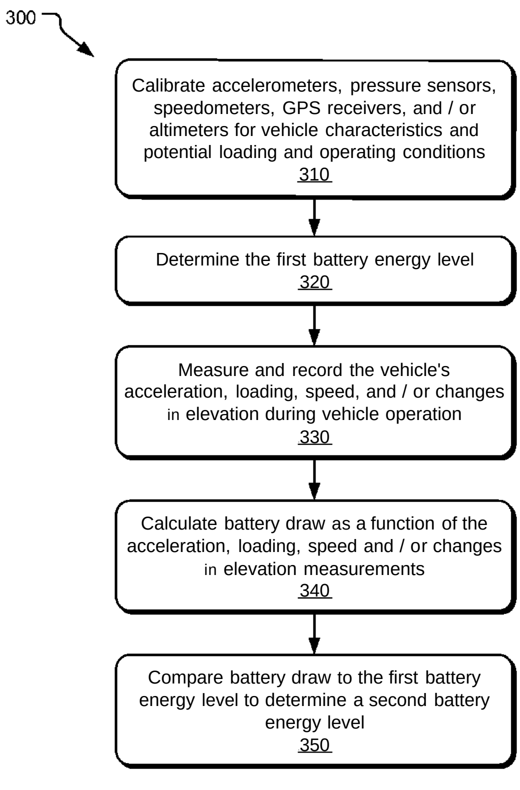

FIG. 3

(57) Abstract: An electric vehicle battery energy level is calculated by measuring acceleration, load, speeds, and/or changes in elevation (motion measurements) 330 that the vehicle 104 experiences during operation. By correlating motion measurements of a field vehicle to motion measurements of a test vehicle during operational profile testing, the amount of energy consumed out of the field vehicle battery is calculated 340. The amount of energy consumed is then compared with the battery's initial energy level 350 resulting in the calculation of an electric vehicle battery energy level without directly measuring the actual current drawn out of the battery.

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TITLE

Vehicle energy measurement system

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CROSS REFERENCE

[0001] This application claims the benefit of priority pursuant to 35 U.S.C. § 119(e) of U.S. provisional application no. 61/001,487 filed 31 October 2007 entitled "User distributed shared vehicle system," which is hereby incorporated herein by reference in its entirety.

[0002] The present application is also related to Patent Cooperation Treaty application no. PCT/US2008/067036 filed 13 June 2008 entitled "Shared vehicle management system," which is hereby incorporated herein by reference in its entirety.

BACKGROUND

[0003] The presently disclosed technology relates to electric vehicle battery energy level monitoring, measurement, and calculation, including but not limited to, using accelerometer-based measurements to calculate energy expended.

[0004] The task of vehicle battery energy level estimation is commonly divided up into monitoring the current going into the battery during battery charging and monitoring the current going out of the vehicle battery during vehicle use. One known method of monitoring the charging of electric vehicles is to monitor the current passing to the vehicle battery charger. Typical battery energy level monitoring systems can be used to calculate the increase in the vehicle battery energy level based upon battery charge rate and the amount of time the vehicle has been charging.

[0005] When the electric vehicle is consuming electricity stored in the vehicle battery to move, the current state of the art does not provide a convenient aftermarket system or method of monitoring the vehicle battery energy level. Typical onboard vehicle battery energy level estimation equipment measures both the electricity entering the vehicle battery during charging and the electricity exiting the vehicle battery during vehicle use. This type of measurement is typically accomplished by placing a low resistance, high current capacity shunt or a Hall effect sensor near the high current carrying conductor of the battery.

[0006] Vehicle manufacturers have the ability to design the energy level meter into their system and route wires in the vehicle internal wiring harnesses. However, once the vehicle has been manufactured and the battery monitoring system installed, there is typically little electrical access to the energy level monitoring circuitry. This makes it difficult for an aftermarket system to calculate the battery energy level using the original equipment manufacturer's battery monitoring equipment. Further, with the lack of electric vehicle standards, each type of vehicle may have a different interface making it a challenge for an aftermarket system designer to use the original equipment manufacture data. In the present art, aftermarket system designers may install similar redundant equipment to measure the current flowing in and out of the vehicle battery. However, this is often costly, and requires duplication of energy level estimation hardware, the need to tap into high voltage and/or high current power signals, and an ability to report the data to an aftermarket systems computer. Although possible, the cost and safety issues associated with connecting additional equipment to calculate the vehicle energy level makes this approach problematic.

SUMMARY

[0007] The presently disclosed technology overcomes the challenges cited above associated with monitoring an electric vehicle battery energy level by measuring acceleration, load, speed, air resistance, and/or changes in elevation (collectively "motion measurements") the vehicle experiences during operation. Calibration data is collected by recording the motion measurements and correlating them with an amount of energy drawn out of a test vehicle battery in test scenarios. The calibration data may then be used to calculate a field vehicle battery energy level without directly measuring the actual current drawn out of the battery. Small one, two, and three axis accelerometers are commercially available, relatively inexpensive, and can provide an accurate measure of the acceleration experienced by an electric vehicle.

[0008] One advantage of using accelerometers, pressure sensors, speedometers, global positioning system (GPS) receivers, and/or altimeters (collectively "vehicle instruments") to calculate an electric vehicle energy level is elimination of the need to tap into the electric vehicle high voltage and/or high current circuitry. Additionally, the vehicle instruments could be mounted near an onboard computer in an aftermarket package located anywhere on the vehicle.

[0009] Information regarding the reduction of the vehicle energy level during vehicle use is especially useful in a shared vehicle rental system. More specifically, this information can be used by the rental system to determine if a vehicle has sufficient battery energy level to be available for rent. However, the presently disclosed technology could be applicable to any aftermarket system seeking to monitor the vehicle energy level. Further, although the electric

vehicle energy measurement system described herein has operational advantages for a shared electric vehicle, it could also be applied to virtually any type of vehicle propulsion system.

[0010] In a rental fleet implementation, the same vehicle instruments and computer may be used to calculate the battery energy level for every type of vehicle deployed in a rental fleet. New "acceleration to current" coefficients and "constant velocity to current coefficients" may be calculated when a new vehicle type is integrated into the electric vehicle rental system. The vehicle energy measurement system may calculate the number of operational minutes remaining based on the calculated vehicle battery energy level. This calculation may be based on a typical riding style or it may be customized, based on the specific riding style of the current user.

[0011] After a vehicle is returned to a stationary charging station at the end of the vehicle rental period, a charge port current monitor located at the charging station or onboard the vehicle may be used to detect the current flowing into the vehicle battery. A computer in communication with the charge port current monitor through a wired or wireless communication link may then calculate the increase in battery energy level during battery recharge period.

[0012] The presently disclosed technology may be applied to a variety of electric vehicles utilizing a variety of battery technologies. To obtain an accurate calculation of a vehicle battery energy level, the electric vehicle energy measurement system may be calibrated to the type and size of battery used in the vehicle. This calibration process could be performed on a monitored test vehicle to gather the needed operational data to correlate vehicle instrument readings to battery drain.

BRIEF DESCRIPTION OF DRAWINGS

[0013] **FIG.** 1 illustrates a vehicle energy measurement system for an electric vehicle showing the interaction between an electric vehicle, associated instruments, an onboard computer, and a central computer.

[0014] FIG. 2 illustrates a user display of a vehicle energy management system showing battery energy level in charging, vehicle off/parked, and vehicle operating modes.

[0015] FIG. 3 is a flow chart illustrating an exemplary process for calculating energy level for an electric vehicle battery.

[0016] FIG. 4 is a flow chart illustrating an exemplary process for calculating an electric vehicle battery energy level within an electric vehicle rental system.

[0017] FIG. 5 is an exemplary computer system for implementing the presently disclosed technology.

DETAILED DESCRIPTION

[0018] The presently disclosed technology overcomes the challenges cited above associated with monitoring an electric vehicle battery energy level by collecting motion measurements a vehicle experiences during operation. Calibration data is collected by recording the motion measurements and correlating them with an amount of energy drawn out of a test vehicle battery in test scenarios. The calibration data may then be used to calculate a field vehicle battery energy level without directly measuring the actual power drawn out of the battery. Small one, two, and three axis accelerometers are commercially available, relatively inexpensive, and can provide an accurate measure of the acceleration experienced by an electric vehicle. Other vehicle instruments are commercially available and may collect various other motion measurements.

[0019] While the advantages of monitoring an electric vehicle battery energy level according to the presently disclosed technology are discussed below with particularity to electric vehicle rental systems, the vehicle energy measurement system may be applied to any electric vehicle where it is desirable to monitor the battery energy level without directly measuring the battery output during use. Further, the presently disclosed technology may be applied to virtually any vehicle propulsion system where it is desirable to calculate the discharge of stored energy during vehicle use to calculate the status of the stored energy rather than directly measure the status of the stored energy. Such example vehicle propulsion systems include, but are not limited to, fossil fuels (e.g., gasoline, diesel fuel, natural gas, and coal), compressed air, and fuel cells.

[0020] Referring now to FIG. 1, an exemplary implementation of a vehicle energy measurement system 100 is shown. An electric vehicle 104 may be equipped with one or more of accelerometers 108, pressure sensors 112, speedometers 116, global positioning system (GPS) receivers 152, and/or altimeters 152 (collectively "vehicle instruments"). The vehicle instruments may be used to calculate the energy output of the vehicle battery during vehicle operation. As such, according to the presently disclosed technology, it is unnecessary to directly measure the current discharged from the vehicle battery during vehicle operation to measure the battery energy level.

[0021] In one implementation, the accelerometer 108 may **be** the primary means of measuring the energy output of the vehicle battery. The accelerometer 108 may **be** oriented such that a longitudinal axis is oriented along the length of the vehicle 104, a lateral axis is oriented along the breadth of the vehicle 104, and a vertical axis is oriented vertically. Since an electric vehicle may not be always accelerating, it may be desirable to determine if the vehicle 104 is motionless or moving at a constant velocity at a given point in time. Since both a zero velocity and a constant velocity of the vehicle 104 may be indicated by the accelerometer as zero in the longitudinal axis, another method may be utilized to determine a constant velocity. In one implementation, this function is achieved using a speedometer 116 to measure longitudinal speed.

[0022] Alternately, if the vehicle 104 has a known initial velocity of zero, the vehicle 104 moving with a constant longitudinal velocity would first have to experience a longitudinal acceleration. The longitudinal acceleration could be measured with a single longitudinal axis accelerometer 108 with its sensing axis oriented longitudinally. The magnitude of the acceleration experienced from zero to a constant velocity may be correlated into a partial depletion of the vehicle battery energy level. If the vehicle 104 does not experience an opposite longitudinal acceleration, the vehicle continues to move at a constant velocity with a magnitude based upon the duration and magnitude of the longitudinal acceleration.

[0023] The vehicle battery energy level may be further depleted by a known magnitude for each period of time that the vehicle 104 is moving at the constant velocity. Until the accelerometer 108 outputs a further acceleration or deceleration, the battery may supply a relatively constant current to the vehicle 104 moving at a relatively constant velocity. Integration of the power discharged from the battery over time yields the corresponding reduction of the battery energy level.

[0024] In another implementation, additional accelerometers 108 could be used to measure lateral and vertical accelerations of the vehicle 104. Alternatively, one multi-axis accelerometer 108 may be used in place of multiple accelerometers 108 measuring on multiple axes. A laterally oriented accelerometer 108 may measure steering motion accelerations and give an indication that the vehicle is moving and not stationary. Additionally, a vertically oriented accelerometer 108 may detect bumps in the road or vibrations associated with moving at a constant velocity, giving further indication that the vehicle 104 is moving rather than stationary.

[0025] If the vehicle 104 is traveling at a constant velocity on a straight smooth surface, it may be difficult to determine whether the vehicle 104 is moving or stationary at a specific point in time using the techniques described above. However, since it may not be necessary for the system 100 to display instantaneous vehicle battery drain, the system 100 could monitor the amount of time the vehicle 104 continues at zero acceleration and wait until the vehicle 104 decelerates, turns, or encounters a bump to determine that the vehicle 104 is actually traveling at a constant velocity greater than zero. By way of example and not limitation, after a predetermined amount of time of zero acceleration, the system 100 may find that the vehicle 104 is not moving and that perhaps the user has decelerated to zero at a rate beyond the ability of the accelerometer 108 to detect. In one implementation, the predetermined amount of time may be based upon the length of long smooth straight routes that the vehicle 104 might encounter.

[0026] In another implementation, a slight vibration may be designed to occur when the vehicle 104 is in motion. The accelerometer 108 may detect if the vehicle 104 is moving by sensing the vibration. Further, the accelerometer 108 may also calculate the speed of the vehicle 104 by measuring frequency of the vibration. In other implementations, the vibration may serve additional purposes including, but not limited to, audible warnings to nearby pedestrians and providing the user with a sense of the vehicle's speed without providing a speedometer.

[0027] In another implementation, the system 100 may record accelerations that were encountered during vehicle use to monitor the user's behavior. This information may be useful to determine if a particular user rides too aggressively. Some accelerometers have a zero G signal that indicates when the vehicle 104 becomes airborne or starts to freefall. This signal could be useful to monitor and record when and how often the vehicle 104 is jumped off of curbs or other objects. The system 100 may use this information to determine which user was responsible for damage associated with aggressive jumping or mishandling of the vehicle 104. The information may also be used as evidence of a user's aggressive vehicle handling to determine when vehicle damage may have occurred. The information may further be used to terminate certain users with a propensity for damaging vehicles 104 through aggressive driving behavior.

[0028] The weight of a vehicle user may significantly affect the vehicle range and rate of acceleration versus battery consumption. Thus it may be desirable for the system 100 to know the weight of the vehicle user. In one implementation, the system 100 may prompt the user to reveal his/her weight to the system 100. The system 100 may include the user's weight as data to accurately calculate the vehicle range.

[0029] In another implementation, a wired or wireless pressure sensor 112 may measure the difference in tire air pressure between a user-less vehicle 104 and a vehicle 104 with a user on board. The difference in air pressure could be correlated to determine the weight of the user. In yet another implementation, tire pressure could be monitored to detect unwanted aggressive behavior of the user. More specifically, wild variations in tire pressure could be an indication of vehicle jumping, bumping, or dumping onto the ground, or impact with other objects. Further, the vehicle 104 may be unavailable to certain users based on past unwanted aggressive behavior of the user or during certain hours (e.g., at certain locations and/or during certain hours, such as 9:30 pm on Friday night on a college campus).

[0030] In yet another implementation, the user's weight could be calculated by measuring the maximum acceleration encountered during a specific period of vehicle use associated with the particular user. Heavier users may experience a smaller maximum acceleration while lighter users may experience a larger maximum acceleration. By estimating the weight of the user and measuring the acceleration during a period, it may be possible to calculate with greater accuracy the reduction in the vehicle battery energy level.

[0031] Alternatively, if the user's weight is unknown, the system 100 may assume a default user weight greater than that of an average person, e.g., 220 lbs. This user weight estimation approach may yield a energy level that is not under-calculated for most users. In one implementation, the system 100 may indicate to the user that if he/she weighs less than 220 lbs., then he/she could expect to have greater range than calculated by the system 100. Additionally, users over 220 lbs may be warned that the vehicle range may be less than calculated by the system 100.

[0032] Some vehicles 104 may incorporate regenerative braking. If regenerative braking is employed on the vehicle 104, the system 100 may calculate the amount of energy flowing into the vehicle battery by monitoring the vehicle deceleration. More specifically, if the vehicle 104 slowly decelerates, the system 100 may determine that an inherent resistance (e.g., wind resistance, rolling resistance, and mechanical friction) in the vehicle operation is the cause and no regenerative braking current is directed into the vehicle battery. However, once a threshold magnitude of deceleration is measured by the accelerometer 108, the system 100 may determine that regenerative braking is the cause and calculate the amount of energy transferred into the vehicle battery.

[0033] Additionally, if regenerative braking is employed, the system 100 may attribute a percentage of the braking deceleration to regenerative braking and calculate the energy transferred into the vehicle battery based on that percentage. Further, if the vehicle 104 experiences a magnitude of braking where mechanical braking is desired to supplement the regenerative braking, the system 100 may attribute a maximum amount of deceleration to the regenerative braking system where the additional mechanical braking does not affect the vehicle battery energy level.

[0034] In one implementation, an accelerometer 108 is equipped to additionally detect static acceleration and/or angle of tilt. When the vehicle 104 ascends a hill, the accelerometer 108 may detect a change in the angle of tilt. The system 100 may use the change in tilt combined with the vehicle velocity to calculate a change in elevation. Alternatively, the accelerometer 108 may detect that the vehicle 104 is ascending when the static acceleration provided by gravity changes direction. The system 100 may interpret this data by attributing a portion of the earth's 1 G of gravity acceleration in the rearward longitudinal direction. The system 100 may then calculate that the vehicle 104 requires more energy to ascend. Similarly, when descending a hill, the accelerometer 108 detects a corresponding change in direction of the static acceleration provided by gravity. The system 100 calculates that the vehicle 104 does not require as much energy descending a hill and adjusts energy draw accordingly.

[0035] The system 100 may automatically reset velocity to zero when there is zero acceleration for a predetermined time, making it less likely that the system 100 will generate erroneous data over long periods of operation time.

[0036] In another implementation, a barometric pressure altimeter 152 could be attached to the vehicle 104 to measure elevation changes encountered during vehicle operation. The system 100 may then calculate the effect of the elevation changes on the rate of battery discharge. With an altimeter 152, accelerometers 108 that do not sense tilt or static accelerations such as gravity may be used.

[0037] In another implementation, the location, speeds, and/or accelerations of the vehicle 104 may be tracked via GPS or a local positioning system. The system 100 may use stored data containing terrain elevation for the vehicle area of operation combined with location data received from the vehicle 104 to calculate changes in elevation. The effect of the change in elevation on the rate of battery discharge may then be calculated by the system 100.

[0038] The outputs (128, 156, 136, 132) of the accelerometer 108, pressure sensor 112, a speedometer 116, GPS receiver 152, and/or an altimeter 152, respectively, may be connected, by way of a wired or wireless signal, to a computer 120 onboard the electric vehicle 104. In one implementation, the onboard computer 120 is equipped with an onboard display 124 configured to convey energy level information to the vehicle user. Additionally, if any of the vehicle instruments outputs an analog signal, a signal conditioner 162 may be used to convert the analog signal to a digital signal before being transmitted to the onboard computer 120. In another implementation, the onboard computer 120 has a built-in signal conditioner to convert any analog signals it may receive into digital signals.

[0039] The onboard computer 120 may be connected to a central computer 140 by way of a communication link 144. Alternatively, the vehicle instruments may be in direct wired or wireless communication with the central computer 140. The communication link 144 may transmit information relating to the vehicle energy level using recharge and operation data. In one implementation, the communication link 144 may be a wired communication link between the vehicle 104 and the central computer 140 via a charge port 148. The onboard computer 120 may then send the data, via a wired or wireless connection, to the central computer 140 via the charge port 148. In another implementation, the communication link 144 may be a wired link separate from the charge port 148 directly connecting the onboard computer 120 to the central computer 140. In yet another implementation, the communication link 144 may be a wireless connection established via satellite or ground-based communications technologies, for example, ZigBee, other IEEE 802.15.4 compliant technologies, WIFI, and Bluetooth between the vehicle 104 and the central computer 140.

[0040] In one implementation, there is no central computer 140. The vehicle onboard computer 120 may perform all the calculations necessary to determine vehicle battery energy level. The vehicle battery energy level may optionally be displayed to the user via a user display 124. In another implementation, the onboard computer 120 may collect the data from the vehicle instruments and transmit that data to the central computer 140. The central computer 140 may then calculate the vehicle battery energy level. Further, the vehicle battery energy level may be transmitted back to the vehicle 104 and displayed to the user via user display 124.

[0041] Potential vehicle users may be concerned that a partially charged vehicle 104 may not have sufficient battery energy level to fulfill their mobility needs if a long journey is planned. The system 100 may display energy level information on the vehicle user display 124 that can be used by a potential vehicle user when selecting the vehicle 104 for use. Since it may not be necessary for the vehicle 104 to be fully charged to meet the user's mobility needs, the vehicle 104 may be released to the user partially charged if the battery energy level is sufficient to meet the user's mobility needs. The user may rely on the user display 124 to determine if the vehicle 104 is sufficiently charged and/or to calculate how much longer the vehicle 104 will operate before running out of stored energy.

[0042] Referring now to FIG. 2, one implementation of the user display 124 of FIG. 1 is shown. The user display 200 is shown corresponding to three distinct vehicle states. First, a display 204 is shown corresponding to a charging vehicle. Next, a display 208 is shown corresponding to a vehicle that is turned off and/or parked. Finally, a series of displays 212 are shown corresponding to a vehicle in operation.

[0043] The user display 200 indicates the vehicle battery energy level graphically 216 as well as a available range 220 that the vehicle can be expected to travel. Further, the user display 200 may indicate a time of vehicle return 224. Referring specifically to the user display 204 corresponding to a charging vehicle, a potential vehicle user may approach a charging vehicle to ascertain if the vehicle has sufficient energy stored in the vehicle battery to meet the user's mobility needs. The user may either use the time the vehicle must be returned 224 and/or the available range 220 to make this decision. Further, the user may use the graphical overall battery energy level indicator 216 to make his/her decision to use the vehicle. The graphical information shown by the energy level indicator 216 can be used by a potential user to quickly and easily compare the battery energy level for several vehicles of similar type without needing to read numeric predicted range values.

[0044] If a user comes upon a vehicle that is off and/or parked, but not at a charging station, the user display 208 may indicate that the vehicle is secured 228. This may mean that the vehicle is already in use by another user and not available to this user. The user display 208 may further indicate the time in which the vehicle must be returned 224 and the current time of day 232. This information may aid the user in returning the vehicle on time so that it may be charged and ready for the next user. Further, the current relative energy level of the vehicle is displayed graphically 216.

[0045] User displays 212 illustrate various example energy levels when a vehicle is in operation. When a user selects a vehicle to use and disconnects it from the charging station, the energy level indicator 216 shown in display 236 indicates a full range for the usage period available to the user. Graphically displaying relative battery energy level indication for the usage period rather than overall battery energy level may make it easier for the user to understand how much battery capacity is available throughout the vehicle usage period. During the usage period the relative energy level indicator 216 constantly shows the user the present battery energy level relative to the battery energy level when the usage period began as opposed to relative to the total capacity of the battery.

[0046] Further, a range remaining indicator 220 before the vehicle battery is depleted is shown to provide the user with a measure of the distance available to further quantify the vehicle capacity to deliver the user to his/her destination. Additionally, a return time 252 is shown indicating when the user must return the vehicle. The relative energy level indicator 216 coupled with the range remaining 220 may be more accessible by the user to determine how much energy is remaining in the battery at a glance, as compared to requiring the user to remember how many bars on an overall energy level indicator 216 were illuminated or how many miles of predicted range were displayed when the usage period began. For example, when the graphical relative battery energy level indicator 216 displays 50% of the battery capacity, the user knows at a glance that he/she has used 50% of the energy that was available when the usage period began. Further, the range remaining indicator 220 can be used to assist the user in determining if he/she will reach his/her destination(s) before the vehicle battery is completely discharged.

[0047] The return time 252 may also be displayed as a countdown to the time the vehicle is due back at the charging station or other location. As the user operates the vehicle, the relative energy level indicator 216 moves proportionally based on the relative battery drain during the vehicle usage period to indicate the remaining battery energy level available to the user as shown in 240. The display 200 may be designed to warn a user of low energy thresholds. For example, when the battery is discharged beyond 50% of the initial energy level available to the user at the start of the usage period, the energy level indicator 216 may begin to flash, alerting the user to the battery depletion as shown in 244. As another example, when the battery is discharged beyond 75% of the initial energy level or less than 10 minutes remain on the use period, the entire display 200 may flash, alerting the user to return the vehicle immediately as shown in 248.

[0048] As briefly described above, estimation of the battery energy level may be displayed to the user as a percentage of the total battery capacity. However, conveying to a user that a particular vehicle has 60% of its maximum energy level available does not provide sufficient information to determine whether the vehicle will meet the user's mobility needs. This is especially true when the user is unfamiliar with the electric vehicle selected because the distance one type of vehicle will travel with 60% of its battery capacity may be significantly different than a different type of vehicle (e.g. a Segway may be able to travel 9 miles with a 60% energy level where an eGo scooter may be able to travel 14 miles with a 60% energy level). It may be more useful to communicate the vehicle range to the user. However, distance measurements may vary from country to country and the perception of distance may vary from person to person.

[0049] Accordingly, the battery energy level of a rental vehicle could also be communicated by the approximate operating time the vehicle has remaining. For example, a Segway with a 60% energy level may display that it is capable of operating for 45 minutes and an eGo scooter may display that it is capable of operating for 35 minutes with a 60% energy level. Minutes are a more universal measure when compared to miles and kilometers and the user's perception of time may be superior to their perception of distance.

[0050] Further, since the vehicle instruments reside on the vehicle and are being monitored by the onboard and/or remote computer, the user's calculated operation time may be refined based upon how the user is operating the vehicle. If the user operates the vehicle aggressively, the calculated operational time could be reduced. If, on the other hand, the user was gentle in accelerating and decelerating the vehicle, the operational time may be extended. The calculated vehicle operational time could be shown on the vehicle display and updated to reflect real time changes to the vehicle battery energy level. This type of feedback could be used by the user to learn how to operate the vehicle more efficiently.

[0051] Further, in a rental system implementation, the user could be charged a variable rental rate based upon how much energy was consumed by the user during the rental period and/or impose a fine for overly aggressive vehicle operation. This information could also be used by the user who has under-calculated his mobility needs and realizes that his 20 minute trip has taken 25 minutes. As a result, the user may be made more aware of how much energy he consumes during the rental.

[0052] Referring now to FIG. 3, a method 300 for calculating an electric vehicle battery energy level is shown. The method 300 begins with calibration of the accelerometers, pressure sensors, speedometers, GPS receivers, and / or altimeters (vehicle instruments) for the specific vehicle and its potential load and operating conditions 310. This calibration step 310 may be the result of extensive field testing of the vehicle under varied conditions while directly measuring the rate of electric battery discharge. The measurements may be used to determine formulae governing the vehicle energy measurement system 300. Some example calibration data is included below for reference.

[0053] Once the vehicle instruments have been calibrated, a first battery energy level may be determined 320. In one implementation, if the vehicle is connected to a battery charger, the voltage level on the battery may be monitored while charging to determine the battery energy level. In an alternative implementation, the time the vehicle is connected to the battery charger and the magnitude of the current passing into the vehicle battery can be monitored to estimate the additional energy being delivered to the vehicle battery.

Additionally, during extended periods when the vehicle is not in use (e.g. at night), there may be ample time for the vehicle battery to become fully charged. If a full charge is achieved, the battery energy level estimation algorithm may be "reset" to a known level of battery capacity.

[0054] Once the vehicle is removed from the charging station and is placed in use, the vehicle acceleration, load, speed, air resistance, and / or change in elevation (motion measurements) may be measured and recorded 330. The vehicle instruments may gather this data and transmit the data either to a computer onboard the vehicle or to a remotely located computer for recording and/or analyzing the data. Next, battery draw is calculated 340 as a function of the motion measurements. This operation may be performed by the computer onboard the vehicle or a remotely located computer. Finally, the calculated battery draw is compared with the first battery energy level to determine a second calculated electric vehicle battery energy level 350.

[0055] Referring now to FIG. 4, specifically in a rental system implementation, the vehicle energy measurement system 400 may calculate a newly returned vehicle battery energy level using data collected during the vehicle rental period and comparing that data with a known first energy level. More specifically, the rental vehicle instruments may be calibrated for the specific vehicle and its potential load and operating conditions in operation 405. Once the vehicle instruments have been calibrated, the first battery energy level may be determined in operation 410 and the vehicle may be provided to a first rental user in operation 415.

[0056] The first rental user may operate the vehicle to provide his/her transportation. While the first rental user is operating the vehicle, motion measurements are made and recorded in operation 420. Then the battery draw as a function of the motion measurements is calculated in operation 425. When the first rental user returns the vehicle to a rental station, the calculated battery draw is compared to the first battery energy level in operation 430 to determine a second battery energy level upon return of the vehicle. Further, if the vehicle is docked at a rental station, it may be recharged. The rate of recharge may be monitored in operation 435 to track the battery energy level over time while recharging.

[0057] A second rental user may desire to use the rental vehicle before the battery is fully recharged. In this case, a desired duration of use may be received from the second rental user in operation 440. A third battery energy level necessary to fulfill the second rental user's needs may be calculated and compared to a present battery energy level to determine the sufficiency of the energy level in operation 445. If there is sufficient battery energy level to fulfill the needs of the second rental user, the vehicle is provided to the second rental user in operation 450. If the vehicle is not sufficiently charged, the vehicle may not be rented to the second rental user. Optionally, another vehicle that has sufficient energy level may be rented to the second rental user in operation 455. In another implementation, vehicles may be released for rent to rental users only after the vehicle batteries are fully charged. This may simplify monitoring the battery energy level because the vehicle always starts with a fully charged battery.

[0058] There are many implementations contemplated in which vehicle instruments may be used to calculate the amount of energy consumed by an electric vehicle in an effort to calculate an electric vehicle battery energy level. The following description details some implementations with specificity.

[0059] A computer may be situated onboard the vehicle and directly connected to the vehicle instruments or remotely located with a wireless signal connecting the computer to the vehicle instruments. Further, there may be both an onboard computer and a remotely located computer performing various combinations of the functions described herein wired or wirelessly connected together. The computer referred to herein refers to any of the described implementations of onboard, remotely located, and/or central computers.

[0060] Each type of vehicle in a rental fleet may be profiled by a system operator using test equipment to monitor the outputs of vehicle instruments while simultaneously monitoring the current drawn out of the vehicle battery. Each vehicle type may be put through a series of operational activities that represent typical vehicle movements that may be encountered during a rental use. Below in Table A is exemplary accelerometer calibration data collected from a rental Segway accelerating from zero velocity. Depending upon how aggressively the user operates the vehicle governs the magnitude of the current drawn out of the vehicle battery.

Table A - Average Current Drawn from Vehicle Battery	
Acceleration Range	Electric Current
0.50G to 0.46G	200 amps
0.45G to 0.41G	175 amps
0.40G to 0.36G	150 amps
0.35G to 0.31G	100 amps
0.30G to .026G	90 amps
0.25G to 0.21G	80 amps
0.20G to 0.16G	60 amps
0.15G to 0.11G	45 amps
0.10G to 0.06G	25 amps

0.05G to 0.01G	15 amps

[0061] With this operational data, the computer may calculate the amount of energy a vehicle consumes by monitoring the vehicle acceleration from zero velocity. In addition, to calculate the amount of energy consumed by the battery, the quantity of time spent at each acceleration range may be desired. A real time clock may be utilized to monitor the quantity of time the vehicle remained within each of the measured acceleration ranges. Further, the above operational data could be applied to any forward acceleration or there may be speed related data charts that may calculate the current drawn out of the vehicle battery when the vehicle is moving at a velocity and then experiences acceleration. A sample chart of calibration data is shown below that incorporates vehicle speed before acceleration.

Table B - Average Current Drawn from Vehicle Battery

Acceleration Range	0MPH	5MPH	9MPH	12MPH
0.50G to 0.46G	200 amps	NA	NA	NA
0.45G to 0.41G	175 amps	NA	NA	NA
0.40G to 0.36G	150 amps	200 amps	NA	NA
0.35G to 0.31G	100 amps	150 amps	NA	NA
0.30G to .026G	90 amps	125 amps	150 amps	NA
0.25G to 0.21G	80 amps	100 amps	130 amps	NA
0.20G to 0.16G	60 amps	85 amps	110 amps	NA
0.15G to 0.11G	45 amps	65 amps	90 amps	100 amps
0.10G to 0.06G	25 amps	50 amps	65 amps	80 amps
0.05G to 0.01G	15 amps	30 amps	40 amps	50 amps

[0062] The chart above in Table B illustrates that if a Segway is traveling at 5 miles per hour and is accelerated by .33 Gs, the current drawn out of the vehicle battery is 150 amps. The computer may utilize the real time clock to monitor the amount of time the vehicle remained within each of the measured acceleration ranges. For example, if the .33G acceleration occurs for two seconds, the vehicle consumes 0.0833 amp hours (150 amps x 2/3600 seconds/hour = 0.0833 amp hours). By using the vehicle instruments, including an accelerometer and a real time clock, and integrating the accelerations experienced by the vehicle, the computer may calculate how much energy is used to accelerate the vehicle.

[0063] Not all vehicle battery draw is typically associated with accelerating the vehicle. Even when a vehicle is traveling on a straight level path at a constant velocity, the motor is consuming energy from the battery. To determine the velocity of the vehicle, a speedometer may measure the wheel speed of the vehicle and send that information to the computer. Alternatively, the computer may integrate the acceleration and deceleration data over time to calculate velocity. In either case, when a vehicle is moving at a constant rate with zero acceleration, it is consuming a quantity of energy from the battery. The amount of current that the vehicle consumes at specific speeds may be recorded and the amount of energy needed to move the vehicle at those speeds may then be calculated by utilizing the real time clock to determine the amount of time the vehicle draws quantities of current out of the battery. Below in Table C is an example of the calibration data collected from a vehicle traveling at a constant velocity.

Table C	
Constant Speed (MPH)	Average current drawn from vehicle battery
12.5	25 amps
11	22 amps
10	20 amps
9	19 amps
8	17 amps
7	16 amps
6	15 amps
5	13 amps
4	11 amps
3	9 amps
2	6 amps
1	4 amps

[0064] Using the above data, while traveling 12.5 miles per hour the vehicle consumes 25 amps of current from the battery. If the user travels at this speed for 2 minutes he/she will have consumed 0.83 amp hours (25 amps x 2 minutes/60 minutes/hour = 0.83 amp hours).

[0065] Different vehicle types may draw different amounts of current from the battery so it may be desirable to independently calibrate an energy usage profile for each vehicle type. Additionally, the weight of the user may affect the amount of energy required to move the vehicle. A heavier user will require more energy for a given operational profile than a lighter user. This is especially true of smaller personal electric vehicles where the user's weight is a greater portion of the total weight of the vehicle.

[0066] In one implementation, the computer accounts for the variation in user weight by calculating the vehicle range based upon a larger than average (e.g., 250 pound) user. The calibration data would thus over-calculate the amount of energy consumed by a lighter weight user during vehicle use. By under-calculating the energy consumed by the lighter weight user, it is unlikely that the user would inadvertently run out of energy before the calculated exhaustion of the battery. Further, lighter users may discover that they could ride the vehicle longer than calculated.

[0067] In another implementation, the computer may account for variation in user weight during the rental transaction. When the user makes a request to rent a vehicle he/she may obtain an estimate of how long the vehicle will operate by reading the vehicle display. For example, the display may indicate that the vehicle is capable of operating for 42 minutes. If the rental transaction is successful, the computer may determine that the user's weight is different than the 250 pound default and adjust the calculated operational time. The computer may make this determination based on the user's manual input of his/her weight or via one or more pressure sensors on the bike registering the user's weight and transmitting the data to the computer.

[0068] Alternatively, the vehicle energy level may be reduced at a different rate based on the user's weight rather than making and operational time or distance adjustment. Rather than adding or subtracting distance or minutes available based on the difference between a specific user's weight and the default weight, the onboard computer may increase or decrease the rate at which the time and/or distance counts down. To the user, it would appear that the calculated electric vehicle energy measurement algorithm is operating seamlessly, rather than abruptly adjusting when the user's weight is known. Linear performance may instill confidence in the system's operations.

[0069] During vehicle use, the vehicle energy level may be further adjusted based on how aggressively the user operates the vehicle. For example, suppose the vehicle energy level indicator indicates that the vehicle is available for 25 minutes of riding. If the user rides the vehicle more aggressively, the user display may indicate that the vehicle is only capable of operating for 12 minutes at the current riding style. Conversely, if the user adopts a more gentle riding style and/or does not travel at the vehicle top speed, the computer may calculate and indicate to the user that the vehicle may be operated for an additional amount of time. In hilly operational environments, there may be less of an opportunity to extend the vehicle calculated operational time based upon the user's riding style because one big uphill at the end of the rental may be unanticipated and the vehicle might not complete the journey to the charge port at the top of the hill.

[0070] In another implementation, two types of motion, acceleration and velocity, are monitored for battery draw and may be stored in two different memory tables. One set of computer memory locations (i.e., a first memory table) may be used to document the different rates of acceleration that the vehicle may experience. The other set of computer memory locations (i.e., a second memory table) may be used to document speeds at which the vehicle may operate.

[0071] At a predetermined periodic time period (e.g., every 1/10 of a second), the speed of the vehicle may be measured and recorded by incrementing the computer memory location associated with the maximum vehicle speed experienced during the just-passed time period. Additionally, the computer memory location associated with the maximum acceleration experienced by the vehicle during the just-passed time period may also be incremented by one.

[0072] By incrementing the appropriate memory locations every time period, the computer's memory may hold a running history of the vehicle speed and/or acceleration experienced during the vehicle use. The computer may then process the data, assigning a battery draw to each memory location. Once the integrated speed and acceleration energy consumption values are calculated, the onboard computer may sum all the integrated speed and acceleration energy values to obtain a total amount of energy consumed during the vehicle use. This energy consumption total for the vehicle use may then be subtracted from the battery energy capacity to determine how much energy remains in the vehicle battery. Table D below is an example of data that could be stored in memory and used to calculate how much energy is required to keep the vehicle moving at a constant rate.

Table D			
Memory Location Content	Energy Consumed per Time-period	Energy Consumed During Entire Rental	Constant Vehicle Speed (MPH)
12	0.003	0.036	1
15	0.005	0.075	2
19	0.012	0.228	3
35	0.025	0.875	4
60	0.033	1.98	5
120	0.089	10.68	6
230	0.110	25.3	7
388	0.160	62.08	
455	0.210	95.55	9
520	0.300	156	10
Energy Consumed for the entire rental:		352.804 watt-hours	

[0073] Using the above data, when traveling at 7 miles per hour, the vehicle consumed 0.110 watt-hours during the 0.1 second time period. Over the 23 seconds that the vehicle traveled 7 miles per hour it consumed 25.3 watt-hours. Summing the energy consumed by the vehicle to operate at the various constant speeds encountered during the vehicle use consumed 352.8 watt-hours. A similar data table in the computer's memory may be created for accelerations experienced by the vehicle during the vehicle use. The speed and acceleration tables could be used together to calculate the total amount of energy drawn out of the battery during the vehicle use.

[0074] Upon return of the vehicle, the data in the computer memory tables may be accessed by the computer to calculate the draw on the vehicle battery. The amount of energy consumed by the user during the last vehicle use may be used to calculate the vehicle battery energy level upon vehicle return. Thus the computer may calculate how much energy is available for the next vehicle user.

[0075] Additional implementations of a calculated electric vehicle energy measurement method and system may not use any accelerometers; rather implementing one or more speedometers that could be used to measure the speed of the vehicle. The speedometers could be implemented with a magnet or magnets mounted on a vehicle wheel and a reed switch that could sense the magnet's presence on each revolution of the wheel. The computer may monitor the wheel's rotational speed and calculate acceleration based upon the change in the wheels rotational velocity.

[0076] Accordingly, the calculated electric vehicle energy measurement system may operate with out accelerometers, possibly reducing the cost of the system. The addition of a single axis accelerometer oriented to detect the slope of the terrain being traversed may allow the system to detect hills and include the hills' affect on the electric vehicle energy consumption in calculating the calculated electric vehicle battery energy level.

[0077] An exemplary computer system 500 for implementing the calculated electric vehicle battery energy level processes above is depicted in FIG. 5. The computer system 500 of a vehicle or a central system management may be a personal computer (PC), a workstation, a notebook or portable computer, a tablet PC, a handheld media player (e.g., an MP3 player), a smart phone device, a video gaming device, or a set top box, with internal processing and memory components as well as interface components for connection with external input, output, storage, network, and other types of peripheral devices. Internal components of the computer system in FIG. 5 are shown within the dashed line and external components are shown outside of the dashed line. Components that may be internal or external are shown straddling the dashed line. Alternatively to a PC, the computer system 500, for example, for running applications associated with the calculated electric vehicle battery energy level system, may be in the form of any of a server, a mainframe computer, a distributed computer, an Internet appliance, or other computer devices, or combinations thereof.

[0078] In any implementation or component of the system described herein, the computer system 500 includes a processor 502 and a system memory 506 connected by a system bus 504 that also operatively couples various system components. There may be one or more processors 502, e.g., a single central processing unit (CPU), or a plurality of processing units, commonly referred to as a parallel processing environment (for example, a dual-core, quad-core, or other multi-core processing device). The system bus 504 may be any of several types of bus structures including a memory bus or memory controller, a peripheral bus, a switched-fabric, point-to-point connection, and a local bus using any of a variety of bus architectures. The system memory 506 includes read only memory (ROM) 508 and random access memory (RAM) 510. A basic input/output system (BIOS) 512, containing the basic routines that help to transfer information between elements within the computer system 500, such as during start-up, is stored in ROM 508. A cache 514 may be set aside in RAM 510 to provide a high speed memory storage for frequently accessed data.

[0079] A hard disk drive interface 516 may be connected with the system bus 504 to provide read and write access to a data storage device, e.g., a hard disk drive 518 or flash memory, for nonvolatile storage of applications, files, and data. A number of program modules and other data may be stored on the hard disk 518, including an operating system 520, one or more application programs 522, and data files 524. In an example implementation, the hard disk drive 518 may store the media service, recording, and synchronization application 526, the media data repository 564 for storage of media selections for presentation to a sender, and the audio recording data repository 566 for storing audio performances recorded by a sender according to the example processes described herein above. Note that the hard disk drive 518 may be either an internal component or an external component of the computer system 500 as indicated by the hard disk drive 518 straddling the dashed line in FIG. 5. In some configurations, there may be both an internal and an external hard disk drive 518.

[0080] The computer system 500 may further include a magnetic disk drive 530 for reading from or writing to a removable magnetic disk 532, tape, or other magnetic media. The magnetic disk drive 530 may be connected with the system bus 504 via a magnetic drive interface 528 to provide read and write access to the magnetic disk drive 530 initiated by other components or applications within the computer system 500. The magnetic disk drive 530 and the associated computer-readable media may be used to provide nonvolatile storage of computer-readable instructions, data structures, program modules, and other data for the computer system 500.

[0081] The computer system 500 may additionally include an optical disk drive 536 for reading from or writing to a removable optical disk 538 such as a CD ROM or other optical media. The optical disk drive 536 may be connected with the system bus 504 via an optical drive interface 534 to provide read and write access to the optical disk drive 536 initiated by other components or applications within the computer system 500. The optical disk drive 530 and the associated computer-readable optical media may be used to provide nonvolatile storage of computer-readable instructions, data structures, program modules, and other data for the computer system 500.

[0082] A display device 542, e.g., a monitor, a television, or a projector, or other type of presentation device may also be connected to the system bus 504 via an interface, such as a video adapter 540 or video card. Similarly, audio devices, for example, external speakers or a microphone (not shown), may be connected to the system bus 504 through an audio card or other audio interface (not shown).

[0083] In addition to the monitor 542, the computer system 500 may include other peripheral input and output devices, which are often connected to the processor 502 and memory 506 through the serial port interface 544 that is coupled to the system bus 506. Input and output devices may also or alternately be connected with the system bus 504 by other interfaces, for example, a universal serial bus (USB), an IEEE 1394 interface ("Firewire"), a parallel port, or a game port. A user may enter commands and information into the computer system 500 through various input devices including, for example, a keyboard 546 and pointing device 548, for example, a mouse. Other input devices (not shown) may include, for example, a joystick, a game pad, a tablet, a touch screen device, a satellite dish, a scanner, a facsimile machine, a microphone, a digital camera, and a digital video camera.

[0084] Output devices may include a printer 550 and one or more loudspeakers 570 for presenting the audio performance of the sender. Other output devices (not shown) may include, for example, a plotter, a photocopier, a photo printer, a facsimile machine, and a press. In some implementations, several of these input and output devices may be combined into single devices, for example, a printer/scanner/fax/photocopier. It should also be appreciated that other types of computer-readable media and associated drives for storing data, for example, magnetic cassettes or flash memory drives, may be accessed by the computer system 500 via the serial port interface 544 (e.g., USB) or similar port interface.

[0085] The computer system 500 may operate in a networked environment using logical connections through a network interface 552 coupled with the system bus 504 to communicate with one or more remote devices. The logical connections depicted in FIG. 5

include a local-area network (LAN) 554 and a wide-area network (WAN) 560. Such networking environments are commonplace in home networks, office networks, enterprise-wide computer networks, and intranets. These logical connections may be achieved by a communication device coupled to or integral with the computer system 500. As depicted in FIG. 5, the LAN 554 may use a router 556 or hub, either wired or wireless, internal or external, to connect with remote devices, e.g., a remote computer 558, similarly connected on the LAN 554. The remote computer 558 may be another personal computer, a server, a client, a peer device, or other common network node, and typically includes many or all of the elements described above relative to the computer system 500.

[0086] To connect with a WAN 560, the computer system 500 typically includes a modem 562 for establishing communications over the WAN 560. Typically the WAN 560 may be the Internet. However, in some instances the WAN 560 may be a large private network spread among multiple locations, or a virtual private network (VPN). The modem 562 may be a telephone modem, a high speed modem (e.g., a digital subscriber line (DSL) modem), a cable modem, or similar type of communications device. The modem 562, which may be internal or external, is connected to the system bus 518 via the network interface 552. In alternate implementations the modem 562 may be connected via the serial port interface 544. It should be appreciated that the network connections shown are examples and other means of and communications devices for establishing a network communications link between the computer system and other devices or networks may be used.

[0087] The technology described herein may be implemented as logical operations and/or modules in one or more systems. The logical operations may be implemented as a sequence of processor-implemented steps executing in one or more computer systems and as interconnected machine or circuit modules within one or more computer systems. Likewise, the descriptions of various component modules may be provided in terms of operations executed or effected by the modules. The resulting implementation is a matter of choice, dependent on the performance requirements of the underlying system implementing the described technology. Accordingly, the logical operations making up the implementations of the technology described herein are referred to variously as operations, steps, objects, or modules. Furthermore, it should be understood that logical operations may be performed in any order, unless explicitly claimed otherwise or a specific order is inherently necessitated by the claim language.

[0088] In some implementations, articles of manufacture are provided as computer program products. In one implementation, a computer program product is provided as a computer-readable medium storing an encoded computer program executable by a computer system. Another implementation of a computer program product may be provided in a computer data signal embodied in a carrier wave by a computing system and encoding the computer program. Other implementations are also described and recited herein.

[0089] All directional references (e.g., proximal, distal, upper, lower, upward, downward, left, right, lateral, front, back, top, bottom, above, below, vertical, horizontal, clockwise, and counterclockwise) are only used for identification purposes to aid the reader's understanding of the present invention, and do not create limitations, particularly as to the position, orientation, or use of the invention. Connection references (e.g., attached, coupled, connected, and joined) are to be construed broadly and may include intermediate members between a collection of elements and relative movement between elements unless otherwise indicated. As such, connection references do not necessarily infer that two elements are directly connected and in fixed relation to each other. The example drawings are for purposes of illustration only and the dimensions, positions, order, and relative sizes reflected in the drawings attached hereto may vary.

[0090] The above specification, examples, and data provide a complete description of the structure and use of example implementations of the invention. Although various implementations of the invention have been described above with a certain degree of particularity, or with reference to one or more individual implementations, those skilled in the art could make numerous alterations to the disclosed implementations without departing from the spirit or scope of this invention. In particular, it should be understood that the described technology may be employed independent of a personal computer. Other implementations are therefore contemplated. It is intended that all matter contained in the above description and shown in the accompanying drawings shall be interpreted as illustrative only of particular implementations and not limiting. Changes in detail or structure may be made without departing from the basic elements of the invention as defined in the following claims.

CLAIMS

What is claimed is:

1. A vehicle energy measurement system comprising

a vehicle equipped with an energy storage and one or more instruments adapted to measure acceleration data and speed data;

a memory adapted to store the acceleration data and speed data; and

a computer adapted to calculate energy consumption based at least on the acceleration data and speed data and to calculate a second energy level by subtracting the calculated energy consumption from a known first energy level.

2. The system of claim 1, wherein the instruments are further adapted to measure weight data of a vehicle user, the memory is further adapted to store the weight data, and the computer is further adapted to calculate energy consumption based in part on the weight data.

3. The system of claim 1, wherein the instruments are further adapted to track locations of the vehicle, the memory is further adapted to store the locations of the vehicle, and the computer is further adapted to calculate energy consumption based in part on the locations of the vehicle.

4. The system of claim 1, further comprising a vehicle regenerative braking system adapted to add energy to the energy storage, wherein the computer is further adapted to calculate a quantity of energy addition to the energy storage based on the acceleration data and speed data.

5. The system of claim 1, further comprising a user presentation device on the vehicle adapted to present the second energy level as a percentage of a total energy capacity of the vehicle.

6. The system of claim 1, further comprising a user presentation device on the vehicle adapted to present the second energy level as a percentage of the first energy level.

7. The system of claim 1, further comprising a user presentation device on the vehicle adapted to present the second energy level as a quantity of vehicle operating time remaining.

8. The system of claim 1, further comprising a user presentation device on the vehicle adapted to present the second energy level as a quantity of distance the vehicle is capable of traversing remaining.

9. The system of claim 1, wherein the energy storage is an electric battery.

10. The system of claim 1, wherein the instruments are selected from a group comprising at least one of an accelerometer, a pressure sensor, a speedometer, a GPS receiver, and an altimeter.

11. The system of claim 1, wherein the computer is physically located on the vehicle.

12. The system of claim 1, wherein the instruments and the computer are connected wirelessly.

13. The system of claim 1, wherein the acceleration data comprises vehicle vibration corresponding to vehicle speed.

14. A method of measuring vehicle energy consumption comprising

calibrating vehicle instruments for characteristics and potential load conditions of a vehicle;

determining a first energy level;

measuring characteristics of vehicle movement during vehicle operation;

calculating energy consumption as a function of the characteristics of the vehicle movement; and

comparing the calculated energy consumption to the first energy level to determine a second energy level.

15. The method of claim 14, further comprising

presenting the second energy level as a percentage of a total energy capacity of the vehicle.

16. The method of claim 14, further comprising

presenting the second energy level as a percentage of the first energy level.

17. The method of claim 14, further comprising

presenting the second energy level as a quantity of vehicle operating time remaining.

18. The method of claim 14, further comprising

presenting the second energy level as a quantity of distance the vehicle is capable of traversing remaining.

19. The method of claim 14, wherein the vehicle instruments are selected from a group comprising at least one of an accelerometer, a pressure sensor, a speedometer, a GPS receiver, and an altimeter.

20. The method of claim 14, wherein the characteristics are selected from a group comprising vehicle acceleration, load, speed, and changes in elevation.

21. A method of measuring vehicle energy consumption comprising:

calibrating vehicle instruments for characteristics and potential load conditions of a vehicle;

determining a first energy level;

providing the vehicle to a first user;

measuring characteristics of vehicle movement during vehicle operation;

calculating energy consumption as a function of the characteristics of vehicle movement;

receiving the vehicle from the first user; and

comparing the calculated energy consumption to the first energy level to determine a second energy level.

22. The method of claim 21, further comprising

monitoring an energy addition to the vehicle;

combining the energy addition with the second energy level to determine a third energy level;

receiving a desired quantity of vehicle use from a second user;

determining if the third energy level is sufficient to satisfy the desired quantity of use from the second user; and

providing the vehicle to the second user if the third energy level is sufficient to satisfy the desired quantity of use from the second user.

23. The method of claim 21, wherein the vehicle instruments are selected from a group comprising at least one of an accelerometer, a pressure sensor, a speedometer, a GPS receiver, and an altimeter.

24. The method of claim 21, wherein the characteristics are selected from a group comprising vehicle acceleration, load, speed, and changes in elevation.

25. The method of claim 21, further comprising

presenting an energy level remaining as a percentage of a total energy capacity of the vehicle to the first user.

26. The method of claim 21, further comprising

presenting an energy level remaining as a percentage of the first energy level to the first user.

27. The method of claim 21, further comprising

presenting an energy level remaining as a quantity of vehicle operating time remaining to the first user.

28. The method of claim 21, further comprising

presenting an energy level remaining as a quantity of distance the vehicle is capable of traversing remaining to the first user.

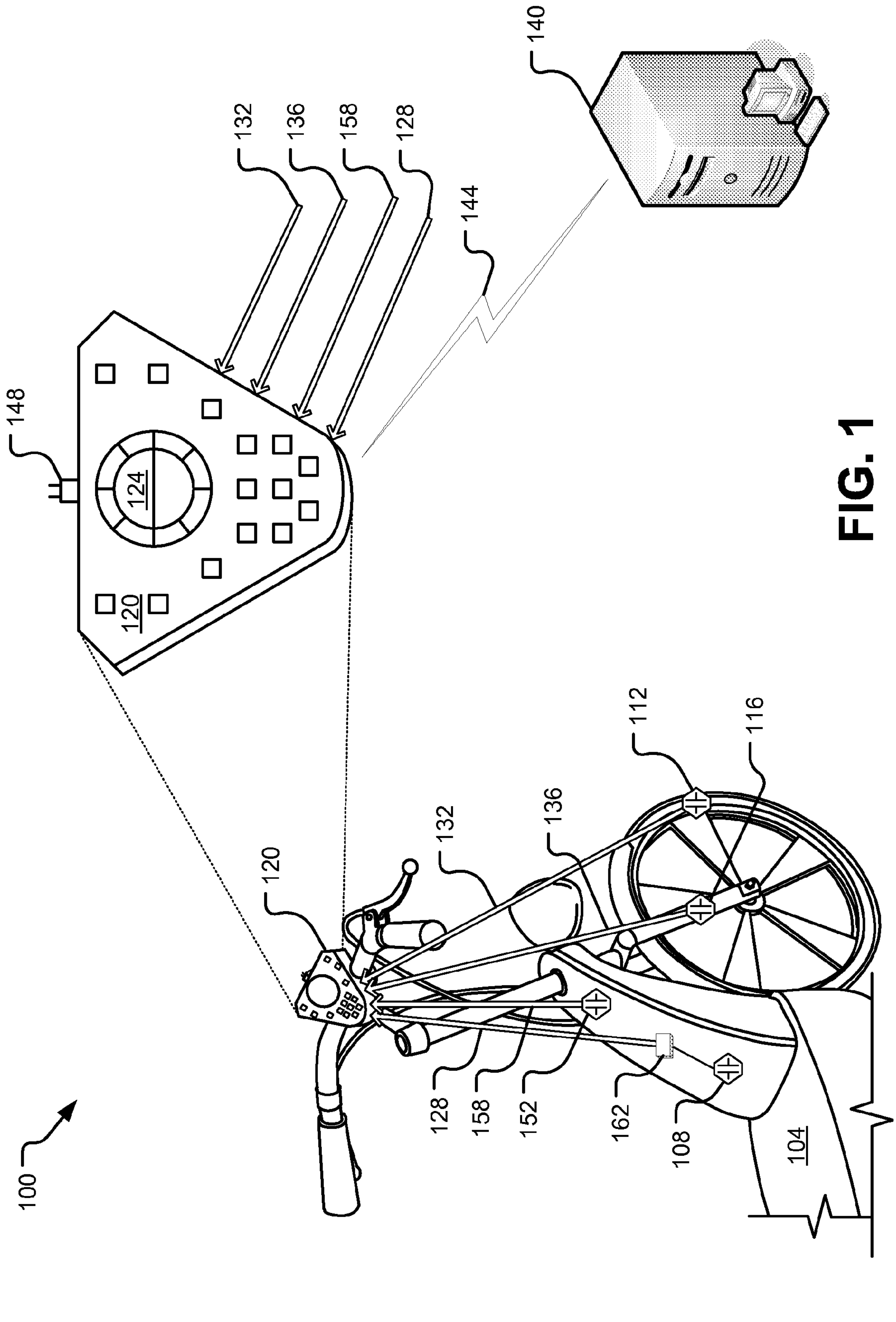


FIG. 1

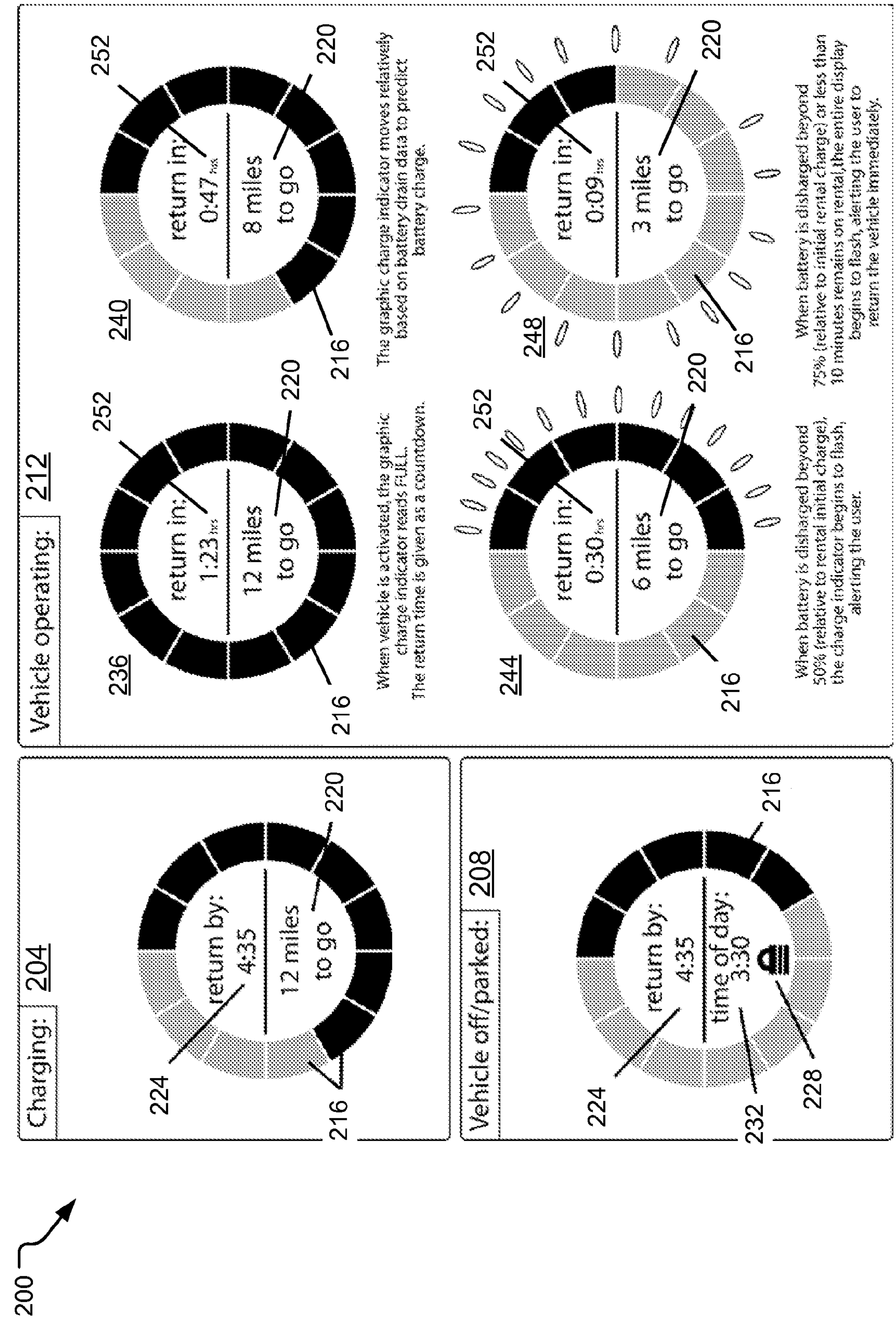

200
Charging: 204
return by: 4:35
12 miles to go
224
216
220
Vehicle off/parked: 208
return by: 4:35
time of day: 3:30
224
232
228
216
Vehicle operating: 212
236
return in: 1:23 hrs
12 miles to go
252
220
216
When vehicle is activated, the graphic charge indicator reads FULL. The return time is given as a countdown.
240
return in: 0:47 hrs
8 miles to go
252
220
216
The graphic charge indicator moves relatively based on battery drain data to predict battery charge.
244
return in: 0:30 hrs
6 miles to go
252
220
216
When battery is disharged beyond 50% (relative to rental initial charge), the charge indicator begins to flash, alerting the user.
248
return in: 0:09 hrs
3 miles to go
252
220
216
When battery is disharged beyond 75% (relative to initial rental charge) or less than 10 minutes remains on rental, the entire display begins to flash, alerting the user to return the vehicle immediately.

FIG. 2

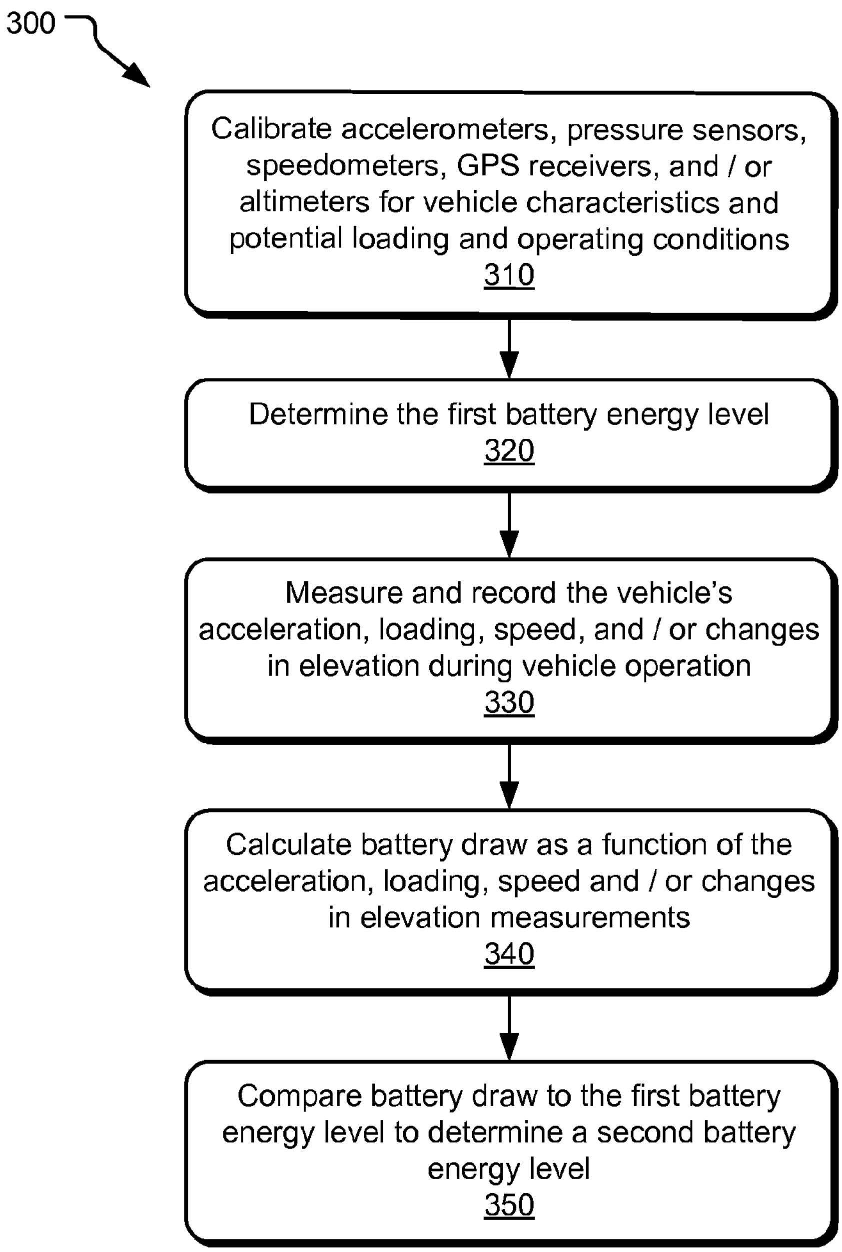

300
Calibrate accelerometers, pressure sensors, speedometers, GPS receivers, and / or altimeters for vehicle characteristics and potential loading and operating conditions
310
Determine the first battery energy level
320
Measure and record the vehicle's acceleration, loading, speed, and / or changes in elevation during vehicle operation
330
Calculate battery draw as a function of the acceleration, loading, speed and / or changes in elevation measurements
340
Compare battery draw to the first battery energy level to determine a second battery energy level
350

FIG. 3

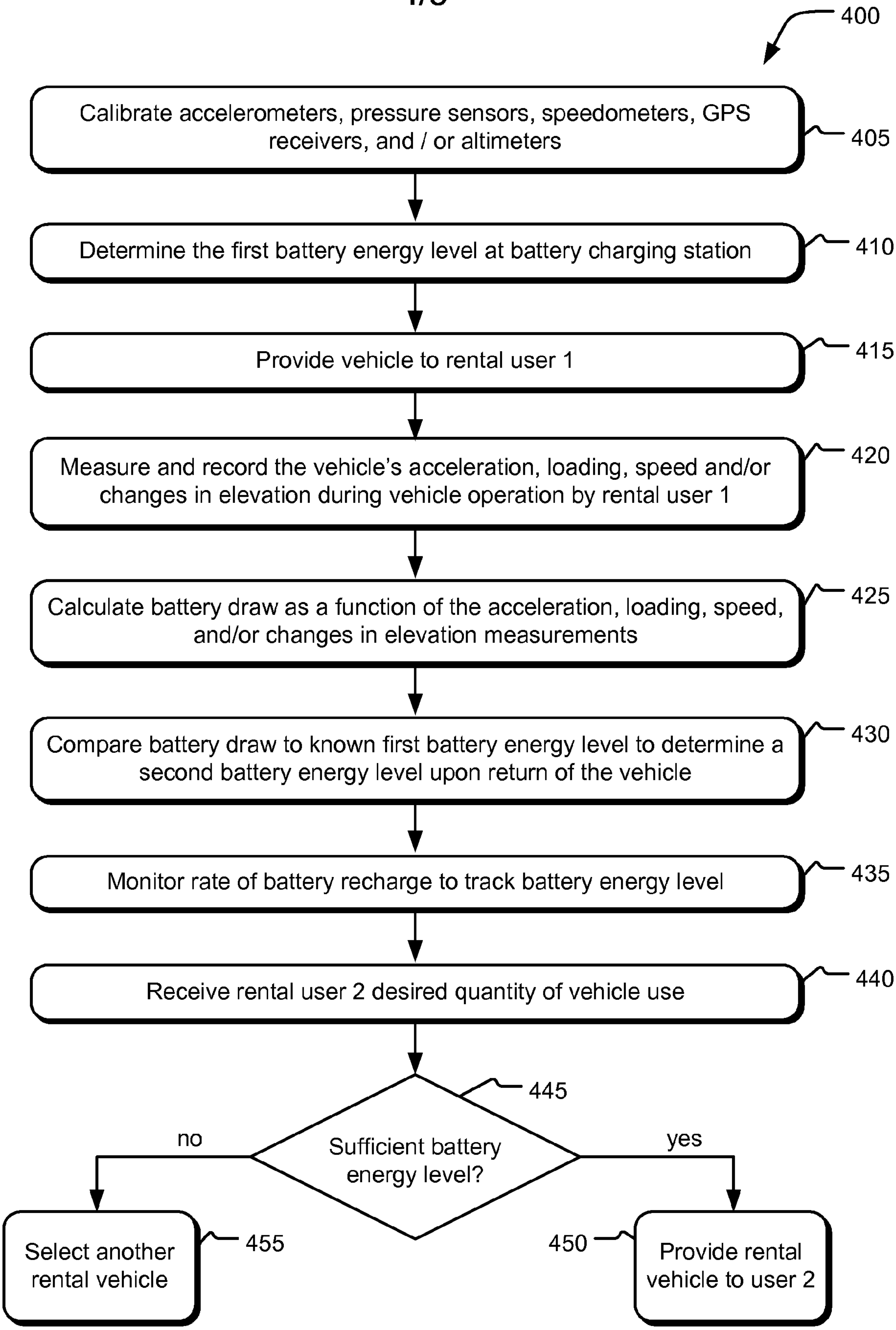
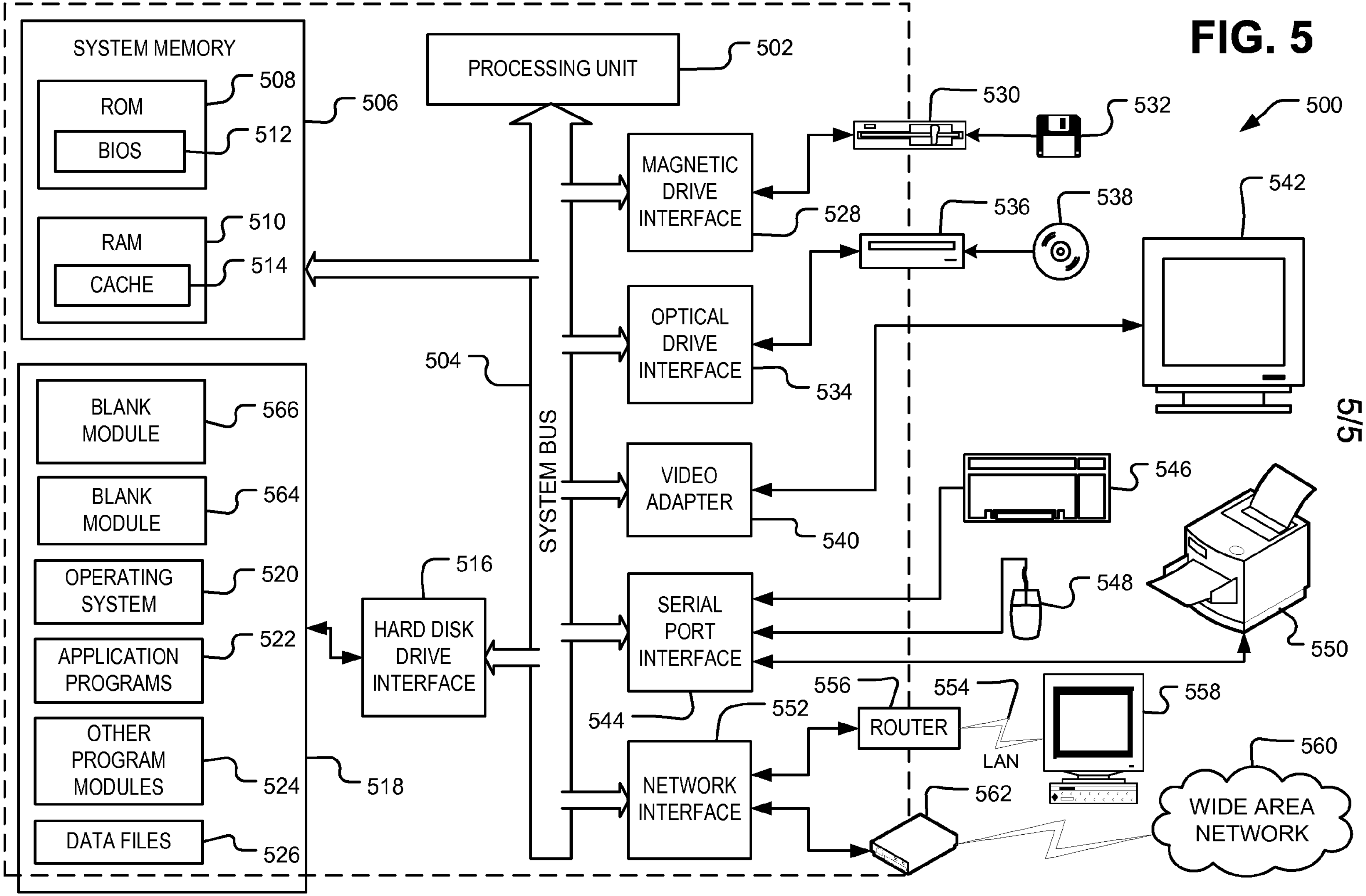

400
Calibrate accelerometers, pressure sensors, speedometers, GPS receivers, and / or altimeters
405
Determine the first battery energy level at battery charging station
410
Provide vehicle to rental user 1
415
Measure and record the vehicle's acceleration, loading, speed and/or changes in elevation during vehicle operation by rental user 1
420
Calculate battery draw as a function of the acceleration, loading, speed, and/or changes in elevation measurements
425
Compare battery draw to known first battery energy level to determine a second battery energy level upon return of the vehicle
430
Monitor rate of battery recharge to track battery energy level
435
Receive rental user 2 desired quantity of vehicle use
440
Sufficient battery energy level?
445
no
yes
Select another rental vehicle
455
450
Provide rental vehicle to user 2

FIG. 4

5/5

FIG. 5


500
SYSTEM MEMORY
508
ROM
BIOS
512
506
RAM
510
CACHE
514
PROCESSING UNIT
502
504
SYSTEM BUS
BLANK MODULE
566
BLANK MODULE
564
OPERATING SYSTEM
520
APPLICATION PROGRAMS
522
OTHER PROGRAM MODULES
524
518
DATA FILES
526
516
HARD DISK DRIVE INTERFACE
MAGNETIC DRIVE INTERFACE
528
530
532
536
538
OPTICAL DRIVE INTERFACE
534
542
VIDEO ADAPTER
540
546
548
550
SERIAL PORT INTERFACE
544
556
554
ROUTER
LAN
558
552
NETWORK INTERFACE
562
560
WIDE AREA NETWORK