MICROCHIP

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Improving Battery Run Time with Microchip's 4 µA Quiescent Current MCP16251/2 Boost Regulator

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INTRODUCTION

The purpose of this document is to highlight the importance of batteries and the efficient power transfer at light loads in battery-powered applications. This application note will cover topics from battery considerations and how to get more run time, to presenting a boost converter solution that fulfills many industry requirements.

The solution provided by Microchip focuses around the MCP16251/2 devices, which are compact, high-efficiency, fixed-frequency, synchronous step-up DC-DC converters. Along with the other boost devices from Microchip, MCP1640B/C/D and MCP1623/4, they form the low-voltage boost converter family that provides an easy-to-use power supply solution for applications powered by either one-cell, two-cell or three-cell alkaline, NiCd, NiMH and one-cell Li-Ion or Li-Polymer batteries.

PRIMARY BATTERY CONSIDERATIONS

The Microchip family of boost converters enables designers to utilize a single 1.5V primary battery as a power source in applications that require higher operating voltages. Primary batteries are cost-effective and widely available throughout the world, can support a variety of drain rates and are available in a variety of sizes and chemistries. There are a number of factors designers should keep in mind when choosing a battery solution for their project.

Primary batteries typically have much greater shelf life stability than rechargeable chemistries. Most alkaline batteries have a shelf life of up to 10 years, while Energizer® Ultimate Lithium batteries have a shelf life of up to 20 years. The low quiescent current of the MCP16251/2 devices allows designers to create single-cell power solutions that can potentially last multiple years on a single battery.

Designers should avoid deeply discharging alkaline batteries because it will increase the possibility of leakage. Even though a battery boost circuit might be able to operate at input voltages as low as 0.35V, discharging batteries below 0.8V is not advised. Below 0.8V on the battery, parasitic drains should be kept as low as possible and preferably removed entirely.

Operating temperature may impact device performance differently depending on the battery chemistry that is used, and cold environments in particular may reduce run time. A typical alkaline cell will operate from -18°C to +55°C. If an application operates at temperatures below zero, an alkaline battery will provide greatly reduced performance or the device may not work at all. Designers should consider alternate options, such as Energizer Ultimate Lithium batteries, which have a wider operating temperature range of -40°C to +60°C.

THE MICROCHIP FAMILY OF BOOST REGULATORS

Microchip's boost converter family was designed to start from a low input voltage and operate down to 0.35V. The family of boost devices has a set of features that makes them an efficient solution for applications that require a minimum number of components and is supplied from one-cell, two-cell, three-cell alkaline, NiMH, NiCd or single-cell Li-Ion batteries.

TABLE 1: BOOST REGULATOR FEATURES

Feature	Description
Low quiescent current	This feature is very important for battery-powered applications as it increases the run time.
Pulse Width Modulation (PWM)/Pulse Frequency Modulation (PFM) mode operation	Along with the very low quiescent current, this ensures high efficiency for the entire load range.
Integrated synchronous switch	Typical boost converters cannot disconnect the output from the input because of the boost diode; replacing this with a PMOS switch increases the overall efficiency and allows the user to disconnect the output from the input.
Internal compensation	The error amplifier and the associated compensation network are integrated in the device, ensuring a stable response to either load or line variations and reducing the number of external components.
Low noise anti-ring control	The Microchip boost devices use a low noise anti-ring switch that dampens the oscillation typically observed at the switch node of a boost converter when operating in Discontinuous Inductor Current mode and therefore reduces the high frequency radiated noise.
Peak Current mode control	This ensures a fast response to any perturbations in the output current or the input voltage.
Soft start	The start-up procedure is divided into three steps: 1. The output is connected to the input through the PMOS switch. During this time, the output capacitor is charged with a current limited to approximately 100 mA. 2. After charging the output capacitor to the input voltage, the device starts switching. The device runs open-loop with a fixed duty cycle until the feedback voltage reaches approx 0.8V. During this time, the boost switch current is limited to 50% of its nominal value to avoid high peak currents at the battery, or output overshoots during start-up. Once the V_{FB} voltage reaches 0.8V, normal closed-loop PWM operation is initiated. 3. Once the device has entered closed-loop operation, an internal capacitor is charged with a very weak current source, which in turn serves as the reference voltage for the converter. This provides a robust start-up, without any overshoot on the output voltage.

A small overview of the characteristics for the Microchip family of boost devices is provided in Table 2.

TABLE 2: THE MICROCHIP FAMILY OF BOOST DEVICES

Parameter	MCP1623/4	MCP16251/2	MCP1640/B/C/D
Mode	PWM only or PWM/PFM	PWM/PFM	PWM only or PWM/PFM
Start-Up Voltage	0.65V	0.82V	0.65V
Input Voltage	0.35V – 5.5V	0.35V – 5.5V	0.35V – 5.5V
Peak Switch Current	425 mA	650 mA	850 mA
Quiescent Current	19 µA	4 µA	19 µA
V_{OUT} Accuracy	±7.4%	±3%	±3%
Switching Frequency	370 – 630 kHz	425 – 575 kHz	425 – 575 kHz
Shutdown	True Load Disconnect	Input to Output Bypass or True Load Disconnect	Input to Output Bypass or True Load Disconnect
Packages	6-lead SOT-23	6-lead SOT-23	6-lead SOT-23
	8-lead 2x3 DFN	8-lead 2x3 TDFN	8-lead 2x3 DFN
Key Attributes	Lowest Cost	Lowest Quiescent Current	Highest Performance

LONGER BATTERY RUN TIME AND HIGH EFFICIENCY OVER THE ENTIRE LOAD RANGE

One of the advantages of the MCP16251/2 compared to the other boost family members is the low quiescent current (4 µA compared to 19 µA). Along with the PFM mode, the higher PWM-to-PFM threshold and the high-value feedback resistors, this has resulted in a converter that greatly increases the run time of battery-powered applications at low load. In PFM mode, the device switches and increases the output voltage up to an upper threshold limit, where a comparator is triggered. This induces a sleep mode behavior in which the device draws only 4 µA from the output of the converter. Once the device has stopped switching, the output voltage starts to decrease until it reaches the lower threshold limit, which causes the converter to start switching and bring the output voltage back up.

When choosing the feedback resistor, a compromise should be made between no load input current and the noise that the application can tolerate. Higher value resistors will decrease the no load input current (Figure 1) but will increase the noise that is introduced in the system and may cause instability issues.

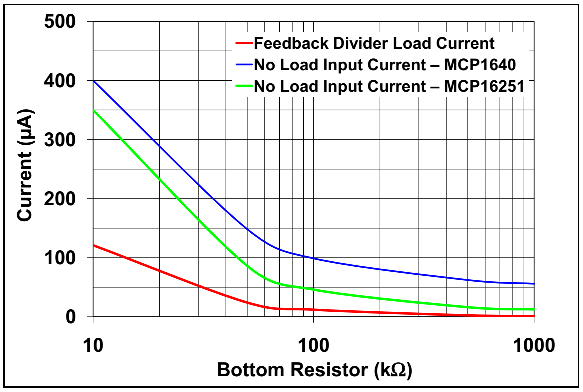

FIGURE 1: No Load Input Current (V_{IN} = 1.5V, V_{OUT} = 3.3V).

Compared to the MCP1640B/C/D and the MCP1623/4, the MCP16251 has a smaller no load input current (Figure 2), which in turn provides a higher efficiency across the entire load range (Figure 3).

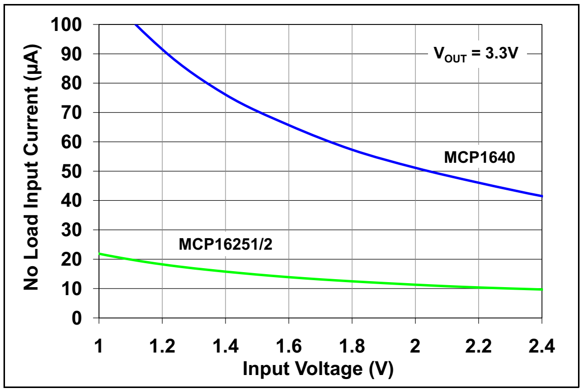

FIGURE 2: No Load Input Current.

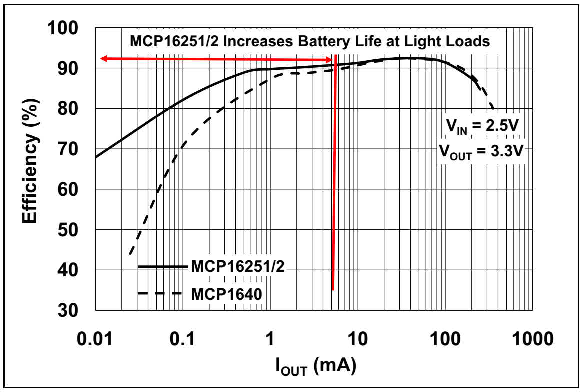

FIGURE 3: *Efficiency vs. Output Current.*

Although the PFM mode has the advantage of reduced current consumption, care must be taken when the load is sensitive to small frequency components. The discontinuous switching operation causes the output voltage to have a triangular waveform with a variable frequency based on the output load (Figure 4). For the scope shot in Figure 4, we have a 170 mV peak-to-peak ripple at a frequency of 2.5 kHz. For applications that require a clean voltage which cannot tolerate a small peak-to-peak low-frequency component, we recommend using the MCP1640B/D or the MCP1623, which run in continuous PWM mode.

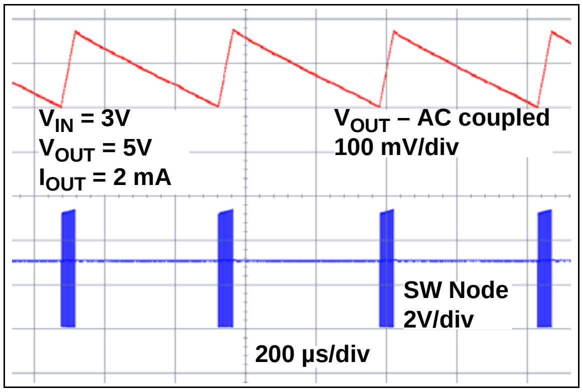

FIGURE 4: *MCP16251 Output Voltage.*

MCP16251 Run Time Results

In low-power, long run time applications, the efficiency of the boost converter at very low loads can affect the run time of a circuit by a significant amount. Energizer Application Support has provided the following service estimate to illustrate how a lower quiescent current can increase your run time in low-drain applications. These estimates are for a device that operates at 3.3V and with a constant 100 µA background drain. Once every 10 minutes, the circuit wakes up and pulls 50 mA for 0.2 seconds. Service estimates are given in days.

TABLE 3: RUN TIME RESULTS

Battery	MCP16251	MCP1640
Energizer Max® AAA	130 days	115 days
Energizer Max® AA	280 days	247 days
Energizer® Ultimate Lithium AA	408 days	359 days
Energizer® Ultimate Lithium AAA	150 days	132 days

Note 1: Assumes the batteries are drained to 0.9V

2: V_{OUT} = 3.3V, I_{OUT} = 100 µA/50 mA every 10 minutes for 0.2 seconds

MCP16251 AND MCP1640B EVALUATION BOARD

In order to develop a complete solution, the boost converters in the Microchip family share the same pinout and require the same number of components.

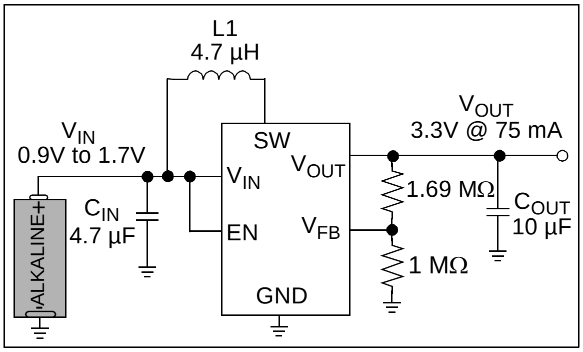

FIGURE 5: *Typical Application.*

The MCP16251 and MCP1640B Synchronous Boost Converters Evaluation Board (ADM00458) is used to evaluate and demonstrate Microchip Technology's MCP16251 and MCP1640B products.

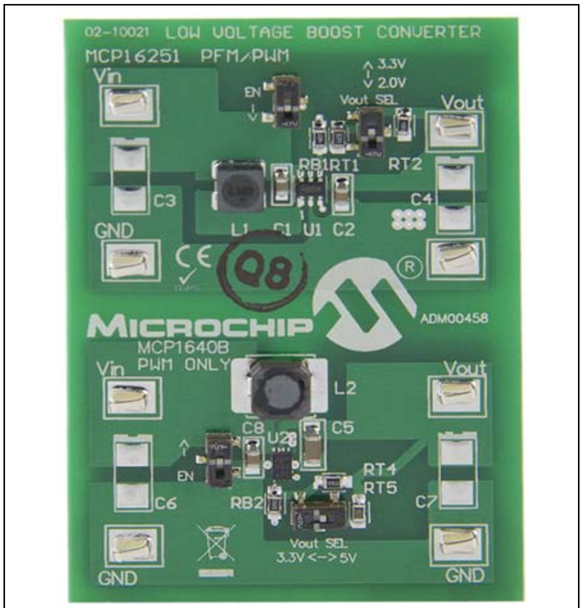

FIGURE 6: *MCP16251 and MCP1640B Evaluation Board.*

This board demonstrates the MCP16251/MCP1640B in two boost converter applications with multiple output voltages. It can be used to evaluate both package options, 6-lead SOT-23 and 8-lead 2x3(T)DFN. The MCP16251 and MCP1640B Synchronous Boost Converter Evaluation Board was developed to help engineers reduce the product design cycle time. Three common output voltages can be selected: 2.0V, 3.3V and 5.0V. The output voltage can be changed with a mini-dip switch that changes the external resistor divider.

A switch connected to the EN pin is used to enable and disable the converters. When enabled, the MCP16251/MCP1640B regulate the output voltage; when disabled, the MCP16251/MCP1640B disconnect the path from input to output for "true disconnect".

CONCLUSION

The MCP16251/2 targets battery-powered applications that require low standby quiescent current and high efficiency. Due to the features integrated in the device, the run time of battery-powered applications with long idle periods is extended, while still providing an efficient power transfer when higher current is needed at the output.

NOTES:

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