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(54) Battery charge monitor

(57) A charge monitor for a battery (e.g. the battery of a battery powered vehicle) comprises a transducer (20) monitoring the current flowing into or from the battery, a visual display (16) and a microprocessor control circuit (10) to track the amount of charge in the battery at all times and for driving the visual display accordingly. The monitor is able to take account of charge put back into the battery during regenerative braking and is able to track and display a number of items of information relating to the battery, in addition to its instantaneous charge, e.g. the distance which may be travelled at the current speed, the number of hours of usage remaining, whether the economy of use in improving or deteriorating, the number of battery charges and discharges and an indication of excessive current drain.

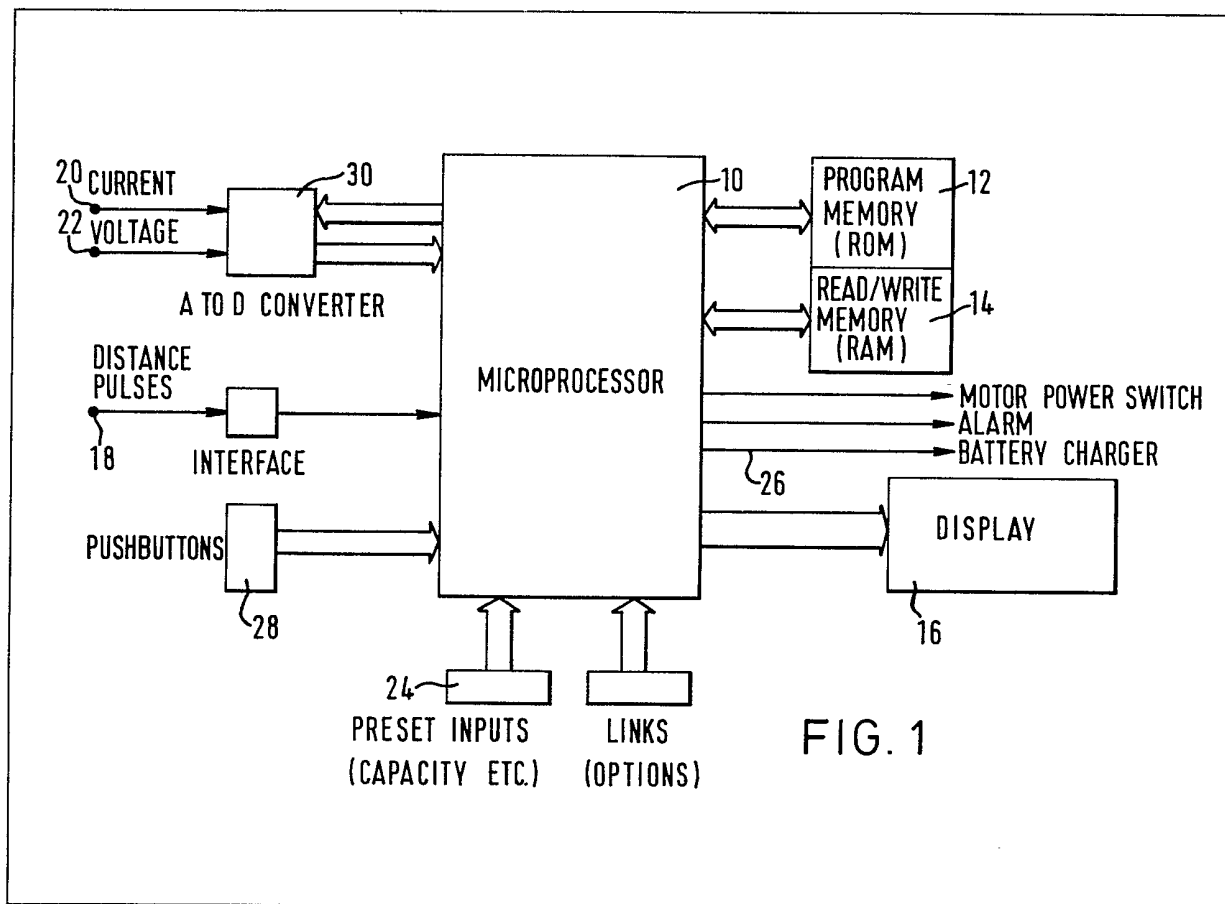


FIG. 1

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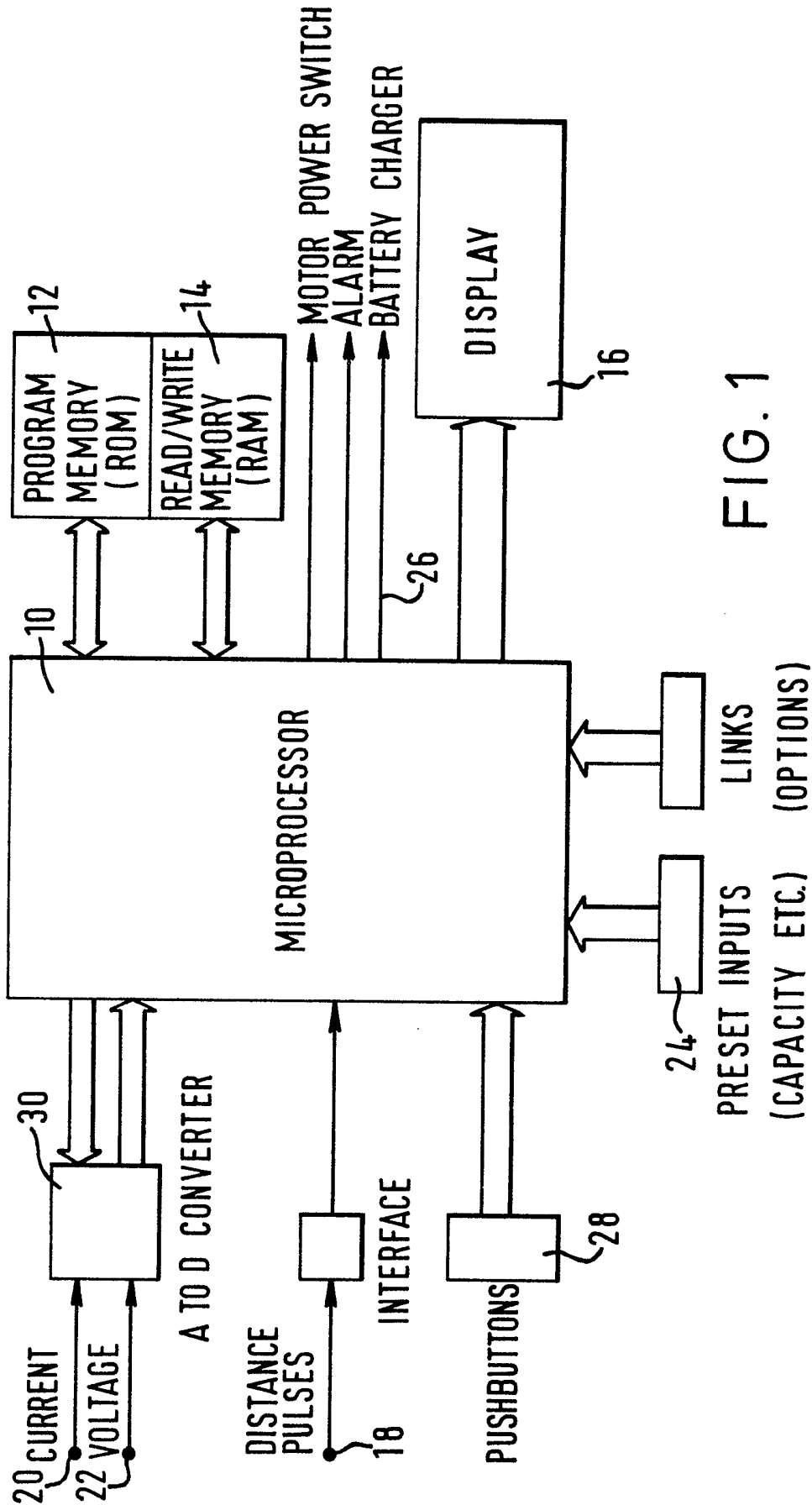


FIG. 1

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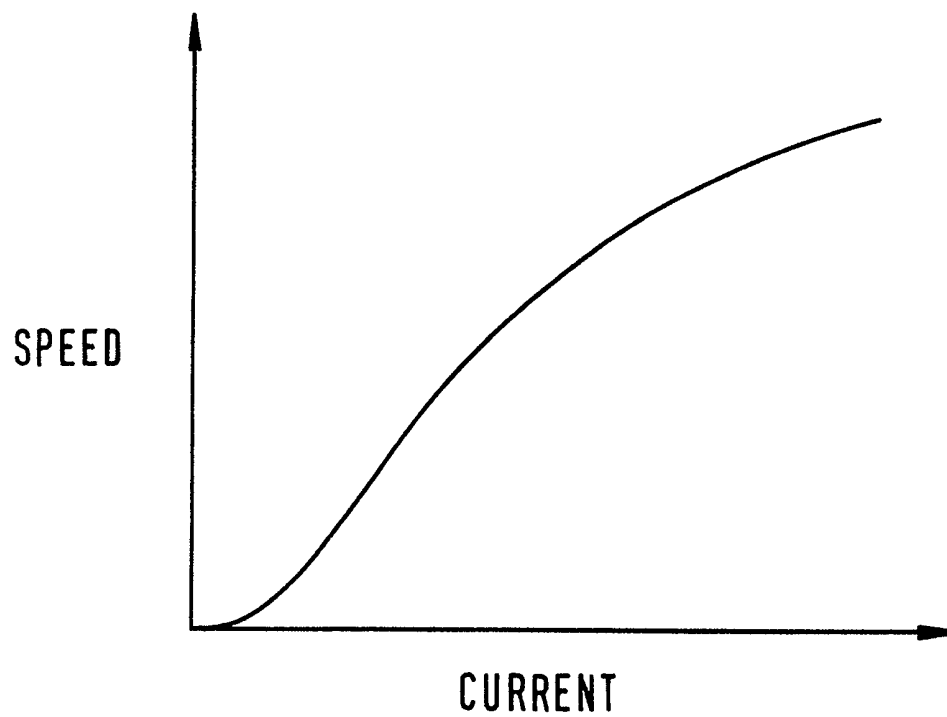


FIG. 2

SPECIFICATION

Battery charge monitor

This invention relates to a charge monitor for the battery of a battery powered vehicle.

5 There is a large and increasing number of battery powered vehicles in service. These are mainly industrial or commercial vehicles, but there is the future prospect of far greater numbers of battery powered private cars. At present the acceptance of battery powered cars falls far short of the potential, firstly owing to the limited range of a vehicle with present technology and secondly owing to a scarcity of "re-fueling" places.

10 In accordance with this invention, there is provided a charge monitor for the battery of a battery powered vehicle, said monitor including a transducer for monitoring the current flowing into or from the battery, a visual display and a control circuit connected to the transducer to track the amount of charge in the battery at all times and for driving the visual display accordingly.

Conveniently the monitor should track the amount of charge in the battery even when the vehicle is not in use (no load on the battery) or while the battery is being charged.

15 Preferably the monitor is arranged to calculate and display either or both of the following: (a) the distance (e.g. number of miles) left that the vehicle can travel at the present speed, continuously updating the display according to the speed and rate of charge consumption; (b) the number of hours of usage left at the present rate of charge consumption, again continuously updated. The latter display is especially desirable for industrial vehicle usage, enabling a determination to be made whether the vehicle can complete the shift without being withdrawn for battery charging or changing.

20 Conveniently, the monitor may be arranged to indicate to the driver whether he is improving or deteriorating his economy. For example the monitor may include a green indicator illuminated when the driver is improving or maintaining his economy, and a red indicator illustrated when the economy is deteriorating or flashing when the economy is very low. In this manner, the monitor shows the driver how he is affecting consumption by his style of driving, so that he can adjust to improve the situation.

25 Preferably the monitor measures the amount of charge put back into the battery by regenerative braking, so that a more accurate evaluation is made of the amount of charge in the battery and of the remaining range of the vehicle.

30 Preferably the monitor counts and stores the number of charge and discharge cycles which the battery has undergone. Firstly this is a guide as to the viability of the battery and any need for maintenance or replacement and secondly, because the quality of the battery and its ability to store charge deteriorates with its historical number of charge and discharge cycles, this number may be used to modify the range evaluations with the age of the battery.

35 Preferably the monitor is arranged to control the charging of the battery by taking into account its condition of discharge and its ability to accept charge according to the number of cycles of charge and discharge which the battery has undergone. An output from the monitor may then be used to control a switch to power the battery charger. By only allowing some nominal amount of overcharge and then switching the charger off, charging energy can be saved and may well give the battery a longer life.

40 Preferably the monitor is arranged to monitor the performance of the vehicle and notice degradation in that performance, in terms of the speed against current consumption.

A safety feature may be provided wherein warning of excessive current is given, perhaps due to a failure of a component. Different currents are tolerable for different lengths of time and the monitor is preferably arranged to monitor the current level and its duration at that level and take appropriate action if a set of predetermined safe conditions is exceeded. The appropriate action may be to cut off the current and/or produce an alarm signal under automatic command from the monitor.

45 Conveniently the monitor can track the battery voltage output with time and it can monitor the voltage against current. The variation of the voltage with time as the load current is changed, (for example the drop in output voltage as a load is applied and the time taken for the voltage to recover when the load is removed) may be monitored to indicate the condition of the battery and its state of charge. This gives a useful extra control parameter for refining the above mentioned display values and making them more accurate.

50 An embodiment of this invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic block diagram of the microprocessor control system of a battery charge monitor in accordance with the invention; and

55 *Figure 2* is a diagram showing a typical relationship between vehicle speed and battery current.

Referring to *Figure 1*, the monitor comprises a microprocessor 10 with associated memories 12, 14 (being respectively a ROM program memory and a RAM data memory), and a visual display 16. The monitor further comprises an input 18 from a distance transducer, inputs 20, 22 from current and voltage measuring circuits and inputs 24 for various preset constants such as battery capacity. An output 26 is provided to control a battery charger and switches or push-buttons 28 to select various alternative items of information for display. The current measuring circuit may comprise a current probe such as a linear Hall effect device or a small series resistor which will deliver a voltage drop proportional to the current flowing from (or to) the battery. The microprocessor controls an analogue to digital converter 30 to transform the voltage from whichever source to a digital value. The inputs 24 for the constants may be direct input values as from thumbwheel switches or they may indicate which of a selection of values stored in the microprocessor's

memory to use. By setting up the battery capacity, say, from thumbwheel switches a wide range of battery sizes can be accommodated.

The microprocessor is arranged to keep track of the current flowing from the battery and the time for which it flows and then to calculate the number of Ampere-hours used. If it is programmed with the initial charge of the battery it can then calculate the number of Ampere-hours remaining by the equation:

$$Q = Q_0 - \int_0^T i \cdot dt$$

where Q and Q_0 are the present and initial charges of the battery and i is the current being taken from the battery at any instant.

The microprocessor is arranged to perform this integration by summing the values of the current at regular intervals (300ms say). Thus, it keeps track of the battery's charge at all time so range can be calculated, even when the driver returns to his vehicle after a break, or even after a partial charge. If the distance travelled between consecutive distance pulses from the distance transducer is d and the time taken over this distance is t while the current flowing out of the battery is i , then the remaining range R is given by:

$$R = \frac{Q \cdot d}{i \cdot t}$$

The microprocessor controls the A to D converter to measure the current. It also detects and debounces the distance input pulses and measures the time between them. It then performs the above calculations and drives the display to show the continuously updated value of the range R .

From same measurements, the number of hours left is calculated from the following equation and may be displayed by pressing an appropriate selector button:

$$\text{Hours left (H)} = \frac{Q}{i \times 3600}$$

The monitor is also arranged to compare the present consumption rate (e.g. the amount of charge used over the last tenth of a mile) with a consumption rate figure for the recent past.

$$\text{Consumption rate} = \frac{q}{d} \text{ (charge per distance)}$$

Past consumption may be averaged over several intervals or digitally filtered. The microprocessor measures and records the amount of charge used each interval and then performs the comparison between the new and past figures. If the new rate is less than say 110% of the past it illuminates a green indicator. If it is more than the 110% but less than 150% say, it illuminates a red indicator. However if it is more than 150% then it switches the red indicator on and off periodically so that it flashes.

The current measuring circuit is designed to work for both positive and negative currents. Equation (1) then automatically accounts for charge being put back into the battery by reverse currents during regenerative braking and charging.

The microprocessor is arranged to monitor the lengths of time for which current enters the battery (regenerative braking and charging) and make a decision as to which are actually charging cycles, and then it counts the number of these cycles for display on demand. An alternative, depending upon the type of battery and the manufacturer's recommendations, is to mathematically integrate together all current into the battery and knowing the capacity of the battery use this total to calculate the equivalent number of charge cycles

$$\text{Number of cycles (N)} = \int_0^T |i| \cdot dt \quad (\text{for negative } i)$$

Manufacturer's information can also be used to apply a factor, which is related to the number of charge cycles, to adjust the battery's nominal capacity Q_0 , as it degrades. From equation (1) the microprocessor monitors the state of charge of the battery, and it is arranged to signal when the battery has received enough

to restore it to a fully charged state. The signal may be used as an output which controls the charger through a relay or triac and switches off the supply to the charger circuit.

The microprocessor is arranged to measure the performance of the vehicle by relating its velocity to the current consumption either instantaneously or averaged over a longer period of time. Even for optimum performance the relationship will be non linear - it will be generally as shown in Figure 2. The average performance figure is more meaningful than the instantaneous one as factors such as acceleration and slopes will tend to cancel out with time. This practical figure can be compared by the microprocessor with a theoretical one for that speed and a percentage performance value produced.

A current overload safety feature is performed by the microprocessor which monitors current and also the time that that current exists. When the current is judged excessive the microprocessor accesses a table of preset values in its data memory, which values have been defined by the vehicle manufacturer, to ascertain how long that current is allowed to flow. When the actual current duration reaches this preset level, an audible or visual alarm may be triggered or the current supply may be switched off. A lower limit might be set which varies with speed and which the monitor inhibits the speed controller from exceeding.

The microprocessor has inputs for voltage and current measurements and it has the ability to measure real time. Taking these three parameters, it is arranged intermittently (for example when the vehicle is standing still, say at traffic lights) to measure the recovery for instance of the battery. This gives a measure of the condition and state of the battery and may be used to modify the above-mentioned calculated figures to prevent an accumulation of errors over the life of the battery.

CLAIMS (Filed on 22.2.83)

1. A charge monitor for a battery (e.g. of a battery powered vehicle), said monitor including a transducer for monitoring the current flowing into or from the battery, a visual display and a control circuit connected to the transducer to track the amount of charge in the battery at all times and for driving the visual display accordingly.

2. A charge monitor as claimed in claim 1, further comprising means for recording an initial charge of the battery and said control circuit being arranged to integrate the monitored current flow with time and to calculate from it, and from the recorded initial charge, the instantaneous charge in the battery.

3. A charge monitor as claimed in claim 1 or 2, for the battery of a battery powered vehicle, further comprising a distance monitor and said control circuit being arranged to respond to the distance monitor to measure the time taken for the vehicle to travel an incremental distance, to the current flow at that time and to the instantaneous battery charge, to calculate and display the remaining range of the vehicle at the same speed.

4. A charge monitor as claimed in any preceding claim, in which said control circuit is arranged to respond to the instantaneous current flow and to the instantaneous battery charge to calculate and display the time for which a load of the battery can continue to be energised under the same current flow condition.

5. A charge monitor as claimed in any preceding claim, for the battery of a battery powered vehicle, in which said control circuit is arranged to respond to the (or a) distance monitor of the charge monitor and to the current flow to calculate a charge consumption rate of the vehicle (in terms of charge consumed per unit distance travelled) for each of successive time periods, and further in which the control circuit is arranged to compare the charge consumption rate calculated for each time period with a charge consumption rate in respect of a previous period and to provide an indication if the newly calculated rate is greater than the previous by more than a predetermined amount.

6. A charge monitor as claimed in any preceding claim, including means responsive to charging and discharging of the battery and in which the control circuit is arranged to determine and display a number representing the number of charge cycles which the battery has undergone.

7. A charge monitor as claimed in claim 6, in which the control circuit is arranged to calculate a value for the charge capacity of the battery which value is modified according to said number representing the number of charge cycles which the battery has undergone, the charge monitor including means for indicating when the battery charge reaches said charge capacity.

8. A charge monitor as claimed in any preceding claim, for the battery of a battery powered vehicle, further arranged to measure the vehicle performance in terms of its speed relative to its current consumption.

9. A charge monitor as claimed in any preceding claim, further arranged to measure the time for which any current of greater than a predetermined value persists and to provide an alarm indication if such current flows for greater than a predetermined period.

10. A charge monitor as claimed in any preceding claim, further arranged to monitor variations of the battery voltage with time as the load current changes and accordingly to determine data indicating the condition of the battery.

11. A charge monitor as claimed in any preceding claim, when installed in a battery powered vehicle to monitor the battery or batteries thereof.

12. A charge monitor for a battery, substantially as herein described with reference to the accompanying drawings.