Low Power DC/DC Converters

Smallest solution size, highest efficiency and lowest quiescent current

OĞUZHAN DEMİRCİ
Agenda

• Product Overview
  – Modules
  – Ultra Low IQ
  – HotRod Package
  – Industrial Converters

• DCS Control
  – Why do we need DSC-control?
  – Which type of control is possible?
    • Voltage mode vs. Hysteretic control
  – Benefits of DSC-control

• Reference Designs
  – PMP9763 Energy Buffering Concept
  – PMP9767 Efficient, LDO-less Power Supply for a 12-bit 500-MSPS ADC
  – PMP9755 & PMP9766 Backup Power Concepts
Low Power DC/DC Converters

Product Overview

Oğuzhan Demirci
Low Power DC/DC Solutions

- Medical
- Home Automation
- Tele/Datacom
- Computing
- Wearables
- Automotive
- Industrial
Low Power DC/DC TPS61 / 62 / 63

Small total solution size and cost
→ Few (typ. 3) and small external components
  QFN, SON or WSCP needs only \( C_{\text{IN}} \), \( C_{\text{OUT}} \), \( L \)

High efficiency (up to 97%) and very low \( I_{Q} \) down to 360nA
→ Long operating & standby time and low system temperature

Low EMI and low system noise
→ DCS-Control™ topology, low \( V_{\text{OUT}} \) ripple (10mV), high PSRR (90dB),
  Spread Spectrum,

Easy-to-use, synchronous DC/DC with integrated compensation
→ Quick development time and high system reliability
  MicroSiP™ modules <6.7mm² with fully integrated \( C_{\text{IN}} \), \( C_{\text{OUT}} \), \( L \) solution
Low Power DC/DC Modules – TPS82xxx MicroSiP™ Integration

Controller
external FETs, Inductor, Capacitors

Converter
external Inductor, Capacitors

uSIP Module
No externals

uSIP Module
external Capacitors
## MicroSiP™ Module Portfolio

<table>
<thead>
<tr>
<th></th>
<th>TPS82740</th>
<th>TPS8267x</th>
<th>TPS8269x</th>
<th>TPS8268x</th>
<th>TPS82085</th>
<th>TPS82480*</th>
<th>TPS82135*</th>
<th>TPS82130</th>
<th>TPS82140*</th>
<th>TPS82150*</th>
<th>TPS81256 BOOST</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>V_{IN}</strong></td>
<td>2.2V to 5.5V</td>
<td>2.3V to 4.8V</td>
<td>2.3V to 4.8V</td>
<td>2.5V to 5.5V</td>
<td>2.5V to 6V</td>
<td>2.4V to 5.5V</td>
<td>3.0V to 17V</td>
<td>2.5V to 5.5V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>V_{OUT}</strong></td>
<td>1.8V to 3.3V (16 voltages pin-selectable)</td>
<td>1.05V to 2.1V (12 output voltage options)</td>
<td>2.2V to 3.0V (5 output voltage options)</td>
<td>0.90V to 1.80V (5 output voltage options)</td>
<td>0.8V to V_{IN} (adjustable)</td>
<td>0.6V to 5.5V (adjustable)</td>
<td>0.9V to 5V (adjustable)</td>
<td>5.0V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>I_{OUT}</strong></td>
<td>200mA</td>
<td>600mA</td>
<td>800mA</td>
<td>1600mA</td>
<td>3000mA</td>
<td>2000mA</td>
<td>6000mA</td>
<td>3500mA*</td>
<td>3000mA*</td>
<td>1000mA*</td>
<td>550mA</td>
</tr>
<tr>
<td><strong>Module size</strong></td>
<td>2.3x2.9x1mm</td>
<td>2.3x2.9x1mm</td>
<td>2.3x2.9x1mm</td>
<td>2.3x2.9x1mm</td>
<td>2.8x3.0x1.3mm +external Caps</td>
<td>tbd</td>
<td>2.8x3.0x1.5mm +external Caps</td>
<td>2.6x2.9x1mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Solution size incl. L, C_{IN}, C_{OUT}</strong></td>
<td>6.7mm²</td>
<td>6.7mm²</td>
<td>6.7mm²</td>
<td>6.7mm²</td>
<td>35mm²</td>
<td>tbd</td>
<td>42mm²</td>
<td>9mm²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>I_{Q}</strong></td>
<td>0.36µA</td>
<td>17µA</td>
<td>24µA</td>
<td>7mA</td>
<td>17µA</td>
<td>23µA</td>
<td>20µA</td>
<td>43µA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>95%</td>
<td>90%</td>
<td>95%</td>
<td>88%</td>
<td>95%</td>
<td>96%</td>
<td>90%</td>
<td>91%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* in development

TI Information – Selective Disclosure

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3A MicroSiP™ Power Module
TPS82085

MicroSiP™ package saves 45% PCB area
TI’s smallest 3A buck module (2.8 x 3.0 x 1.3mm SiL package with integrated inductor)

Efficiency up to 95% and 17µA I_Q extend battery operating time and keeps the system cool

1% V_FB accuracy, line/load regulation and low output ripple for reliable supply operation

Fast transient response with DCS-Control™
3A MicroSiP™ Power Module
TPS82085

![Efficiency Graph](image)

- **Efficiency (%)** vs **Load (A)**
- **V_{OUT} = 1.8 V**
- **V_{IN} = 3.0 V**
- **V_{IN} = 3.5 V**
- **V_{IN} = 4.0 V**
- **V_{IN} = 5.0 V**
# Ultra-Low Power Portfolio

<table>
<thead>
<tr>
<th>Output current</th>
<th>100mA</th>
<th>300mA</th>
<th>400mA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low V\textsubscript{IN} Buck</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TPS62730</td>
<td>30nA bypass, 1x1.5 SON</td>
<td>TPS62740</td>
<td>360nA I\textsubscript{Q}, 2x3 SON</td>
</tr>
<tr>
<td>TPS82740</td>
<td>360nA I\textsubscript{Q}, 2.3x2.9 Module</td>
<td><strong>NEW</strong></td>
<td><strong>NEW</strong></td>
</tr>
<tr>
<td><strong>Mid V\textsubscript{IN} Buck</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TPS62120</td>
<td>V\textsubscript{IN} 2-15V, 10µA I\textsubscript{Q}</td>
<td>TPS62745</td>
<td>V\textsubscript{IN} 3.3-10V, 400nA I\textsubscript{Q}</td>
</tr>
<tr>
<td>TPS62743/6/8</td>
<td>360nA I\textsubscript{Q}, 1.6x0.9 WCSP</td>
<td><strong>NEW</strong></td>
<td><strong>NEW</strong></td>
</tr>
<tr>
<td><strong>Boost</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TPS61220</td>
<td>5µA bypass</td>
<td>TPS61291</td>
<td>I\textsubscript{Q}=15nA bypass</td>
</tr>
<tr>
<td>TPS61096</td>
<td>1µA I\textsubscript{Q}, 2x2 SON</td>
<td><strong>NEW</strong></td>
<td><strong>NEW</strong></td>
</tr>
<tr>
<td>TPS61099</td>
<td>800nA I\textsubscript{Q}, 0.9x1.2 WCSP</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dual Output</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TPS610898</td>
<td>300nA I\textsubscript{Q}, Boost, with LDO / Load Switch, 1.5x1.5 SON</td>
<td><strong>NEW</strong></td>
<td><strong>NEW</strong></td>
</tr>
<tr>
<td>TPS62770</td>
<td>360nA I\textsubscript{Q}, Buck, with Boost, WCSP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TI Information – Selective Disclosure
TPS62740 Family Extension – part 1
Ultra-Low Power Buck Converter

**TPS62740**
- 2.2V to 5.5V \( V_{IN} \)
- 300mA \( I_{OUT} \)
- 360nA quiescent current, 90% efficiency for \( I_{OUT} > 10\mu A \)
- 16 pin-selectable voltages (100mV steps) 1.8V to 3.3V
- Integrated Load Switch
- Power Good output
- 2 x 3mm SON

**TPS62742**
- 3.0V to 5.5V \( V_{IN} \)
- 400mA \( I_{OUT} \)
- 360nA quiescent current, 90% efficiency for \( I_{OUT} > 10\mu A \)
- 16 pin-selectable voltages (100mV steps) 1.8V to 3.3V
- Integrated Load Switch
- Power Good output
- 2 x 3mm SON

**TPS62743**
- 2.0V to 5.5V \( V_{IN} \)
- 300mA \( I_{OUT} \)
- 360nA quiescent current, 90% efficiency for \( I_{OUT} > 10\mu A \)
- 8 pin-selectable voltages 1.2V to 3.3V
- 1.6 x 0.9mm WCSP

**TPS62746**
- 2.0V to 5.5V \( V_{IN} \)
- 300mA \( I_{OUT} \)
- 360nA quiescent current, 90% efficiency for \( I_{OUT} > 10\mu A \)
- 2 pin-selectable voltages 1.2V / 1.8V
- Integrated \( V_{IN} \) Switch
- 1.6 x 0.9mm WCSP

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Texas Instruments
TPS62740 Family Extension – part 2
Ultra-Low Power Buck Converter

**TPS62748**
- 2.0V to 5.5V\(_{\text{IN}}\)
- 300mA\(_{\text{OUT}}\)
- 360nA quiescent current, 90% efficiency for \(I_{\text{OUT}} > 10\mu\text{A}\)
- 2 pin-selectable voltages (1.2V / 1.8V)
- Integrated Load Switch
- 1.6 x 0.9mm WCSP

**TPS62745**
- 3.3V to 10V\(_{\text{IN}}\)
- 300mA\(_{\text{OUT}}\)
- 400nA quiescent current, 90% efficiency for \(I_{\text{OUT}} > 15\mu\text{A}\)
- 16 pin-selectable voltages (100mV steps) 1.8 to 3.3V
- Power Good output
- 2 x 3mm SON

**TPS82740A/B**
- 2.2V to 5.5V\(_{\text{IN}}\)
- 200mA\(_{\text{OUT}}\)
- 360nA quiescent current, 90% efficiency for \(I_{\text{OUT}} > 10\mu\text{A}\)
- 2x8 pin-selectable voltages (100mV steps) 1.8V to 3.3V
- Integrated Load Switch
- Power Good output
- 2.3 x 2.9 x 1.1mm MicroSIP module (integrated \(C_{\text{IN}}, C_{\text{OUT}}, L\))
TPS62743 - Ultra-Low Power Buck Converter

![Graph showing efficiency vs. output current for different input voltages (V_IN = 2.5 V, 3.0 V, 3.6 V, 4.2 V, 5.0 V) with V_out = 1.8V.](image)
Solution size reduction with MicroSiP™

TPS62740 in SON package w/ external passives components

TPS62743 in WSCP package w/ external passives components

TPS82740 in MicroSiP™ package w/ external passives components

MicroSiP™ Module 4 x smaller!
HotRod™ Package
Easy-to-Use, Low Resistance, Good Thermals

- QFN
  Flexible Assembly easy
  Hi Resistance
  Good thermals

- WCSP
  Low power
  Handling bare die
  Low Resistance
  Bad thermals

- HotRod
  Best Performance
  Like a QFN
  Low Resistance
  Good thermals

- HotRod™ eliminates wire bonds by attaching the power device and/or die directly to the leadframe. This construction results in a cost effective advanced packaging that improves electrical and thermal performance.
TPS630250
Industry smallest $2A_{\text{OUT}}$ single-inductor Buck-Boost

**FEATURES**

- 2.3V to 5.5V$_{\text{IN}}$, 2A output current supported over entire $V_{\text{IN}}$ range
- Automatic Power-Save Mode with 35μA $I_Q$
- $V_{\text{OUT}}$ ripple <50mV in PFM mode
- Load Disconnect
- TPS630250 (adj $V_{\text{OUT}}$), ‘251(2.9V$_{\text{OUT}}$), ‘252(3.3V$_{\text{OUT}}$)
- 20 pin WCSP 1.7x2.1mm
- 14 pin HotRod™ QFN 2.5x3mm

**APPLICATIONS**

- Smart Grid back-up power
- ePOS Point of Sales
- Single Li-Ion cell powered applications

**BENEFITS**

- Supports new chemistry Li-Ion batteries which enable lower cutoff voltages
- Efficiency higher than 90% (97% peak) over the complete load range extends battery life
- High $V_{\text{OUT}}$ accuracy over the complete load range
- Protects the device against reverse current as well as eliminates parasitic drain from battery when converter is disabled
- Total solution size <44 mm$^2$

- Easy-to-Use QFN
- Low Resistance
- Good thermals
TPS630250 Thermal Results

20 pin WCSP 1.7x 2.1mm

14 pin HotRod™ QFN 2.5x3mm

Vin=3.6V, WCSP, Vout=3.3V, Iout=3A

Vin=3.6V, HotRod, Vout=3.3V, Iout=3A
Low Power DC/DC Industrial Buck Converter
TPS62097 – 2A Step-Down Converter

FEATURES
• iDCS-Control™ with Forced-PWM mode and adjustable switching frequency (1.5-2.5 MHz)
• 1% Vout accuracy (V_{OUT} = 0.8V – Vin)
• Adjustable startup and voltage tracking
• V_{IN}: 2.5V to 6V
• 100% duty cycle mode for lowest dropout
• 17µA quiescent current in Power Save Mode
• Output voltage discharge function
• -40 to +125ºC Tj
• Package 2x2mm HotRod™ package

APPLICATIONS
• Factory Automation
• Programmable Logic Control
• Test & Measurement
• Industrial Point-of-Load

BENEFITS
• RF-friendly DC/DC converter for noise-sensitive, precision industrial applications
• Fast transient response for FPGAsupply
• High flexibility for multiple loads
• Small solution size 28mm²

DIAGRAM
DCS-Control → iDCS-Control

**DCS-Control**

Direct Control with Seamless Transition into Power Save Mode

**iDCS-Control** (Intelligent DCS-Control)

Added features:

1) *Selective PWM switching frequency by an external resistor*

2) *Forced PWM or Power Save Mode*

<table>
<thead>
<tr>
<th>Mode Pin</th>
<th>Switching Frequency</th>
<th>PWM/PFM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode = AGND</td>
<td>2MHz</td>
<td>Auto entry/exit PWM/PFM</td>
</tr>
<tr>
<td>Resistor at Mode pin</td>
<td>Selectable from 1.5MHz to 2.5MHz</td>
<td>Forced PWM only</td>
</tr>
</tbody>
</table>
Low Power DC/DC Industrial Buck Converter
TPS62097 – 2A Step-Down Converter

The device offers the following options and features:

Choice between highest efficiency or low output voltage ripple
  ➔ Mode pin

High efficiency combined with small total solution size
  ➔ HotRod package, small $R_{DSON}$

Control of voltage rails for multiple loads (sequencing)
  ➔ Voltage Tracking, adj. Soft Start, Power Good

A low system noise for data converter and sensors
  ➔ Selectable frequency between 1.5MHz to 2.5MHz

![Graph]

$V_{OUT} = 3.3V$

$V_{IN} = 4.2\, V$

$V_{IN} = 5.0\, V$
**TPS61088**

**10A Peak Current Synchronous Boost with Adjustable Current Limit**

**FEATURES**

- Input voltage range: 2.7V - 12V
- Output voltage range: 4.5V - 12.6V
- 10A peak current limit (Resistor-Programmable)
- Low Rdson: 11mΩ / 13mΩ
- Synchronous boost with +/- 1.5% accuracy
- Up to 91% efficiency (Vin=3.3V, Vout=9V, Iout=3A)
- Isd (into Vin) 1µA in shut down mode
- Programmable soft start
- PFM / forced PWM mode (adjustable Switching Frequency: 200 kHz to 2.2 MHz)
- Over voltage protection, over current protection, thermal shutdown
- 3.5mmx4.5mm QFN-20 package

**APPLICATIONS**

- Quick Charge Power Bank
- POS terminal / Printer
- Bluetooth Speaker
- E-cigarette

**BENEFITS**

- High power capability
- Compact solution
Low Power DC/DC New Boost Converter

Ultra-Low Power

TPS61220
5μA I_Q

TPS61291
15nA I_Q bypass

TPS61230
5A Switch

TPS61098
300nA I_Q

Boost + LDO/LoadSwitch

TPS61088
10A Switch

Wide V_IN, Wide V_OUT

TPS61175

Fast Switch

PMOLED / WLED Backlight

High Power

TPS61040
4A Switch

TPS61042

TPS61043

TPS61045

Wide V_OUT

Texas Instruments
Low Power DC/DC Collateral

- Low-power DC/DC highlights and device overview SLYT522B
- Low-power DC/DC Converter with DCS-Control™ brochure SLYT543
- Low-power DC/DC Converter Modules SLVT175
- End Equipment / Customer Presentations on ESP
DCS-Control
Direct Control with Seamless transition into power-save mode

• Why do we need DSC-control?
• Which type of control is possible?
  • Voltage mode vs. Hysteretic control
• Benefits
• Understanding frequency variation in the DCS-control
Why do we need DSC-control?

- Smaller solution size / higher power density

- Higher efficiency
  - Extends operation time of application
  - Reduces overall system temperature

- Longer operating and stand-by time
  - Active communication with application, e.g. DVS
  - Lower quiescent current, Snooze Mode

- Lower solution cost
  - Less external components
  - Smaller external components

- Lower EMI and system noise
  - No need for filtering
  - Supporting audio, optical and RF systems
Which type of control is possible?
Traditional Voltage mode PWM Control

- OSC = Fixed Frequency
- Internal Compensation
- PFM Detection Circuitry
- PFM Circuitry
Which type of control is possible?

Summary – PWM control architecture

• **Complex** and silicon intensive (costly) Power Save Mode entry, exit and operation mode circuits
• Loop **compensation** required
• Fixed switching frequency with +/-20% typical tolerance

We need something new to reach the next level
Which type of control is possible?  
Basic Hysteretic Control

\[ f_s = \frac{(V_{in} - V_{out}) \cdot V_{out} \cdot ESR}{V_{hys} \cdot L \cdot V_{in}} \]

Switching Frequency Varies and is a Function of ESR, L and Vhys
Which type of control is possible? Considerations – Hysteretic Control

- Possibly **simplest** control circuit
- **Fastest response** to input voltage and output voltage perturbations among all control techniques
- Switching frequency depends on $V_{\text{hys}}$, $L$, $V_{\text{in}}$, $V_{\text{out}}$ and ESR
  - Frequency variation
- Inherently **stable** operation

Technical items to be solved

- Modern DC-DC converters have **no output capacitor ESR**
- Compensate for effects preventing good **output voltage accuracy**
- Implementation of **Power Save Mode**
- Control or acceptance of switching **frequency variation**
Which type of control is possible? DCS-Control™

Proprietary Ramp Circuitry Feeds VOS (Vout) to Comparator

- Proprietary Ramp Circuitry Feeds VOS (Vout) to Comparator
- Direct control & compensation
- Error Amplifier for Precise DC Regulation
- Hysteretic Comparator for Fast Response to Changes in Output Voltage
- On Timer for Power Save Mode and Constant Operating Frequency

Feedforward Capacitor Only Required for Power Save Mode Performance
Improvements with DCS-Control® Topology

TPS62040 (Voltage Mode)

TPS62080 (DCS-Control™)

No Load Output Ripple = 26.3 mV

No Load Output Ripple = 6.9 mV

→ Output Voltage Ripple is reduced by >70%

CH1 – VOUT @ 20mV/div, AC Coupled
CH2 – IL @ 200 mA/div
CH3 – ILOAD @ 200 mA/div

t = 20ms per division
Improvements with DCS-Control Topology

TPS62110 (Voltage Mode)

TPS62150 (DCS-Control™)

Seamless transition between PWM and Power Save Mode  ➔ No disturbing bursts

CH1 – VOUT @ 50mV/div
CH2 – IL @ 1A/div
CH3 – ILOAD @ 1A/div
Improvements with DCS-Control Topology

Fastest transient response TPS62090

Load Step 0.2A to 2A

CH2: Vout, CH4=Iload, CH1=Inductor current

Immediate and fastest response to a load step due to 100% switch turn on
Efficiency with DSC-control (TPS62130)

- **Input Voltage (V):**
  - VIN=12V
  - VIN=17V

- **Output Current (A):**
  - Vout: 5V
  - fsw: 1.25MHz
  - fsw: 2.5MHz

- **Efficiency (%):**
  - VIN=12V
  - VIN=17V

- **Input Voltage (V):**
  - IOUT=1mA, 10mA, 100mA, 1A
Identifying DCS-Control™ devices

Datasheet:
- Bullets on 1st page
- Simplified Block Diagram

Features:
- DCS-Control™ Topology
- Input Voltage Range 4.75 to 28V
- Quiescent Current typ. 4.8µA (Sleep Mode)
- 100% Duty Cycle Mode
- Active Output Discharge
- Power Good Output
- Output Current of 500mA

Example for TPS62130, TPS62140, TPS62150

Check: [www.ti.com/dcs-control](http://www.ti.com/dcs-control)
PMP9767

Efficient, LDO-less Power Supply for a 12-bit 500-MSPS ADC
Efficient, LDO-less Power Supply for a 12-bit 500-MSPS ADC

**TI Designs Number:** PMP9767

### Solution Features
- > 80% total efficiency using SMPS
- > 40% input current reduction compared to LDO solution
- Same performance as LDO power solution

### Featured Applications:
- Portable test and measurement
- Portable data acquisition
- Industrial applications
- Software Defined Radio

### Solution Benefits
- Lower system temperature
- ~2x operating time on batteries
- Less input power required
- 12-bit performance maintained
- SNR > 61 dB
- SFDR > 77 dB

### Tools & Resources
- **PMP9767 Tools Folder:**
  (Test report, schematics, etc.)
- **TPS62231 / TPS62237**
  (0.5A ultra small buck)
- **TPS79601**
  (1A LDO regulator)
- **ADS540x**
  (12-bit, >=500MPS ADC)
PMP9767 Test Results

TPS6223x maintained nearly 62 dBFS SNR and 78 dBc SFDR at 230 MHz frequency and 500 MSPS clock rate, while improving efficiency from 47 to 82%, saving over 250 mA current to the ADC.

PMP9767 shows a proven SMPS solution for powering a data converter with higher efficiency, a clean enough voltage, and reasonable cost.
PMP9755 / PMP9766
Backup Power Solutions for Line Powered Applications
Typical backup power example in smart Grid

In case of a power loss the backup solution will provide the energy to the system. This energy can be used to save the latest data and send it to a data concentrator.
Backup Power Solution for Data Concentrator Circuit Using TPS61030

TI Designs Number: PMP9755

**Solution Features**
- Single Super Capacitor to Power RF Module
- 1.7V~2.65V Super Capacitor Operating Voltage
- Seamless Transition Between Main Power and Capacitor Power
- This Circuit is Tested on an Evaluation Board

**Applications:**
- Data Concentrator

**Solution Benefits**
- Low Cost and Simple Circuit
- Small Super-Capacitor Value
- 1min Operating Time using backup energy

**Block Diagram & Evaluation Board**

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TPS61021 sample now 0.9V~3.6V & 4A input
Max. 4V output
At this point, the power from Grid fails and drops down to zero. But the TPS61030 start switching to maintain the $V_{\text{OUT}}$ for the Loads. $V_{\text{OUT}}$ keeps stable at Super-capacitor voltage is 1.7V and $I_{\text{LOAD}}$ is 2A peak. (use an E-Load to simulate the GPRS Module)
Supercapacitor Backup Power Supply with Active Cell Balancing Using TPS63020

**TI Designs Number:** PMP9766

### Solution Features
- Active Backup Capacitor Cell Balancing
- Automatic switchover from main power to backup power
- No Glitches at the Transition from Main Power to Backup Power Operation

### Solution Benefits
- Simple & Low-Cost Design, small BOM
- Up to 15W Output Power
- Wide useable Backup-Capacitor Voltage Range (1.8 to 5.5 V) results in smaller Solution Size and smaller Backup Capacitance
- Flexible Design, Easy Adaptable to Different System Energy Requirements

### Tools & Resources
- **BOM:**
  - TPS63020 (5.5Vin, 4A sync buck-boost)
  - TPS25940A (2.7V-18V eFuse)
  - LP2998 (termination regulator)
- **Boards available** (contact M. Helmlinger)
To show the functionality of the active cell balancing circuit, a 1:2 Supercapacitor mismatch was used (C1=3F, C2=6F).
During the pre-charging and charging operation the LP2998 is regulating the VCMID equal to VC/2.

If the main power fails, the TPS63020 converter immediately starts regulating the system voltage to its programmed output voltage. In this example 0.5 watts are supported for 6.5s in backup operation.
Energy Buffering Concept for Smart Meter Power Management

TPS62740 Low Iq Power Management
# Smart Meter Power Management with Energy Buffering based on TPS62740

**TI Designs Number:** PMP9763

## Solution Features
- Buck (MCU) and Boost (RF-PA) Rail
- Battery Load Decoupling with Energy Buffering
- Ultra Low $I_Q$ Design
- Longer Battery Runtime by VDD Down Conversion

## Solution Benefits
- Supports long life batteries
- Extends battery runtime due to lower MCU supply and 360nA $I_Q$
- Buffers energy with EDLC Super-Cap
- Does not require HLC

## Tools & Resources
- **PMP9763 Tools Folder:**
  - application-note, schematics, Gerber files, etc.
- **BOM:**
  - TPS62740 (360nA $I_Q$ Buck in 3x2 WSON)
  - TPS61291 (Low $I_Q$ Boost w/ Bypass)
Long Life Wireless Sensor Requirements

Wireless Sensors like:
- Water-Meter
- Gas-Meter
- Heat-Cost-Allocator
- Smoke-Detector
- Connected Home
- IOT

**Typical for this Systems:**
1. Runtime last for ages
2. Low average power consumption
3. High power for data transmission (rarely)
The Common Power Management Challenge

- Long-Life-Batteries
  - Li-SOCl₂ type
  - ...
- Energy Harvesters
  - Solar Panels
  - ....

Limited Source

3.6V open circuit
~3mA

>1.8V, <1mA

Control System

Data Transmission

~3.6V, up to 2.5A, pulsed (rarely)

Wireless Sensor
Primary Batteries Specification

Needs: **Long Life**, **Low Self Discharge**, **High Energy Density**

- **Li-MnO₂** - Lithium-manganese dioxide (3V)
- **Li-SOCl₂** - Lithium-thionyl chloride (3.6V)

*) Source: Saft
Primary Batteries‘ Cell Voltage

Cell voltage (V)

% of capacity discharged

- Li-SOCl₂
- Li-SO₂
- Li-MnO₂
- Li-FES₂
- Alkaline-MnO₂
- Zn-Air

Source: Saft
Recent Solutions: „Power Pack“

- LiSOCl₂
- HLC* or Stacked Super-CAP
- Loq-Buck TPS62740
- uController
- e.g. Buck/Boost TPS63...
- Data Transmission

*) Hybrid Layer Capacitor for peak power assistance
Power Consumption Comparison example (CC430)

Supply Current [\mu A] vs. Supply Voltage [V]

- CC430 (VCC=2.1V) via TPS62740
- CC430 directly connected (VCC=supply voltage)

30% lower current consumption when operated with TPS62740 (3.6V to 2.1V)

⇒ +30% Battery lifetime
Super Cap Power Concept

Single Super Cap secondary
- No stacked Capacitors (2.7Vmax)
- No balancing
- No HLC has to be used
- low (e.g. 1.9V) Voltage to reduce standby current
Sequence

$V_{MAX}$

$V_{MIN}$

idle | charge | idle | discharge | idle

1 | 2 | 3 | 4 | 1

$V_{SEL}[V]$ | 1.9 | Step 1.9 .. 2.7 | 2.7 | 1.9 | 1.9

LOAD | 0 | 0 | 0 | active | 0

TIME [$\sim$] | 13 min | | 200µs |
Efficient Super Cap charging

1. Charge current is limited by resistor:
   \[ I_{\text{CAP}} = \frac{\Delta U}{R} \]

2. Power Loss is minimized due to Voltage stepping
   \[ P_{\text{LOSS}} = \frac{\Delta U^2}{R} \]

Example: \( R = 30 \Omega \)
- \( I_{\text{CAP}} = \sim 3.3 \text{mA} \)
- \( P_{\text{LOSS MAX}} = \sim 0.3 \text{mW} \)
Summary / Outlook of PMP9763

- Mix of low current and high current peaks is a challenge for power management concepts
- Long life batteries require energy buffering concepts
- Ultra Low Quiescent Devices needs to be used

- Save battery lifetime
- No Stacked Caps + Balancing needed
- No HLC needed
- Efficient charging due to Voltage Stepping
- Reference Design PMP9763 available