AN193

Selecting the MP2760's BATFET

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ABSTRACT

Portable devices today increasingly require a longer usage time, shorter charging time, and limited system voltage (V_{SYS}). A shorter charging time requires a higher charging current (I_{CHG}) within the heat loss tolerance. To achieve a limited V_{SYS} and accurate I_{CHG}, many manufacturers use a narrow-voltage DC (NVDC) architecture for battery-charging applications.

The MP2760 is an I^2C-controlled, 1-cell to 4-cell buck-boost charger with NVDC power path management. A battery FET (BATFET) driver is included to control an external N-channel MOSFET, which regulates the system's minimum voltage ($V_{SYS\_REG\_MIN}$) and provides a battery supplement function. Different BATFET characteristics may affect I_{CHG}.

This application note discusses the features of the MP2760, as well as the relationship between I_{CHG} and the BATFET's characteristics. It also provides a design example for selecting the BATFET.

INTRODUCTION

The MP2760 provides a BATFET driver (via the BGATE pin) to support NVDC power path management. The device can regulate the system voltage at $V_{SYS\_REG\_MIN}$, even when the battery is depleted.

Figure 1 shows the NVDC power path management structure.

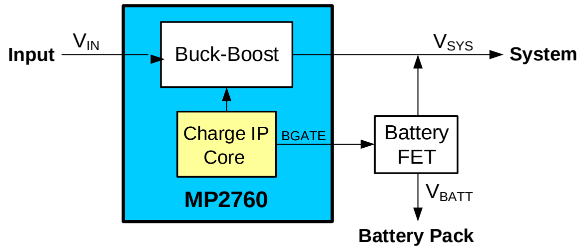

Figure 1: NVDC Power Path Management Structure

The MP2760 has a configurable V_{SYS_MIN}. When $V_{BATT} < V_{SYS\_REG\_MIN}$ (where $V_{SYS\_REG\_MIN} = V_{SYS\_MIN} + V_{TRACK}$), the BATFET driver controls the charging current loop (trickle charge, pre-charge, and linear constant-current (CC) charge). This ensures that V_{SYS} is regulated at $V_{SYS\_REG\_MIN}$.

When $V_{BATT} > V_{SYS\_REG\_MIN}$, the BATFET fully turns on, and the charging current loop (switching CC charge) and battery voltage loop (constant voltage (CV) charge) are implemented via the buck-boost converter's pulse-width modulation (PWM) control. V_{SYS} always tracks the actual battery voltage, which is limited above V_{BATT} by V_{TRACK}.

Figure 2 shows the system voltage regulation, where R_{SYS_BAT} is the total resistance between the system and battery.

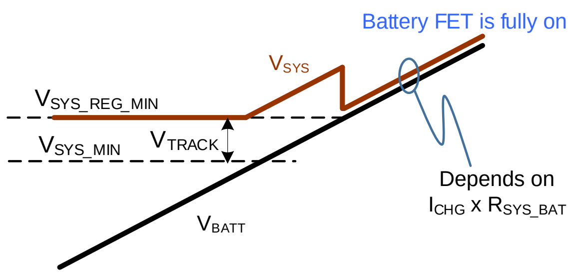

Figure 2: System Voltage Regulation

Figure 3 show the MP2760's charging profile.

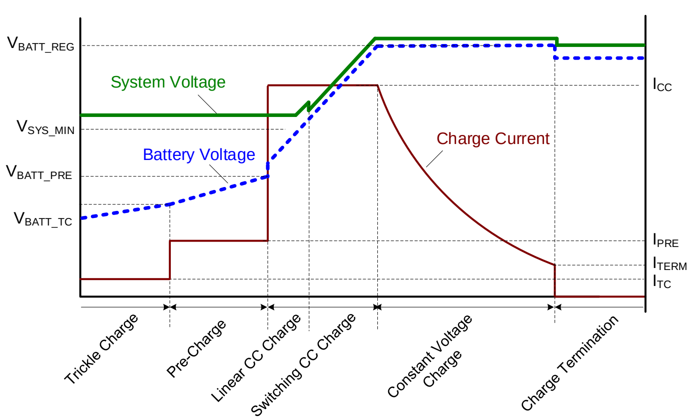

Figure 3: Complete Charging Cycle Profile

METHOD DETAILS

Linear Charging Current

When V_{BATT} is below $V_{SYS\_REG\_MIN}$, BATFET works linearly. In 1-cell applications, the charge pump is powered by V_{CC}, which is the internal LDO output that can provide a 3.6V voltage for the internal circuit. The charge pump's input determines the maximum charge pump output (V_{CP}). V_{CP} is then used to drive the external BATFET via a current source.

The current source's output impedance (Z_{ISRC}) should be several hundred kΩ, and the charge pump's output impedance (Z_{O_CP}) should be between several kΩ and several tens of kΩ. If the selected BATFET's gate-to-source threshold voltage (V_{GS_TH}) results in an insufficient DC voltage bias (about 2V) for the current source, then Z_{ISRC} drops to several tens of kΩ, and I_{CHG} drops below its configured value (I_{CHG_CONF}) due to inadequate loop gain. Therefore, a proper BATFET must be selected to meet the required minimum charging current (I_{CHG_REQ}), especially for 1-cell applications.

Figure 4 shows the simplified block diagram of the BATFET's linear on loop in a 1-cell application.

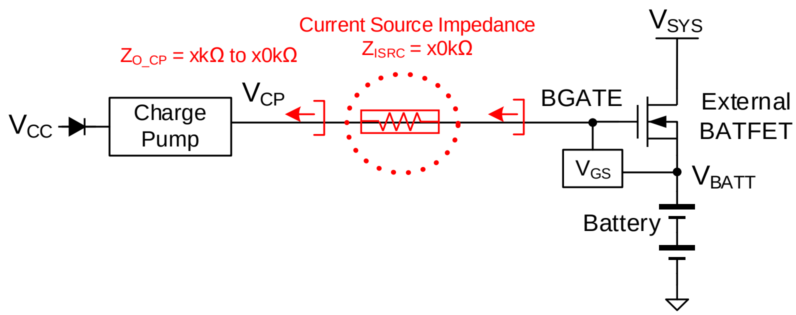

Figure 4: Simplified Block Diagram of the BATFET's Linear On Loop in 1-Cell Applications

Figure 5 shows the relationship between the MP2760's I_{CHG} and the BATFET's gate-to-source voltage (V_{GS}) when I_{CHG_CONF} is set to 1A, which reflects the driving ability under 1-cell applications. In 2-cell to 4-cell applications, the charge pump's input is sufficiently high, and the current source that drives BATFET does not become saturated. Due to this, this application note only provides guidance on selecting BATFET in 1-cell applications.

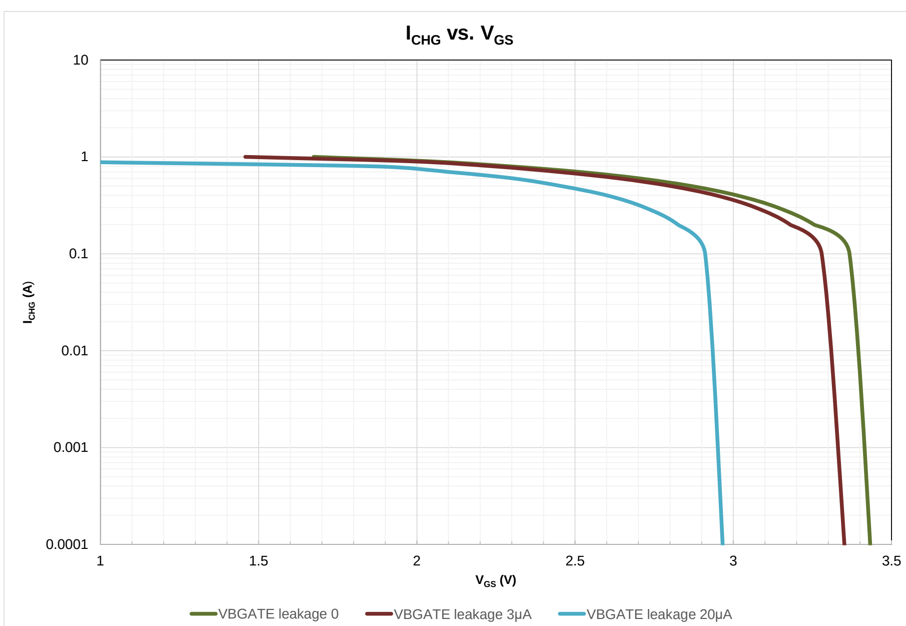

Figure 5: I_{CHG} vs. V_{GS} of the MP2760's BATFET (I_{CHG_CONF} = 1A)

Figure 6 shows the transfer characteristics of three different N-channel MOSFETs. These characteristic curves are paired with the curves from Figure 5 on page 4.

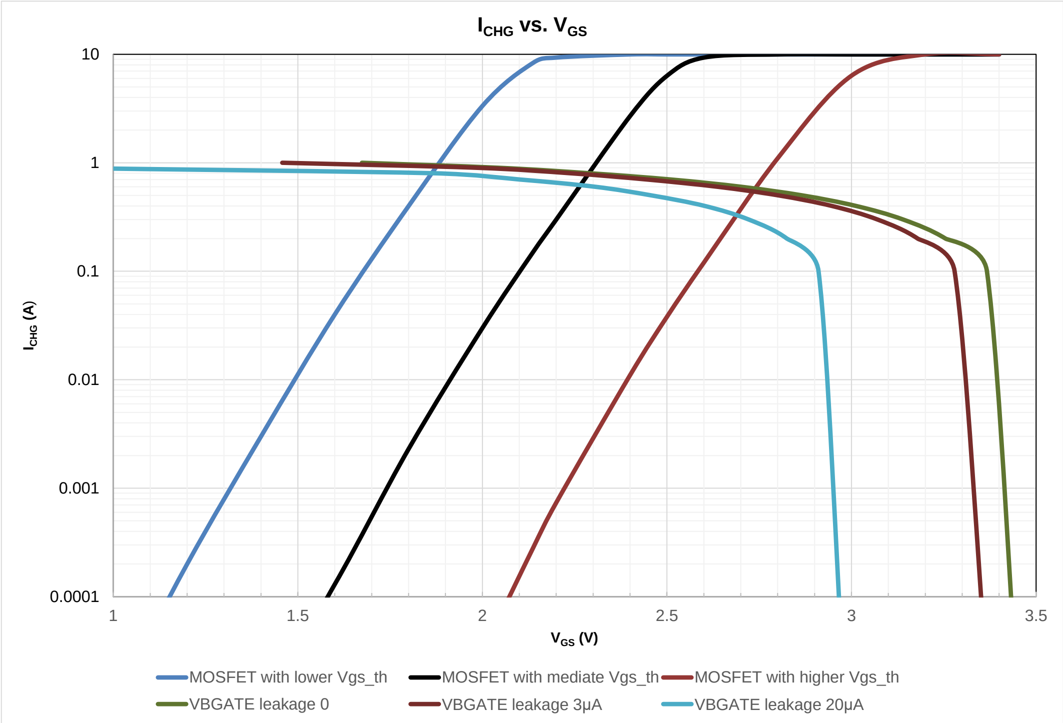

Figure 6: Estimated I_{CHG} When the MP2760's BATFET Works Linearly with Different MOFSET Types (I_{CHG_CONF} = 1A)

Based on Figure 6, it is possible to estimate the BGATE pin voltage (V_{BGATE}) and I_{CHG} values for different MOSFET types. Table 1 lists the estimated V_{GS} and I_{CHG} values to select a MOSFET with the optimal transfer characteristics.

Table 1: Estimated V_{GS} and I_{CHG} Values (1) (2) (3)

V_{BGATE} Leakage (μA)	V_{TH} Low Sample		V_{TH} Typical Sample		V_{TH} High Sample	
	V_{GS} (V)	I_{CHG} (A)	V_{GS} (V)	I_{CHG} (A)	V_{GS} (V)	I_{CHG} (A)
0	1.86	0.95	2.29	0.8	2.74	0.55
3	1.86	0.95	2.29	0.8	2.73	0.52
20	1.85	0.85	2.26	0.6	2.69	0.32

Notes:

1) These estimated values result from a 1A I_{CHG_CONF}. When I_{CHG_CONF} increases by 500mA, the actual I_{CHG} also increases by about 500mA.
2) This application note only discusses 1-cell applications.
3) If there is any external leakage current (I_{LKG}) pulled from BGATE, such as the BATFET's gate-to-source discharge resistance (R_{GS}), the results are different.

If the selected MOSFET is not sufficient to make I_{CHG} reach I_{CHG_REQ}, there are two methods to ensure I_{CHG} reaches I_{CHG_REG}, described below:

1. Increase the BATFET's drain-to-source voltage (V_{DS}) by increasing V_{TRACK} to shift its transfer characteristics curve left. This results in a higher I_{CHG}. Note that V_{TRACK} cannot be set too high because a higher V_{DS} causes additional losses on the BATFET.
2. Set I_{CHG_CONF} higher to meet the minimum I_{CHG} requirement.

Switching Charging Current

When V_{BATT} exceeds $V_{SYS\_REG\_MIN}$, the BATFET fully turns on, and its linear on loop does not impact I_{CHG}. Instead, I_{CHG} is limited by V_{TRACK}, as calculated with Equation (1):

$$I_{CHG} = \frac{V_{TRACK}}{R_{SNS} + R_{DS(ON)} + R_{PCB}} \quad (1)$$

Where R_{SNS} is the I_{CHG} sense resistance, $R_{DS(ON)}$ is the on resistance of the BATFET when it is fully on, and R_{PCB} is the parasitic resistance of the PCB.

Based on Equation (1), $R_{DS(ON)}$ must satisfy the constraints estimated with Equation (2):

$$R_{DS(ON)} < \frac{V_{TRACK}}{I_{CHG\_REQ}} - R_{SNS} - R_{PCB} \quad (2)$$

If the BATFET $R_{DS(ON)}$ is not low enough, V_{TRACK} can be set higher via the I^2C to ensure that I_{CHG_REQ} is met.

DESIGN EXAMPLE

This section demonstrates how to successfully select a proper BATFET in a 1-cell application to meet the I_{CHG} requirement for both linear charge mode and switching charge mode.

Consider the following design parameters as an example. I_{CHG_REQ} is set to 0.8A in linear charge mode and 4A in switching charge mode. Based on the following conditions, in linear charge mode, I_{CHG_CONF} is 1A, the minimum drain-to-source voltage (V_{DS_MIN}) is 100mV, and R_{GS} is 1MΩ. In switching charge mode, I_{CHG_CONF} is 4A, V_{TRACK} is 100mV, and R_{SNS} is 10mΩ.

Figure 7 shows the MP2760's typical application circuit.

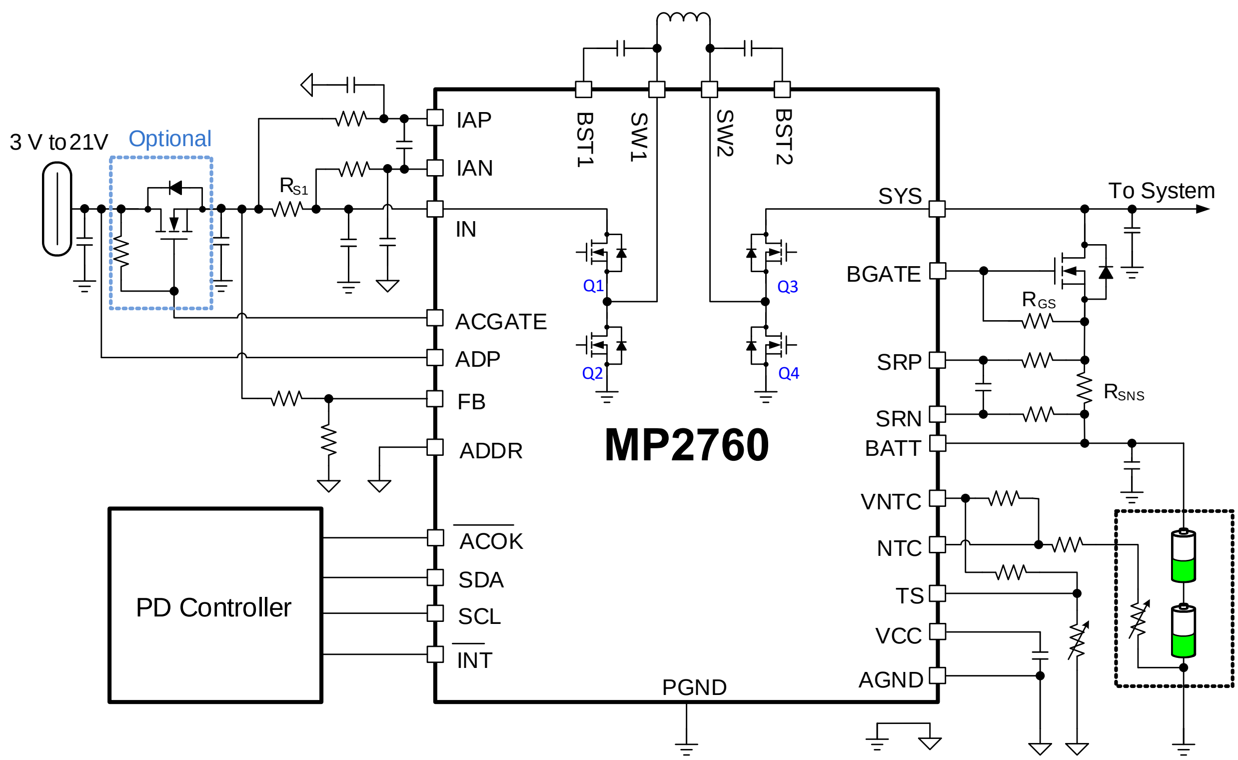

Figure 7: Typical Application Circuit of the MP2760

Linear Charge Mode

To meet the I_{CHG} requirement for linear charge mode, follow the steps below:

1. Based on Figure 6 on page 5, when I_{CHG_REQ} is set to 0.8A, V_{GS} is between 2V and 2.5V.
2. The leakage current (I_{LKG}) pulled from the external BGATE can be calculated with Equation (3):

$$I_{LKG} = \frac{V_{GS}}{R_{GS}} = \frac{2V\text{ to }2.5V}{1M\Omega} = 2\mu A\text{ to }2.5\mu A \quad (3)$$

3. Based on Table 1 on page 5, when I_{CHG_REQ} is set to 0.8A, V_{GS} is about 2.29V.
4. Select an N-channel MOSFET with a proper transfer characteristics curve at V_{DS} = 0.1V, where the drain-to-source current (I_{DS}) exceeds 0.8A when V_{GS} is 2.29V.

Switching Charge Mode

Ignoring the parasitic impedance on the PCB, the BATFET $R_{DS(ON)}$ can be calculated with Equation (4):

$$R_{DS(ON)} < \frac{100mV}{4A} - 10m\Omega = 15m\Omega \quad (4)$$

CONCLUSION

The NVDC architecture has been increasingly implemented in battery charger applications. The MP2760 is a battery charger that provides NVDC power path management using an external BATFET. The BATFET selection impacts NVDC performance, especially in 1-cell applications.

This application note proposed a method for selecting a proper BATFET with suitable characteristics, ensuring the I_{CHG} requirements are met in both linear charge mode and switching charge mode.

ADDITIONAL READING

For more information about MPS battery management products, contact an MPS FAE or visit the MPS website.

REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	9/22/2022	Initial Release	-