Application Report

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Extracting Maximum Power From an Adapter Without Overload Using the bq2589x Battery Charger's ICO Feature

BCP SCS

ABSTRACT

To maximize the output power of any adaptor to charge battery, the bq2589x family of battery chargers includes the Input Current Optimization (ICO) feature. This application explains how the ICO feature configures the charger's input current limit to the maximum allowed in order to avoid overloading the charger's input power source.

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1 Background

Wall adapters used to power portable electronic devices come in a variety of voltage and current ratings. Most battery chargers inside the portable devices include one or more fast response feedback control loops to prevent the charger from pulling too much current from their wall adapter, thereby collapsing it. One such loop is the input current limit dynamic power management (IINDPM) loop. The designer, through external resistor, I2C register, or the charger's D+/D- circuitry automatically sets a predetermined value for the amount of input current the charger is allowed to pull from the adapter. The charger's dynamic power path management circuitry then distributes this input power to the system load and uncharged battery, reducing charge current if necessary to provide the demanded dc or transient system load. In the event the adapter cannot provide its rated output current or because of highly resistive connections from the source to the charger, the charger's input pin voltage droops. This could also happen when an adapter unknown to D+/D- detection (for example, a 3rd party adapter) is attached and the charger sets the IINDPM setting too high. When this happens, the second feedback loop, input voltage input dynamic power management or VINDPM, activates and reduces the charge current to prevent the charger from crashing the adapter as highlighted in Figure 1.

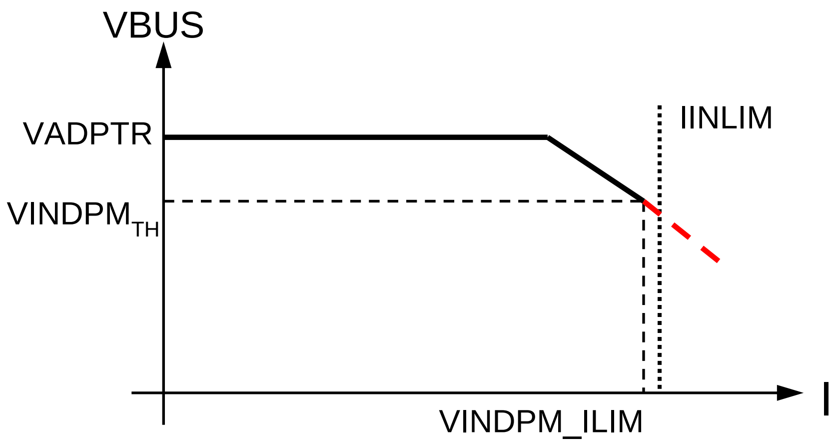

Figure 1. Effective input current limit set by VINDPM (VINDPM_ILIM)

At startup, the charger sets a default VINDPM threshold (for example, 600 mV below the unloaded input voltage). The host software can change the INLIM or VINDPM voltage thresholds via I²C anytime. If the input voltage droop is due to highly resistive connections, then allowing the charger's VINDPM loop to continuously be in control and regulate the charger's input voltage to prevent further droop is acceptable. If, however, the droop is due to adapter overload, reducing the charger's input current limit to a level where the adapter is not in overload is preferable. More detail about IINDPM and VINDPM can be found using the SLUA400.

The bq2589x ICO circuitry identifies and sets the maximum (optimal) current the charger can pull from the adapter without collapsing the adapter.

2 Operation

If the bq2589x EN_ILIM bit (REG00[6]) is set, then the actual input current limit is the lower of the value set by the ILIM pin resistor or as reported by the IDPM_ILIM registers (in other words, the ILIM pin resistor clamps the maximum input current limit value). The remainder of the application note assumes EN_ILIM = 0 which results in the IDPM_ILIM reporting the actual input current limit in use.

With ICO disabled (REG02[4] = 0) or until the ICO algorithm has optimized the input current limit, the ICO_OPTIMIZED bit (REG14[6]) = 0 indicating optimization is disabled or in progress. The IDPM_ILIM register (REG13[0:5]) reports the same value as configured in the IINLIM register (REG00[0:5]) by the D+/D- algorithm (bq25890, bq25895) or PSEL bit (bq25892, bq25896) at startup, or by host software.

If ICO is enabled, the charger waits for the first VINDPM event to occur, in other words for the desired output power to exceed the allowed input power. When V(BAT) > VMINSYS, the ICO algorithm does the following:

- Reduces IDPM_LIM to 500 mA then
- steps up the current limit until the input voltage drops to VINDPM threshold then
- lowers the IDPM_ILIM register slightly below the point where VINDPM is reached.
- The ICO_OPTIMIZED bit is set to 1.

Figure 2 is a graphical representation of the ICO algorithm list above. It is assumed that the system load or charge current increases at the point where the VBUS voltage is no longer at the adapter voltage (VADPTR).

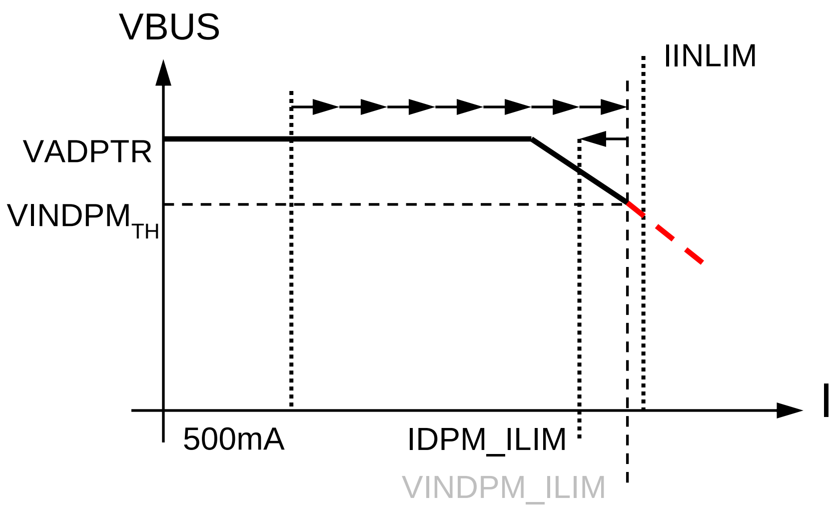

Figure 2. Graphical representation of ICO during operation

Figure 3 is a scope shot of ICO in action on a board with 0.5-Ω input resistance from a 6-V supply, 5.3-V VINDPM threshold. The charge current increases from 1 A to 4 A causing the input voltage to droop to VINDPM and triggering and ICO

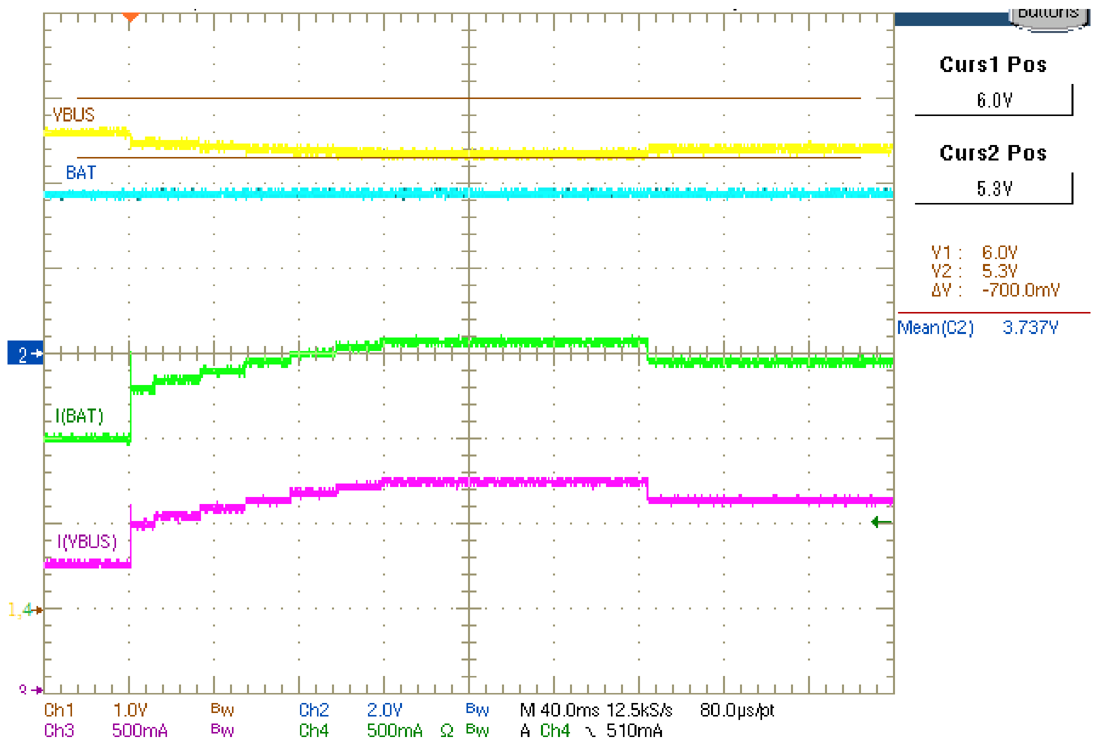

Figure 3. Automatic ICO detection after increase in charge current with V(BAT) > VMINSYS

In order to ensure that the system has enough power when V(BAT) < VMINSYS, the ICO algorithm works simpler by:

- setting the input current equal to the IINLIM register value (which is clamped to a lower value by the VINDPM control loop), then
- stepping down the current limit until the charger exits VINDPM control.
- The IDPM_ILIM register is updated to this input current limit value and
- the ICO_OPTIMIZED bit is set to 1.

Figure 4 is scope shot of this on the same board but with a V(BAT) < VMINSYS.

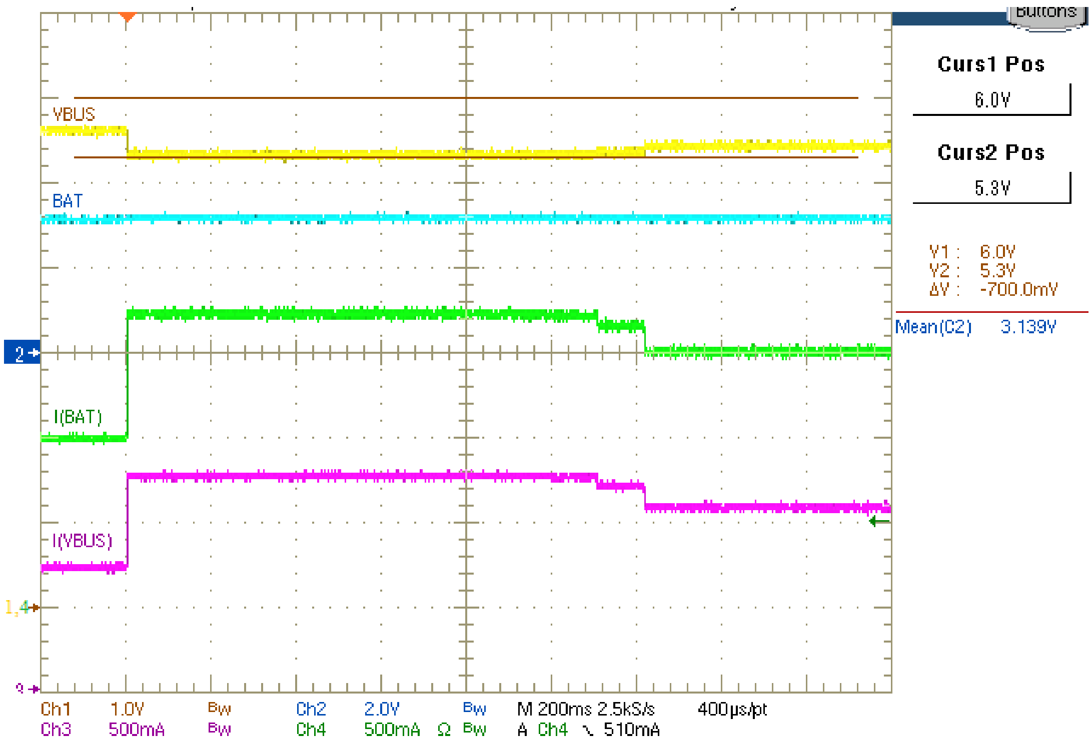

Figure 4. Automatic ICO detection after increase in charge current with V(BAT) < VMINSYS

The input current limit remains optimized and will not automatically run the ICO detection algorithm again unless the following occurs:

- another VINDPM event or
- IINLIM register changes or
- VINDPM_OS register (when FORCE_VINDPM=0) changes or
- VINDPM register (when FORCE_VINDPM=1) changes

In addition, for the bq25890/5x parts with D+/D-, if DCP/HVDCP adapter is detected at startup, the ICO algorithm automatically runs.

The host software can also force ICO detection using the FORCE_ICO bit (REG09[7]) or toggling the ENable_ICO (REG02[4]) bit, which defaults to 1. As shown in Figure 5, when forcing detection, the ICO detection algorithm first disables charge for 10 ms and applies a 10 mA sink on BAT, in order to determine whether V(BAT) is greater than or equal to VMINSYS, and then precedes as previously described.

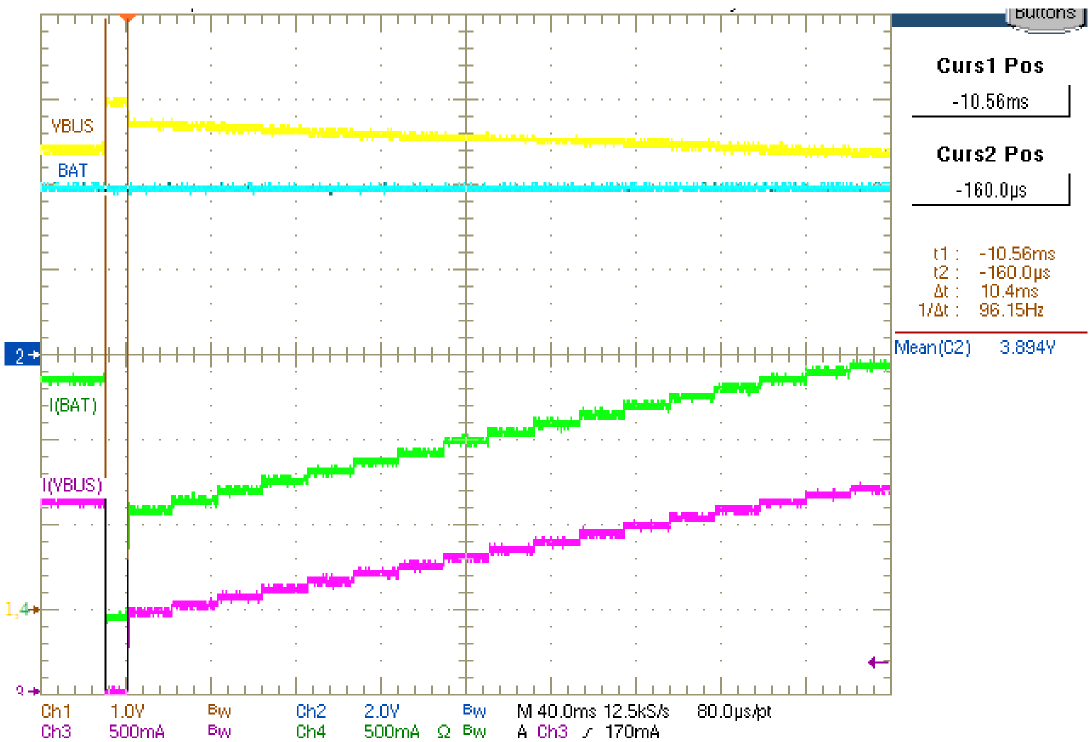

Figure 5. Forced ICO Detection With V(BAT) > VMINSYS

3 Summary

A charges VINDPM loop is the last line of defense in preventing the charger from collapsing its input source, i.e. adapter. While the charger is fully capable of indefinitely regulating its input current limit using the VINDPM loop, running a wall adapter in an overload state is unhealthy for the adapter. The designer sets the input current limit register, either through external ILIM resistor or IINLIM register to match the adapter's rated current. In the event of malfunctioning adapters or highly resistive adapter cables, the bq2589x ICO circuitry finds the charger optimal input current limit setting for maximum power extraction without adapter overload. The Table 1 summarizes possible cases for input current limit registers.

Table 1. Current Limit Registers

TEST CONDITIONS				RESULTS		
Adapter	**Max ILIM Per Pin Resistor**	**INLIM Register**	**ICHG Register**	**IDPM_LIM Register**	**ICO Status Register**	**Actual Input Current Limit**
Case 1						
5 V at 3 A	2 A	3.25 A	5 A	3.25 A	1	2 A – clamped by ILIM resistor
Case 2						
5 V at 1.5 A	2 A	3.25 A	5 A	1.5 A	1	1.5 A – ICO finds optimal setting
Case 3						
5 V at 3 A	3 A	2 A	5 A	2 A	1	2 A – clamped to INLIM
Case 4						
5 V at 3 A	3 A	3.25 A	2 A	3.25 A	0 – ICHG doesn't require 3.25 A input	3.25 A

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