Author: Carlos Martinez

Introduction

The X40420, X40421 devices have a Power On Reset (POR) circuit, low voltage monitors for two supplies, an automatic switch between a main voltage source and a backup supply, a watchdog timer, 4kbits of EEPROM and a fault detection register. Some of these features are resettable, such as the POR time period, the watchdog timer duration and block protection of the EEPROM. All of these features make the X40420, X40421 very versitile devices in a power supply management application.

One of the key features of these devices is the battery switchover circuit. This application note explores the operation and use of this function. The X40420, X40421 devices provide internal FET switches that connect either the main V_{CC} supply or the backup V_{BATT} supply to a V_{OUT} pin. In addition, the device provides a control signal that activates an external switch, when V_{OUT} connects to V_{CC}, to support higher load current requirements. The use of this circuit is fairly simple, but a number of design issues need to be considered.

The main areas of exploration consist of:

- Operation of the internal switch.
- Operation of the high current pass element
- Backup (V_{BATT}) supply type.

Operation of The X40420, X40421 Internal Switch

The internal switch of the X40420, X40421 can be represented by the circuit of Figure 1 with a typical switch response to a varying V_{CC} as shown in Figure 2. Figure 2 depicts the battery voltage changing over time and in response to varying loads. This is typical in an actual application, but in tests made for this document, a separate bench power supply takes the place of the battery, so the battery supply does not vary.

The waveform of Figure 2 shows that V_{OUT} always connects to V_{CC}, unless V_{CC} is less than both V_{BATT} and the undervoltage threshold, V_{TRIP}. Only when V_{CC} is less than both V_{BATT} and V_{TRIP} will V_{OUT} connect to V_{BATT}. This procedure is intended to minimize the drain of the battery during low voltage conditions, while maintaining the highest possible voltage on V_{OUT}.

To demonstrate this operation, use the circuit of Figure 3 and monitor V_{CC}, V_{OUT}, V_{BATT} and either RESET or BATT-ON. The RESET signal gives an indirect indication of the V_{TRIP} voltage, because it goes active (LOW) when V_{CC} drops below V_{TRIP}. BATT-ON indicates when the internal switch changes state. For the tests in this document, V_{TRIP} is set to 2.85V.

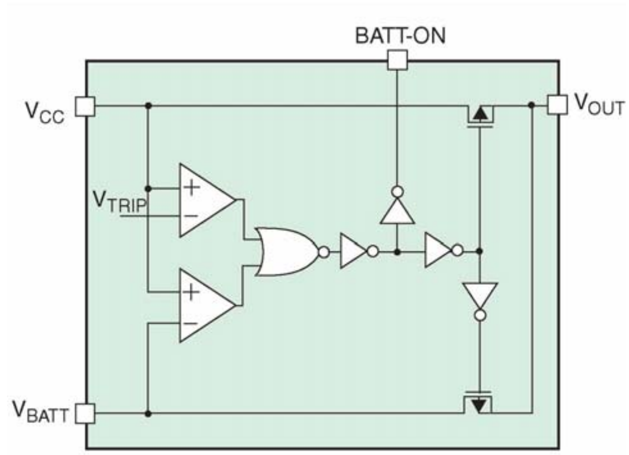


FIGURE 1. X40420, X40421 BATTERY SWITCH CIRCUIT (SIMPLIFIED)

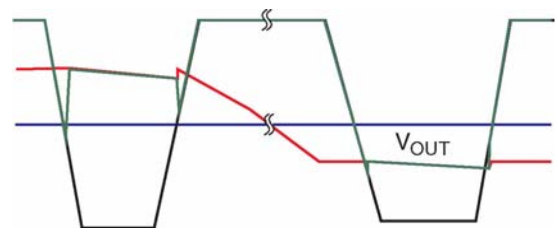


FIGURE 2. TYPICAL BATTERY SWITCH OPERATION

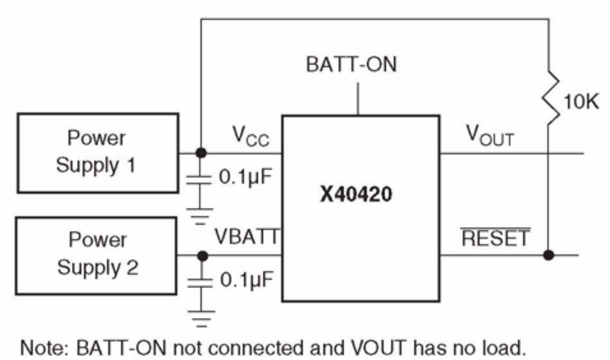


FIGURE 3. BATTERY SWITCH TEST CIRCUIT

The oscilloscope picture of Figure 4 shows the actual performance of the device when Power Supply 2 (V_{BATT}) is set to 3V (making it higher than V_{TRIP}) when V_{CC} fails. The picture of Figure 5 shows the performance of the circuit when V_{CC} turns on with V_{BATT} at 3V. Note that when V_{CC} powers up, RESET stays active LOW for a period of time. This time is selectable, via the two wire port, as 50ms, 200ms, 400ms or 800ms.

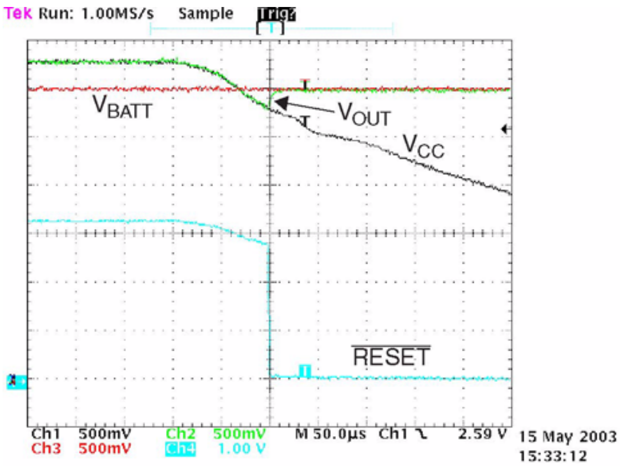


FIGURE 4. V_{CC} FAIL, V_{BATT} = 3V, NO LOAD, NO SWITCH FET

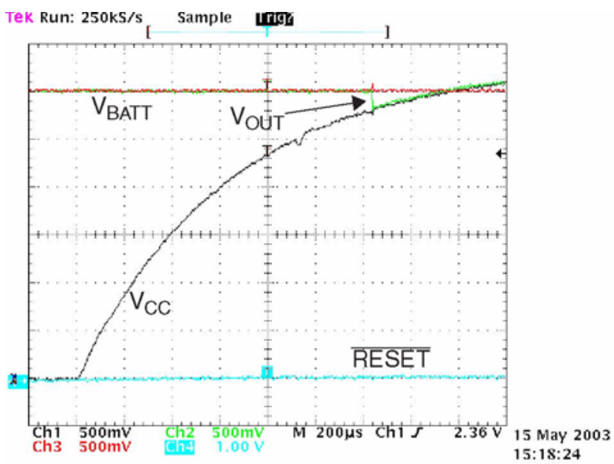


FIGURE 5. V_{CC} POWER-UP, V_{BATT} = 3V, NO LOAD, NO SWITCH FET

The picture of Figure 6 shows the performance when V_{BATT} is set to 2.5V (making it lower than V_{TRIP}) when V_{CC} fails. Figure 7 shows what happens when V_{CC} turns on with V_{BATT} at 2.5V. In all of these cases, there is no load on V_{OUT} and there is no external switch for additional current handling capability. These curves match the typical response very well. The next issues to look at are current handling ability and the use of an external switch.

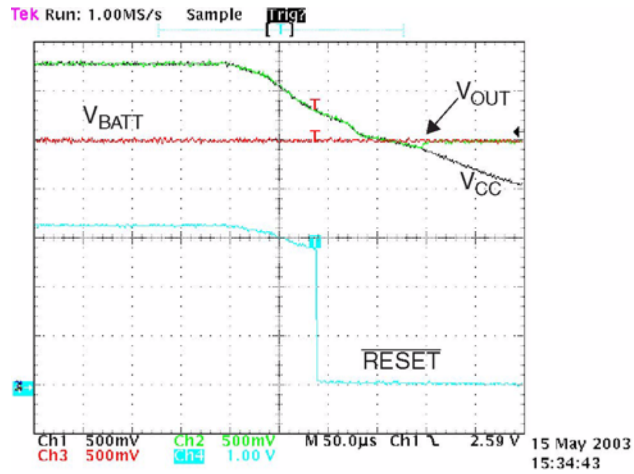


FIGURE 6. V_{CC} FAIL, V_{BATT} = 2.5V, NO LOAD, NO SWITCH FET

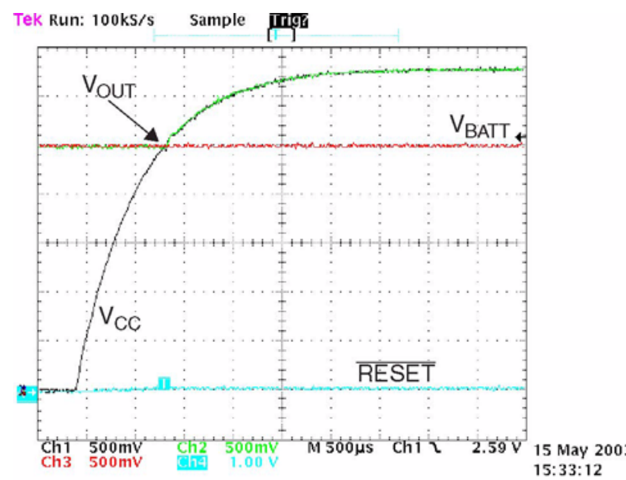


FIGURE 7. V_{CC} POWER-UP, V_{BATT} = 2.5V, NO LOAD, NO SWITCH FET

Switching With an Active Load

In the next series of tests, an active load simulates the operation of a circuit that draws more current in an active mode than in standby, as would happen with a static RAM (for example). In this test the load is 220µA in backup and 50mA in normal operation. The load circuit is shown in Figure 8, with the 15kΩ pullup resistor providing the 220µA load when RESET is LOW and the 62Ω resistor providing the load when RESET is HIGH. There is no external switch being used in this test. Since the on resistance of the X40420, X40421 internal FET is about 8Ω, a 50mA load in normal operation results in a voltage drop across the X40420, X40421 internal FET of 0.4V at a V_{CC} of 3.3V. This is shown in Figure 9 and in Figure 10, which shows the load being reconnected when RESET releases.

A similar set of gures show the results when the V_{BATT} voltage is set to 2.5V. These are shown in Figure 11 and Figure 12.

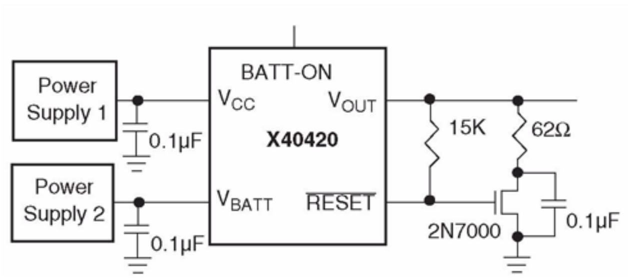


FIGURE 8. BATTERY SWITCH TEST CIRCUIT WITH ACTIVE LOAD

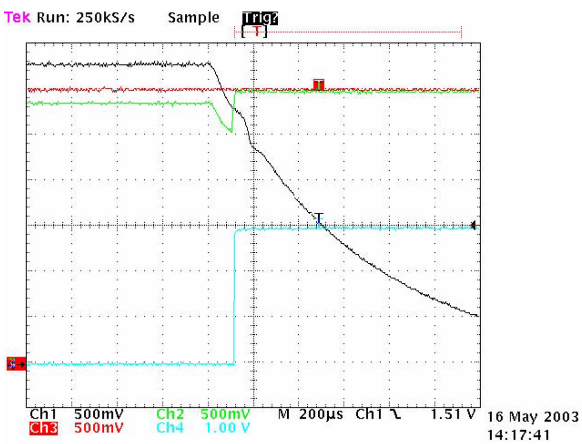


FIGURE 9. V_{CC} FAIL, V_{BATT} = 3V, ACTIVE LOAD, NO SWITCH FET

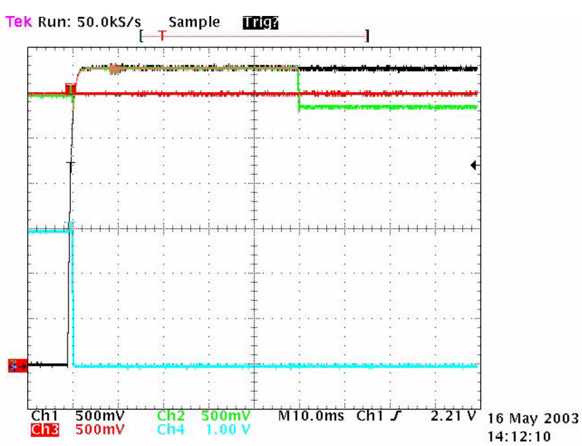


FIGURE 10. V_{CC} POWER-UP, V_{BATT} = 3V, ACTIVE LOAD, NO SWITCH FET

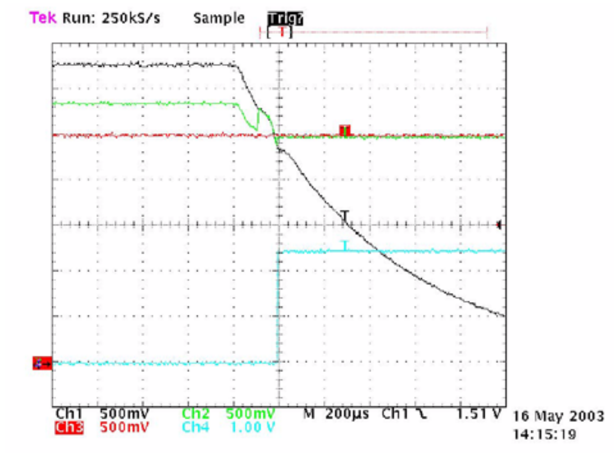


FIGURE 11. V_{CC} FAIL, V_{BATT} = 2.5V, ACTIVE LOAD, NO SWITCH FET

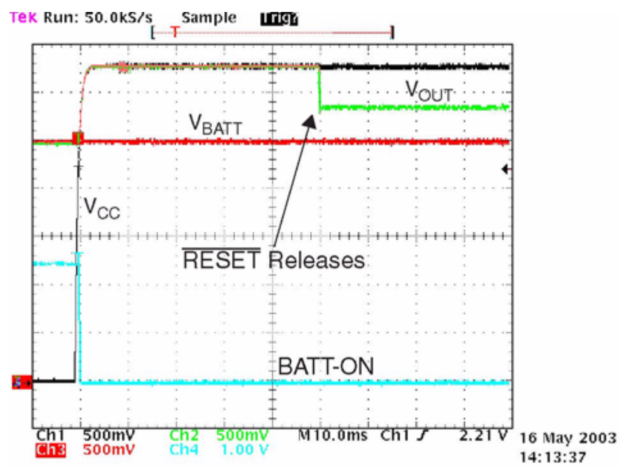
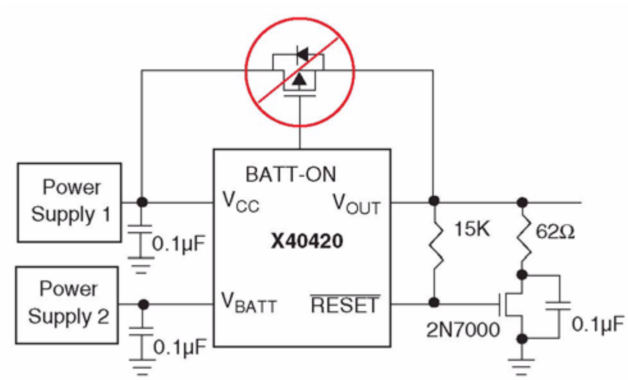


FIGURE 12. V_{CC} POWER-UP, V_{BATT} = 2.5V, ACTIVE LOAD, NO SWITCH FET



Note: When Power Supply 1 = 0V and Power supply 2 is 3V, V_{OUT} is connected to ground through the diode.

FIGURE 13. USING A SINGLE EXTERNAL FET SWITCH FET

Using an External Switch

In a majority of applications, using only the internal switch on the X40420, X40421 will provide insufficient current. For example, a bank of SRAMs could require several hundred milliamps in normal operation.To handle this requirement, the X40420, X40421 has a BATT-ON pin to control an external switch. BATT-ON goes LOW when the device is powered by V_{CC} and goes HIGH (pulled up to V_{OUT}) when powered by a battery. This logic polarity turns on a P-channel FET when operating from V_{CC}.

A PNP transistor could also be used as a switch, but there are two limitations with a normal PNP transistor. First, the PNP transistor has a typical V_{CE}(sat) of 0.5V. This means that the voltage drop from V_{CC} to V_{OUT} is at least a half a volt. Second, a power PNP transistor requires about 150mA of base current for 1A of collector current. So, for a 200mA load, BATT-ON would need to sink at least 30mA. This is more than the X40420, X40421 can typically provide.

Using an FET as a switch also presents a problem. A MOSFET power transistor generally has a body diode that blocks the current path when the FET is off (see Figure 13). However, when the main supply fails, the body diode is forward biased by the voltage on V_{OUT} (from V_{BATT}) back to V_{CC}. This loads the V_{OUT} voltage and prevents normal operation.

To use an FET switch requires the use of back to back devices. These are available in single packages so their use does not increase board space or component count. The circuit for connecting the FETs is shown in Figure 14.

The dual FET circuit has advantages over a PNP transistor, because there is very little gate current required to provide very large load currents and there is typically a lower voltage drop across the switch, even with two devices, than with the PNP transistor. Using low voltage P-channel FETs should give an optimum combined ON resistance of less than 3Ω and in some cases less than 1Ω. At 50mA, a 3Ω FET on resistance results in a voltage drop of 150mV.

The following tests use an IRF7104.This was not the best choice for this application, since gate to source voltages are specied from 4.5 to 10V and the tests are run at 3V. As a result, the switch is not turned on as hard as it could be and the combined on resistance is about 5Ω.This results in a drop of 250mV from V_{CC} to V_{OUT}. A better choice of FET would have been the IRF7504 or, even better, the IRF7756. These have specied R_{DSon} resistance values well below 1Ω on each FET with gate to source voltages of 2.7V and 1.8V, respectively.

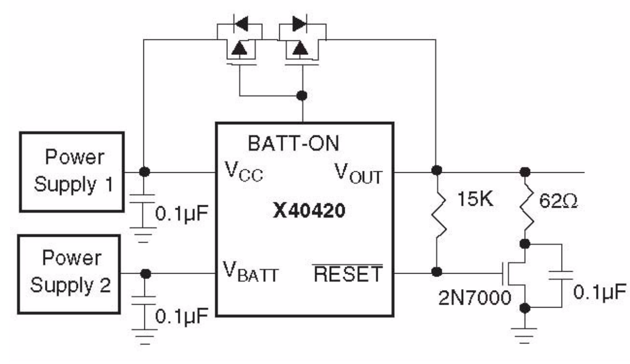


FIGURE 14. BATTERY SWITCH TEST CIRCUIT WITH ACTIVE LOAD AND EXTERNAL FET

Performance of the X40421 with external FET switches is shown in Figure 15, Figure 16, Figure 17, and Figure 18. These charts show power fail and power-up at battery voltages of 3V and 2.5V. These battery levels are just above and just below the V_{CC} undervoltage trip point.

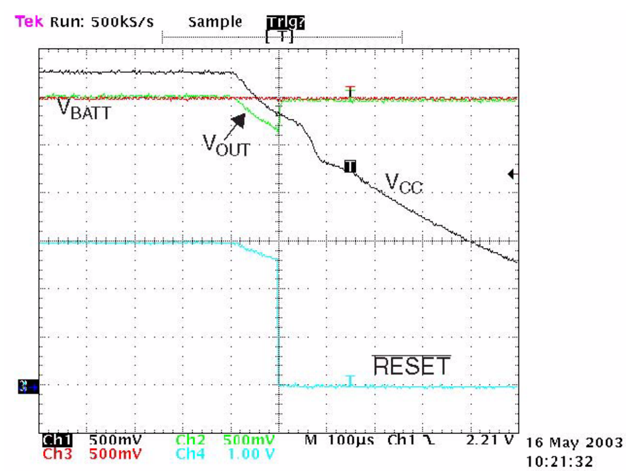


FIGURE 15. V_{CC} FAIL, V_{BATT} = 3V, ACTIVE LOAD, WITH SWITCH FETs

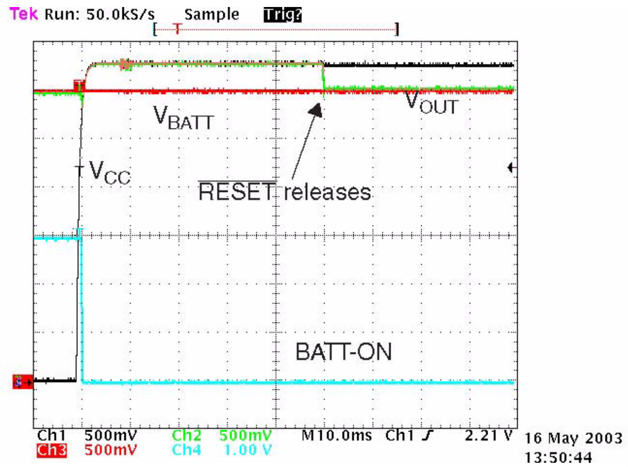


FIGURE 16. V_{CC} POWER-UP, V_{BATT} = 3V, ACTIVE LOAD, WITH SWITCH FETs

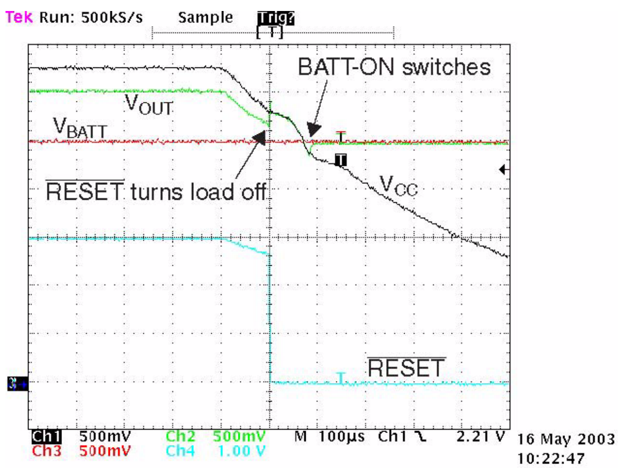


FIGURE 17. V_{CC} FAIL, V_{BATT} = 2.5V, ACTIVE LOAD, WITH SWITCH FETs

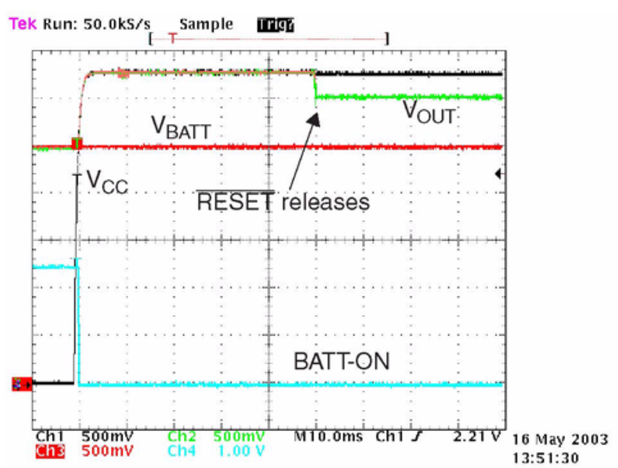


FIGURE 18. V_{CC} POWER UP, V_{BATT} = 2.5V, ACTIVE LOAD, WITH SWITCH FETs

Type of Backup Supply

The nal issue to consider is the type of backup supply. It can be a battery, a supercapacitor or a separate power supply. Using a separate power supply poses no additional issues. Using a supply such as a supercap requires a charging source. This can be as simple as connecting a diode between V_{CC} and V_{BATT} as shown in Figure 19. In this way, the capacitor is always charged and ready in the event of a power failure. However, the supercap is generally considered for use when there may only be power outages shorter than a few hours or days.

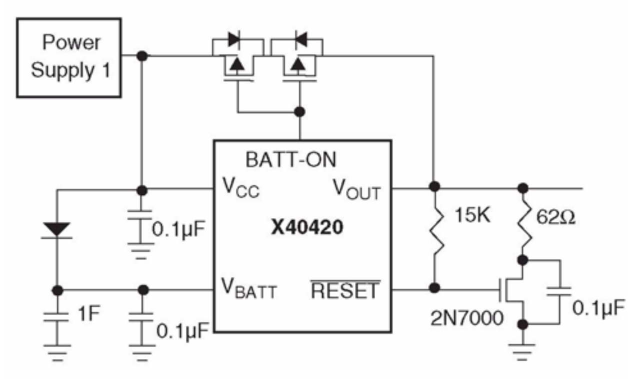


FIGURE 19. BATTERY SWITCH TEST CIRCUIT WITH ACTIVE LOAD AND EXTERNAL FET USING A SUPERCAP BACKUP

Another type of backup supply is a battery. This can be a primary or secondary type. A primary battery cannot be recharged, so the diode in Figure 19 should NOT be used. A Lithium primary battery can last up to 10 years “on the shelf” and can provide small amounts of current for a long time, but these should be replaced after a long power outage, since they are not recharged.

A safety issue for those using a primary cell concerns the potential for the circuit allowing a charging current into the cell when operating from V_{CC} or when switching from V_{CC} to V_{BATT}. This cannot happen with the X40420, X40421. When the internal switch connecting V_{CC} to V_{OUT} is on, the switch to the V_{BATT} supply is off. The switch connecting V_{BATT} to V_{OUT} is only turned on when V_{CC} is lower than V_{BATT}. This prevents any current ow into a primary cell. Figure 20. shows the circuit used to test the switchover current prole before, during, and after a V_{CC} failure.

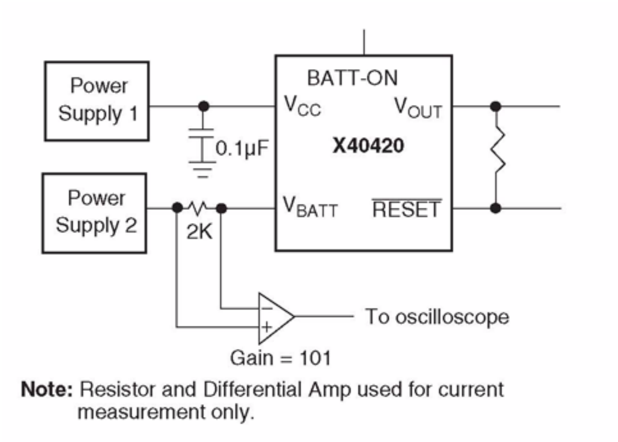


FIGURE 20. BATTERY SWITCH BATTERY CURRENT TEST CIRCUIT

The actual curves are shown in Figure 21. and Figure 22 for V_{BATT} = 3V and V_{BATT} = 2.5V, respectively. In the figures, the current trace readout is about 10µA per division. This is calculated as:

$$\frac{\frac{2V}{div} \div 101}{2k\Omega} = \frac{9.9\mu A}{div}$$

As such, the battery current before the switchover is less than 1µA. After the switchover it is about 6µA as the battery now powers the chip. During the switchover the current peaks at about 25µA. This is current that ows from the battery to the main supply through the two control FETs internal to the X40420, X40421 as they are changing states. These curves show that the current is always positive, demonstrating that there is no current owing into the battery.

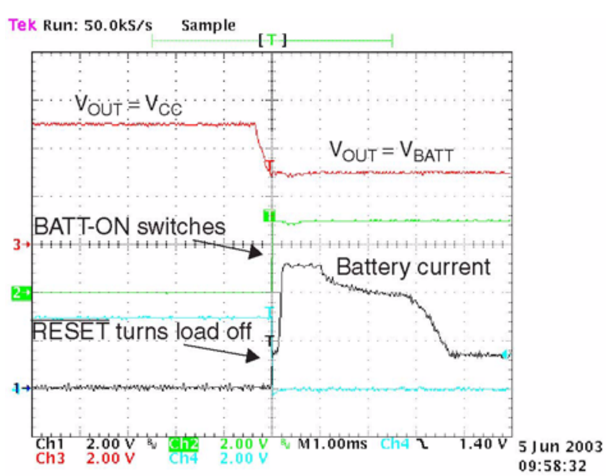


FIGURE 21. BATTERY CURRENT DURING SWITCHOVER (3V BATTERY)

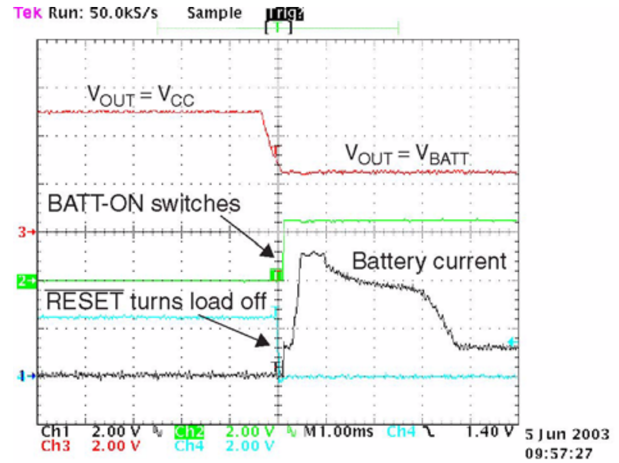


FIGURE 22. BATTERY CURRENT DURING SWITCHOVER (2.5V BATTERY)

To meet the Underwriters Laboratories (UL) requirements, as documented in the “Standard for Information Technology Equipment Including Electrical Business Equipment, UL 1950, dated February 26, 1993”, a circuit that connects to a Lithium primary cell must have either a redundant reverse charge protection or reverse charge limit of 3mA maximum. The single FET in the X40420, X40421 devices is not sufcient. To meet the UL requirement, either a series resistor or diode is required between the V_{BATT} pin and the battery as shown in Figure 23.

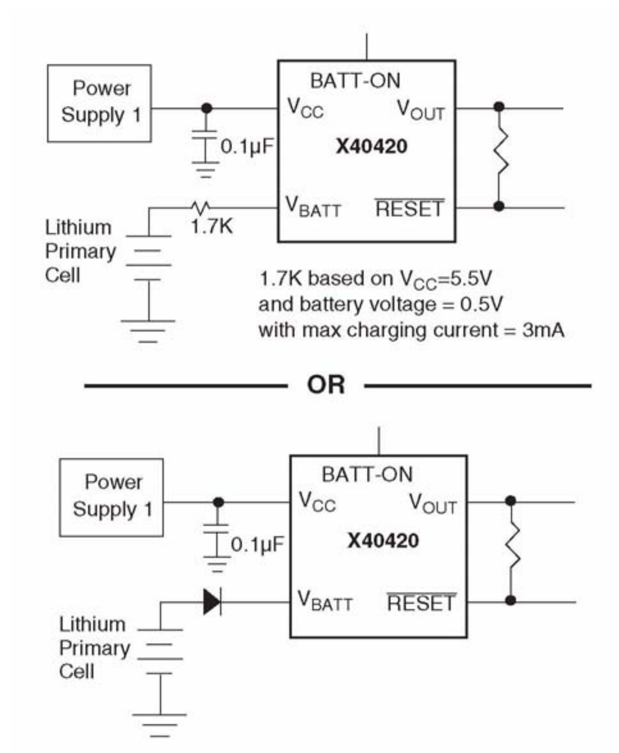


FIGURE 23. CIRCUIT ADDITIONS FOR USE OF PRIMARY CELLS TO MEET UL REQUIREMENTS

Another type of battery, often used in this type of application, is a secondary cell. A secondary cell can be recharged.When using this type of cell in the system, use a separate charger circuit that is approved for the specic cell.The X40420, X40421 will not recharge a secondary cell.

Conclusion

The X40420, X40421 devices provide a number of features valuable in the management of voltages in a system. One of the key features of the device is the ability to switch to a battery backup supply in the event the primary supply fails. In addition, it has a control output to turn on an FET switch to provide a high current to the load when operating from the main supply. These features provide a reliable, easy to use method of providing a non-interrupted source of power to SRAMs and microcontrollers in a variety of application.