Application note – XC9145 series

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Introduction

Overview

In energy-efficient designs using supercapacitors, selecting a boost converter with ultra-low current consumption is critical for extending the supercapacitor operational time in low-power applications (< ~5W). This application note covers the features, benefits, and typical use cases of the XC9145 boost converter series, and how it can be used with the Ligna S-Power 2S or 2R supercapacitors.

The XC9145 series offers low power consumption and is an affordable solution for energy-efficient applications.

Features

- Ultra-low quiescent current of 400nA
- Starting at 0.675 USD each for quantities of 1k+
- Comes in fixed output voltage 3.0V ~ 5.5V (0.1V increments)
- Input Voltage range: 0.65V - 5.5V
- Inductor current limit 1.3A
- Comes in packages
  - SOT-25 (2.8x2.9x1.3mm)
  - USP-6C (1.8x2.0x0.6mm)
  - WLP-6-05 (1.08x1.28x0.4mm)

Typical Applications

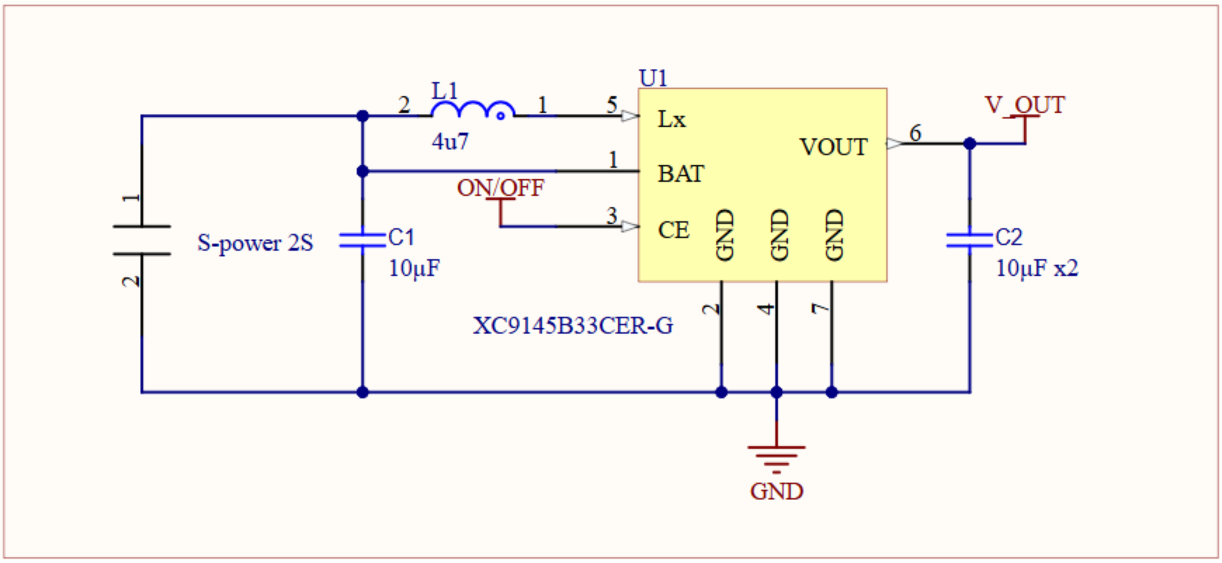

Figure 1, Typical application circuit

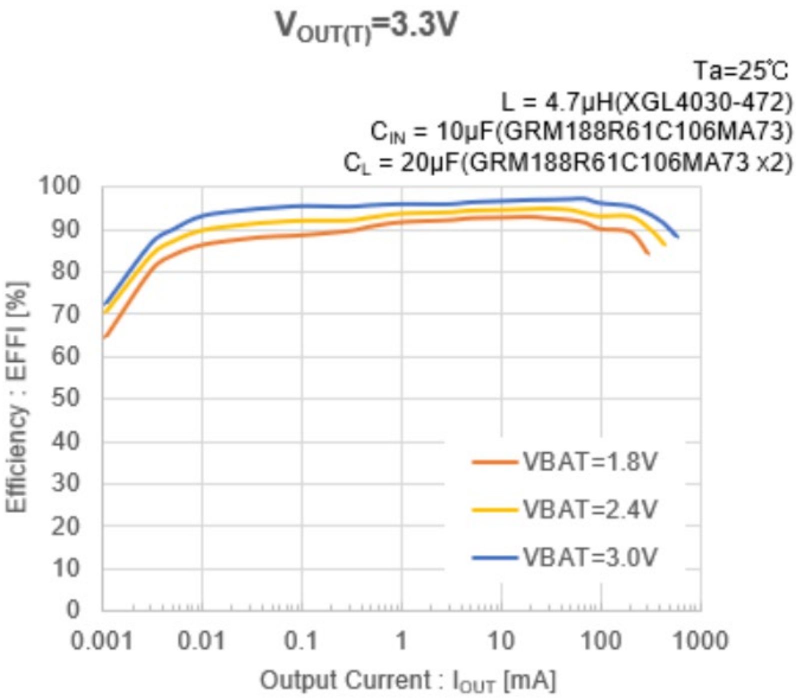

Figure 2, Typical characteristics

Energy calculation for a Ligna Supercapacitor using boost converter

This section outlines the process for calculating the extracted energy from a Ligna S-Power 2S single-cell configuration using an XC9145 boost converter. The parameters C, V_{init}, and ESR are derived from the Ligna S-Power 2S datasheet, while V_{bat} corresponds to the lowest input voltage of the XC9145 series. The load current I_{load} is estimated based on typical LoRa device operations at moderate transmission power levels (+14 dBm to +17 dBm), which typically require a transmission pulse current of approximately 60 mA.

Initial Parameters:

Ligna S-Power 2S Capacitance:

$C = 1.2F$

XC9145 Lowest Input Voltage:

$V_{bat} = 0.65V$

Ligna S-Power 2S Maximum Rated Voltage:

$V_{init} = 2.7V$

Load Current for Typical LoRa Device:

$I_{load} = 60\ mA$

Ligna S-Power 2S Equivalent Series Resistance (ESR):

$ESR = 0.5\ \Omega$

Calculating the current drawn from the supercapacitor:

Power at the output of XC9145:

$$P_{out} = 0.6mA * 3.3V = 0.198W$$

From Fig 2. Efficiency (η) at VBAT = 0.65 ≈ 85%, therefore input power to the XC9145 = Pout/0.85.

$$P_{in} = \frac{P_{out}}{\eta} = \frac{0.198W}{0.85} = 0.233\text{W}$$

The current drawn from the supercapacitor can therefore be calculated as = Pin/VBAT.

$$I_{scap} = \frac{P_{in}}{V_{bat}} = \frac{0.233W}{0.65V} = 358\ mA$$

Calculating the internal voltage of a supercapacitor, accounting for resistive losses:

The internal voltage V_{scap} cannot be directly measured at the terminals because the measured terminal voltage V_{bat} includes the voltage drop across the Equivalent Series Resistance (ESR) caused by current flow. To find V_{scap}, add the voltage drop ($ESR * I_{scap}$) to V_{bat}:

$$V_{scap} = V_{bat} + ESR * I_{scap} = 0.65V + 0.5\Omega * 358\text{mA} = 0.829\text{V}$$

The energy extracted from the S-Power 2S supercapacitor can be calculated as:

$$E_{extracted} = \frac{1}{2} * C * \left({V_{init}}^2 - {V_{scap}}^2\right) = 0.5 * 1.2F * (2.7^2V - 0.829^2V) = 3.962\text{J}$$

Supercapacitor Hold-Up Time Modelling

To accurately calculate the supercapacitor hold-up time for a given application, the system can be modeled with a small-time step, dt, where dt≪ supercapacitor hold-up time. The following equations can be used:

$$V_{scap}(t+dt) = V_{scap}(t) - I_{scap}(t)dt/C$$

$$I_{scap}(t+dt) = \frac{P_{out}/\eta}{V_{in}(t)}$$

$$V_{in}(t+dt) = V_{scap}(t+dt) - I_{scap}(t+dt) * ESR$$

Where:

V_{scap} is the internal voltage of the supercapacitor excluding the voltage drop due to I_{scap} x ESR.

I_{scap} is the current drawn from the supercapacitor into the input of the boost converter

C is the supercapacitor's capacitance.

P_{out} is the output power of the system.

η is the efficiency of the system.

V_{in} is the input voltage to the boost converter, which includes the voltage drop due to I_{scap} x ESR.

When V_{in} = V_{min} = 0.65V for the XC9145 stop.

For efficiency values:

η =95% when V_{in} = 2.7V

η =85% when V_{in} = 0.65V

In this case, we use an average efficiency value of η = 90% as a constant efficiency approximation for simplicity.

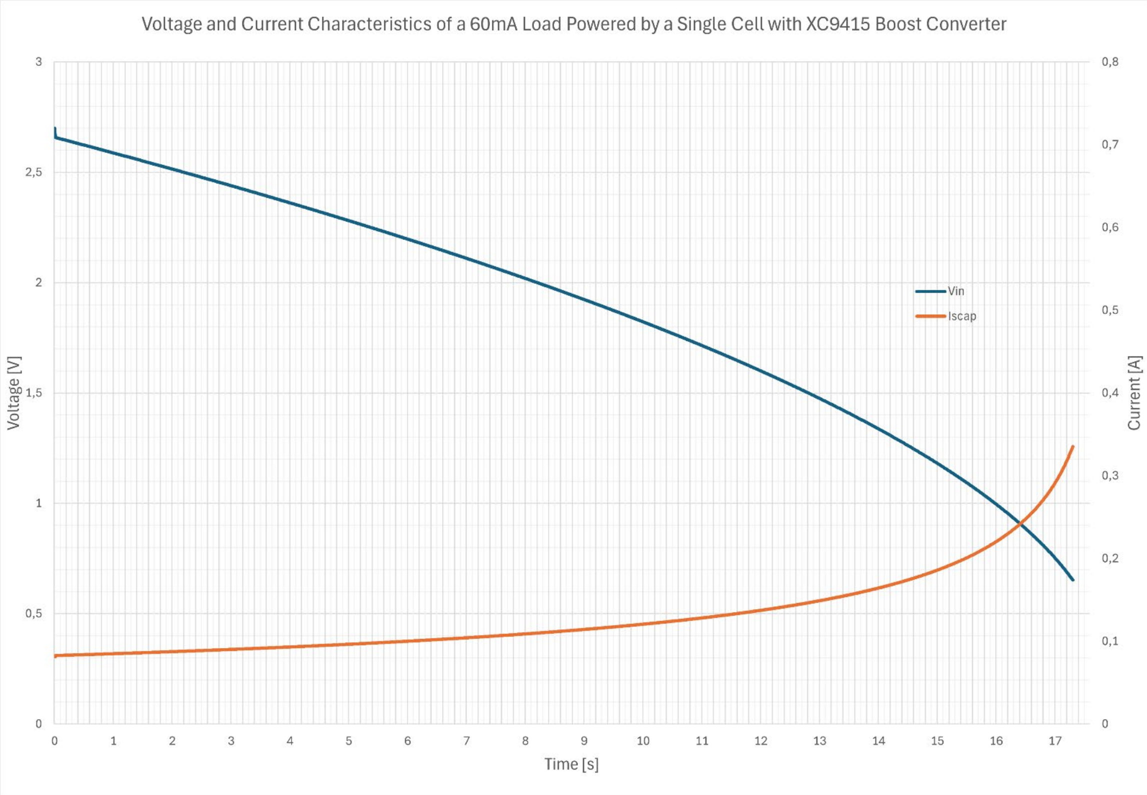

Figure 3, Voltage and current characteristics of a 60ma load powered by a single cell with XC9415 Boost Converter

The chart in Figure 3 shows this simulation using a constant 90% efficiency. You can see that as the supercapacitor voltage decreases, the current increases to keep the power constant, which further increases the rate of supercapacitor discharge, leading to an even higher current draw. This cycle creates a feedback loop, where the decreasing voltage results in an increasing current, accelerating the discharge process. This is why a constant power system needs to be modelled – there is no simple equation to calculate the hold-up time. According to the simulation, the supercapacitor can support this application for 17.3 seconds.