Application Note

Method for TI Gauge to Avoid SOC Jump on Smart Phone Application

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ABSTRACT

TI-gauge products are widely used in personal electric application and industrial application, for example, smart phone, note book, wearable device, drone, vacuum robot, E-bike, and so on because of their excellent performance. For TI gauge in a smart phone, with the application scenario becomes more and more complicated, more and more new issues come up. We need to fine tune the parameters of the gauge, to achieve excellent performance. This application note uses BQ27546-G1 in the battery pack of smart phone as an example, to introduce how to fine tune the parameters of the gauge and achieve excellent performance.

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1 Introduction

With the fast progress of the new technology in smart phone, such as the fast charge technology, 5G technology, the application scenario becomes more and more complicated. For the fast charge technology, the end of charge current is much higher, which means the traditional valid charge termination would not be met for many charge and discharge cycles. For the 5G technology, the power consumption will be much higher and more dynamic even when the phone is in idle state (with screen off).

This can induce accumulated error on SOC (State of Charge), and can also cause that the error cannot be cleared. And finally cause SOC jump issue. The symptom is that the phone may be turned off suddenly even when SOC is still quite high. This is very bad user experience. We need to fine tune the parameters of the gauge to cover the requirement of such changes.

2 Where SOC Error Comes From

2.1 SOC Error Induced from Voltage Measurement

When the impedance track algorithm of gauge is POR, or reset, or meet some specific conditions, the gauge will read OCV (Open Circuit Voltage) and find the initial DOD point DOD0, then calculate the initial RM (Remain Capacity), FCC (Full Charge Capacity), SOC. If the read OCV is inaccurate, this will cause the gauge to calculate the inaccurate the initial DOD point DOD0, then the inaccurate initial SOC.

Most TI gauge devices need voltage calibration on each device, to achieve best voltage accuracy. If the voltage calibration is not performed, or performed wrong, this can cause inaccurate voltage measurement, in more detail, inaccurate OCV, then finally the inaccurate SOC.

And there are also other cases in which the gauge is POR or reset when the cell voltage is not stable enough, this will also cause the gauge to read inaccurate initial OCV, then finally the inaccurate SOC.

2.2 SOC Error Induced from Current Measurement

Most of TI gauge devices need current calibration on each PCM, to achieve best current accuracy. If the current calibration is not performed, or performed wrong, this may cause the inaccurate current measurement, and then the inaccurate coulomb counting, then finally cause the inaccurate SOC.

Another factor is the temperature drift of the current sense resistor. In a 50W fast charge smart phone, the peak charge current can be high up to 12 A. But the typical discharge current of a smart phone is several hundred mA. This big difference on the current amplitude in the charge direction and discharge direction will cause big difference on the temperature on the current sense resistor.

For example, if the temperature difference Δt is 20°C, with a 100PPM/°C sense resistor, it will cause +0.2% error in charge direction, compared with the discharge direction. This means in every cycle, the gauge will accumulate more +0.2% capacity in charge direction. This error will accumulate if it cannot be cleared. With more cycles, the accumulated error will cause big error on SOC.

3 Self-Correction Mechanism of Impedance Track Algorithm

TI impedance track algorithm have built-in self-correction mechanism. Once the gauge is in relax mode, the gauge waits until an OCV reading is taken, which occurs after:

1. 5 hours from when Current() < **Quit Current**
2. Or a dV/dt condition of < 1 µV/s is satisfied.

Once an OCV reading is taken, the gauge will clear the accumulated charge, named **PassedCharge**, and re-calculate the DOD0, and then RM, FCC, SOC. This will clear all the errors before that. So even there is error before, after an OCV reading is taken, the gauge will turn to be accurate.

4 How the New Application Scenario Affects the Self-Correction Mechanism

As previously mentioned, to let self-correction mechanism occur, the primary condition is that the gauge must be in relax mode.

The gauge is configured to enter the relax mode when the current in charge direction < **Quit Current**, and lasts for the corresponding time; or when the current in discharge direction > - **Quit Current**, and lasts for the corresponding time. Figure 4-1 shows how the gauge determines the relax/charge/discharge mode.

And if the current > - **DSG Current Threshold**, the gauge will exit relax mode and enter discharge mode.

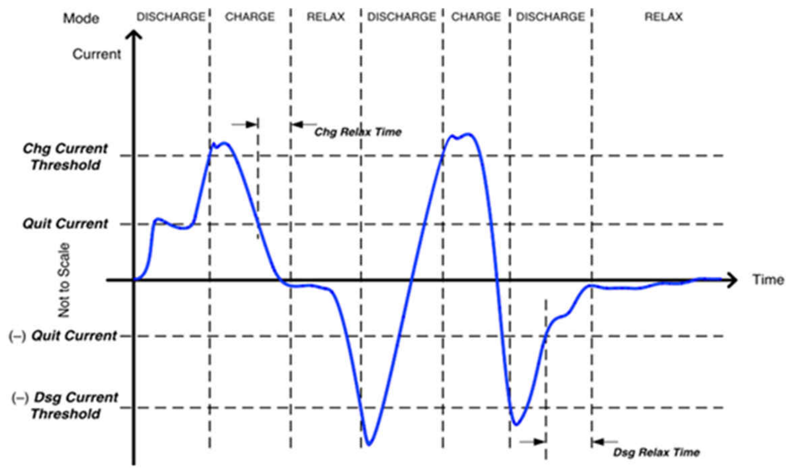

Figure 4-1. Gauge Operating Mode

Figure 4-2 shows the power consumption of a 5G smart phone when it is in idle state. The basic current is ~10mA, and some spikes can be high up to 130mA. This amplitude may be > - **DSG Current Threshold** and cause the gauge to exit relax mode before 5 hours pass.

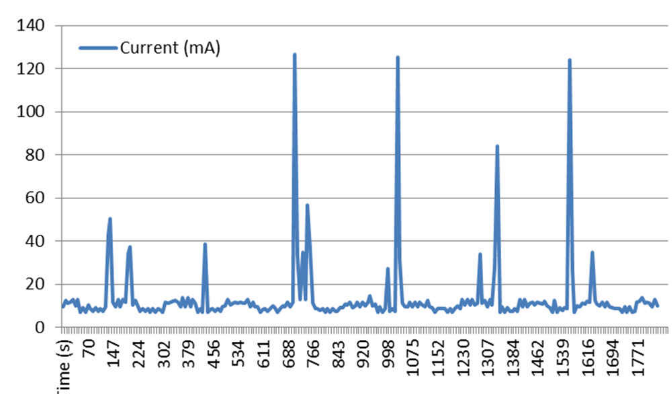

Figure 4-2. Power Consumption When the Phone Is In Idle State

5 dV/dt Condition of < 1 μV/s is not Satisfied

In general, without the fast charge technology, it can take 4~5 hours to charge an empty battery pack to full. So most of the users will have to connect the adapter and charge the phone for overnight. In this scenario, after charge to full, the charger powers the system. And there is no current flowing into or out of the battery pack. This is a very stable condition. So the self-correction mechanism has high possibility to occur.

But with the fast charge technology, it can just take 30 minutes, or even 15 minutes to charge the empty battery pack to full. This changes users' habit. Some users can not connect the adapter and charge the phone for the whole night, because they just need to connect the adapter for 30 minutes after wake up, then they can use the phone for the whole day. In this scenario, it doesn't have a very stable condition which is good for OCV reading.

And from Figure 4-2, we can also see the current is very dynamic even when the phone is in idle state. This leads to unstable voltage, and causes dV/dt condition of < 1 μV/s is not satisfied.

6 Fine Tune Gauge Parameters

We have discussed the self-correction mechanism, and the two scenarios which can affect the conditions of the self-correction mechanism. In this section, based on the analysis above, we will discuss how to fine tune the parameters to cover those cases and improve the performance.

The basic idea is to make use of the scenario of overnight, when the user goes to sleep. This scenario will happen on every user and every day. In this scenario, the phone is in idle state for the whole night. We expect the gauge can has high possibility to read OCV.

The best case is that the adapter is connected and charge the battery pack for the whole night. As mentioned above, this provide a very stable condition for the gauge to read OCV.

But we also need to consider the case that the adapter is not connected for the whole night. To let the gauge have high possibility to read OCV, we can relax the condition of OCV reading by fine tuning the parameters.

6.1 Increase the Current Threshold

The primary condition of OCV reading is the gauge must be in relax mode. We can fine tune the parameters of Current Threshold to let the gauge have higher possibility to stay in relax mode when the phone is in idle state.

The idea is to let the gauge easier to enter relax mode and more difficult to exit the relax mode, we can:

1. Increase the **Quit Current** and shorten the **Dsg Relax Time**. For example, the default value of **Quit Current** is 40mA. We can increase it to 100mA. And the default value of **Dsg Relax Time** is 60S, we can change it to 1S. This makes the gauge easier to enter relax mode when the phone is in idle state.
2. Increase the **Dsg Current Threshold**. For example, the default value of **Dsg Current Threshold** is 60mA. We can increase it to 260mA. This makes the gauge more difficult to exit the relax mode when the phone is in idle state.

Table 6-1. Current Threshold

* Field Order: Class name	Subclass name	Parameter name	Default Value	Updated Value
Gas Gauging	Current Thresholds	Dsg Current Threshold	60	260
Gas Gauging	Current Thresholds	Chg Current Threshold	75	130
Gas Gauging	Current Thresholds	Quit Current	40	100
Gas Gauging	Current Thresholds	Dsg Relax Time	60	1
Gas Gauging	Current Thresholds	Chg Relax Time	60	1

6.2 Relax the Time From When Current() < Quit Current is Not Met

It is 5 hours that it is needed from when Current() < **Quit Current**. We can also shorten this time from 5 hours to 2 or 3 hours. This helps to increase the possibility to read OCV when the phone is in idle state.

Table 6-2. Relax the Time

* Field Order: Class name	Subclass name	Parameter name	Default Value	Updated Value
Gas Gauging	IT Cfg	Qmax Max Time	18000	7200

6.3 Relax the dV/dt Condition

The nominal default dV/dt condition to read OCV is < 1 μV/s. We can loosen this condition to increase the possibility to read OCV when the phone is in idle state. The corresponding parameter is Max V Delta. In this example, we increase it by 5 times.

Table 6-3. Relax the dV/dt Condition

* Field Order: Class name	Subclass name	Parameter name	Default Value	Updated Value
Gas Gauging	IT Cfg	Max V Delta	10	50

7 Test Result

We have met many SOC jump issue in the field, in one of the top smart phone brands in China, who is using BQ27546-G1. Figure 7-1 is one snippet of log data from the host, which shows SOC big jumps: from 9% to 0%.

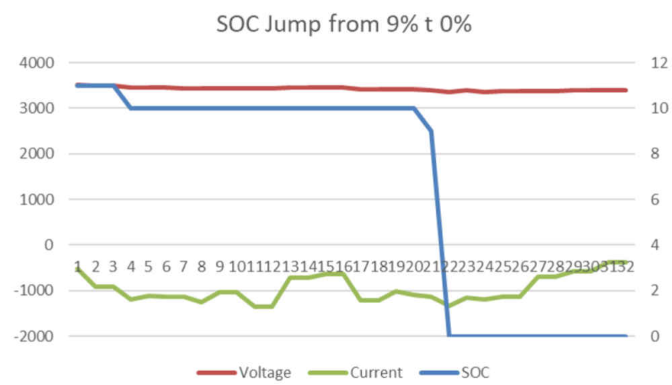

Figure 7-1. SOC Jump From 9% to 0%

In some cases, the user returned the phone. So we can get the phone (and the battery pack) for further analysis and found the root cause. But in most of the cases, we cannot get the phone. And cannot find the root cause. Without knowing the root cause of the error, we still need to fix the issues. So we propose this solution.

But after we apply this solution, and change the related parameters on those phones which are already in the field, this kind of SOC jump issue has been reduces greatly. This proves the solution does fix SOC jump issue.

We should also understand that we are relaxing the condition of OCV reading to achieve the higher possibility to read OCV. This can clear the accumulated error and avoid SOC jump issue. But the trade-off is the accuracy of OCV reading. In this scenario, the accuracy of OCV reading is still relevant when the phone is in idle state for the entire night.

8 Summary

This application note describes the self-correction mechanism, the two conditions of the self-correction mechanism, the two scenarios which can affect the conditions of the self-correction mechanism, and finally how to fine tune the parameters to cover those cases and improve the performance. This solution has been applied to two of the top four smart-phone brands in China.

9 References

- Texas Instruments, *BQ27546-G1*technical reference manual.
- Texas Instruments, *End of Discharge SOC Jump Elimination* application report.
- Texas Instruments, *Theory and Implementation of Impedance Track Battery Fuel-Gauging Algorithm* application report.