

Solving the backup power supply challenge for electricity meters with high-power wireless communications

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Electricity meter designers are continually being challenged by the demanding requirements from meter performance during grid outages. Smart meters must continue to operate during brief power outages and send notification messages through a wireless radio, which consumes a significant amount of energy. The Supercapacitor backup power supply for E-Meters reference design (PMP30528) is an example of two main power supply rails and two backup rails. The input DC voltage to this design can be between 7 V and 17 V. During a grid power failure, an automatic switch to a single SuperCap backup power occurs without any external logic or microcontroller (MCU) involvement. When main power supply rails are restored, the circuitry automatically reverts back to them and starts charging the SuperCap.

Supply Rails in Mains Powered Mode

The two main supply rails with 5 V @ 150 mA and 3.9 V @ 2 A are generated by the buck converters U1 (TPS62173) and U2 (TPS62147), respectively. Both U1 and U2 are highly efficient and easy-to-use synchronous step-down DC/DC converters. The TPS6217x device family supports up to 6 V @ 500 mA, but here, the fixed 5 V output variant is used. See Figure 1 for a visual. This voltage rail is easily modified to 1.8 V or 3.3 V if TPS62171 or TPS62172 are used.

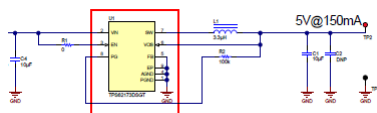


Figure 1. 5 V Primary Supply Rail with TPS62173

The TPS62147 provides up to 2 A continuous output current, which is a perfect fit for supplying RF Power Amplifiers (PAs) used in 2G, 3G, or LTE modems or for Wireless M-Bus with up to 1 W transmission power.

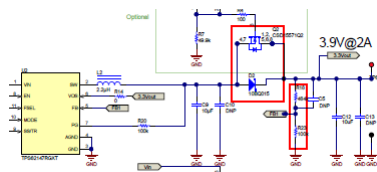


Figure 2. 3.9 V Primary Supply Rail with TPS62147

Figure 2 shows the 3.9 V output, which can be adjusted between 3 V and 5 V by modifying the output voltage divider R18, R23 at U2 and R34, R38 at U5. Figure 3 shows the transition between U2 and U5.

Backup Supply Rails Powered from the SuperCap

The most relevant function of delivering power for the last gasp RF communication is implemented with the TPS61022 boost converter (U5) shown in Figure 3. To maximize the usable energy from the SuperCap, it is important to discharge the latter to as low voltage as possible. U5 delivers power over the discharge range from 2.7 V down to 0.5 V (its minimum input voltage).

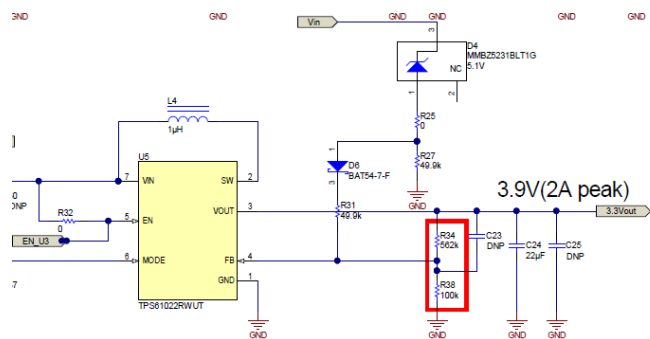


Figure 3. Boost Rail from SuperCap with D4 and D6 for Seamless Transition between U2 and U5

Figure 5 shows the circuit that charges the SuperCap (its capacity can vary depending on the required RF power and holdup duration) with a constant adjustable voltage of 2.7 V. When the input voltage fails ($V_{in} = 0$ V), U2 stops and the U5 converter seamlessly takes over the power supply and boosts the SuperCap output voltage to 3.9 V.

The SuperCap capacitance, its maximum charge voltage, and the lowest discharge voltage define the available energy for the RF sub-system backup feature. This reference design charges a 25 F SuperCap device to 2.7 V, providing a stable output of 3.9 V @ 200 mA for approximately 70 s. To achieve an automated (without any MCU interaction) transition from the normal operating mode (e.g. $V_{in} = 11$ V) to the backup operational mode from SuperCap, the outputs of U2 and U5 are connected together. Figure 2 shows the Zener diode that blocks the reverse current. The Zener diode D4 is connected to the feedback pin of U5 to prevent the controller from switching when the input voltage is present ($7 \text{ V} < V_{in} < 12 \text{ V}$).

D2 is directly in series with the load and its conduction loss is proportional to the output current since the forward voltage drop is almost a fixed voltage. A diode reduces the efficiency significantly, generates a lot of heat, and needs both a large package and a copper area to get remove the heat. This design uses a CSD15571Q2 NexFET Power MOSFET (Q2) as an ideal diode rectifier. When the Q2 conducts, its voltage drop is proportional to its $R_{DS(on)}$, which is low, significantly lowers the forward voltage drop of the diode. This reduces both the power loss and the temperature rise and significantly improves the overall efficiency of the power conversion.

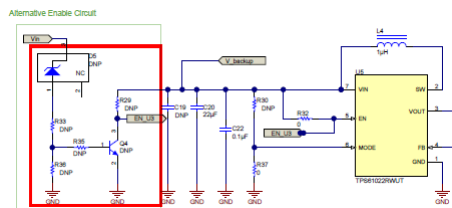


Figure 4. TPS61022 Boost Controller in Shutdown Mode Through EN Pin

The TPS61022 has a 5.7-V output overvoltage protection, output short circuit protection, thermal shutdown protection, and a built-in undervoltage lockout (UVLO) feature. Figure 4 shows the Alternative Enable Circuit around transistor Q4 sets the voltage on the EN pin depending on the V_{in} voltage.

After the TPS61022 starts and the output voltage is above 2.2 V, the TPS61022 works with input voltage as low as 0.5 V for a maximum discharge of the SuperCap.

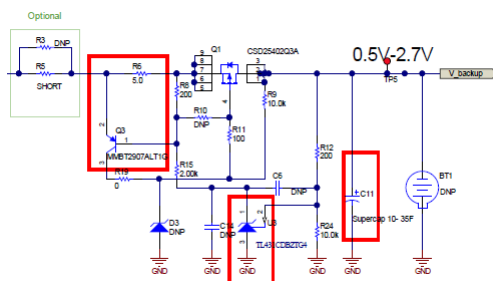


Figure 5. SuperCap C11 with Discrete Charger

When the input voltage V_{in} of the PMP30528 board is above a definable threshold, Q4 turns the controller into shutdown mode. During shutdown, the load is completely disconnected from the input power and the TPS61022 is turned off and consumes only 0.25 μ A.

TI's P-Channel NexFET Power MOSFET device CSD25402Q3A (Q1) is the core of the discrete charger circuit for the SuperCap. Since a P-Channel MOSFET remains turned off when the gate-source voltage is zero and turns on when the voltage is negative, a low cost PNP device Q3 is used to drive Q1. The current sense resistor R5 connected to Q3 defines the charging current and an adjustable shunt regulator TL431 limits the charging voltage. This circuit behaves like a linear regulator, where the input current is equal to the output current and therefore the power dissipation depends on the charging current.

Nearly all of the losses are converted to heat, so the power dissipation must be kept below the thermal limit. The current charging time is about 10 minutes for a SuperCap of 25 F. The two optional resistors, R3 and R5, can help dissipate the extra heat when a shorter charging time is needed.

Peak Power Demand

The most power hungry block is the high transmit power RF communication sub-system, which can use a cellular network modem or a wireless MCU, such as CC1352P, to create a private RF network with protocols such as Wireless M-Bus or 6LoWPAN. The common voltage range for the RF power amplifiers is between 3.3 V and 3.9 V. You choose the voltage level for the RF PA to work most efficiently and set it accordingly by modifying the R18, R23, R34 and R38 values. The last gasp support requirement for e-meters with wireless communications drives the use of a SuperCap device, which gets charged while main power supply rails are present and automatically delivers power to the RF sub-system when main power supply is lost.

Optionally, some other e-meter sub-systems (like the Host MCU or the metrology) can be powered from the SuperCap as well. The second backup powered rail is 3.3 V @ 50 mA is provided by TPS610981 (U4) boost device, the pin-compatible derivatives thereof integrate either a LDO or a load switch to power additional peripheral devices or sub-systems.

Summary

The PMP30528 reference design implements a fully-automated backup power solution for smart e-meters, which must wirelessly transmit last gasp data after the main power is lost. By completely avoiding any MCU interaction for switching from main power supply to backup power and vice versa, this design is a highly customizable power supply system with an excellent power efficiency and multiple options for fine tuning to meet specific application requirements. A single 2.7 V SuperCap gets discharged down to 0.5 V by the TPS61022 boost converter, which eliminates the cost of implementing two or more stacked SuperCaps and their associated load balancing circuitry.

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