Dynamic Power-Path Management and Dynamic Power Management

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ABSTRACT

Dynamic power-path management (DPPM) and dynamic power management (DPM) are two similar types of integrated power management ICs that combine the task of charging a single-cell Li-ion battery and powering the system. Both topologies reduce the battery charging current to give the system priority, when the adaptor has reached its output current rating. The bq2403x family and TPS65800 IC use the DPPM technology. The bq24702/3 uses the DPM technology.

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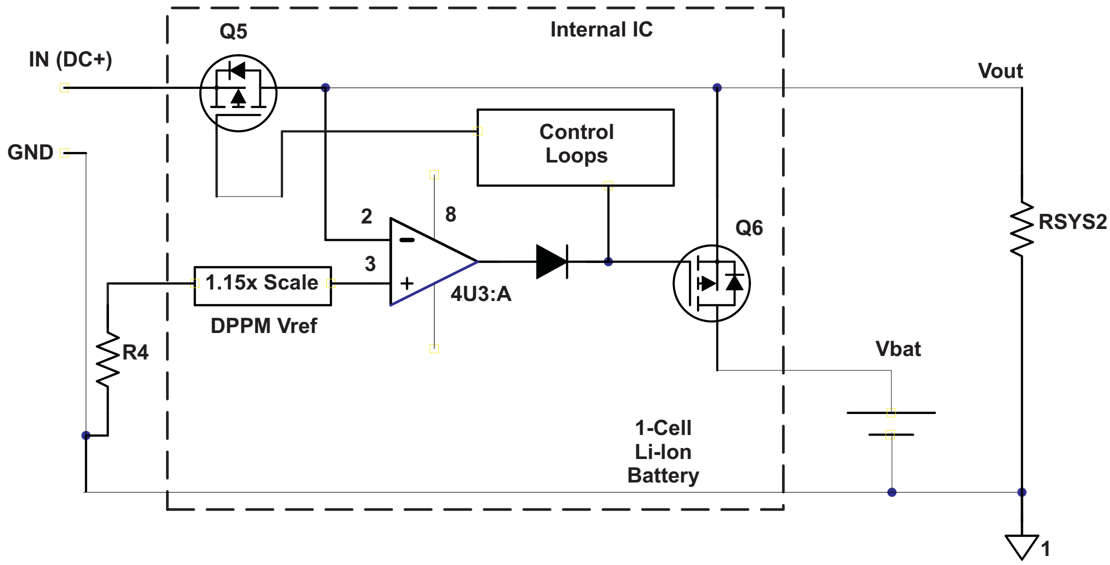

Figure 1. DPPM – Manages Battery Current Based on Output Voltage (Control Loops not Shown for Regulating Battery Constant Current/Voltage or Battery Supplement Mode)

Dynamic power-path management (DPPM) is a current management routine base on the system voltage, where if the system voltage drops to a preprogrammed threshold, due to loss of power or a current-limit threshold, the battery charging current is sufficiently reduced to prevent any further drop in the system voltage.

The pros of DPPM are:

- Allows selection of a lower cost adaptor.
- Better protection from system crashes due to low-power adaptors and power grid brown-outs.
- Better efficiency than running off battery.

A lower cost adaptor may be chosen based on the average load (average system load, 0.5 A plus fast-charge load 1 A) instead of a peak load. If a peak system load requires an additional 0.75 A, over the average load, then the charging current is reduced by this amount during the peak load transient. The DPPM system voltage based routine would detect a current-limited adaptor or brown-out condition when the system voltage dropped to the detection threshold. Reducing the charging current helps to keep the system from crashing as long as the system load current alone does not exceed the input current limit. Note that this assumes that the battery is absent or fully depleted; otherwise, the battery would provide the necessary power to the system.

The efficiency is best when there is less voltage drop from the input to the system output. During DPPM, if the DPPM threshold is set above the battery voltage, the efficiency is higher than the configuration where the threshold is set below the battery and the output drops to the battery voltage. For a high threshold setting, DPPM mode delivers a slightly lower efficiency than the DPM routine. If DPPM is entered a low percentage of the time, then the efficiencies results between DPPM and DPM are similar. Charging efficiency is only a concern if the product temperature has a heat issue. The size of the BAT FET is more of a concern for run time and is often larger (lower resistance) in a DPPM design because it requires fewer power FETs.

The cons of DPPM are:

- System output voltage transients may affect sensitive circuits like audio amplifiers
- Slightly lower charging efficiency than DPM

The system output voltage drops due to the system and charging load exceeding the current limit of the input adaptor. The lower the DPPM threshold is set, the more the output can fall when the adaptor reaches current limit. This sudden change in system voltage can give some audio circuits noise issues. The best way to minimize this is to set the DPPM threshold as high as possible to minimize the output voltage transient. The supply tolerances, IR drops, and tolerances of the DPPM threshold are factors to consider when programming this threshold.

The efficiency is slightly lower during DPPM than DPM, and proportional to the time spent in DPPM.

2 DPM Discussion

Dynamic power management (DPM) is an input current limit routine which monitors the input current via an input current-sense resistor (see Figure 2). A sense resistor, Rsns, and program resistor, R3, are chosen to program the input current-limit threshold. If this threshold is reached, due to the combined load of the system and battery charger current, the charging current is reduced as necessary to keep the input current from increasing further. This is implemented by the U2A amplifier, which overrides the constant current/voltage loop and drives Q3 toward its off state, thus holding the load demand constant.

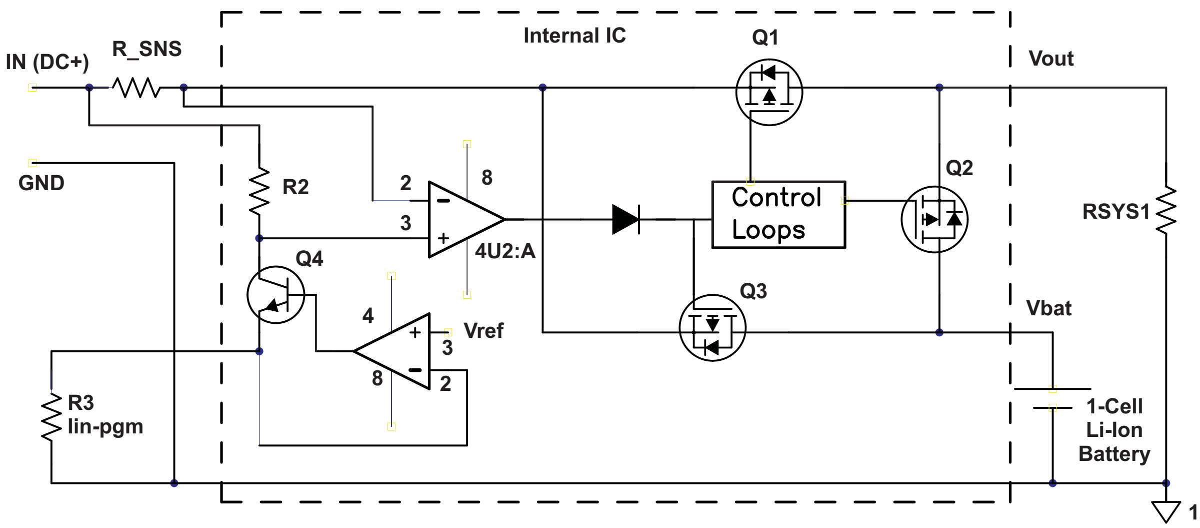

Figure 2. Dynamic Power Management - Manages Battery Current Based on Input Current

The pros of DPM are:

- Allows selection of a lower cost adaptor.
- System voltage remains constant during DPM operation.
- Better efficiency

A lower cost adaptor may be chosen based on the average load (average system load, 0.5 A plus fast-charge load 1 A) instead of a peak load. If a peak system load requires an additional 0.75 A over the average load, then the charging current is reduced by this amount during the peak load transient. This is the case for both DPM and DPPM.

The system's voltage remains constant because the adaptor does not enter current limit. This supply is connected directly to the system; so, the only change in system voltage is due to the IR drop, across Q1, associated with the load change.

Because this system voltage remains relative high, the dissipation in power between the input and output is minimized and thus the efficiency remains high.

The cons of DPM are:

- Wrong adaptor (too low of current rating) may crash system.
- Power grid brown-outs may cause system to crash.

If an adaptor is used which has a lower current limit threshold than the programmed DPM level, then during peak loads the adaptor's voltage drops along with the system voltage, due to the adaptor entering current limit. The DPM circuit does not detect voltage drops and does not reduce the charging current.

Similarly, if the AC power grid droops in voltage causing the adaptor to drop out of regulation, the DPM routine does not reduce the charging current and the system will likely crash.

3 Power Transfer Issues

The designer has to consider the timing issues associated with switching between the sources. The battery FET typically takes less than 10 µS to be driven on after the output drops to the battery voltage. If the battery has sufficient capacity to handle the system load, then this prevents any system glitches. If the battery is missing, it can take up to 100 µs, after the lost input drops to within 125 mV of the battery voltage, for the new source to be connected. This requires the system capacitance to provide the system load during this time. A 100-µF capacitor can deliver 100 mA for 100 µs and will discharge by 100 mV [C=i/(dv/dt)].

4 Design Example for Setting the DPPM Threshold Using the bq24032A IC

Given:

DPPM Scaling Factor (SF): 1.139 – 1.150 – 1.162 (min – nom – max)

RDSon for the adaptor input FET (Q5 –Figure 1) shown in Figure 3.

Vout REG is shown in Figure 4.

Idppm shown is shown Figure 5.

Find:

1. Specify an adaptor, based on calculations from the given data, that keeps the output from dropping out of regulation at its rated output current level.
2. Calculate the largest value for Rdppm that keeps the loop out of DPPM just prior to the input supply current limiting. Note that if Vdppm-out, with its tolerances, is set too high (larger than the output voltage regulation), then the DPPM loop prevents charging.
3. Choose a nominal resistor that does not exceed the maximum resistance value.
4. Calculate the minimum Vdppm-out threshold from selected resistor in step 3.
5. Calculate the nominal Vdppm-out threshold value from selected resistor in step 3

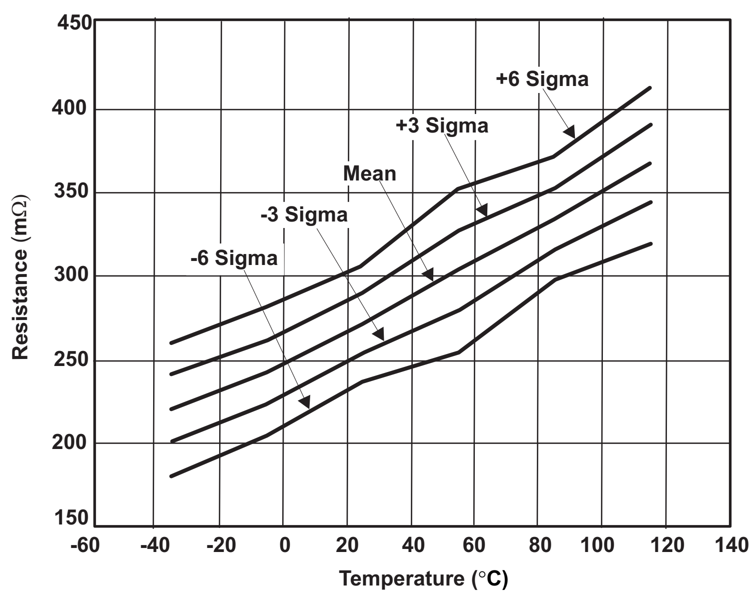

Figure 3. RDSon for Pass FET — Resistance (mV) vs Temperature (°C)

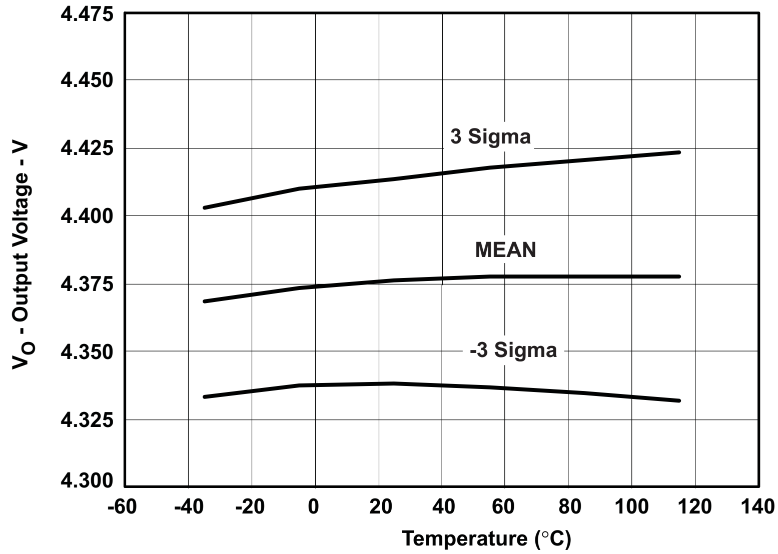

Figure 4. Output Regulation Voltage — Vout (V) vs Temperature (°C)

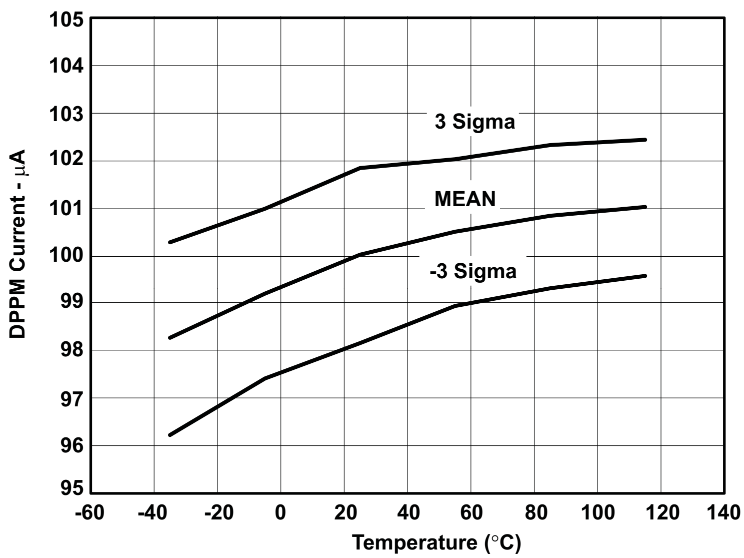

Figure 5. DPPM Current — I_{DPPM} (µA) vs Temperature (°C)

Solution:

1. Determine the input source specification that prevents drop-out when not in current limit. First, calculate the minimum input voltage needed to maintain OUT pin regulation.

   $V_{IN\text{-}MIN} = I_{In} \times RDS_{ON\text{-}MAX} + V_{REG\text{-}MIN} = 1.5\ A \times 380\ m\Omega + 4.33\ V = 4.9\ VDC$

   The RDSon value was chosen from Figure 3 at 120°C at Sigma 3. The output minimum regulation was chosen from Figure 4 at 120°C.

   Next, calculate the nominal adaptor voltage needed to stay above the calculated minimum input voltage, assuming a selection of a ±5% voltage regulating supply.

   $$V_{IN-NOM} = \frac{V_{IN-MIN}}{1 - \%toll} = 4.9VDC/(1 - 0.05) = 5.158VDC,\ \text{for a 5\% tolerance supply.}$$

   Choose a supply with a nominal voltage of 5.158 VDC ±5% with a current rating of 1.5 A (a standard output of 5.2 V ±5%, 1.5-A supply works fine).

2. Calculate the largest value Rdppm that avoids DPPM mode when the output is at its minimum

regulation voltage. If the DPPMout threshold is set above the OUT pin regulation voltage, the charging current will be disabled.

$$R_{DPPM-MAX} = \frac{V_{DPPM-OUT-MAX}}{SF_{MAC} \times I_{DPPM-MAX}} = 4.33V/(1.162 \times 102.4\mu A) = 36.36k\Omega$$

3. Choose a nominal resistor that does not exceed the value in step 2.

   $R_{DPPM\text{-}1\%}$ = 0.99 × $R_{DPPM\text{-}MAX}$ = 0.99 × 36.39k = 36.026 kΩ. Choose a 36-kΩ, 1% resistor.
4. Calculate the minimum Vdppm-out threshold from the selected resistor in step 3. $V_{DPPM\text{-}OUT\text{-}36k1\%\text{-}MIN}$ = $R_{DPPM\text{-}MIN}$× $I_{DPPM\text{-}MIN}$× SF_{MIN} = (0.99×36k) × 98 µA × 1.139 = 3.978 VDC. From Figure 5, the minimum DPPM current was taken at 20°C, because it is unlikely that during full-load operation that the IC temperature would be any colder.

   The lowest DPPM-OUT voltage threshold, using a 36-kΩ, 1% resistor, is ~3.978 VDC.
5. The nominal DPPM-OUT voltage threshold, using a 36-kΩ, 1% resistor, is between the maximum and minimum value, which is ~4.154 VDC.

The tolerance range over temperature for a give IC (3 sigma) is:

Resistor:	± 1%
DPPM Current:	± 2.2%
DPPM Scale Factor:	± 1%
Total DPPM Threshold Factors:	± 4.2%

Cross-Check – Estimated maximum resistor: 4.33 Vout-min/(1.15 × 100 µA) × (100%–4.2%)/100 = 36071 Ω. The maximum DPPM resistor value to set the DPPM threshold the highest without risking a disabling of the charge current is 36 kΩ, 1%.

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