Power Management for IoT SoCs

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The interconnection of billions of autonomous devices to the internet is called **THE INTERNET OF THINGS (IoT)**.
THERE ARE A WIDE RANGE OF APPLICATIONS FOR IoT DEVICES.
MANY NEW IDEAS WILL BE BROUGHT TO THIS FIELD.

BUT A GREAT NUMBER OF THESE WILL COME FROM COMPANIES WITHOUT BACKGROUND OR EXPERIENCE IN DEVELOPING HIGH-TECH DEVICES AND EQUIPMENT.
THESE NEW IoT INVENTIONS WILL NEED TO BE IMPLEMENTED WITH A SINGLE SYSTEM ON A CHIP.

THIS WILL PROVIDE THE HIGHEST LEVELS OF INTEGRATION AND CONSERVATION OF AREA.
Integration Trends

Twenty years ago, SERDES analog blocks were completely separate from the ASIC/SoC.

Today, SERDES analog blocks are fully integrated into the ASIC/SoC.

Previously, power management IC (PMIC) analog blocks were separate from the ASIC/SoC.

Current trends are to fully integrate the PMU into the ASIC/SoC.
ONE OF THE MOST IMPORTANT ASPECTS OF DEVELOPING A CUSTOM SOC FOR AN IOT APPLICATION IS **DIFFERENTIATING** YOUR PRODUCT FROM OTHER COMPETITORS IN THE MARKET.

MANY OF THE FUNCTIONAL BLOCKS THAT ARE USED IN A TYPICAL SOC ARE EITHER STANDARDIZED OR VERY HIGHLY COMMODITIZED.
THE HIGH-PERFORMANCE ANALOG AND MIXED-SIGNAL BLOCKS IN GREEN, HOWEVER, CAN BE AN AREA FOR **CUSTOMIZATION AND DIFFERENTIATION**.
**Advantages of Small-Geometry Processes**

- Power savings for longer battery life.
- Die area savings for smaller devices.

**Challenges of Small-Geometry Processes**

- Transistor mismatch.
- Current leakage.

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**MOST IOT SOC DESIGNS ARE IMPLEMENTED IN SMALL-GEOMETRY PROCESSES (55 NM AND SMALLER)**
We have significant experience in overcoming the difficulties of designs in a variety of advanced-processes, down to 5 nm.

USING VIDATRONIC INTELLECTUAL PROPERTY (IP) WILL HELP YOU:

- Reach market faster
- With lower risk
- And less cost
Power Management Unit IP Blocks

- Voltage References
- Low-Dropout Regulators
- DC/DC Converters
- Foundational Blocks
- Serial Interface
- State Machine Control Logic

Power Management Unit (PMU)
Low-Dropout Regulators (LDOs)
Linear Voltage Regulator Fundamentals

- High input voltage
- Lower output voltage
- Voltage dropped across variable internal resistance
- Power dissipated as heat
- Low input-to-output devices called “Low Drop-Out” or LDO
VREG Function

- Varying input voltages
- Varying load currents
- Closed-loop feedback control system
- Loop transfer function & loop stability
- Power-supply noise filtering (PSRR)
Vidatronic’s Power Quencher® LDO

Typical application requiring multiple external LDOs and capacitors.

Vidatronic integrated power management unit (PMU) - inside customer’s microchip
No external LDOs.
No external capacitors required.
Power Quencher® LDO Voltage Regulator – VLDS0001LNT040

Dual-mode LDO for battery-powered devices where low-power is critical.

- No external capacitors required
- Reference Input: from Vidatronic low-power bandgap
- Achieves a low-noise output voltage without the need for external capacitors, saving package pins and PC board space
- Includes high drive mode select control input, voltage-select control input, power-down control input, soft start, and power-good status output
- Silicon-proven in TSMC 40 nm ULP process

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Power Supply</td>
<td>2.8 to 4.2 V</td>
</tr>
<tr>
<td>Selectable Output Voltages</td>
<td>1.1 or 1.85 V</td>
</tr>
<tr>
<td>Output Voltage Accuracy (includes error of the reference input)</td>
<td>± 15%</td>
</tr>
<tr>
<td>Maximum Continuous Output Current (high drive mode)</td>
<td>3 mA</td>
</tr>
<tr>
<td>Maximum Continuous Output Current (low drive mode)</td>
<td>100 µA</td>
</tr>
<tr>
<td>Quiescent Current (at 3 mA output)</td>
<td>&lt; 20 µA</td>
</tr>
<tr>
<td>Quiescent Current (at 5 µA output)</td>
<td>&lt; 0.75 µA</td>
</tr>
</tbody>
</table>

No external capacitors required

Reference Input: from Vidatronic low-power bandgap

Achieves a low-noise output voltage without the need for external capacitors, saving package pins and PC board space

Includes high drive mode select control input, voltage-select control input, power-down control input, soft start, and power-good status output

Silicon-proven in TSMC 40 nm ULP process
DC-to-DC Converters

Power Management Unit (PMU)

- Voltage References
- Low-Dropout Regulators
- DC/DC Converters
- Foundational Blocks
- Serial Interface
- State Machine Control Logic
DC-to-DC Converters

- Switched-mode voltage conversion
- Input dc is “chopped” to produce an ac voltage which is filtered back to dc
- Very high efficiency
  - Good for battery-powered applications
  - Good thermal
- Noisy

- Voltage Conversions
  - Buck (decrease)
  - Boost (increase)
  - Bypass (pass through)
  - Combinations: Buck/Boost, Boost/Bypass, etc.

- Architectures
  - Traditional inductor-based
    - Requires external inductor and capacitor
  - Switched Capacitor
    - No external components required
DC Voltage-Conversion Comparison

LDOs
- High Power/Heat
- Low Noise
- Output always lower than input

DC-DC Converters
- Low Power/Heat
- High Noise
- Output can be lower or higher than input
Buck DC-DC Converter – VBKS0140T040

**Parameters** | **Specifications**
--- | ---
Input Power Supply | 2.8 to 4.2 V
Selectable Output Voltages | 1.1 or 1.85 V
Output Voltage Accuracy | ± 5%
Maximum Continuous Output Current | 140 mA
Minimum Load Current | 1 mA
Minimum Power Efficiency (5 mA to 140 mA) | > 70%
Minimum Power Efficiency (20 mA to 60 mA) | > 80%
Output Voltage Ripples (at 140 mA) | 20 mV

- **Selectable output voltages:**
  - Nominal low output voltage = 1.1 V
    - Programmable using 4 bits
    - 20 mV programmable steps
  - Nominal high output voltage = 1.85 V
    - Programmable using 4 bits
    - 20 mV programmable steps

- Optimized clocking options eliminate spurious emissions for much lower system noise

- Includes voltage reference, internal oscillator, soft-start, overcurrent protection, and power-good status output

- Silicon-proven in TSMC 40 nm ULP process
Vidatronic’s **Flexsupply™ IP Cores**

Current products designed around a 2.5 V supply function properly when the battery level is high.

When the battery level is low, however, the product stops working entirely.

The Flexsupply™ family of switched-capacitor regulated voltage-doubler IP cores are designed to improve current products so that they can function properly at extremely low battery levels.

After integration into the SoC, the Flexsupply™ IP core provides the correct supply voltage to the SoC, even with low battery levels.
Flexsupply™ Available Modules

The die area of each module is based on current requirements.

<table>
<thead>
<tr>
<th>Product Name</th>
<th>1 mA Module</th>
<th>1 mA Module PLUS</th>
<th>4 mA Module</th>
<th>4 mA Module PLUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>VRDS0002N</td>
<td>1 mA</td>
<td>VRDS0005N</td>
<td>VRDS0008N</td>
<td>VRDS0020N</td>
</tr>
<tr>
<td>DC Drive Capability</td>
<td>1 mA</td>
<td>1 mA</td>
<td>4 mA</td>
<td>4 mA</td>
</tr>
<tr>
<td>LONG Write Pulse Magnitude</td>
<td>1.25 mA</td>
<td>3 mA</td>
<td>5 mA</td>
<td>12 mA</td>
</tr>
<tr>
<td>LONG Write Pulse Duration</td>
<td>2 µs</td>
<td>2 µs</td>
<td>2 µs</td>
<td>2 µs</td>
</tr>
<tr>
<td>SHORT Write Pulse Magnitude</td>
<td>2 mA</td>
<td>5 mA</td>
<td>8 mA</td>
<td>20 mA</td>
</tr>
<tr>
<td>SHORT Write Pulse Duration</td>
<td>200 ns</td>
<td>200 ns</td>
<td>200 ns</td>
<td>200 ns</td>
</tr>
<tr>
<td>Physical Area (40 nm process)</td>
<td>124 µm by 350 µm</td>
<td>244 µm by 350 µm</td>
<td>350 µm by 350 µm</td>
<td>830 µm by 350 µm</td>
</tr>
</tbody>
</table>
Flexsupply™ Switched Capacitor Regulated Doubler

For powering a fixed 2.5 V circuit from variable-voltage battery.

<table>
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<tr>
<th>Parameters</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Power Supply</td>
<td>1.6 to 3.63 V</td>
</tr>
<tr>
<td>Output Voltage</td>
<td>2.5 V</td>
</tr>
<tr>
<td>Maximum Power Efficiency</td>
<td>± 70%</td>
</tr>
</tbody>
</table>

- Die area is based on current requirements
  - Can support 1 mA, 4 mA, 10 mA, etc.
- SLEEP mode supported
- Allows products to continue to perform even at ultra-low battery levels (down to 1.6 V)
- Handles extremely fast/high/long load transients
- Achieves a smooth output voltage with small ripples
- Fully integrated – no external components required
- Silicon-proven in TSMC 40 nm ULP and ULP with embedded flash processes suitable for IoT applications
Low-Power Voltage References

- Voltage References
- Low-Dropout Regulators
- DC/DC Converters
- Foundational Blocks
- Serial Interface
- State Machine Control Logic
ACCUREF™ Voltage and Current Reference IP

For generating a precise, adjustable reference voltage.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Power Supply</td>
<td>2.5 to 5.0 V</td>
</tr>
<tr>
<td>Reference Accuracy (HP Mode)</td>
<td>± 0.3%</td>
</tr>
<tr>
<td>Reference Accuracy (LP Mode)</td>
<td>± 1.0%</td>
</tr>
<tr>
<td>Quiescent Current (HP Mode)</td>
<td>&lt; 20 µA</td>
</tr>
<tr>
<td>Quiescent Current (LP Mode)</td>
<td>&lt; 12 µA</td>
</tr>
<tr>
<td>Power Supply Rejection Ratio (at 100 KHz)</td>
<td>&gt; 90 dB</td>
</tr>
<tr>
<td>Temperature Range</td>
<td>-30 to 125ºC</td>
</tr>
</tbody>
</table>

- Silicon-proven in TSMC 130 nm BCD
- Ultra-low levels of power consumption without sacrificing accuracy or noise performance
- Fully integrated – no external components required
- Two modes of operation: High Performance (HP) and Low Power (LP)
- Integrated temperature sensor and current reference
  - Available without integration for increased area savings

![Diagram of ACCUREF™ Voltage and Current Reference IP](image-url)
# Low Power Voltage Reference – VVR060LT040

<table>
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<tr>
<th>Parameters</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Power Supply</td>
<td>2.8 to 4.2 V</td>
</tr>
<tr>
<td>Output Voltage Accuracy</td>
<td>± 12%</td>
</tr>
<tr>
<td>Power Supply Rejection (at &lt; 1 kHz)</td>
<td>&gt; 50 dB</td>
</tr>
<tr>
<td>Power Supply Rejection (at &lt; 10 kHz)</td>
<td>&gt; 10 dB</td>
</tr>
<tr>
<td>Quiescent Current</td>
<td>&lt; 0.9 μA</td>
</tr>
</tbody>
</table>

- No external components required
- Includes reference good status output
- Silicon-proven in TSMC 40 nm ULP process

![Diagram](image-url)
High-Accuracy Bandgap Voltage Reference – VBR120T040

- No external components required
- Includes bandgap good status output
- Silicon-proven in TSMC 40 nm ULP process

<table>
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<tr>
<th>Parameters</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Power Supply</td>
<td>2.8 to 4.2 V</td>
</tr>
<tr>
<td>Output Voltage Accuracy (untrimmed)</td>
<td>± 4%</td>
</tr>
<tr>
<td>Output Voltage Accuracy (trimmed)</td>
<td>&lt; ± 1%</td>
</tr>
<tr>
<td>Power Supply Rejection (at &lt; 1 kHz)</td>
<td>&gt; 60 dB</td>
</tr>
<tr>
<td>Power Supply Rejection (at &lt; 10 kHz)</td>
<td>&gt; 20 dB</td>
</tr>
<tr>
<td>Quiescent Current</td>
<td>&lt; 40 µA</td>
</tr>
</tbody>
</table>

- No external components required
- Includes bandgap good status output
- Silicon-proven in TSMC 40 nm ULP process
Foundational Blocks

- Voltage References
- Low-Dropout Regulators
- DC/DC Converters
- Serial Interface
- State Machine Control Logic
Available Features

- Enable/Disable
- Soft Start/Soft Shutdown
- Over-Current Shutdown
- Over-Temperature Shutdown
- Undervoltage Detection & Lockout (UVLO)
- Overvoltage Detection
- Power-on-Reset
- Power Switch
Dual Power Switch – VPS0002T040

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Power Supply</td>
<td>1.85 V</td>
</tr>
<tr>
<td>Unswitched Power Input</td>
<td>1.85 ± 5%</td>
</tr>
<tr>
<td>Maximum Continuous Through-Current (each switch)</td>
<td>30 mA</td>
</tr>
<tr>
<td>Maximum Voltage-Drop (at 30 mA each, both switches on)</td>
<td>10 mV</td>
</tr>
</tbody>
</table>

- Includes in-rush current limiting
- Silicon-proven in TSMC 40 nm ULP process
PMU Communication and Control

Foundational Blocks
- Voltage References
- Low-Dropout Regulators
- DC/DC Converters

State Machine Control Logic
Serial Interface
We can combine several Vidatronic IP blocks into a single power management unit for integration into your SoC.

Silicon-proven in TSMC 40 nm ULP.

<table>
<thead>
<tr>
<th>Power Management Unit – VPM0140T040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two Power Quencher® LDOs</td>
</tr>
<tr>
<td>One Low Power Voltage Reference</td>
</tr>
<tr>
<td>One Dual Power Switch</td>
</tr>
<tr>
<td>Two Buck DC-DC Converters</td>
</tr>
<tr>
<td>One High-Accuracy Bandgap Reference</td>
</tr>
</tbody>
</table>
FOR MORE INFORMATION, VISIT

www.vidatronic.com/ip-solutions