SSC2020-P4-15: Single-Event Latch-Up (SEL) Automatic Detection & Recovery for the RT6804-1

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Introduction & History

The RT6804-1 is a 3rd generation multicell battery stack monitor that measures up to 12 series-connected battery cells with a total measurement error of less than 1.2mV. The cell measurement range of 0V to 5V makes the RT6804-1 suitable for most battery chemistries. The RT6804-1 can be powered directly from the battery or an isolated supply.

When the RT6804-1 is upset by a heavy ion, the device no longer responds to SPI commands, and cell voltages are no longer readable. Occasionally, the device recovers on its own, but it can get stuck in this condition for extended periods. Analog Devices determined a circuit was needed to monitor and detect the increased current and trigger an automatic crowbar pull-down to clear the latch-up condition. This proposed mitigation circuit would require a current sense amplifier to monitor the current consumption of the device, a controlling device to interpret the current sense output and trigger the crowbar circuit, and a set of MOSFETs to pull all of the cell monitoring pins as well as V+ and VREG down to GND. For this application circuit to be viable for space customers, all components used are required to have direct or comparable space-qualified replacements. The circuit would also need to minimize the number of components to lower the overall size, weight, and power requirements of the solution.

Circuit Description

The RH6105, a space-qualified current sense amplifier, was selected to monitor the current consumption of the RT6804-1 device. The input resistor network for the RT6804 was configured to output a logic high voltage level when the monitored current is greater than 40 mA. The battery is connected directly to V+ and VREG through the RH6105 resistor network. The output of the current sense amp is connected directly to a digital pin on an ATmegaS128 MCU. This logic level change from the RH6105's output triggers an interrupt in the MCU to turn on the crowbar MOSFETs. Q17 in the circuit below disconnects the power (V+ and VREG) from the monitored device. The remaining MOSFETs connect the cell pins (pins C0-C12) of the RT6804-1 such that they are pulled down to GND to clear the latch-up. After 10 microseconds, the MOSFETs turn off.

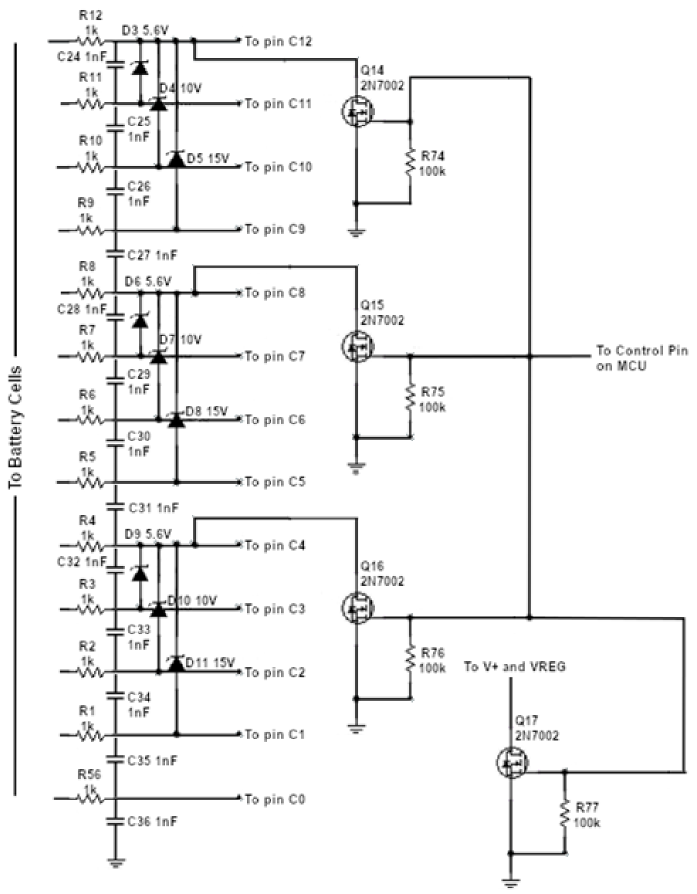

Figure 1: SEL Recovery Circuit

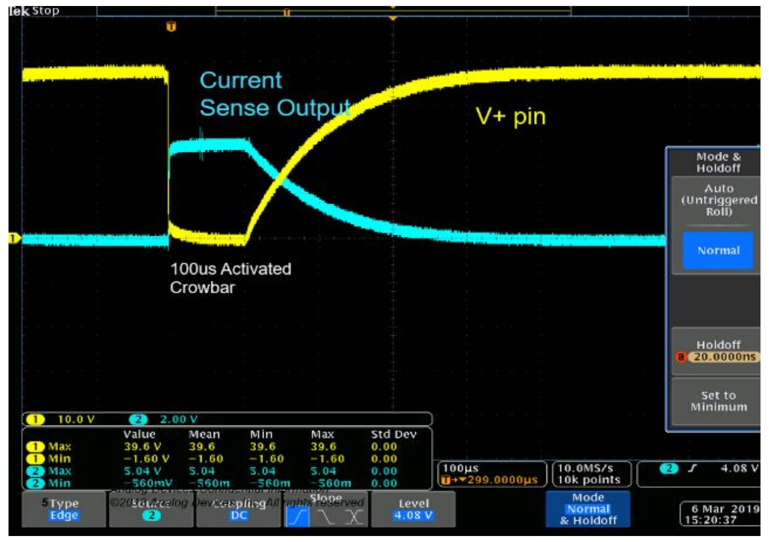

Figure 1: V+ Pin

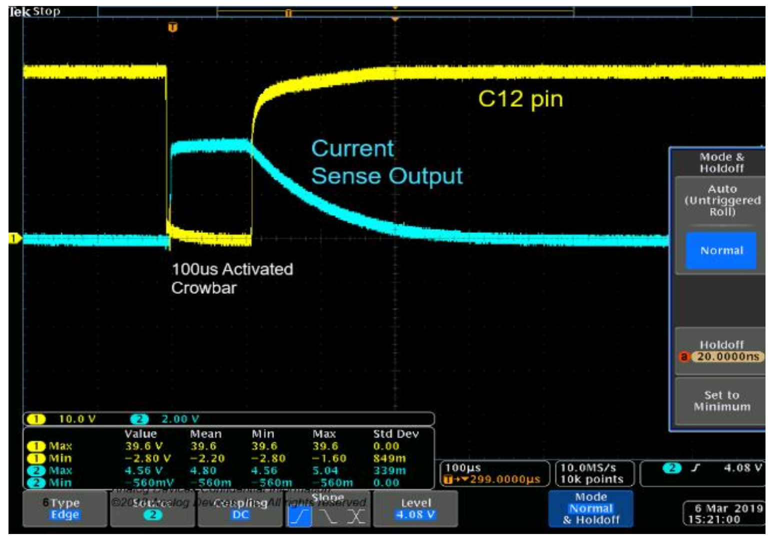

Figure 2: C12 Pin

Experiments

Lab Testing

The mitigation circuit was evaluated in the lab prior to radiation testing to ensure the solution functioned as expected. Figure 2 and Figure 3 show the system's response to a forced current increase, including the output of the current sense amplifier.

Heavy-Ion Testing

Heavy Ion testing was then performed at Texas A&M University Cyclotron Institute to verify the mitigation circuit performance under radiation. The UART interface with the microcontroller and a Python supply monitoring script were used to determine when the crowbar was activated. The microcontroller would then send a message over serial UART when it detected a current increase and activate the crowbar. The current spikes were observed on the supply monitor setup. Figure 4 shows device behavior with the SEL recovery circuit deactivated (MCU does not react to supply current increase). Figure 5 shows the device behavior after the recovery circuit was activated (MCU programmed to trigger the crowbar circuit). Figure 6 shows the recovery time for the mitigation circuit in more detail.

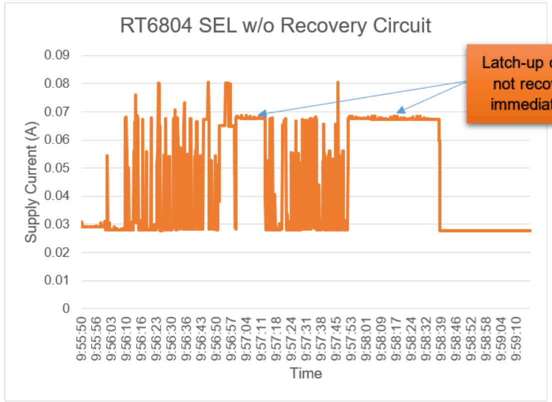

Figure 3: Without Recovery

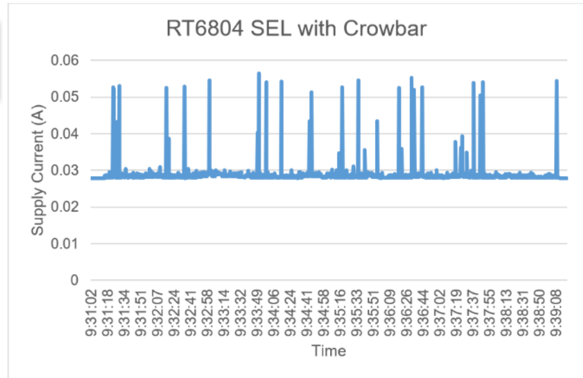

Figure 5: With Recovery

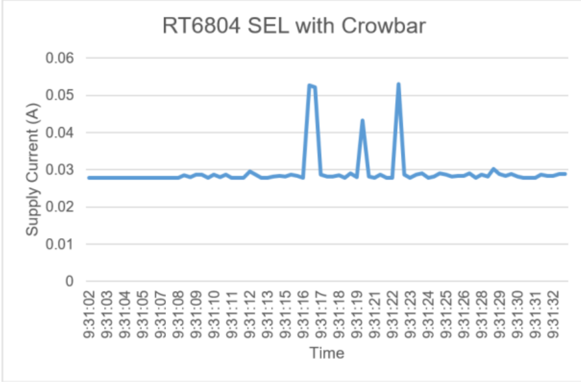

Figure 4: With Recovery, Zoomed to Show Recovery Time