Enhancing Cellphone Battery Performance during GSM pulses Through the Use of a Parallel Supercapacitor

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Abstract:

With the constant addition of features and functionality, battery life and reliability are becoming increasingly vital to those who rely on their smartphones. The transmission signal requires quick pulses of current from the battery, potentially causing the instantaneous voltage of the battery to drop below the phone's minimum voltage of operation. This may cause the power to the battery to be temporarily interrupted. A series of tests were performed on multiple battery chemistries to determine the beneficial effect of placing an AVX supercapacitor in parallel with the battery, to improve the life of the battery as well as the quality of power provided from it.

The Trouble with Batteries

Smartphone battery life can be a source of frustration for those who rely on their phones. Most smartphones require charging every day, due to their relatively short battery life. When tested with constant video playback, most smartphones' battery life ranges from 5 hours to 20 hours, less than a day for heavy users [1].

Rechargeable batteries like those used in many handheld devices develop issues maintaining charge over the life of a battery. Certain battery chemistries, such as NiCd or NiMH, can develop a 'memory,' degrading the maximum charge over the life of the battery.

Even in cases where the battery chemistry doesn't tend to develop a memory, most rechargeable batteries are limited to a certain number of charge and discharge cycles before the battery's maximum capacity begins to diminish. Replacing a battery that has a reduced maximum capacity can potentially be quite expensive, costing anywhere from $30 to $130 depending on the type of phone and battery [2].

To reduce the cost of ownership, and improve the reliability and convenience of the smartphone, certain design changes can be made. Talk time and overall battery life can be extended through the use of parallel supercapacitors integrated into the cell phone, allowing the battery itself to have a more constant draw than what is normally seen.

GSM Pulses: Digital Transmission

Smartphones operate using a digital transmission signal called Global Systems Mobile (GSM). These GSM signals operate in two frequencies, 900MHz and 1800MHz. Within each of these signal bands, there are multiple frequency bands split into 200kHz increments, and each of these increments is split into 8 segments, allowing multiple conversations on a single band [3].

When a smartphone is processing a call, the transmission is acting in its specified frequency with a duty cycle of 0.125. With these short bursts of transmission, it puts a strain on the battery not normally seen in analog signals [3].

In digital systems, such as GSM, the transmissions are occurring in short pulses. This means that for the given signal, the battery only produces power for the purpose of transmission 1/8th of the time. This can cause the battery see quick pulses of energy, and require it to output sudden spikes of current, rather than the slow, controlled output, as is seen in analog transmission.

Depending on the current required of the battery during these short pulses, the battery could potentially experience issues providing enough power. If the current is too high during these pulses, the battery will experience a brief reduction in voltage in order to provide the necessary current, and if the battery drops below the rated minimum voltage

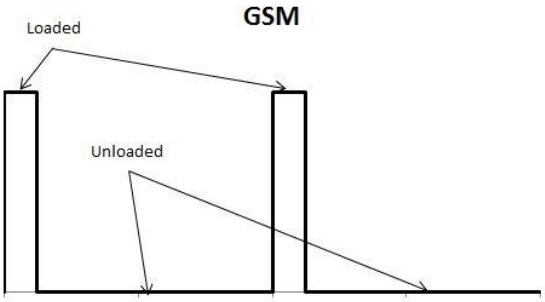

Figure 1 Example GSM pulse with a 0.125 Duty Cycle

of operation for the phone the power to the phone may be interrupted.

The following experiment was developed to simulate the effect of these quick pulses on the overall talk time of a cell phone battery. Data was collected during testing, and recorded during the loaded and unloaded portions of the test, loaded being the ‘high’ portion of a GSM signal, unloaded being the ‘low’ portion (as shown in **Error! Reference source not found.**). The tests were run in two circuit topologies, with parallel supercapacitors present and absent.

Test Conditions

In order to see the effect of a GSM pulse on a rechargeable battery a GSM pulse had to be simulated in test conditions. To this end, a test circuit was devised which would allow the alteration of frequency, duty cycle, and load conditions without major alterations to the physical circuit.

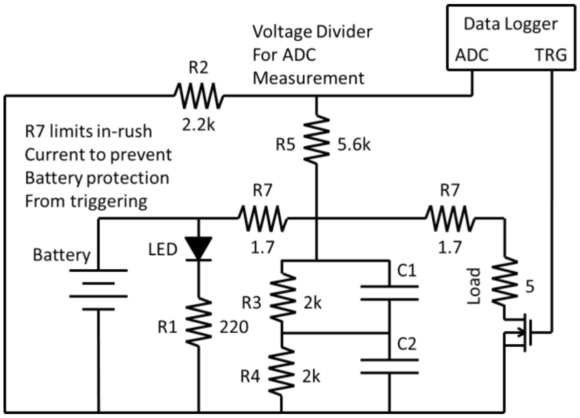

Figure 2 Test Schematic with Parallel Supercapacitor

The schematics shown in Figure 2 and Figure 3 show the circuit topology used in the tests. The GSM pulse was created using a software controlled switch, which could simulate pulsed loading of a smartphone battery. This switch was realized using a MOSFET, and digital controller.

The switch routed power through a variable load, realized in the schematic as a potentiometer. The variable resistor provided the ability to test the circuit at a variety of loading conditions.

This setup allows the use of a sufficiently high-speed software controller to alter all aspects of the circuit while taking test measurements, meaning that there is very little possibility for human error during the course of the test. The controller was set to gather data from both the loaded (signal high) and unloaded (signal low) portions of the simulated GSM pulse. This collected data could then be easily gathered and organized.

Battery Chemistry and Preconditioning

For these tests, three different battery chemistries were studied: NiMH, NiCd, and Li-Ion. Each battery had different power and energy ratings, so two of each battery type was obtained in order to test the effects of parallel capacitance, rather than the strength of one type of battery chemistry.

The AA NiCd batteries were connected in a three-cell stack, creating a power supply of 4.5V, 1000mAh.

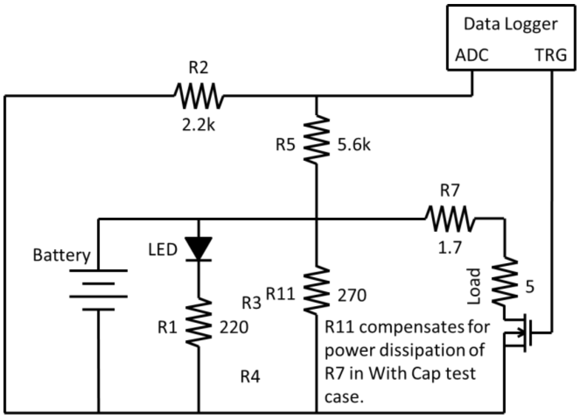

Figure 3 Test Schematic without Parallel Supercapacitor

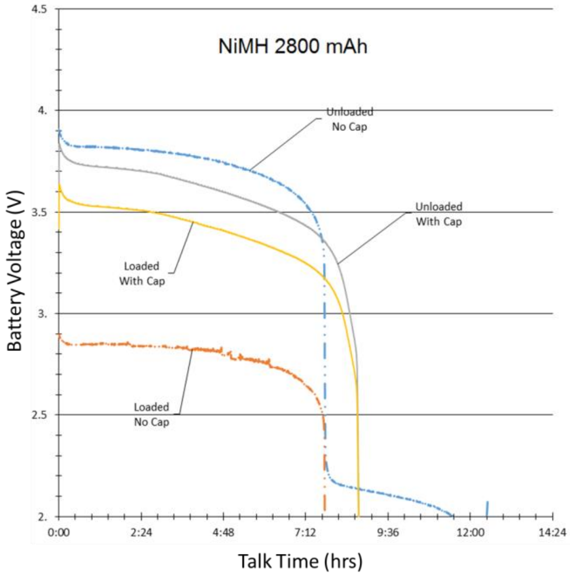

Figure 4 NiMH Test Results

The AA NiMH batteries were connected in a three-cell stack, creating a power supply of 4.5V, 2800mAh. The AA Li-Ion batteries were connected in a two cell stack, creating a power supply of 4.5V, 750mAh.

Each battery stack was then run through three full charge and discharge cycles. The batteries were charged to full capacity using commercially available battery chargers. They were discharged by a means which simulated the loaded phone battery, but left in an infinite loop until the battery was fully discharged.

The Test

Once the charge and discharge cycles were complete, the batteries were then fully recharged, and then discharge through identical loads maintained by the software controller. Each battery was tested in two conditions, one in which it was placed in parallel with a 5F supercapacitor, and one in which it did not have the parallel capacitor.

The results from these tests were recorded individually, and then graphed based on battery chemistry.

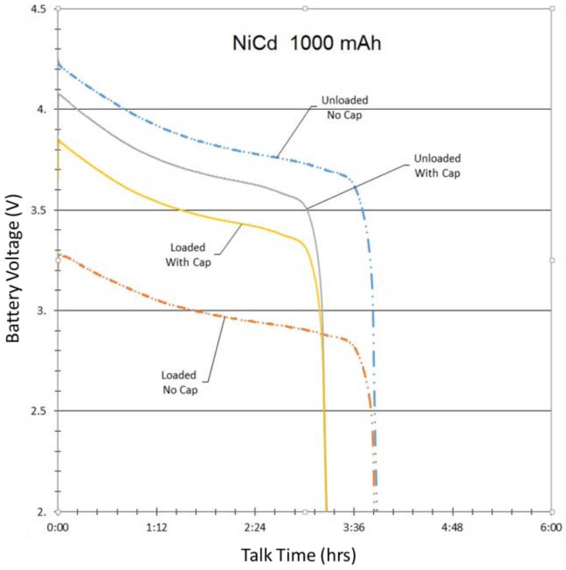

Figure 6 NiCd Test Results

The Results

1. The final results of the NiMH, NiCd, and Li-Ion tests have been compiled and graphed in Figure 4, Figure 5, and Figure 6, respectively. Each graph is separated into four lines, based on test and signal conditions. These conditions are: Unloaded Without – Battery not shunted to the load, and battery has no parallel capacitor.
2. Loaded Without – Battery is shunted to the load, and battery has no parallel capacitor.

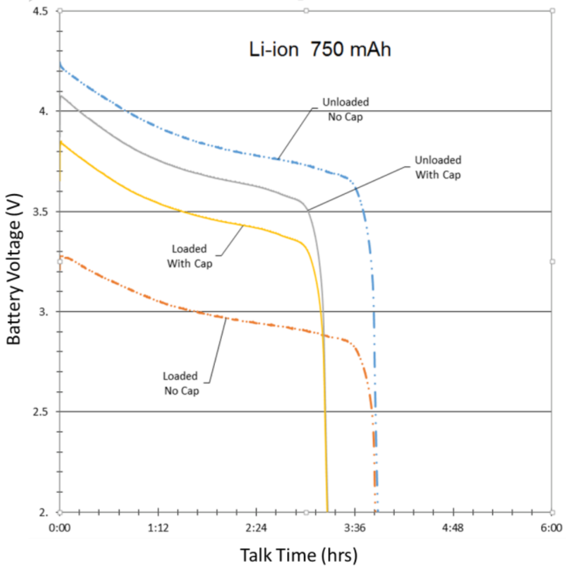

Figure 5 Li-Ion test results

3. Unloaded With – Battery is not shunted to the load, and battery has a parallel capacitor.
4. Loaded With – Battery is shunted to the load, and battery has a parallel capacitor.

The most apparent benefit of the addition of the supercapacitor is the drastic change in voltage difference between loaded and unloaded conditions. When no parallel supercapacitor is attached, the battery voltage drops tremendously when it is forced to provide the sudden spikes of current.

With the supercapacitor present, the battery is not required to supply the entirety of the current for the pulses, as the supercapacitors low ESR and ESL allow it to react more quickly to the sudden current demand than the battery is able to.

Another benefit of the parallel supercapacitor is, because it is able to keep the battery voltage from dropping so significantly, the battery does not drop below an average smartphones minimum operating voltage as quickly, extending the talk time of the phone. If we assume a minimum operating voltage of roughly 3V, then we can see the presence of a parallel supercapacitor enhances the talk time of the battery in all cases.

Final Notes: Sizing the Capacitor

Depending on the application's need, the capacitance needed can vary. If an application requires constant background power to be provided by the battery, with pulse support from the supercapacitor, the supercapacitor should be sized to be able to supply the energy required by the pulse, in this way, the battery will not have nearly the voltage drop as it would have as the only power source.

For applications where the capacitor is only intended to reduce the voltage drop of the battery, the capacitance is not as important as the ESR of the supercapacitor. The ESR of the supercapacitor in parallel with the internal resistance of the battery will ultimately lead to a lower thevenin resistance than what would be seen in either unit alone, reducing the voltage drop when power is pulled from the system.

References

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