Advanced Low Power Reference Design

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Smart Meter Power Management with Energy Buffering

Reference Guide & Test Report

CIRCUIT DESCRIPTION

Smart Wireless Sensors are typically powered by Long-Life Batteries like the LiSOCl2 chemistry - which are limited in current. However, these sensors require high current pulses for transmitting the gathered data wirelessly. This Reference Designs provides a solution for powering the MCU by down conversion of the battery voltage. As well, it provides a high current rail for the power pulses of the radio frequency power amplifier (RF-PA). The pulses are decoupled from the battery by Energy Buffering.

BENEFITS

- Buck Rail for lower MCU voltage
- Boost Rail for the RF-PA
- Load Decoupling with Energy Buffering
- Ultra Low Iq
- Longer Battery runtime by VDD Down Conversion

APPLICATIONS

- IoT Wireless Sensor Nodes
- Smart Flow Meter
- Heat Cost Allocator

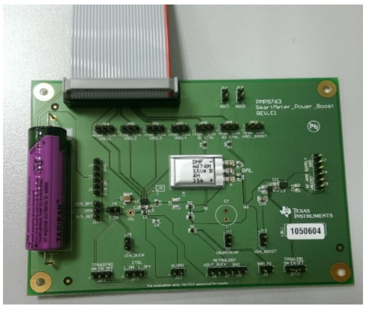
LINKS

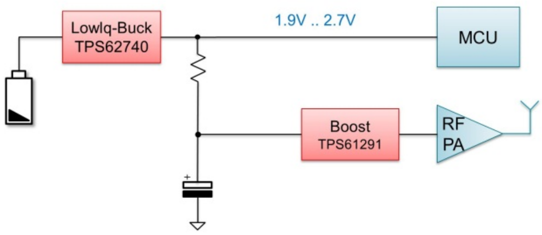
[TPS62740 Product Page]

[TPS61291 Product Page]

[Energy Buffering Application Note]

[PMP9753 Energy Buffering Reference Design]





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1 Introduction

Smart Wireless Sensor Nodes are one of the main enabler in the IoT. These Sensor nodes provide measurement data from anywhere – every time. This means that these nodes are being placed somewhere in the field. They need to gather and process data to be sent to a centralized server.
Therefore they do not only have to be smart (pre-calculation of data), they also have to be wireless (enable the measurement of data without cable infrastructure) and long-life (as every maintenance cycle is cost).
From a power perspective, this means that the overall average power consumption needs to be very low, which is achieved by the usage of Low Power MCU's. It means, however, an occasional high current is needed to transmit the data to the base station. The required voltage and current depends on the radio standard and distance to the receiver.

To achieve long system runtime, Smart Wireless Sensor Nodes are usually powered from Lithium Primary Batteries. These battery types feature a very long lifetime for itself and a high energy density in combination with very low self-discharge. A widely used example is $LiSOCl_2$ chemistry types which feature a very high energy density. This type of battery brings, however, a high internal impedance and the property of losing available capacity due to higher currents.

The smart wireless sensor node can be split in two Blocks with different power requirements (Figure 1):

- The MCU which needs to be supplied all time with a very low average current consumption in the range of hundreds of Micro Amperes.
- The radio frequency power amplifier requires a higher voltage and currents like 200mA for example.

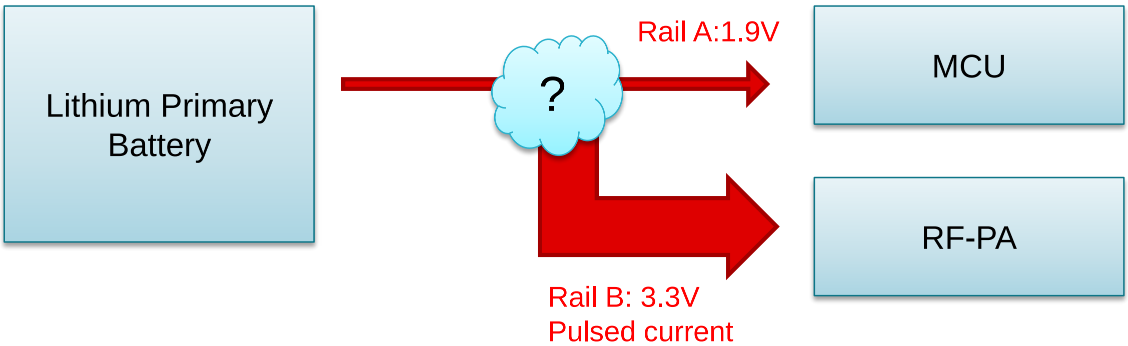

Figure 1: Smart Wireless Sensor Node - Power Block-Diagram

2 Reference Design Description

This Reference Design shows a whole power architecture to provide the optimized rails for a smart wireless sensor. It contains the Energy Buffering Concept based on the TPS62740, a 360nA quiescent current buck converter, in combination with an EDLC (electric double layer capacitor) or a so called Supercapacitor.

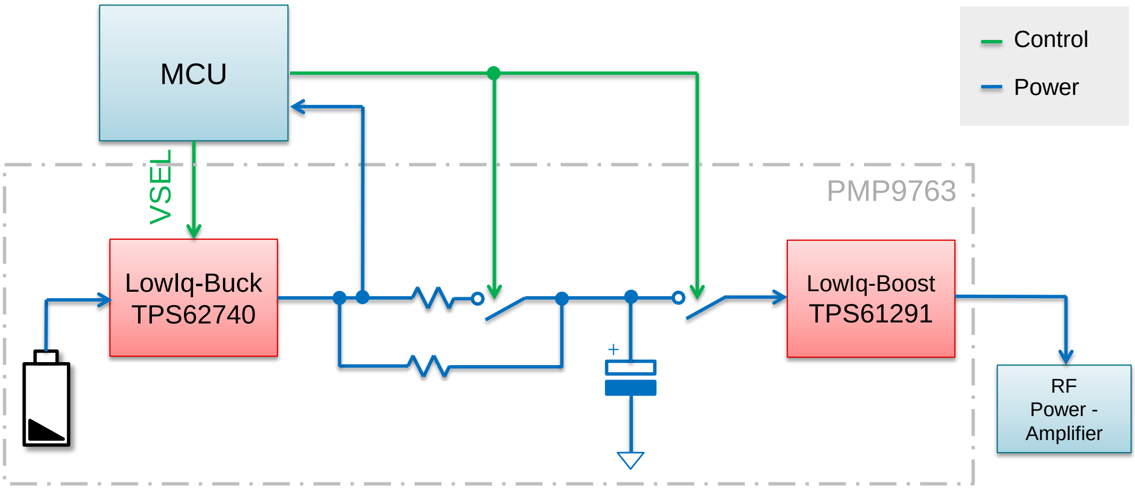

Figure 2: Reference Design Block Diagram

The circuit uses a resistor at the output of the TPS62740 to limit the current into the Storage Capacitor as well as the battery current drawn from the primary cell. The resistor is selected in a way to keep the load, and thereby the battery current, below a level that the primary battery can support. The TPS62740 features digital inputs to adjust the output voltage by four VSEL Pins. During the charging of the EDLC, the output voltage can be stepped up in 100mV steps. This helps to minimize the power losses caused by the resistor.

The step-up converter TPS61291 provides a regulated 3.3V supply with higher current capability out of the storage capacitor without stressing the battery at all. It draws its power from the energy stored in the Storage Capacitor.

In an application like a wireless sensor, the MCU is supplied from the output of the TPS62740 step-down converter. Therefore the voltage must stay above the MCU minimum supply voltage (e.g. 1.9V). The maximum voltage of a single layer super-cap is typically 2.7V which leads to a usable capacitor voltage range of 1.9V to 2.7V. Figure 3 shows the basic flow of a recharge cycle.

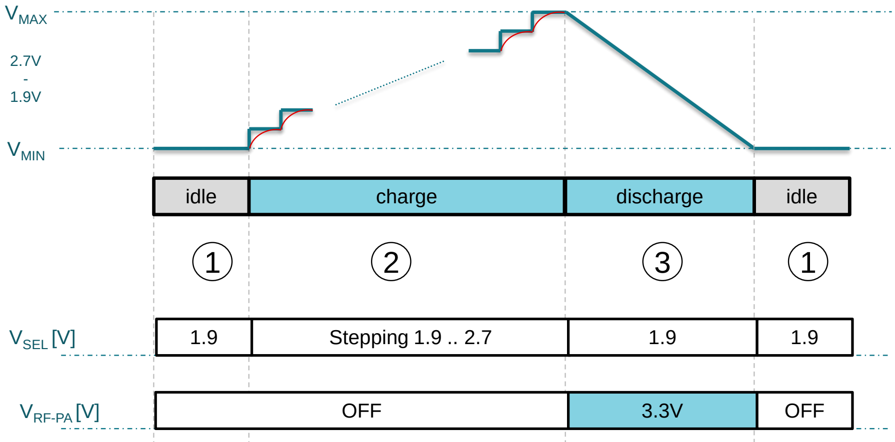

Figure 3: Energy Buffering Sequence

Most of the time the voltage is kept at 1.9V to minimize the losses of the micro-controller and other leakage currents in the application (Phase 1). Before a wireless data transmission, the capacitor is charged up to 2.7V (Phase 2). During transmission, the stored energy in the capacitor can be extracted down to 1.9V (Phase 3). During Phase 3, the boost converter TPS61291 is enabled to step-up the voltage of the storage capacitor to 3.3V for the RF-PA. During all other Phases, this converter is disabled.

For a more detailed description including component and parameter calculations, please see Application Report TIDU628.

3 Schematics

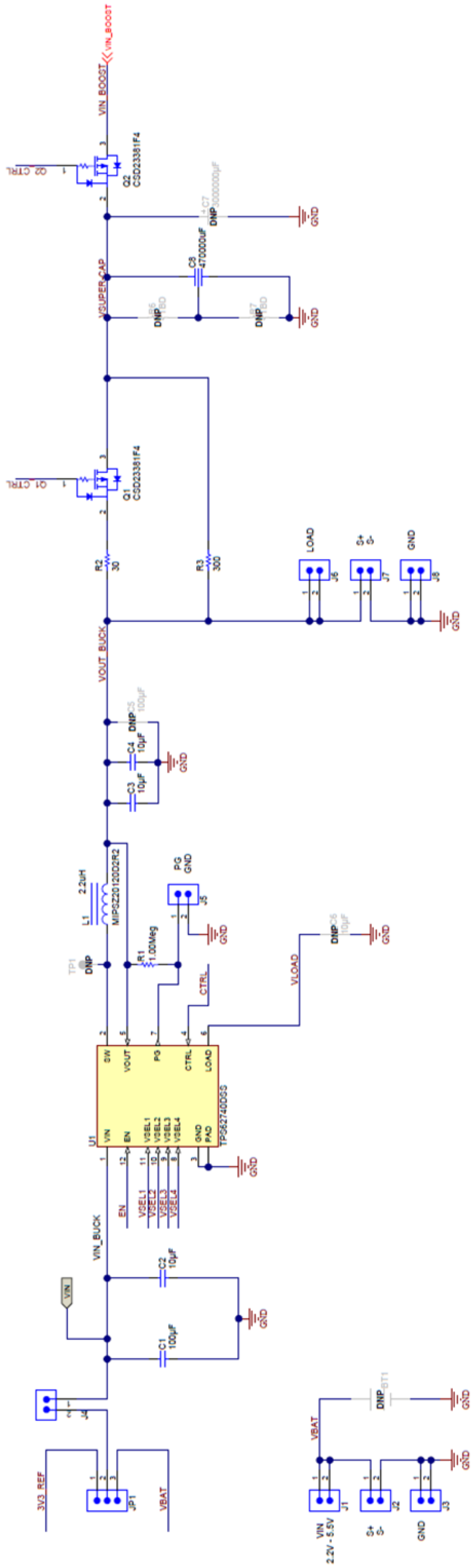

Figure 4: Low-Iq Buck including Energy Buffering Circuit Excerpt

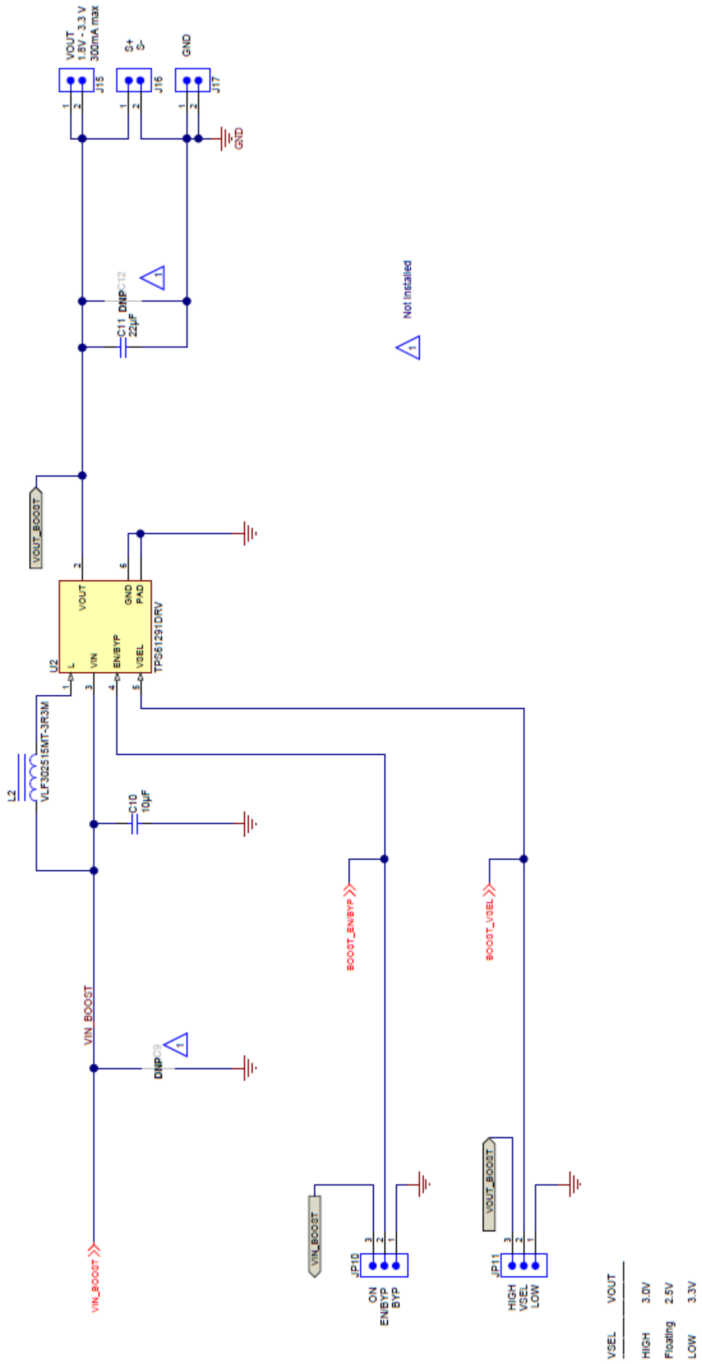

Figure 5: Low-Iq Boost Circuit

4 Measurement Results

This section provides the measurement results of typical scenarios in a smart wireless sensor.
For further measurements on the Energy Buffering technique, please refer to PMP9753 Energy Buffering Reference Design

4.1 Power System Start-Up

Figure 6 shows the start-up waveforms when the system is turned on. The green trace shows the required battery current for the whole power up sequence. This includes providing the MCU supply and the charging of the storage capacitor. The battery current reaches a maximum value of less than 4mA at the beginning.
The magenta trace reflects the battery voltage of 3.6V without any drop due to the limited battery current.
The Buck Converter output voltage is reflected by the yellow trace. This is the MCU supply voltage and is present immediately, which means the MCU can be operated without any significant delay. The voltage of the storage capacitor is shown by the blue trace. The plot shows that the EDLC is charged to the operating voltage of 1.9V. During start-up, the boost converter is shut down and not reflected in this plot.

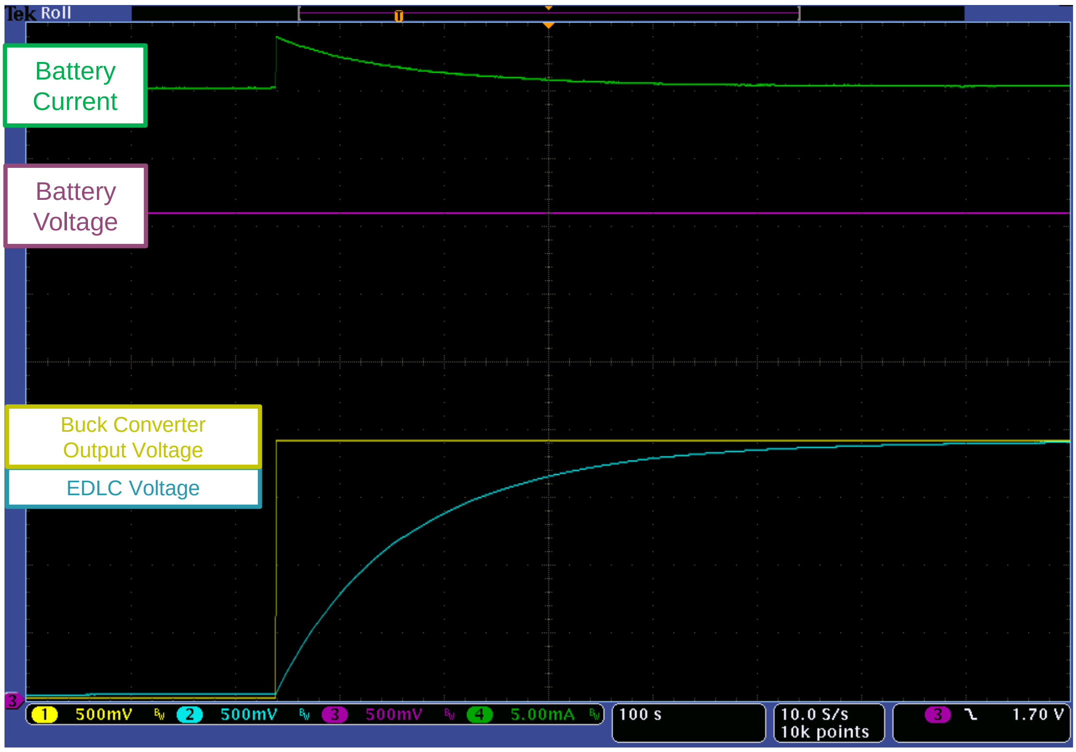

Figure 6: System start-up waveforms

After this sequence, the power system is ready. Startup is just required at the very first initialization when the battery is first inserted.

4.2 Protocol Transmission

For the transmission of data, the required energy is buffered in advance. Figure 7 shows the waveforms of one whole cycle including storing energy in the EDLC and extracting it for a transmission pulse afterwards.
The battery current is shown in the upper part in green. The maximum current drawn out of the battery is less 4mA.
The yellow curve represents the output voltage of the TPS62740 step-down converter. During the charging phase, this voltage is incremented in 100mV steps for efficient charging of the storage capacitor, whose voltage is shown in blue.
After the EDLC is charged to the maximum voltage of 2.7V, the boost converter is enabled and provides a regulated 3.3V for the active time of the power amplifier (magenta trace).

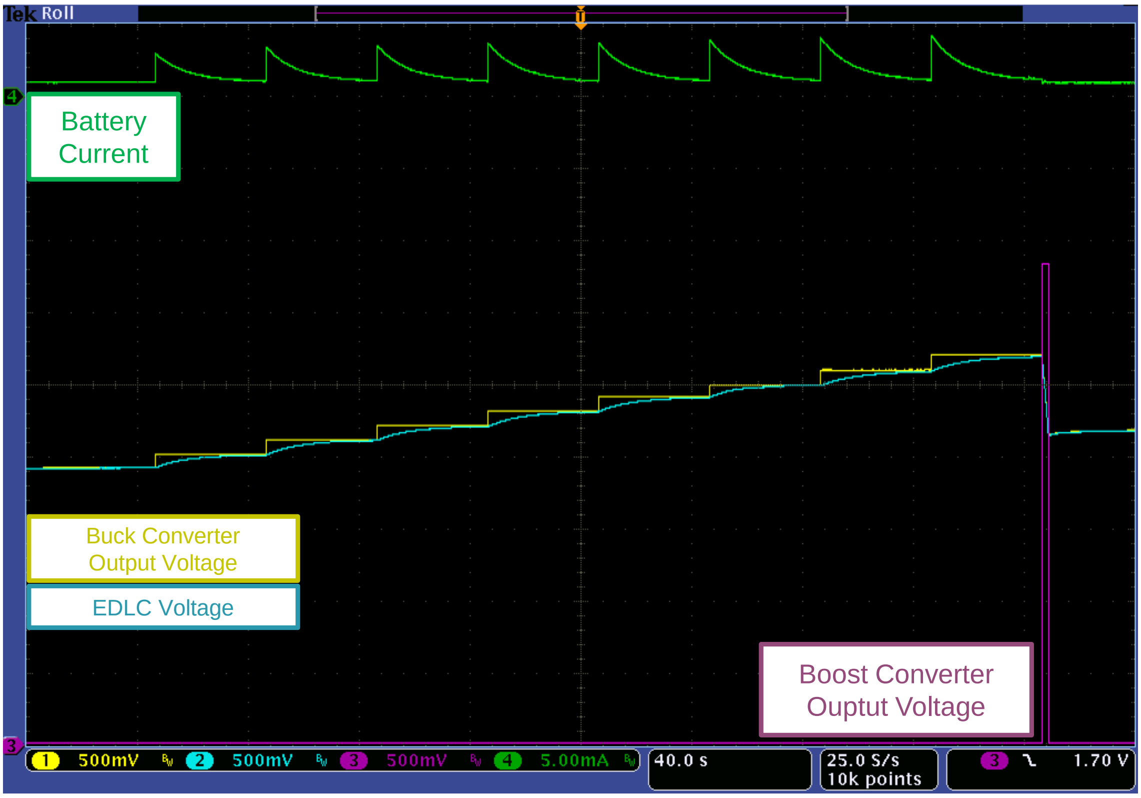

Figure 7: RF-PA Pulse Cycle Overview

5 Summary

Typical Wireless Smart Meters are powered by sources capable of low currents only. They require a low voltage/low current MCU supply rail which is always active. They require as well a high voltage/high current rail for the radio, which only needs to be active during the transmission of data.
This design provides two supply rails with the requirements stated above. One rail is optimized for being always active and low supply currents. The other rail provides higher pulse currents with a voltage of 3.3V.
The design features the load decoupling technique “Energy Buffering” and does not require more than 4mA from the battery. This value, however, is programmable by the user.
For further Information’s on the Energy Buffering technique, please refer to PMP9753 Energy Buffering Reference Design

The design features following advantages:

- Low Iq supply rail for reduced MCU current by the Low-I_Q Buck Converter TPS62740
- 3.3V supply rail for wM-Bus RF-PA’s by the Low-I_Q Boost Converter TPS61291
- Optimized for EDLC Storage Capacitors which are widely available with highest capacity
- Pulsed currents are decoupled from the battery to extend the available capacity from Lithium Primary Batteries
- System runtime is extended by lower voltage supply of the MCU