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(54) **AUTOMOTIVE BATTERY CHARGING SYSTEM TESTER**

(75) Inventors: **Kevin I. Bertness**, Batavia, IL (US); **Michael E. Troy**, Lockport, IL (US)

(73) Assignee: **Midtronics, Inc.**, Willowbrook, IL (US)

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This patent is subject to a terminal disclaimer.

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(58) **Field of Classification Search** 324/426, 324/427; 320/104, 132

See application file for complete search history.

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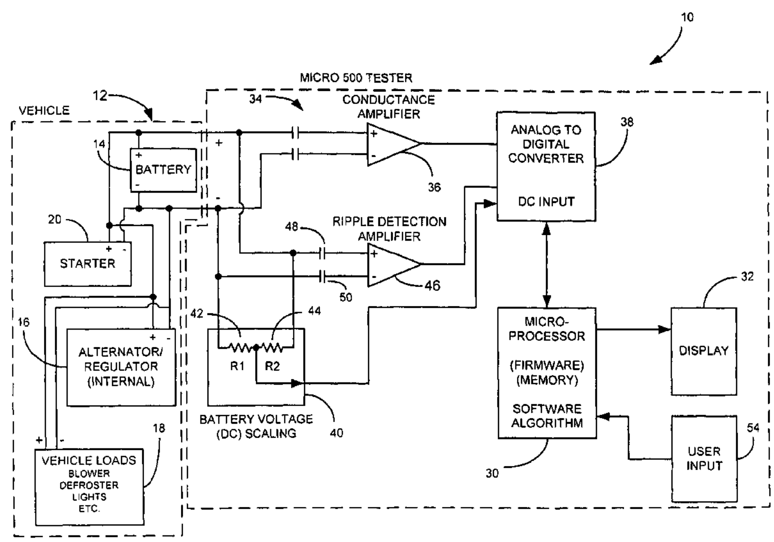
Primary Examiner — Edward Tso
Assistant Examiner — Aaron Piggush
(74) *Attorney, Agent, or Firm* — Westman, Champlin & Kelly, P.A.

(57) **ABSTRACT**

An automotive battery charging system tester for testing the charging system of an automotive vehicle includes AC and DC voltage measurement circuits and a microprocessor controlled testing sequence. The microprocessor is used to perform a series of tests and to instruct an operator to perform steps associated with performing those tests. Through the application of various loads at various engine speeds, the tester is capable of identifying faults in the battery charging system including a bad battery, problems in the alternator or associated electronics, and problems in the starting system.

27 Claims, 8 Drawing Sheets



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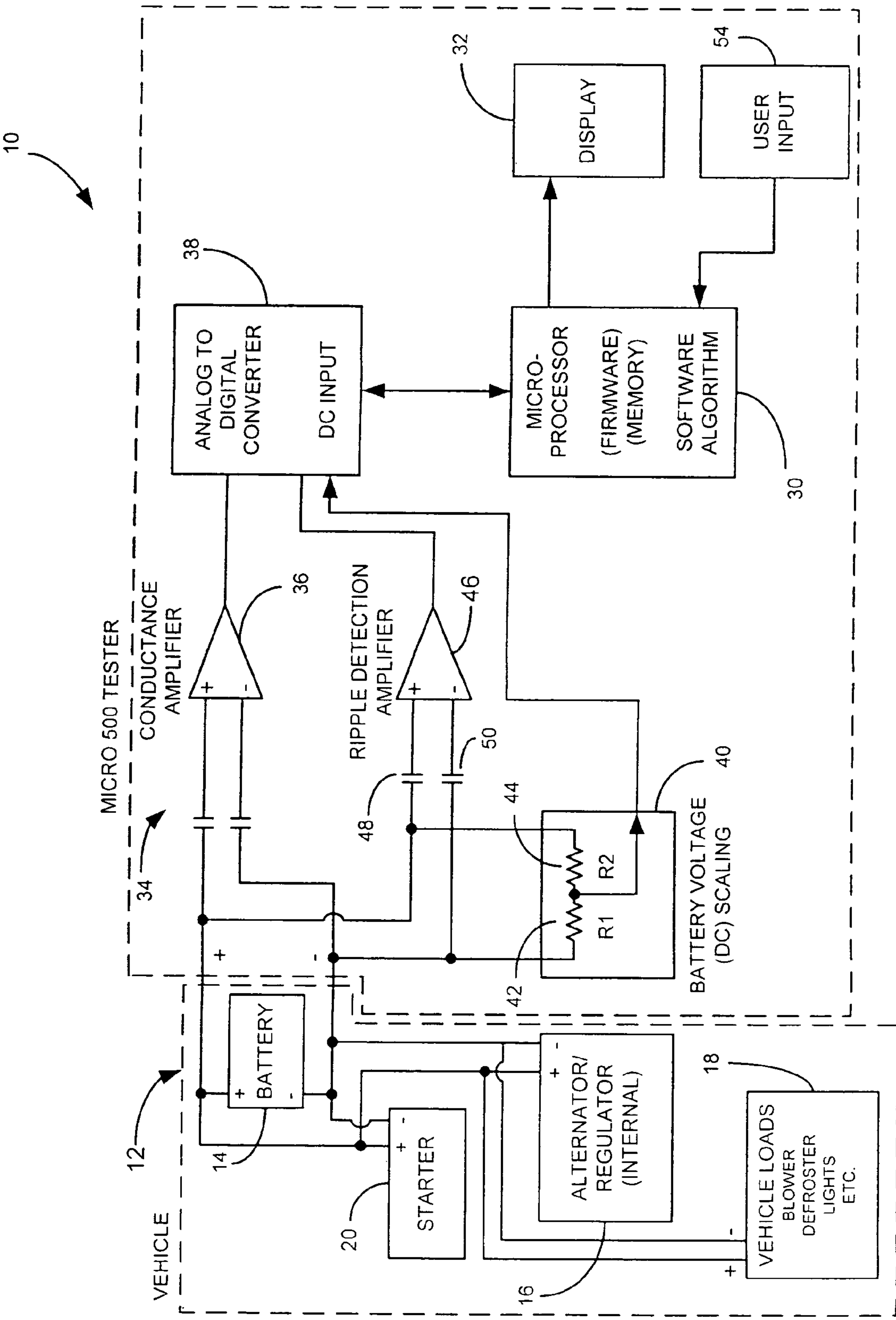
10
MICRO 500 TESTER
34
CONDUCTANCE
AMPLIFIER
36
ANALOG TO
DIGITAL
CONVERTER
DC INPUT
38
MICRO-
PROCESSOR
(FIRMWARE)
(MEMORY)
SOFTWARE
ALGORITHM
30
DISPLAY
32
USER
INPUT
54
RIPPLE DETECTION
AMPLIFIER
46
48
50
44
R2
R1
42
BATTERY VOLTAGE
(DC) SCALING
40
VEHICLE
12
BATTERY
14
STARTER
20
ALTERNATOR/
REGULATOR
(INTERNAL)
16
VEHICLE LOADS
BLOWER
DEFROSTER
LIGHTS
ETC.
18

Fig. 1

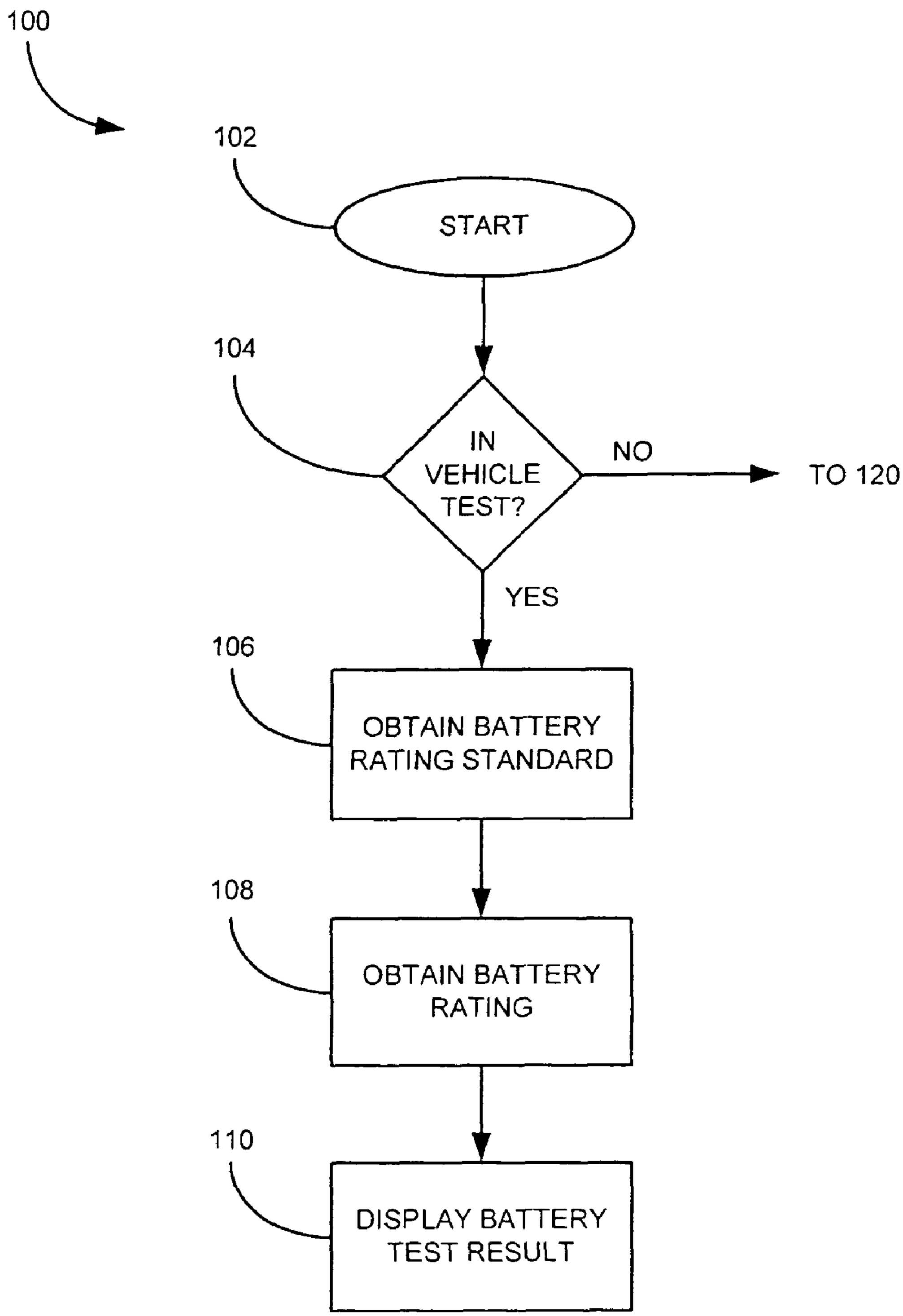
100
102
START
104
IN VEHICLE TEST?
NO
TO 120
YES
106
OBTAIN BATTERY RATING STANDARD
108
OBTAIN BATTERY RATING
110
DISPLAY BATTERY TEST RESULT

Fig. 2

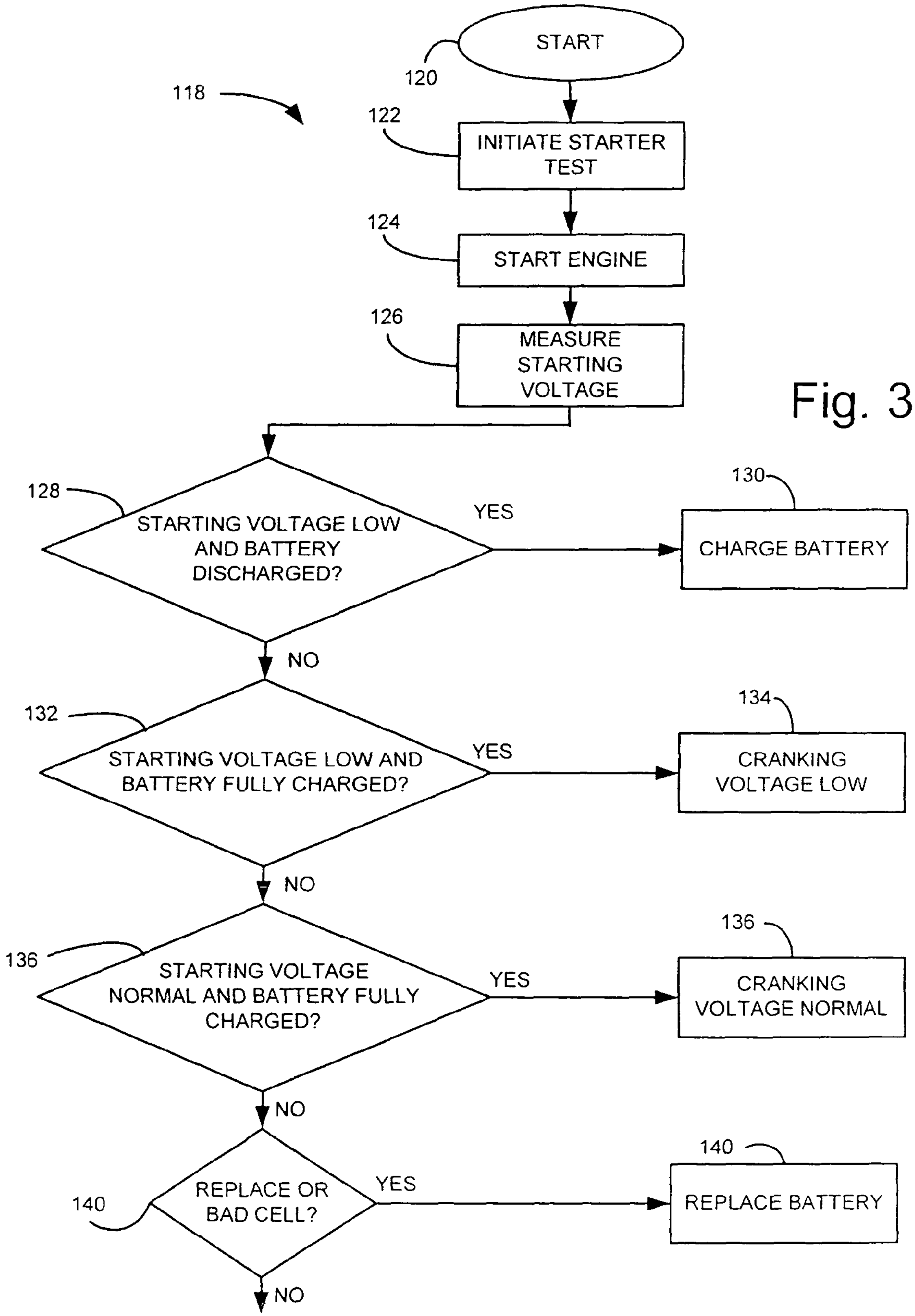
START
120
118
122
INITIATE STARTER TEST
124
START ENGINE
126
MEASURE STARTING VOLTAGE
128
STARTING VOLTAGE LOW AND BATTERY DISCHARGED?
YES
130
CHARGE BATTERY
NO
132
STARTING VOLTAGE LOW AND BATTERY FULLY CHARGED?
YES
134
CRANKING VOLTAGE LOW
NO
136
STARTING VOLTAGE NORMAL AND BATTERY FULLY CHARGED?
YES
136
CRANKING VOLTAGE NORMAL
NO
140
REPLACE OR BAD CELL?
YES
140
REPLACE BATTERY
NO

Fig. 3

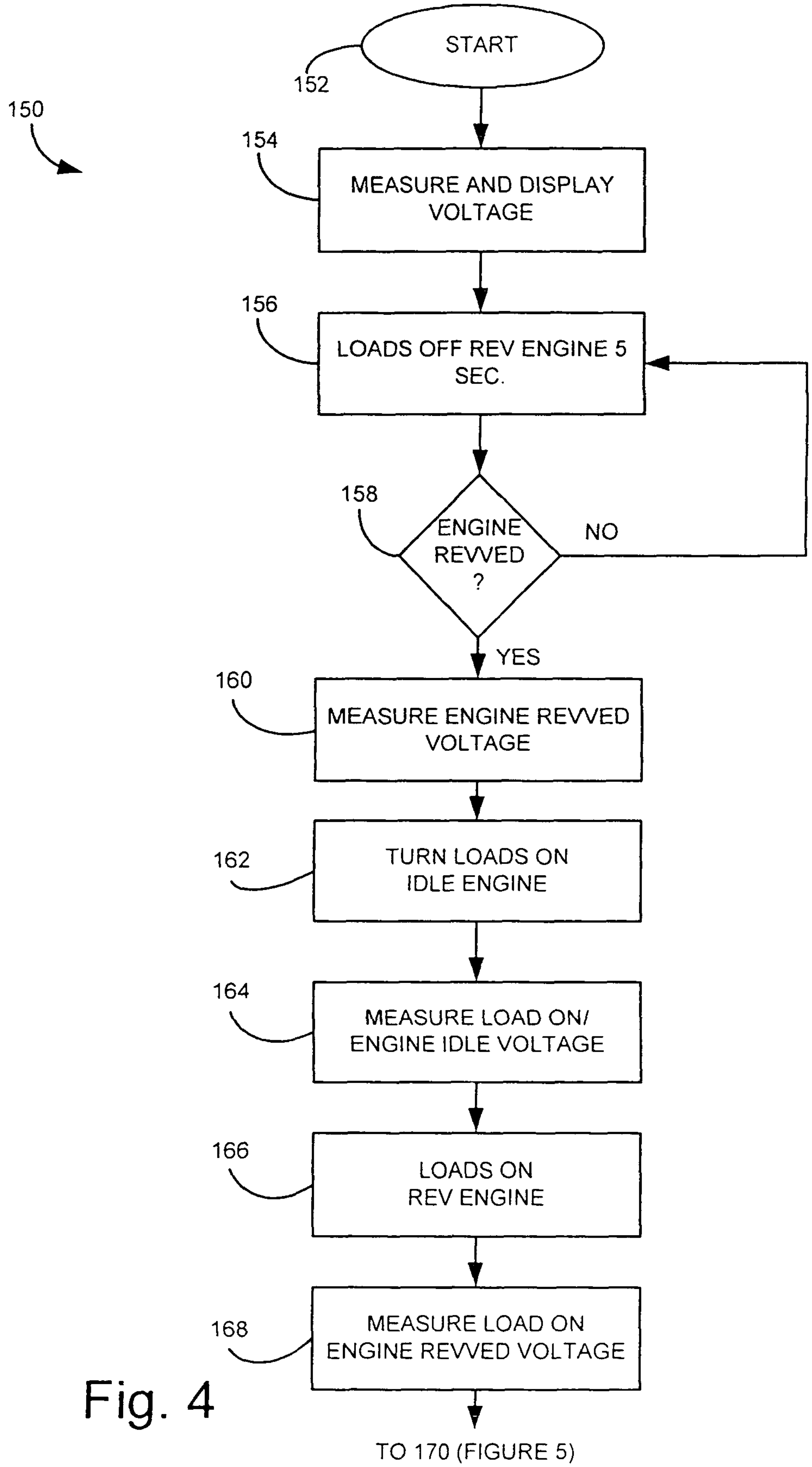
150
START
152
MEASURE AND DISPLAY VOLTAGE
154
LOADS OFF REV ENGINE 5 SEC.
156
ENGINE REVVED ?
158
NO
YES
MEASURE ENGINE REVVED VOLTAGE
160
TURN LOADS ON IDLE ENGINE
162
MEASURE LOAD ON/ ENGINE IDLE VOLTAGE
164
LOADS ON REV ENGINE
166
MEASURE LOAD ON ENGINE REVVED VOLTAGE
168
TO 170 (FIGURE 5)

Fig. 4

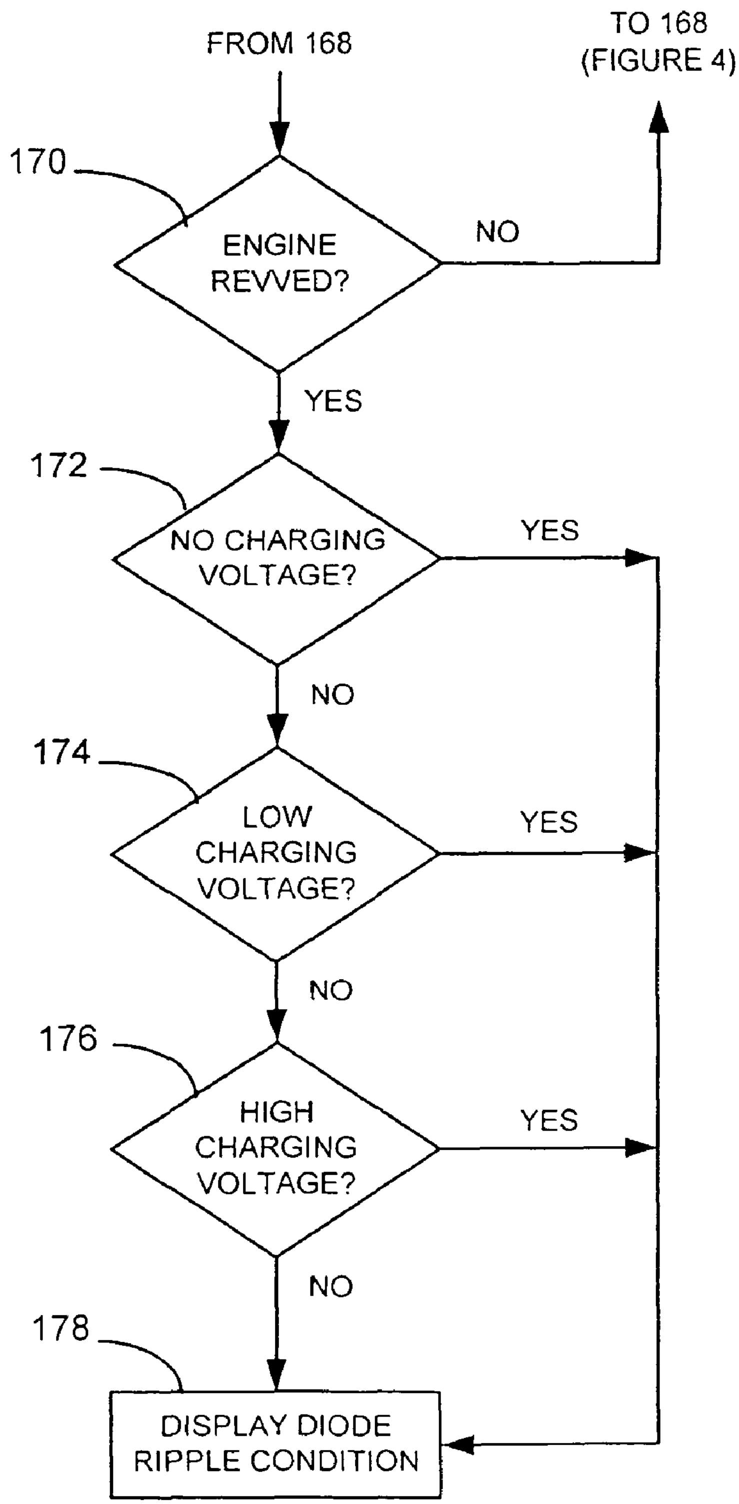
FROM 168
TO 168
(FIGURE 4)
170
ENGINE
REVVED?
NO
YES
172
NO CHARGING
VOLTAGE?
YES
NO
174
LOW
CHARGING
VOLTAGE?
YES
NO
176
HIGH
CHARGING
VOLTAGE?
YES
NO
178
DISPLAY DIODE
RIPPLE CONDITION

Fig. 5

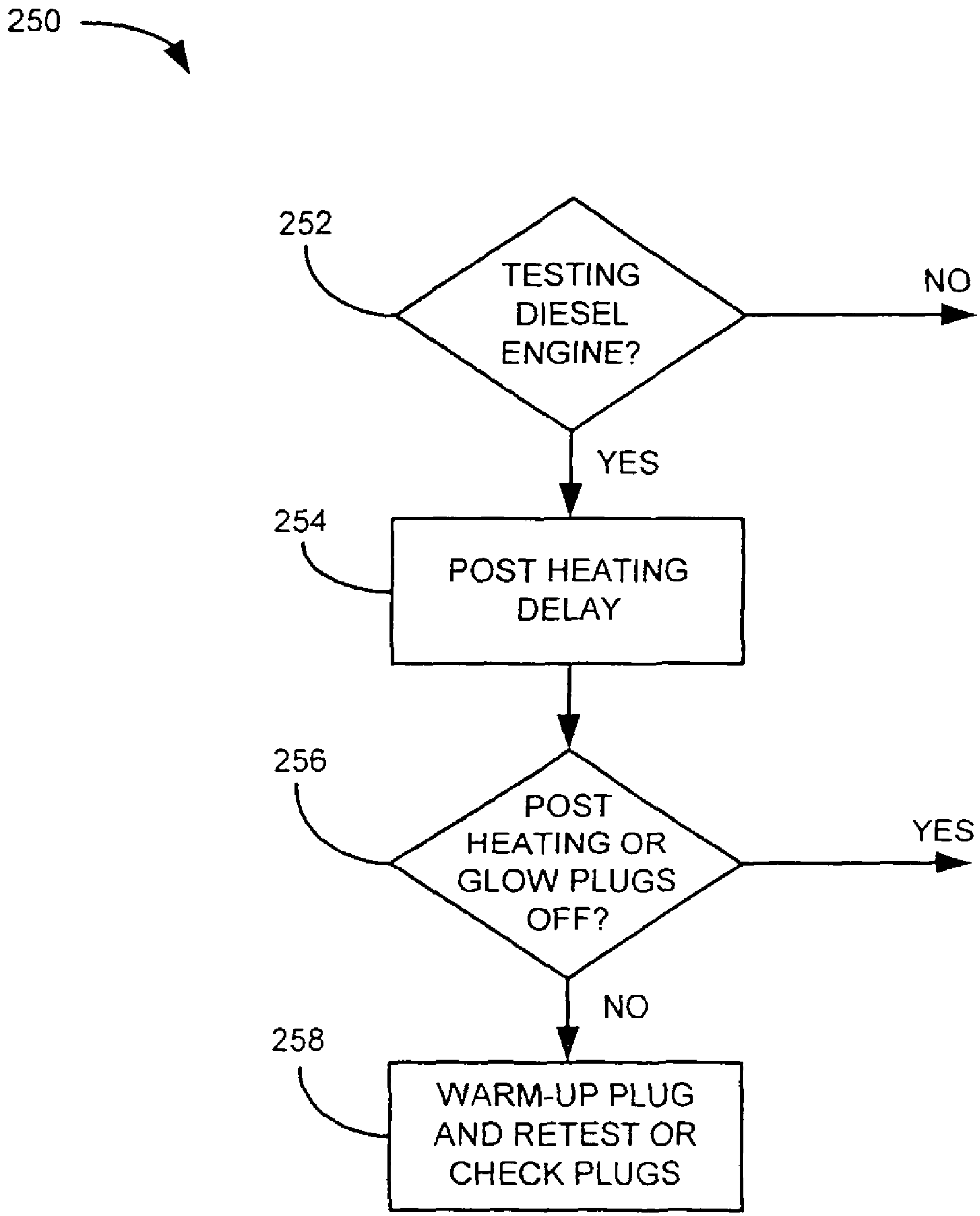
250
252
TESTING DIESEL ENGINE?
NO
YES
254
POST HEATING DELAY
256
POST HEATING OR GLOW PLUGS OFF?
YES
NO
258
WARM-UP PLUG AND RETEST OR CHECK PLUGS

Fig. 6

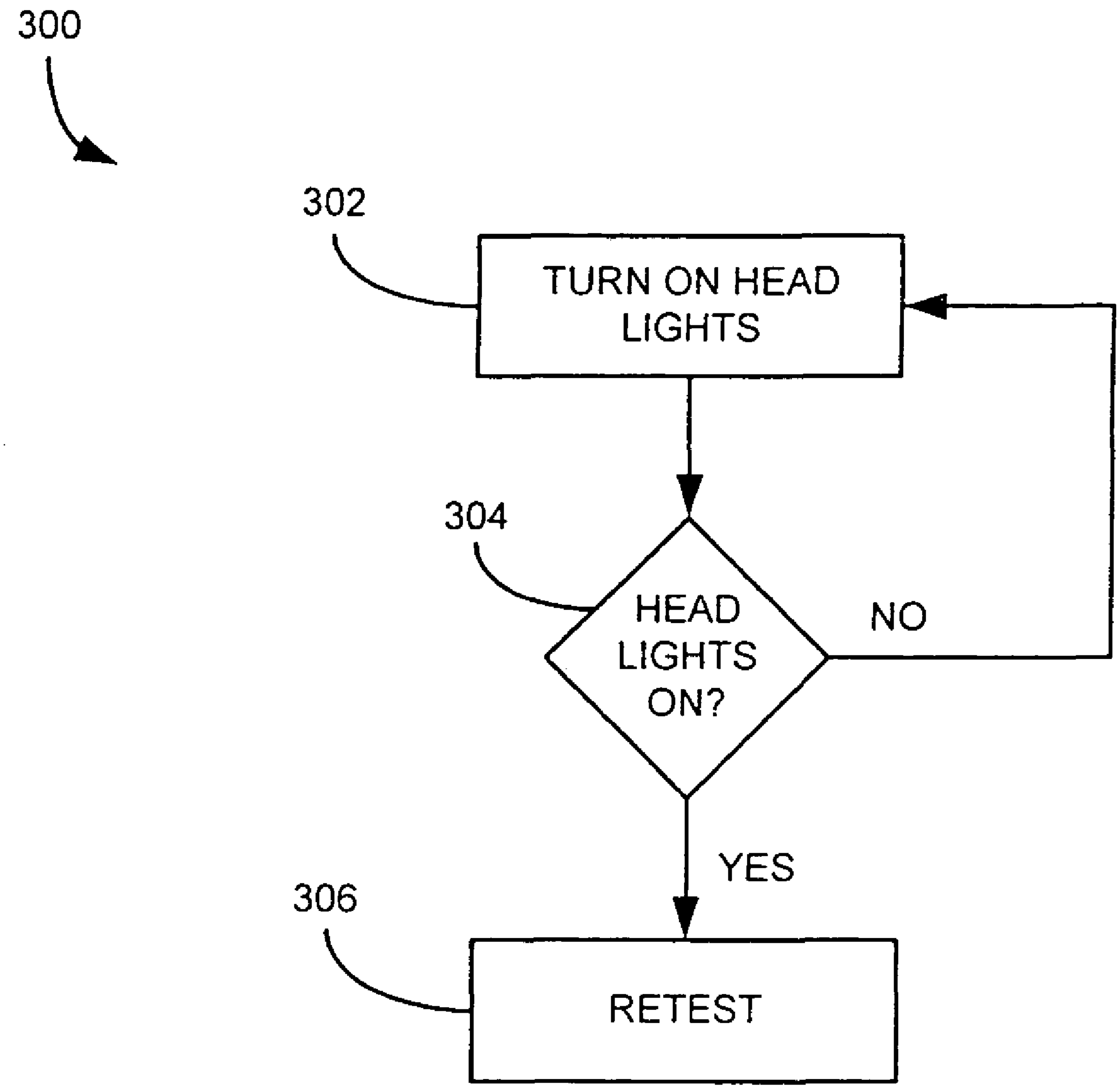
300
302
TURN ON HEAD LIGHTS
304
HEAD LIGHTS ON?
NO
YES
306
RETEST

Fig. 7

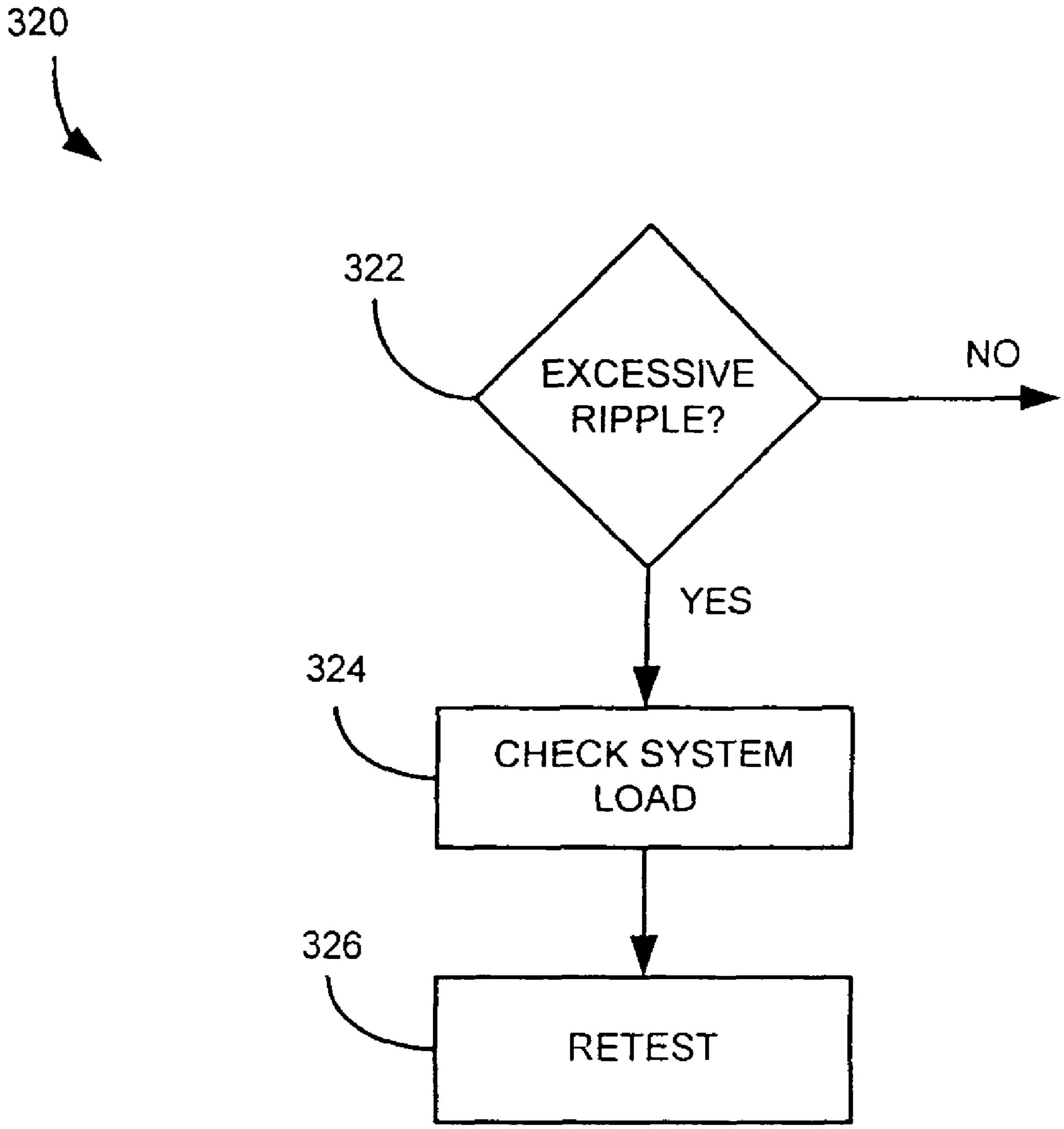
320
322
EXCESSIVE RIPPLE?
NO
YES
324
CHECK SYSTEM LOAD
326
RETEST

Fig. 8

AUTOMOTIVE BATTERY CHARGING SYSTEM TESTER

The present application is a Continuation-In-Part of application Ser. No. 10/098,741, filed Mar. 14, 2002 which is a Continuation-In-Part of U.S. patent application Ser. No. 09/575,629, filed May 22, 2000, now U.S. Pat. No. 6,445,158, which is a Continuation-In-Part of Ser. No. 09/293,020, filed Apr. 16, 1999, now U.S. Pat. No. 6,351,102; application Ser. No. 09/575,629 is also a Continuation-In-Part of Ser. No. 09/426,302, filed Oct. 25, 1999, now U.S. Pat. No. 6,091,245; which is a Divisional of Ser. No. 08/681,730, filed Jul. 29, 1996, now U.S. Pat. No. 6,051,976, the contents of which are hereby incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

The present invention relates to devices for testing an automotive vehicle. More specifically, the present invention relates to a battery charging system tester for an automotive vehicle.

Automotive vehicles include a storage battery for operating electronics in the vehicle and using an electric starter to start the vehicle engine. A battery charging system is coupled to the engine and is powered by the engine when the vehicle is running. The charging system is used to charge the storage battery when the vehicle is operating.

Many attempts have been made to test the battery of the vehicle. One technique which has been pioneered by Dr. Keith S. Champlin and Midtronics, Inc. of Burr Ridge, Ill. relates to measuring the conductance of batteries to determine their condition. This technique is described in a number of U.S. patents, for example, U.S. Pat. No. 3,873,911, issued Mar. 25, 1975, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Pat. No. 3,909,708, issued Sep. 30, 1975, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Pat. No. 4,816,768, issued Mar. 28, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Pat. No. 4,825,170, issued Apr. 25, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH AUTOMATIC VOLTAGE SCALING; U.S. Pat. No. 4,881,038, issued Nov. 14, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH AUTOMATIC VOLTAGE SCALING TO DETERMINE DYNAMIC CONDUCTANCE; U.S. Pat. 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No. 6,137,269, issued Oct. 24, 2000, entitled METHOD AND APPARATUS FOR ELECTRONICALLY EVALUATING THE INTERNAL TEMPERATURE OF AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Pat. No. 6,163,156, issued Dec. 19, 2000, entitled ELECTRICAL CONNECTION FOR ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,172,483, issued Jan. 9, 2001, entitled METHOD AND APPARATUS FOR MEASURING COMPLEX IMPEDANCE OF CELLS AND BATTERIES; U.S. Pat. No. 6,172,505, issued Jan. 9, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,222,19, issued Apr. 24, 2001, entitled METHOD AND APPARATUS FOR DETERMINING BATTERY PROPERTIES FROM COMPLEX IMPEDANCE/ADMITTANCE; U.S. Pat. No. 6,225,808, issued May 1, 2001, entitled TEST COUNTER FOR ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,249,124, issued Jun. 19, 2001, entitled ELECTRONIC BATTERY TESTER WITH INTERNAL BATTERY; U.S. Pat. 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No. 6,351,102, issued Feb. 26, 2002, entitled AUTOMOTIVE BATTERY CHARGING SYSTEM TESTER; U.S. Pat. No. 6,359,441, issued Mar. 19, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,13,303, issued Mar. 26, 2002, entitled ALTERNATOR DIAGNOSTIC SYSTEM; U.S. Pat. No. 6,392,414, issued May 21, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,417,669, issued Jul. 9, 2002, entitled SUPPRESSING INTERFERENCE IN AC MEASUREMENTS OF CELLS, BATTERIES AND OTHER ELECTRICAL ELEMENTS; U.S. Pat. No. 6,424,158, issued Jul. 23, 2002, entitled APPARATUS AND METHOD FOR CARRYING OUT DIAGNOSTIC TESTS ON BATTERIES AND FOR RAPIDLY CHARGING BATTERIES; U.S. Pat. No. 6,441,585, issued Aug. 17, 2002, entitled APPARATUS AND METHOD FOR TESTING RECHARGEABLE ENERGY STORAGE BATTERIES; U.S. Pat. No. 6,445,158, issued Sep. 3, 2002, entitled VEHICLE ELECTRICAL SYSTEM TESTER WITH ENCODED OUTPUT; U.S. Pat. No. 6,456,045, issued Sep. 24, 2002, entitled INTEGRATED CONDUCTANCE AND LOAD TEST BASED ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,466,025, issued Oct. 15, 2002, entitled ALTERNATOR TESTER; U.S. Pat. No. 6,466,026, issued Oct. 15, 2002, entitled PROGRAMMABLE CURRENT EXCITER FOR MEASURING AC IMMITTANCE OF CELLS AND BATTERIES; U.S. Pat. No. 6,534,993, issued Mar. 18, 2003, entitled ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,544,078, issued Apr. 8, 2003, entitled BATTERY CLAMP WITH INTEGRATED CURRENT SENSOR; U.S. Pat. No. 6,556,019, issued Apr. 29, 2003, entitled ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,566,883, issued May 20, 2003, entitled ELECTRONIC BATTERY TESTER; U.S. Pat. No. 6,586,941, issued Jul. 1, 2003, entitled BATTERY TESTER WITH DATABUS; U.S. Pat. No. 6,597,150, issued Jul. 22, 2003, entitled METHOD OF DISTRIBUTING JUMP-START BOOSTER PACKS; U.S. Pat. No. 6,621,272, issued Sep. 16, 2003, entitled PROGRAMMABLE CURRENT EXCITER FOR MEASURING AC IMMITTANCE OF CELLS AND BATTERIES; U.S. Pat. No. 6,623,314, issued Sep. 23, 2003, entitled KELVIN CLAMP FOR ELECTRICALLY COUPLING TO A BATTERY CONTACT; U.S. Pat. No. 6,633,165, issued Oct. 14, 2003, entitled IN-VEHICLE BATTERY MONITOR; U.S. Pat. No. 6,635,974, issued Oct. 21, 2003, entitled SELF-LEARNING POWER MANAGEMENT SYSTEM AND METHOD; U.S. Ser. No. 09/780,146, filed Feb. 9, 2001, entitled STORAGE BATTERY WITH INTEGRAL BATTERY TESTER; U.S. Ser. No. 09/756,638, filed Jan. 8, 2001, entitled METHOD AND APPARATUS FOR DETERMINING BATTERY PROPERTIES FROM COMPLEX IMPEDANCE/ADMITTANCE; U.S. Ser. No. 09/862,783, filed May 21, 2001, entitled METHOD AND APPARATUS FOR TESTING CELLS AND BATTERIES EMBEDDED IN SERIES/PARALLEL SYSTEMS; U.S. Pat. No. 6,469,511, issued Nov. 22, 2002, entitled BATTERY CLAMP WITH EMBEDDED ENVIRONMENT SENSOR; U.S. Ser. No. 09/880,473, filed Jun. 13, 2001; entitled BATTERY TEST MODULE; U.S. Pat. No. 6,495,990, issued Dec. 17, 2002, entitled METHOD AND APPARATUS FOR EVALUATING STORED CHARGE IN AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Ser. No. 60/348,479, filed Oct. 29, 2001, entitled CONCEPT FOR TESTING HIGH POWER VRLA BATTERIES; U.S. Ser. No. 10/046,659, filed Oct. 29, 2001, entitled ENERGY MANAGEMENT SYSTEM FOR AUTOMOTIVE VEHICLE; U.S. Ser. No. 09/993,468, filed Nov. 14, 2001, entitled KELVIN CONNECTOR FOR A BATTERY POST; U.S. Ser. No. 09/992,350, filed Nov. 26, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Ser. No. 10/042,451, filed Jan. 8, 2002, entitled BATTERY CHARGE CONTROL DEVICE; U.S. Ser. No. 10/073,378, filed Feb. 8, 2002, entitled METHOD AND APPARATUS USING A CIRCUIT MODEL TO EVALUATE CELL/BATTERY PARAMETERS; U.S. Ser. No. 10/093,853, filed Mar. 7, 2002, entitled ELECTRONIC BATTERY TESTER WITH NETWORK COMMUNICATION; U.S. Ser. No. 10/098,741, filed Mar. 14, 2002, entitled METHOD AND APPARATUS FOR AUDITING A BATTERY TEST; U.S. Ser. No. 10/112,114, filed Mar. 28, 2002, entitled BOOSTER PACK WITH STORAGE CAPACITOR; U.S. Ser. No. 10/109,734, filed Mar. 28, 2002, entitled APPARATUS AND METHOD FOR COUNTERACTING SELF DISCHARGE IN A STORAGE BATTERY; U.S. Ser. No. 10/112,105, filed Mar. 28, 2002, entitled CHARGE CONTROL SYSTEM FOR A VEHICLE BATTERY; U.S. Ser. No. 10/112,998, filed Mar. 29, 2002, entitled BATTERY TESTER WITH BATTERY REPLACEMENT OUTPUT; U.S. Ser. No. 10/119,297, filed Apr. 9, 2002, entitled METHOD AND APPARATUS FOR TESTING CELLS AND BATTERIES EMBEDDED IN SERIES/PARALLEL SYSTEMS; U.S. Ser. No. 60/387,046, filed Jun. 7, 2002, entitled METHOD AND APPARATUS FOR INCREASING THE LIFE OF A STORAGE BATTERY; U.S. Ser. No. 10/177,635, filed Jun. 21, 2002, entitled BATTERY CHARGER WITH BOOSTER PACK; U.S. Ser. No. 10/200,041, filed Jul. 19, 2002, entitled AUTOMOTIVE VEHICLE ELECTRICAL SYSTEM DIAGNOSTIC DEVICE; U.S. Ser. No. 10/217,913, filed Aug. 13, 2002, entitled, BATTERY TEST MODULE; U.S. Ser. No. 10/246,439, filed Sep. 18, 2002, entitled BATTERY TESTER UPGRADE USING SOFTWARE KEY; U.S. Ser. No. 10/263,473, filed Oct. 2, 2002, entitled ELECTRONIC BATTERY TESTER WITH RELATIVE TEST OUTPUT; U.S. Ser. No. 10/271,342, filed Oct. 15, 2002, entitled IN-VEHICLE BATTERY MONITOR; U.S. Ser. No. 10/310,515, filed Dec. 5, 2002, entitled BATTERY TEST MODULE; U.S. Ser. No. 10/310,490, filed Dec. 5, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Ser. No. 10/310,385, filed Dec. 5, 2002, entitled BATTERY TEST MODULE; U.S. Ser. No. 60/437,224, filed Dec. 31, 2002, entitled DISCHARGE VOLTAGE PREDICTIONS; U.S. Ser. No. 10/349,053, filed Jan. 22, 2003, entitled APPARATUS AND METHOD FOR PROTECTING A BATTERY FROM OVERDISCHARGE; U.S. Ser. No. 10/388,855, filed Mar. 14, 2003, entitled ELECTRONIC BATTERY TESTER WITH BATTERY FAILURE TEMPERATURE DETERMINATION; U.S. Ser. No. 10/396,550, filed Mar. 25, 2003, entitled ELECTRONIC BATTERY TESTER; U.S. Ser. No. 60/467,872, filed May 5, 2003, entitled METHOD FOR DETERMINING BATTERY STATE OF CHARGE; U.S. Ser. No. 60/477,082, filed Jun. 9, 2003, entitled ALTERNATOR TESTER; U.S. Ser. No. 10/460,749, filed Jun. 12, 2003, entitled MODULAR BATTERY TESTER FOR SCAN TOOL; U.S. Ser. No. 10/462,323, filed Jun. 16, 2003, entitled ELECTRONIC BATTERY TESTER HAVING A USER INTERFACE TO CONFIGURE A PRINTER; U.S. Ser. No. 10/601,608, filed Jun. 23, 2003, entitled CABLE FOR ELECTRONIC BATTERY TESTER; U.S. Ser. No. 10/601,432, filed Jun. 23, 2003, entitled BATTERY TESTER CABLE WITH MEMORY; U.S. Ser. No. 60/490,153, filed Jul. 25, 2003, entitled SHUNT CONNECTION TO A PCB FOR AN ENERGY MANAGEMENT SYSTEM EMPLOYED IN AN AUTOMOTIVE VEHICLE; U.S. Ser. No. 10/653,342, filed Sep. 2, 2003, entitled ELECTRONIC BATTERY TESTER CONFIGURED TO PREDICT A LOAD TEST RESULT; U.S. Ser. No. 10/654,098, filed Sep. 3, 2003, entitled BATTERY TEST OUTPUTS ADJUSTED BASED UPON BATTERY TEMPERATURE AND THE STATE OF DISCHARGE OF THE BATTERY; U.S. Ser. No. 10/656,526, filed Sep. 5, 2003, entitled METHOD AND APPARATUS FOR MEASURING A PARAMETER OF A VEHICLE ELECTRICAL SYSTEM; U.S. Ser. No. 10/656,538, filed Sep. 5, 2003, entitled ALTERNATOR TESTER WITH ENCODED OUTPUT; U.S. Ser. No. 10/675,933, filed Sep. 30, 2003, entitled QUERY BASED ELECTRONIC BATTERY TESTER; U.S. Ser. No. 10/678,629, filed Oct. 3, 2003, entitled ELECTRONIC BATTERY TESTER/CHARGER WITH INTEGRATED BATTERY CELL TEMPERATURE MEASUREMENT DEVICE; U.S. Ser. No. 10/441,271, filed May 19, 2003, entitled ELECTRONIC BATTERY TESTER; U.S. Ser. No. 09/653,963, filed Sep. 1, 2000, entitled SYSTEM AND METHOD FOR CONTROLLING POWER GENERATION AND STORAGE; U.S. Ser. No. 09/654,217, filed Sep. 1, 2000, entitled SYSTEM AND METHOD FOR PROVIDING STEP-DOWN POWER CONVERSION USING INTELLIGENT SWITCH; U.S. Pat. No. 6,465,908, issued Oct. 15, 2002, entitled INTELLIGENT POWER MANAGEMENT SYSTEM; U.S. Pat. No. 6,497,209, issued Dec. 24, 2002, entitled SYSTEM AND METHOD FOR PROTECTING A CRANKING SUBSYSTEM; U.S. Pat. No. 6,437,957, issued Aug. 20, 2002, entitled SYSTEM AND METHOD FOR PROVIDING SURGE, SHORT, AND REVERSE POLARITY CONNECTION PROTECTION; U.S. Pat. No. 6,377,031, issued Apr. 23, 2002, entitled INTELLIGENT SWITCH FOR POWER MANAGEMENT; U.S. Ser. No. 10/174,110, filed Jun. 18, 2002, entitled DAYTIME RUNNING LIGHT CONTROL USING AN INTELLIGENT POWER MANAGEMENT SYSTEM; U.S. Ser. No. 60/488,775, filed Jul. 21, 2003, entitled ULTRASONICALLY ASSISTED CHARGING; U.S. Ser. No. 10/258,441, filed Apr. 9, 2003, entitled CURRENT MEASURING CIRCUIT SUITED FOR BATTERIES; U.S. Pat. No. 6,507,196, issued Jan. 14, 2003; entitled BATTERY HAVING DISCHARGE STATE INDICATION; U.S. Pat. No. 5,871,858, issued Feb. 16, 1999, entitled ANTI-THEFT BATTERY; U.S. Ser. No. 10/705,020, filed Nov. 11, 2003, entitled APPARATUS AND METHOD FOR SIMULATING A BATTERY TESTER WITH A FIXED RESISTANCE LOAD; U.S. Ser. No. 10/280,186, filed Oct. 25, 2002, entitled BATTERY TESTER CONFIGURED TO RECEIVE A REMOVABLE DIGITAL MODULE; U.S. Ser. No. 10/681,666, filed Oct. 8, 2003, entitled ELECTRONIC BATTERY TESTER WITH PROBE LIGHT; U.S. Ser. No. 10/748,792, filed Dec. 30, 2003, entitled APPARATUS AND METHOD FOR PREDICTING THE REMAINING DISCHARGE TIME OF A BATTERY; and U.S. Ser. No. 10/767,945, filed Jan. 29, 2004, entitled ELECTRONIC BATTERY TESTER, which are incorporated herein in their entirety.

With the advent of accurate battery testing, it has become apparent that in some instances the battery in the vehicle may be good, and a problem related to the battery charging system is the cause of the perceived battery failure. A vehicle charging system generally includes the battery, an alternator, a regulator and an alternator drive belt. In most modern vehicles, the regulator is built into the alternator housing and is referred to as an internal regulator. The role of the charging system is two fold. First, the alternator provides charging current for the battery. This charging current ensures that the battery remains charged while the vehicle is being driven and therefore will have sufficient capacity to subsequently start the engine. Second, the alternator provides an output current for all of the vehicle electrical loads. In general, the alternator output, the battery capacity, the starter draw and the vehicle electrical load requirements are matched to each other for optimal performance. In a properly functioning charging system, the alternator will be capable of outputting enough current to drive the vehicle electrical loads while simultaneously charging the battery. Typically, alternators range in size from 60 to 120 amps.

A number of charging system testers have been used to evaluate the performance of the vehicle charging system. These testers generally use an inductive "amp clamp." The amp clamp is placed around a cable or wire and inductively couples to the cable or wire such that the current passing through the wire can be measured. This measurement can be made without having to disconnect the wire. In such a system, typically the operator determines the rated size of the alternator. Next, the operator connects the amp clamp to the output cable of the alternator and an electrical load such as a carbon pile load tester, is placed across the battery. This is a large resistive load capable of receiving several hundred amps which will force the alternator to provide its maximum output. The maximum output current can then be measured using the amp clamp connection. If the measured output is less than the rated output, the alternator is determined to be malfunctioning. Such a test is cumbersome as the equipment is large and difficult to handle. Further, it is difficult, particularly with compact engines, to reach the alternator output cable. Further, in some cases, the amp clamp may not fit around the output cable. It is also very easy to place the amp clamp around the wrong cable causing a false test.

Another testing technique is described in U.S. Pat. No. 4,207,611, which issued Jun. 10, 1980 and is entitled APPARATUS AND METHOD FOR CALIBRATED TESTING OF A VEHICLE ELECTRICAL SYSTEM. The device described in this reference monitors voltage changes present at the cigarette lighter of an automotive vehicle in order to determine the condition of the alternator by applying internal loads such as head lamps and blowers, while the engine is running.

SUMMARY OF THE INVENTION

The present invention includes an automotive battery charging system tester for testing the charging system of an automotive vehicle. The tester includes AC and DC voltage measurement circuits and a microprocessor controlled testing sequence. The microprocessor is used to perform a series of tests and instruct an operator to perform steps associated with those tests. Through the application of various loads at various engine speeds, the tester is capable of identifying faults in the battery charging system including a bad battery, problems in the alternator or associated electronics, and problems in the starting system.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a simplified block diagram of an automotive battery charging system tester in accordance with the present invention.

FIG. **2** is a simplified flow chart showing steps in a battery test.

FIG. **3** is a simplified flow chart showing steps in a starter test.

FIG. **4** is a simplified flow chart showing steps in a charging system test.

FIG. **5** is a simplified flow chart showing further steps in the charging system test of FIG. **4**.

FIG. **6** is a simplified flow chart showing steps in a diesel engine charging system test.

FIG. **7** is a simplified flow chart showing steps to remove surface charge.

FIG. **8** is a simplified flow chart showing a ripple test.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** is a simplified block diagram of a battery charging system tester **10** in accordance with one embodiment of the present invention coupled to a vehicle **12**. Vehicle **12** includes a battery **14** having positive and negative terminals, an alternator with internal regulator **16**, various vehicle loads **18**, and a starter motor **20**. In operation, battery **14** provides power to starter **20** and vehicle loads **18** when the engine in vehicle **12** is not running. When the engine in vehicle **12** is running, alternator **16** is used to power vehicle loads **18** and provide a charging current to battery **14** to maintain the charge of battery **14**.

Charging system tester **10** includes a microprocessor **30** which controls operation of tester **10** and provides instructions and test result information to an operator through, for example, a display **32**. Tester **10** includes a battery testing section **34** which is illustrated generally as conductance amplifier **1**. Section **34** operates in accordance with, for example, the conductance based battery testing techniques described in Champlin patents U.S. Pat. No. 3,873,911, issued Mar. 25, 1975, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Pat. No. 3,909,708, issued Sep. 30, 1975, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Pat. No. 4,816,768, issued Mar. 28, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Pat. No. 4,825,170, issued Apr. 25, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH AUTOMATIC VOLTAGE SCALING; U.S. Pat. No. 4,881,038, issued Nov. 14, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH AUTOMATIC VOLTAGE SCALING TO DETERMINE DYNAMIC CONDUCTANCE; U.S. Pat. No. 4,912,416, issued Mar. 27, 1990, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH STATE-OF-CHARGE COMPENSATION; U.S. Pat. No. 5,140,269, issued Aug. 18, 1992, to Champlin, entitled ELECTRONIC TESTER FOR ASSESSING BATTERY/CELL CAPACITY; U.S. Pat. No. 5,343,380, issued Aug. 30, 1994, entitled METHOD AND APPARATUS FOR SUPPRESSING TIME VARYING SIGNALS IN BATTERIES UNDERGOING CHARGING OR DISCHARGING; U.S. Pat. No. 5,572,11, issued Nov. 5, 1996, entitled ELECTRONIC BATTERY TESTER WITH AUTOMATIC COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Pat. No. 5,585,728, issued Dec. 17, 1996, entitled ELECTRONIC BATTERY TESTER WITH AUTOMATIC COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Pat. No. 5,598,098, issued Jan. 28, 1997, entitled ELECTRONIC BATTERY TESTER WITH VERY HIGH NOISE IMMUNITY; U.S. Pat. No. 5,821,756, issued Oct. 13, 1998, entitled ELECTRONIC BATTERY TESTER WITH TAILORED COMPENSATION FOR LOW STATE-OF-CHARGE. Section **34** is illustrated in very simplified form and conductance amplifier **1** provides an output to an analog to digital converter **38** which is related to the internal conductance of battery **14**.

A DC voltage sensor **40** includes voltage scaling resistors **42** and **44** and is coupled to battery **14** to provide an output to analog to digital converter **38** which is representative of the DC voltage across battery **14**. Further, an AC ripple detector amplifier **46** is coupled to battery **14** through capacitors **48** and **50** and provides an output to analog to digital converter **38** which is representative of the AC ripple voltage across battery **14**.

Microprocessor **30** controls analog to digital converter **38** to select which of the three inputs to digitize. Microprocessor **30** includes firmware, memory, and a software program in accordance with the invention. The user input **54** is coupled to microprocessor **30** to provide the information to microprocessor **30** from an operator.

Preferably, tester **10** is portable such that it may be easily moved between vehicles or otherwise transported. Portability of tester **10** is achieved because tester **10** does not require large internal carbon pile loads to load the battery charging system. Instead, as described herein, tester **10** utilizes loads internal to the vehicle **12** in testing the charging system. Further, the battery tester performed by tester **10** is in accordance with the non-load battery testing technique as described above.

FIGS. **2-8** are simplified block diagrams illustrating steps in accordance with the invention. User input for the steps can be through user input device **54** and a display can be provided through display device **32**. In FIG. **2**, block diagram **100** begins at start block **102**. At block **104** the type of vehicle test is selected. If it is an in-vehicle test, control is passed to block **106**. If it is an out of vehicle test, control is passed to block **120**. At block **106**, the user is prompted to input the battery rating standard to be used for the test. Various standards include SAE, DIN, IEC, EN, JIS or a battery stock number. At block **108**, the user is prompted to input the battery rating according to the selected standard. A battery test is then performed at block **110**, the results of the battery test are displayed including battery voltage, battery cold cranking amps, and a general condition of the battery such as good, good but recharged, charged and retest, replace battery or bad cell-replace. Any type of battery test may be used, however, conductance, resistance, impedance or admittance based testing as described in the Champlin and Midtronics patents is preferred.

FIG. **3** is a simplified block diagram **118** for an in-vehicle test. When the user initiates a starter test, for example through an input through user input **54**, control is passed to block **124** and the operator is instructed to start the engine. Microprocessor **30** detects that the engine is being started by monitoring the resultant in drop in voltage across battery **14**. The starting voltage is measured at block **126**. Once the engine starts, and the voltage begins to rise, the tester **10** will display one of four different test results. At block **128**, if the starting voltage is low and the battery is discharged, the message "charge battery" is displayed at block **130**. At block **132**, if the starting voltage is low and the battery has a full charge, the message "cranking voltage low" is displayed at block **134** along with the measured voltage. If at block **11**, the starting voltage is normal and the battery has a full charge, block **138** displays cranking voltage normal along with the measured voltage. If, at block **140**, the battery test result was either replaced or bad cell, block **142** displays the message replace battery. The low and normal cranking voltages can be selected as desired and using known techniques.

FIG. **4** is a block diagram **150** which illustrates steps in a charging system test in accordance with another aspect of the invention. At block **152**, the procedure is initiated by the operator while the engine in vehicle **12** is running. At block **154**, the voltage across battery **14** due to alternator **16** is measured and displayed. The operator may press and enter button on user input **54** to continue operation and at block **156** the operator is instructed to turn off all vehicle loads and rev the engine for 5 seconds. At block **158**, the revving of the engine is detected by monitoring the AC ripple across battery **14** using ripple detection amplifier **46**. If, after 30 seconds, microprocessor **30** does not detect engine revving, control is returned to block **156** and the procedure is repeated. At block **160**, the engine revved voltage is measured and control is passed to block **162** where the operator is instructed to turn loads within the vehicle (i.e., headlights, fans, etc.) on and idle the engine. Again, an enter key on user input **54** is pressed and control is passed to block **164** and tester **10** measures the load on, engine idle voltage. At **166**, the user is instructed to rev the engine with the loads on and another voltage is obtained at block **168**. Control is then passed to block **170** in FIG. **5** and it is determined whether the engine speed has increased. At block **172**, if there is no charging voltage, that is i.e., the charging voltage is less than or the same as the idle voltage, an output is displayed. Similarly, if the charging voltage is low such that the total voltage across the battery is less than, for example, 13 volts, an output is displayed. At block **176**, if a high charging voltage is detected, such as more than 2.5 volts above the idle voltage, an output is displayed. When control reaches block **178**, an output is provided indicative of the diode ripple voltage. This voltage can be obtained during any of the measurements where the engine is revved. If the ripple voltage is greater than, for example, 130 mV, an indication is provided that there is a diode or a stator problem.

FIG. **6** is a block diagram of a diesel test algorithm **250**. If the tester **10** does not detect a charging or a ripple voltage, the tester begins the diesel test algorithm shown at **250**. This allows the glow plugs of a diesel engine to turn off. If, at any time during the procedure, a charging voltage and a ripple are detected, the normal test procedure will resume. At block **252**, the user is asked to input information as to whether the engine under test is a diesel engine. If the engine is not a diesel engine, a charging system problem is indicated. If the engine is diesel, control is passed to block **254** and a post heating delay, such as 40 seconds, passes at block **256**, if there is a post heating or glow plugs off condition, then a charging system problem is indicated. If there is a post heating or glow plug on condition, the operator is instructed to warm up the plugs and retest, or check the glow plugs.

Additionally, the tester **10** can receive a temperature input from the operator and adjust the battery test appropriately.

If the battery test indicates that the battery may have been charged before testing, the user is prompted to indicate whether the test is being performed before charging the battery or after charging the battery and the system is retested.

If the tester **10** determines that the battery may have surface charge, the operator is instructed to turn on the vehicle head lights as indicated in flow chart **300** at block **302**. If a drop in voltage is detected at block **304** indicating that the head lights have been turned on, control is passed to block **306**. If, however, the head lights have not been turned on, control is returned to block **302**. At block **306**, the system is retested. Flow chart **320** of FIG. **8** shows a noise detection algorithm. If excessive ripple is detected during engine idle periods at block **322**, the operator is instructed to check system loads at block **324**. At block **326**, the system is retested.

Based upon the test, an output can be printed or otherwise provided to an operator indicating the results of the battery test, the battery rating, the actual measured battery capacity, the voltage, the voltage during cranking and whether the cranking voltage is normal, the condition of the charging system along with the idle voltage and the load voltage and the presence of excessive diode ripple.

In general, the present invention provides the integration of an alternator test with a battery test, an alternator test with a starter test, a starter test with an battery test, or an alternator test with a battery test and with a starter test. The invention allows information from any of these tests to be shared with the other test(s).

In one aspect, tester **10** measures the voltage across battery **20**. Both the AC and DC voltages are recorded. The AC voltage is used to identify alternator diode and stator faults. The DC voltage measurement is used to determine if the charging system is functioning properly. The electrical loads of the vehicle are used to load the alternator for convenience. However, other types of loads can also be applied. The tester continually monitors the charging voltage across the battery. The operator is instructed to turn on vehicle loads and rev the engine. The charging voltage is recorded with the engine revved. In a properly functioning charging system, this charging voltage should be greater than the measured battery voltage with the engine off. This indicates that current is flowing into the battery and thus the battery is being charged even with loads applied to the charging system. This testing principle does not require knowledge of the alternator size, or even the amount of current that the alternator is producing. In the testing, various DC voltages across the battery are measured including battery voltage with the engine off (stead state voltage), battery voltage with the engine running at idle (idle voltage), battery voltage with the engine revved, for example between 1,000 RPM and 2,500 RPM, and the vehicle loads off and battery voltage with the engine revved and vehicle loads on. The AC voltage across the battery which is measured with the engine running is used to detect excessive ripple which may be caused by a faulty diode or stator. Ripple of over about 130 mV is indicative of a diode or stator problem. Additionally, the ripple can be used by tester **10** to detect changes in engine RPM.

An initial revving of the engine can be used prior to returning to idle to ensure that the alternator field circuit is excited and conducting current. If the idle voltage with the loads off is less than or equal to the steady state voltage, then a charging problem exists. If the charging voltage exceeds the steady state voltage by more than, for example, 0.5 volts, then a regulator problem is indicated.

With the engine revved and the vehicle loads (such as head lights, blower, rear defrost, etc.) turned on, the revved and loaded voltage across the battery is recorded and compared to the steady state battery voltage. If the charging voltage with loads turned on while the engine is revved is not greater than the steady state voltage, then current is not flowing into the battery and the battery is not being charge. This indicates a problem and that the alternator cannot meet the needs of the vehicle while still charging the battery.

With the present invention, the battery test can be used to prevent incorrectly identifying the charging system as being faulty. Thus, the battery test ensures that a good battery is being charged during the charging system test. The measurement of the cranking voltage while the engine is being started is used to determine whether there is a starter problem. In diesel engine applications, the charging system voltage is measured to determine if the engine glow plug operation is effecting the charging system test result. A long cabling (i.e., 10 to 15 feet) can be used such that the tester **10** can be operated while sitting in the vehicle. The battery testing is preferably performed by measuring the conductance, impedance, resistance or admittance of the battery. Further, the battery test with the engine off can be compared with the battery test with the engine on and used to diagnosis the system.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

What is claimed is:

1. An apparatus for testing a charging system of an automotive vehicle, comprising:
- electrical connections configured to couple to a battery of the vehicle;
- a user input configured to receive a battery rating from an operator;
- a display configured to display information to the operator; and
- a microprocessor configured to:
  - prompt the operator to input rating information for the battery using the input;
  - receive the rating information for the battery from the operator from the input;
  - perform a battery test on the battery through the electrical connections to the battery;
  - measure a dynamic parameter of the battery through the electrical connections to the battery;
  - determine a condition of the battery by comparing the measured dynamic parameter to the received rating, the battery test result indicative of a battery condition, the battery condition including a fully charged battery and a battery which is not fully charged;
  - detect revving of the engine by observing an increased frequency of an AC ripple of a voltage measured through the electrical connectors to the battery;
  - detect a diode or stator problem if the AC ripple exceeds a threshold;
  - instruct the operator to start an engine of the vehicle through the display;
  - detect starting of the engine of the automotive vehicle by the operator by a drop in a voltage measured through the electrical connections to the battery;
  - measure a starting voltage through the electrical connections to the battery during starting of the engine of the automotive vehicle; and provide a charge battery output to the operator through the display if the measured starting voltage is low relative to a threshold and the battery test result is indicative of a battery which is not fully charged,
  - provide a cranking voltage low output to the operator through the display if the measured starting voltage is low relative to a threshold and the battery test result is indicative of a fully charged battery;
  - provide a cranking voltage normal output to the operator through the display if the starting voltage is normal relative to a threshold and the battery test result is indicative of a fully charged battery.

2. The apparatus of claim **1** wherein the user input is further configured to receive a rating standard selection from the user.

3. The apparatus of claim **2** wherein the rating standard selection comprises an SAE standard.

4. The apparatus of claim **2** wherein the rating standard selection comprises a DIN standard.

5. The apparatus of claim **2** wherein the rating standard selection comprises an IEC standard.

6. The apparatus of claim **2** wherein the rating standard. selection comprises an EN standard.

7. The apparatus of claim **2** wherein the rating standard selection comprises a JIS standard.

8. The apparatus of claim **1** wherein the battery test is based upon conductance.

9. The apparatus of claim **1** wherein the battery test is based upon resistance.

10. The apparatus of claim **1** wherein the battery test is based upon impedance.

11. The apparatus of claim **1** wherein the battery test is based upon admittance.

12. The apparatus of claim **1** wherein the microprocessor is configured to provide an output selected from the group of outputs consisting of cranking voltage indicating "good battery", "good but recharge battery", "charge and retest battery", "replace battery", and "bad cell-replace battery".

13. The apparatus of claim **1** wherein the microprocessor further measures a voltage when the engine of the vehicle is revved and no vehicle loads are applied.

14. The apparatus of claim **13** wherein the microprocessor further measures a voltage when the engine is idle and a vehicle load is applied.

15. The apparatus of claim **14** wherein the microprocessor further measures a voltage when the engine is revved and a vehicle load is applied.

16. The apparatus of claim **1** wherein the user input is configured to receive a temperature.

17. The apparatus of claim **1** wherein the battery test is a function of a temperature.

18. The apparatus of claim **1** wherein the microprocessor is configured to determine if surface charge exists on the battery.

19. The apparatus of claim **18** wherein the microprocessor prompts an operator to turn on headlights of the vehicle based upon a surface charge determination.

20. The apparatus of claim **1** wherein the output further comprises an output selected from the group of outputs consisting of measured capacity, voltage, voltage during cranking, idle voltage, and load voltage.

21. The apparatus of claim **1** wherein the microprocessor records AC and DC voltages in a memory.

22. The apparatus of claim **1** wherein the microprocessor records a voltage across the battery in a memory.

23. The apparatus of claim **1** including a battery voltage scaling circuit.

24. The apparatus of claim **1** including DC voltage sensor adapted to measure a DC voltage of the battery and an AC voltage ripple detector adapted to measure the AC ripple voltage.

25. The apparatus of claim **1** wherein the microprocessor measures a steady state battery voltage with the engine off, a battery voltage with the engine revved, a battery voltage with the engine idling and a load applied to the battery, and a battery voltage with this engine revved and a load applied to the battery.

26. The apparatus of claim **1** wherein the microprocessor is adapted to receive an input indicating that the vehicle contains a diesel engine and wherein the microprocessor waits for glow plugs of the diesel engine to warm up and charging to start prior to performing a test.

27. The apparatus of claim **1** wherein the tester is portable.

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