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More-Efficient Boost Converter Extends Battery Life For Wearable Medical Patches

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The Internet of Things (IoT) is placing the patient at the center of the healthcare system, with real-time monitoring of vital signs that enables better fitness, disease prevention, and just-in-time medical intervention. Wearable medical devices, in the form of patches, incorporate sensors to monitor heart rate, respiration, temperature, steps taken, sleep cycle, stress levels, and whether the user has fallen or otherwise become incapacitated. These devices transmit vital signs over a Bluetooth Low Energy wireless link to a base station and from there to the cloud, where patients and doctors can access real-time data.

With their ability to continuously record and transmit a patient's state of health, wearable medical devices are transforming the healthcare industry. But these devices do pose some difficulties in power management.

This article reviews the challenge of powering a wearable medical patch placed on a patient's chest (Fig. 1) while meeting the requirement to operate for five days on a single disposable zinc-air battery. When regulated by a *typical* boost converter, the battery voltage fails to meet the device operating time requirement. However, when powered by a high-efficiency, low-quiescent boost converter, the same device meets and exceeds the five-day runtime demand.

In this article we describe the power consumption profile of an example wearable medical patch, and explain how this profile is used to calculate battery run time given the specified battery capacity. We then calculate the runtime provided in this application by the MAX17224 nanoPower synchronous boost converter and contrast this runtime with that of a competing boost converter IC.

Fig. 1. Patient wearing a medical patch.

A Typical Wearable Medical Patch System

Fig. 2 shows the block diagram for a typical medical patch. A disposable zinc-air battery supplies a capacity of up to 160 mAh to power the on-board controller, sensors, and radio through a dc-dc stepup regulator.

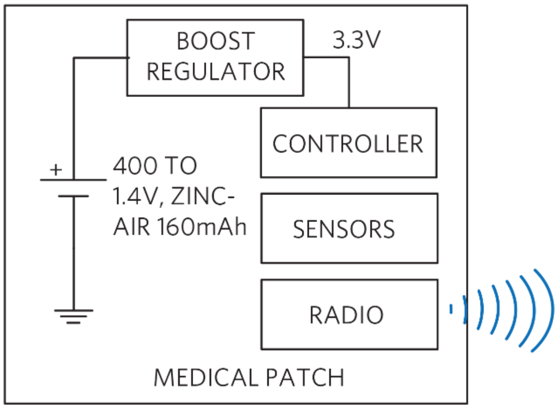

Fig. 2. Block diagram of a typical medical wearable patch.

In one example, the various sensors collect data for 4 seconds, which are then transmitted by the radio to a centralized receiver with 100-ms bursts. In detection mode, the boost converter is loaded with a current of 50 µA, while in transmission mode, it provides 48 mA to support the radio current pulse. The boost converter load profile is shown below in Fig. 3.

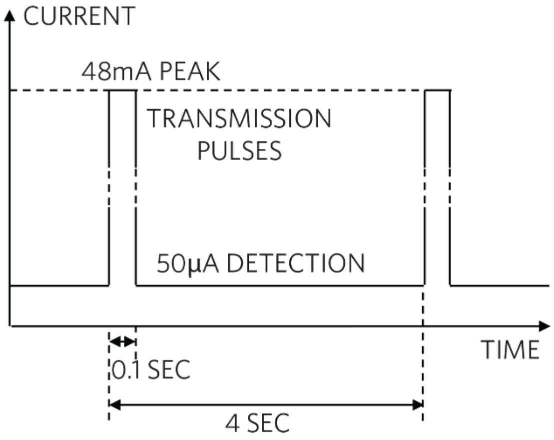

Fig. 3. Current profile of a wearable medical patch.

In one typical medical wearable patch application, the system must last for five days using only a single disposable zinc-air battery. A typical boost voltage regulator has a quiescent current of 10 µA, 85% peak efficiency, and 81% efficiency at low current. Assuming 1.4-V input and 3.3-V output voltage, we can calculate the average current drawn from the battery as follows:

$$I_{AVE} = \left(\frac{3.3\ V}{1.4\ V} * \frac{48\ mA}{0.85} + 10\ \mu A\right) * \frac{100\ ms}{4\ s} + \left(\frac{3.3\ V}{1.4\ V} * \frac{50\mu A}{0.81} + 10\mu A\right) * \frac{3.9\ s}{4\ s} = 1372\ \mu A$$

This average current of 1372 µA will cause the battery to fall short of five days of operation (160 mAh/1.372 mA = 117 hours).

The Challenges

Achieving high efficiency and low quiescent current with a small-size PCB is challenging for any voltage regulator. Increasing the frequency of operation of the voltage regulator will reduce the size of passives but increase losses, thereby reducing its efficiency. The regulator's ability to operate over an input voltage range that extends down to fractions of a volt is critical, as the battery voltage falls continuously during operation.

The proliferation of wearable applications creates a need for multiple customized versions of voltage regulators, especially with respect to input/output voltage and current specifications. Accordingly, a medical wearable patch manufacturer may be forced to maintain a sizeable and costly inventory of different regulators and the passives required to support them. However, new devices with wide operating ranges and programmable output voltages can reduce or eliminate the need for stocking multiple regulator models.

A State-Of-The-Art Solution

As an example, the MAX17224 nanoPower synchronous boost converter offers very high efficiency, a 400-mV to 5.5-V input range, a 1-A peak inductor current limit, and an output voltage that is selectable using a single standard 1% resistor. A novel True Shutdown mode yields leakage currents in the nanoampere range, making this a truly nanopower device.

Referring to Fig. 4, the input quiescent current (I_{QINT}) for the IC is 0.5 nA (enable open after startup) and the output quiescent current (I_{QOUT}) is 300 nA.

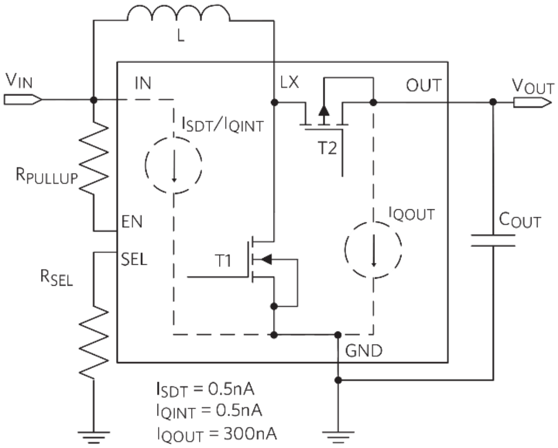

Fig. 4. Shutdown and quiescent currents in the MAX17224 boost converter.

To calculate the total input quiescent current, the additional input current needed to feed the output current (I_{QOUT_IN}) must be added to I_{QINT}. Since the output power is related to the input power by the efficiency ($P_{OUT} = P_{IN} \times \eta$), it follows that:

$$I_{QOUT\_IN} = I_{QOUT} \times (V_{OUT}/V_{IN})/\eta$$

If $V_{IN} = 1.4$ V, $V_{OUT} = 3.3$ V, and efficiency $\eta = 88\%$ at low current, we have:

$$I_{QOUT\_IN} = 300 \text{ nA} \times (3.3/1.4)/0.88 = 803.5 \text{ nA}$$

Adding the 803.5 nA to the input current of 0.5 nA yields a grand total input quiescent current of 804 nA (I_{QINGT}). This quiescent current is 12 times lower than the 10 µA of a typical stepup voltage regulator, as discussed in the previous case.

Efficiency Advantage

The boost converter IC features low-R_{DSON}, on-board powertrain MOSFETs that yield excellent efficiency even when operating at frequencies high enough to warrant a small overall PCB size (Fig. 5).

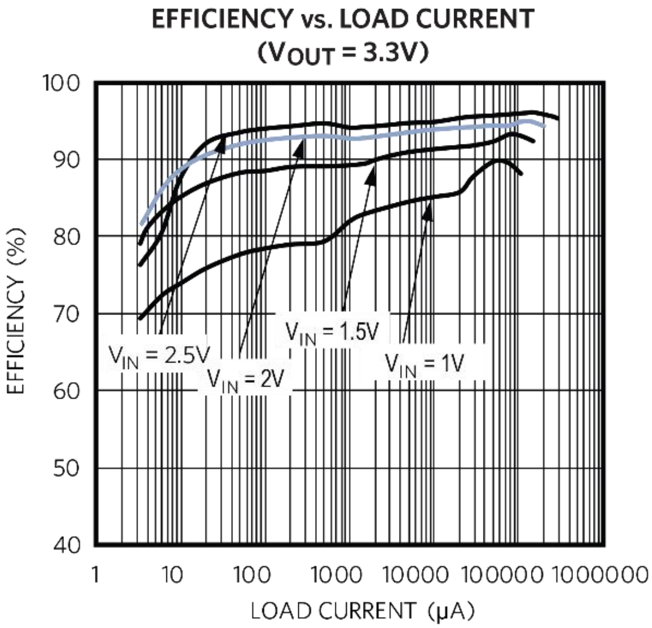

Fig. 5. With its low-on-resistance, on-chip power switches, the MAX17224 boost converter achieves efficiencies in the 80s and 90s (percentages) while operating even at voltages as low as 1 V.

With the boost converter's 92.5% efficiency at peak current and 0.8-µA quiescent current, the wearable medical patch can meet and exceed the required 5 days of operation (see the table).

Table. Battery life comparison between the MAX17224 and a competing boost converter. V_{IN} =1. 4 V, V_{OUT} = 3.3 V and battery capacity = 160 mAh.

	Boost efficiency, η (%)	Boost quiescent current (µA)	Boost average load (mA)	Battery duration (hours)	Battery duration (days)
MAX17224	92.5	0.8	1.26	127	>5
Competitor	85	10	1.37	117	<5

Enable Transient Protection Mode

The IC includes an option for an enable transient protection (ETP) mode. When activated by the presence of a pullup resistor, extra on-chip circuitry powered by the output capacitor assures that EN stays high during short transient disturbances at the input. In this case, the quiescent current calculated above increases by a few tens of nanoamps.

BoM Advantage And Smart V_{OUT} Selection

The MAX17224 eliminates the traditional resistor-divider that is used to set the output voltage value in favor of a single-output selection resistor (R_{SEL}), as shown in Fig. 4. The chip uses a proprietary scheme to read the R_{SEL} value that consumes up to 200 µA at startup only.

A single standard 1% R_{SEL} resistor sets one of the 33 different output voltages, separated by 100-mV increments between 1.8 V and 5 V. The result is a small reduction in BOM (one less resistor), simplified inventory (a single regulator for multiple applications), and lower quiescent current.

Conclusion

The IoT, combined with low-power wireless data transmission protocols, is enabling the continuous and real-time monitoring of patient life signs by means of wearable devices. We reviewed the challenges of powering a wearable medical patch with a small disposable 160-mAh zinc-air battery. While a typical boost converter that regulates the battery voltage falls short of the five-day operating requirement for wearables, a boost converter with high-efficiency and low-quiescent can meet this requirement.

The ability to boost a voltage as low as 400 mV enables the MAX1722x family to support a broad spectrum of wearable applications beyond battery operated devices. Alternatives to battery power sources like Methanol fuel cells, with their low voltage output (0.5 V or less) are finding applications in small wearables like hearing aids, thanks to boost converters with low-input-voltage operation.

Reference

MAX17220–MAX17225 400mV to 5.5V Input, nanoPower Synchronous Boost Converter with True Shutdown

About The Author

Eddie Lee is the director of Business Management in the Core Power Management group at Maxim Integrated. Before joining Maxim, he served as senior product marketing manager at Fairchild and ON Semiconductor. Eddie has more than 20 years of industry experience including different engineering positions at Intersil, Advanced Analogic Tech, and Finisar. He has a bachelor of science in electrical engineering from Ryerson University in Canada and a master's degree in engineering management from Santa Clara University.

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For more information on designing boost converters, see How2Power's Design Guide, locate the "Topology" category and select "Boost".