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Solid-state relays simplify monitoring electric-car battery voltage

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FIGURE 1 SHOWS the propulsion system of an electric vehicle. It includes an electric motor, drive electronics, a mechanical transmission, vehicle control/power management, a charging system, and a battery. The long-term performance of the electric vehicle depends on ensuring the electrical health of the battery and its charging system. The battery system in an electric or a hybrid-electric car comprises a series connection of 75 to150 individual 2V cells. This series connection generates a potential voltage of 150 to 300V. The measurement of an individual cell's terminal voltage creates a testing dilemma. The high electrical potential precludes the use of standard differential op amps connected across each cell. The measurement of each cell's voltage entails using a switching network that interconnects an isolated or floating A/D converter between the two terminals of each cell in the string. A measurement method also needs a switching system to sequence this "voltmeter" across each of the 150 cells.

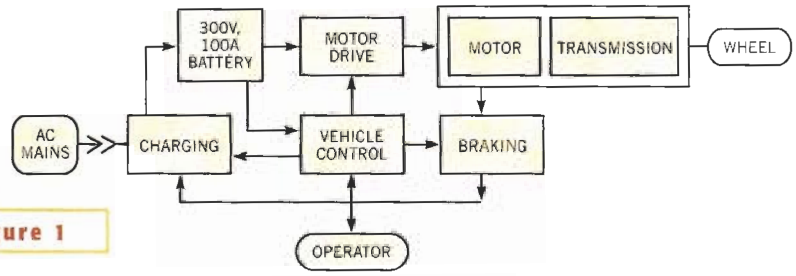

Figure 1

The components of a typical electric vehicle include an electric motor, drive electronics, a mechanical transmission, vehicle control/power management, a charging system, and a battery.

The functional block diagram is an example of an electric car's battery system (**Figure 2**). The battery comprises a series connection of 150 2V cells. This configuration provides a combined potential of 300V. This high dc potential requires the use of an isolated voltage-measurement system. A microcontroller-based isolated voltmeter and isolated switch controller do not provide this function. The cell-measurement system comprises a switching array of 151 of Fairchild Semiconductor's (www.fairchildsemi.com) HSR-412 SSRs (solid-state relays), which provide an off-state blocking voltage of 400V. Each relay is an SPST (single-pole, single-throw), NO (normally open), optically activated switch. As little as 3 mA, or 5 mW, of LED-drive current energize these relays. This low turn-on power consumption eliminates the need for relay-driver ICs.

The first step in measuring the cell's potential is to connect the isolated voltmeter across each cell. A closer look at **Figure 2** reveals how to effect this connection. The input to the isolated voltmeter connects to a two-wire measurement bus. The terminals of this bus are designated A and B. The test points across the various battery cells are designated SSR(N) and SSR(N+1), where (N) is the cell number you are currently measuring. You make Cell 1's voltage measurement by closing SSR_1 and SSR_2 and leaving all the remaining 149 relays off, or open. Closure of the two SSRs connects Cell 1's positive potential to Node A of the absolute converter through the output of SSR_1, and the cell's negative potential to Node B through SSR_2. You measure the second cell in the stack by opening SSR_1 and closing SSR_3 while SSR_2 remains on (closed). This sequence connects Cell 2's positive potential to Node B through the output of SSR_2 and the cell's negative potential to Node A through the output of SSR_3. The process then repeats until all cells have been measured. At this time, the

TABLE 1—THE ALTERNATING POLARITY OF THE A AND B NODES AS THE INDIVIDUAL CELLS ARE MEASURED

Cell number	SSR on (positive cell terminal	SSR on (negative cell terminal)	Voltage at Point A	Voltage at Point B
1	1	2	1	2
2	2	3	2	1
3	3	4	1	2
4	4	5	2	1
5	5	6	1	2
*	*	*	*	*
*	*	*	*	*
148	148	149	1	2
149	149	150	2	1
150	150	151	1	2

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voltmeter returns to Cell 1 and restarts the process.

Table 1 shows the alternating polarity of A and B wires as the cells are measured. To measure the voltage of an individual cell (N), SSR(N) and SSR(N+1) are energized and all other SSRs are off, or open. The alternating polarity of the measurement lines requires the addition of an absolute-value converter between the bus lines and the microcontroller's analog-to-digital input. The microcontroller controls the sequence of measurement events. To measure a cell, the microcontroller sends out a discrete 8-bit digital address corresponding to the cell being measured. This address goes to a decoding block composed of 11 74HC154 multiplexers. The data is transmitted through an array of eight channels of high-speed HCPL2631 optocouplers. The optocouplers provide the common-mode voltage isolation between the 300V battery voltage and the chassis ground. The dual-channel density of the HCPL-2631 optoisolator reduces component count in the block to four. The system addresses the individual cells every 3 msec. This time is how long it takes to turn on and turn off the HSR412 SSR. A cell-voltage measurement takes place 600 μsec after the cell has been addressed. The SSR's turn-on time is less than 500 μsec, thus permitting a 100-μsec acquisition time for the microcontroller's 10-bit A/D converter. The sum of the turn-on and -off times of an SSR times the number of cells measured determines the cycle time. When you use the HSR412, the measurement time for 150 cells is less than 450 msec.

When you measure an individual cell, the V(N)-to-V(N+1) bus potential is approximately 2V. This figure is the differential-mode voltage. The V(N)-to-V(N+1) potential to chassis ground ranges from 2 to 300V, depending on the cell under measurement. This 300V common-mode voltage is well within the 400V off-state blocking voltage of the HSR412. The switch-matrix-control circuits must also be able to accommodate this 300V common-mode voltage. The SSR easily solves this problem. The LED-to-SSR switch isolation voltage is 4 kV rms, which is more than adequate for a 300V system. The 300V common-mode voltage requires that an isolated dc/dc converter powers the microcontroller. The microcontroller records the absolute value of the cell voltage and stores this value and cell number in its onboard memory. At the conclusion of an entire measurement cycle, the microcontroller formats the data to comply with a standard automotive serial-bus format. An example is CAN Bus. Once formatted, the data routes to the vehicle-control computer via a bidirectional, optically isolated link. This link uses two high-speed HCPL-0600 logic-compatible optocouplers. Once that data is received and acknowledged, the measurement cycle can repeat.□

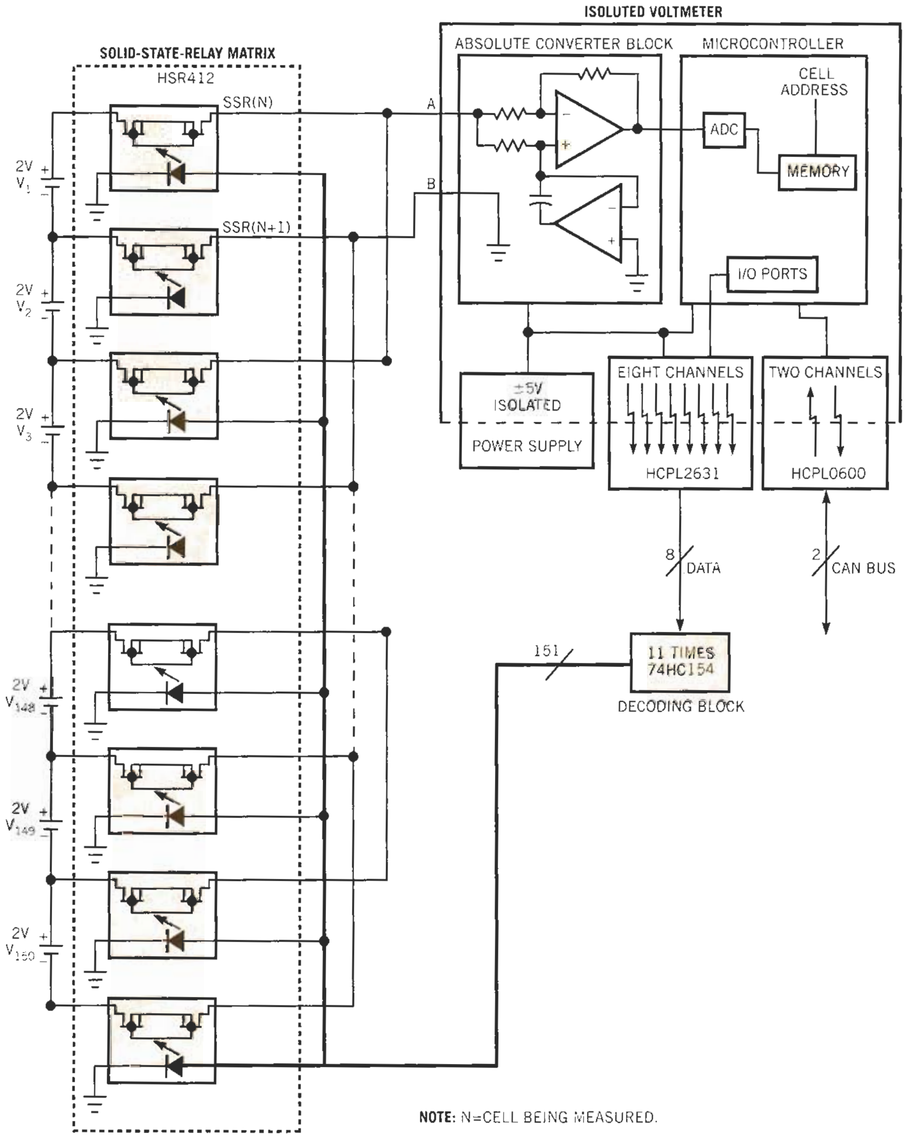

Figure 1 An SSR-based switch matrix allows you to measure individual cells in an electric car's battery.