Redefining Low-Power Design With Silicon, System and Software Techniques

Arrow Vision Series

Silicon Labs
What is Power?

- Examples of high-power systems
- Examples of low-power systems
Why Is Power Efficiency Important?

- Regardless of the power source, an embedded system benefits from being power efficient
  
  - **Extended battery life**—battery-operated embedded systems can operate for a long time without replacing the battery
  
  - **Lower cost**—reduce number of batteries, move to cheaper batteries or use lower cost components for the power supply
  
  - **Increased reliability**—product life increases when the system operates at a lower temperature; reducing heat dissipation can prolong system life
  
  - **Energy compliance**—meet the increasing number of regulatory compliance standards (Energy Star, Ecolabels, One Watt Initiative)
Complexity of Low-Power System Design

- Design effort is proportional to design target
  - 10 mA → effort
  - 10 µA → 10X effort
  - 10 nA → 100X effort

- Different applications (use cases) require different approaches
  - Active mode vs. sleep mode requirements will vary by application
  - Applications may use different types of sensors, communication methods

Run-Time
- Clocking only what is necessary, as fast as necessary
- Voltage scaling proportional to clock speed

Environmental
- Trade-offs between data retention and current leakage at high temperature

Life Cycle
- Batteries (supply voltages) degrade over time
- Electrical characteristics may drift over time

Optimizations Needed for Many Scenarios
Silicon Considerations - Minimize Average Current

- **Typical Application**
  - Wake-up
  - Perform task in active mode
  - Go to sleep

- **Goal is to minimize average current**

### Graph:
- **Current**
  - $I_{AVG}$ (line)
  - Sleep mode
  - Wake-up time
  - Active mode
  - Smart Wake Events

- **Time**
  - $I_{AVG}$ (line)

- **Legend:**
  - High sleep current
  - Slow wake up time
  - High active mode current
  - Slow CPU
  - Low sleep current
  - Fast wake up time
  - Low active mode current
  - Fast CPU
Address All Aspects of Low Power Design

- **Sleep: reduce power, do more**
  - Sleep as long as possible
  - Wake quickly from RTC, pin, data traffic
  - Every nanoamp counts

- **Active: reduce power and time**
  - Lower the core voltage
  - Run at optimal clock speed
  - Reduce number of CPU cycles

- **System: reduce wasted power**
  - DC-DC “buck” converter reduces active mode power as much as 40%
  - Use lowest power modes available
  - Beware of delay loops, weak pull-ups, flash boundaries, etc.
Reducing the Sleep Mode Power

- Stay asleep as long as possible using sleep mode peripherals
- Reduce power by eliminating regulator and optimizing peripherals

### Sleep Mode Power Budget

<table>
<thead>
<tr>
<th>Sleep Mode Peripherals e.g. UART, counter, comparator, sensor i/f</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power optimized RTC</td>
</tr>
<tr>
<td>Power optimized segment LCD</td>
</tr>
<tr>
<td>Wake from pin, RTC, or data traffic</td>
</tr>
<tr>
<td>Memory and state retention</td>
</tr>
</tbody>
</table>

**Important for sleep mode**
Reducing the Active Mode Power

- Minimize active mode time with fast wake, DMA, HW accelerators
- Advance power management unit to reduce active mode power

**Active Mode Power Budget**

- **Sleep**
- **Active**
- **System**

**Important for active mode**

- Fast wake from sleep mode (<5us)
- Direct memory access (DMA)
- HW accelerators e.g. AES, CRC, encoder
- Voltage scaling
- Selective clock gating
- Optimizing clock speed
Reducing the Total System Power

- Efficiently convert input voltage to lowest operating core voltage
- Analyze and optimize all parts of the system for power reductions

**System Power Budget**

**Tips for system power reduction**

- Efficiently convert energy with dc-dc converter and LDO regulators
- Execute code out of RAM
- Interrupt driven SW vs delay loops
- Beware of weak pull-ups
- Use Power Estimator tool to optimize overall power
High-Efficiency Voltage Regulation

DC-DC conversion results in up to 40% less current than using an LDO regulator.

Total draw from the battery

Traditional MCU

- LDO + HEAT

- RF XCVR

- LDO (for rest of chip) + HEAT (wasted energy)

- Total draw from the battery: 24 mA @ 3.6V

SiM3L1xx

- LDO

- RF XCVR

- VDDRF

- DCDC

- SiM3L1xx

- Total draw from the battery: 14.5 mA @ 3.6V
Software Considerations

- In a perfect world
  - You wouldn’t have to read a reference manual
  - Code is written for you
  - Software could be designed before hardware
  - Errors are highlighted immediately
  - Power consumption is no longer a mystery
  - You can add features without working all weekend

AppBuilder makes the engineer’s job easier
Software Tools to Make Initialization Easy

- AppBuilder provides a simple GUI for the following:
  - Peripheral initialization and configuration
  - Pinout configuration
  - Clocking configurations supporting multiple power modes

Choose Peripherals

Add Properties

Define Pinout

No reference manuals required
Power Profiling: Knowing Is Half the Battle

- Quickly estimate and optimize power consumption
  - Highlights peripherals consuming the most current
  - Real-time updates as configurations change
  - Tips provide suggestions of ways to reduce power

AppBuilder with Power Profiling

Power Tips

- **Peripherals**
  - Disable any unwanted peripherals. Stopping the clock to the peripheral may disable the peripheral, but if the peripherals operate on a clock independent from the AHB or APB clocks, only the peripheral registers will be disabled.

- **Clocks**
  - If possible, switch to the internal oscillators to reduce power consumption.
  - Switch the AHB and APB clocks to Low Power Oscillator.
Create Different Power Modes

- Easily create multiple mode configurations
  - Each mode has its own canvas with independent settings
    - Examples: sleep mode, active with ADC mode, active without ADC mode
  - Mode transitions make switching between modes painless

Create modes

Select peripherals
set properties

Define mode transition
Fixing Errors Made Easy

- Non-intrusive window highlights errors
- Double clicking on error jumps to appropriate window and highlights cause
- Saves designers hours of frustration

```
Error in configuration highlighted
```

```
Error description in the Error List also shows the source peripheral and the mode
```

```
Why won't this work!
```
### Other Important AppBuilder Features

#### View Source Code

```c
if (defined(SI32_NO_PINRESET_DELAY))
#else
if (SI32_RSTSRC_0->RESETFLAG.PINRF == 1)
if (SI32_RSTSRC_0->RESETFLAG.PORRF == 0)
if (SI32_RSTSRC_0->RESETFLAG.VMONRF == 0))
{
    // Set the SysTick timer to count down 10M ticks at 20MHz (500 nsec)
    SysTick->LOAD = 0x0A000000;
    SysTick->VAL = 0;
    SysTick->CTRL = SysTick_CTRL_CLKSOURCE_Msk | SysTick_CTRL_ENABLE_Msk;
}
```

#### Set up clocking

- LPOSC0 (20 MHz)
- LPOSCDV0 (2.5 MHz)
- EXTOSC0 (32.768 kHz)
- RTC0 (32.768 kHz)
- LFOSCO (32.768 kHz)
- PLL0 (46.08 MHz)
- USB0 (18 MHz)

#### Print Pinout

64 pin TQFP

#### Export to IDE

- Precision32
- Keil
- IAR

### Export Source

- Target Toolset: Precision32
- Target Compiler: GCC
- Export Location: C:\Users\sntada...
- Workspace option:
- Open After Export: [ ]
Free Comprehensive IDE & Compiler

- Project explorer, core registers, and peripherals views
- Debug view
- Code Editor view
- Console and Memory views
- SDK Selector
- Human readable registers
- Quickstart view
Introducing the SiM3L1xx Family
Lowest Power 32-bit MCUs
Introducing the Lowest Power 32-bit MCUs

Precision32™
L-series ultra low power MCUs

Ultra-low-power MCU family based on ARM® Cortex™-M3 core
<250 nA in sleep with RTC, full memory retention and 3.8 μs wake
175 μA/MHz in active from flash at 3.6V
580 nA LCD controller for 4 x 40 active segments with contrast
“Power-aware” software tools to minimize system power
Rich set of autonomous peripherals
32 – 256 kB flash memory sizes
SiM3L1xx – Inside the Lowest Power 32-bit MCUs

- **Flexibility built in to adapt to a wide range of applications**
  - Goal #1: Stay in sleep mode as much as possible
  - Goal #2: Optimize active mode for lowest power
  - Goal #3: Offer flexibility to adapt to different use cases

- **Active mode optimizations**
  - Dc-dc converter reduces power consumption
  - Data Transfer Manager (DTM) offloads CPU
  - Static and dynamic voltage scaling
  - Redesigned LCD controller reduces physical display power consumption

- **Sleep mode optimizations**
  - RAM and register retention with fast wake-up
  - Peripherals operate autonomously while in sleep mode
  - Nine peripheral wake sources and up to 14 pin wake sources

Architecture and peripherals engineered to achieve lowest power consumption
Ultra-Low-Power Solution for “Internet of Things”

Wirelessly-connected devices for the IoT

Smart water, gas and heat meters

Security and energy monitoring

Home and building automation

Key Needs

Ultra-low power
Battery-optimized
Wireless connectivity
Sensor flexibility
Small form factor
Use Case – Achieving Ultra-Low Power

- Applications can be grouped into three categories:
  - Those that care mostly about active mode power
  - Those that care mostly about sleep mode power
  - Those that have varying duty cycles and need optimization for both modes

- SiM3L1xx family was designed from the ground up to optimize each one of these use cases

![Power consumption diagram](image)
Battery-powered applications pose a unique set of design challenges

Many common battery chemistries support >3V operation
- However, circuits inside the MCU typically require 1.8 V or less
- Instead of using an inefficient linear regulator, the SiM3L1xx MCU uses an industry-first:
  *a high-efficiency dc-dc converter to power the MCU*

High-efficiency dc-dc converter reduces active mode power by 40%
- Extends the life of the battery
- Enables the use of smaller (less expensive) batteries

System-level power consumption depends on many variables
- MCU, sensors, wireless transceivers, other external components, etc.

External components can be powered using the integrated dc-dc converter
- Configuring the dc-dc output to the lowest acceptable setting of other components connected to the MCU reduces overall system power
Use Case – Wireless Connectivity

- IoT applications that require wireless connectivity are especially challenged to keep overall system power down

- **Data Transfer Manager (DTM) provides a unique solution**
  - Targeted for constructing or receiving radio packets
  - Autonomous operation without CPU intervention

- **Other SiM3L1xx peripherals can also operate without CPU intervention**
  - Allows the MCU to stay in sleep mode longer or perform other tasks

- **Autonomous peripheral benefits**
  - Extends battery life by providing 30-40% power savings

![Diagram showing the flow of data from Raw Data through AES Encryption, CRC, Encoder, SPI to Radio TX, with DMA and DTM connections.](image-url)
Use Case – Sensor Flexibility

- Applications increasingly depend on sensors to provide information

- The SiM3L1xx family implements an innovative Sensor Interface Manager to enhance the ability to interface to sensors
  - Based on an analog front-end (AFE) stimulus and response architecture
  - Supports capacitive, inductive, Wheatstone bridge/resistive divider, Reed switch/pulse output, and switch closure topologies
  - Fully programmable excitation block (duration, period)
  - Fully programmable inputs (threshold-based, sampling rates, counting modes)

- Sensor interface operates in sleep mode
  - Current consumption approximately 500 nA @ 2 msec scan rate
Full-Featured Low-Power Enablement

- Low-power peripherals can operate while in sleep mode
  - LCD controller
  - Real-time clock (RTC)
  - UART
  - Sensor interface
  - Comparator
  - Low-power timer
  - Pin wake

- Redesigned LCD controller to reduce display current

- Full RAM and state retention while in sleep mode

- Variety of configurable wake-up sources
  - 9 peripheral wake sources
  - Up to 14 pins for wake-up

- Flexibility to dynamically scale voltages
Example #1: Smart Metering Applications

- **Ideal for battery-powered metering applications**
  - Ultra-low-power operation for long battery life
  - Flexible, low-power sensor and LCD interfaces

- **Sensor interface supports variety of circuits**
  - Digital inputs
  - Switch topology circuits (reed switches)
  - LC resonant circuits

- **SiM3L1xx MCUs are optimized for metering applications:**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Function</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor interface</td>
<td>Measures usage of meter</td>
<td>Reduces size and BOM cost</td>
</tr>
<tr>
<td>LCD controller</td>
<td>Efficiently control external display</td>
<td>Reduces system power</td>
</tr>
<tr>
<td>dc-dc converter</td>
<td>Improves battery efficiency</td>
<td>Longer battery life and reduced system cost</td>
</tr>
<tr>
<td>Ultra-low-power sleep mode</td>
<td>50 nA sleep mode, 200 nA sleep mode with RTC</td>
<td>Further reduction in battery life and system cost</td>
</tr>
<tr>
<td>Small 5.5 mm x 5.5 mm package</td>
<td>Small circuit footprint</td>
<td>Fits into space-constrained modules</td>
</tr>
</tbody>
</table>
Example #2: Battery-Powered LCD Applications

- Many end products requiring an LCD are battery powered
  - Fitness monitors, remote controls, handheld electronics, etc.
- Integrated LCD controller reduces power consumed by the display by 40%
  - Includes mode to maintain constant LCD contrast over entire product life
  - MCU solution for power-sensitive applications requiring an LCD
- SiM3L1xx MCUs are optimized for battery-powered LCD applications:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Function</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCD controller</td>
<td>Provides low-power LCD interface to MCU</td>
<td>Reduces power consumed by display by 40%</td>
</tr>
<tr>
<td>50 MHz ARM Cortex-M3</td>
<td>Provides high-performance processing</td>
<td>Allows MCU to perform many tasks in a short amount of time</td>
</tr>
<tr>
<td>Low-power charge pump</td>
<td>Powers sleep mode logic at lower voltages</td>
<td>Reduces system power</td>
</tr>
<tr>
<td>Analog peripherals</td>
<td>Best-in-class analog (ADC, VREF, IDAC, Comparators)</td>
<td>Reduces system cost</td>
</tr>
<tr>
<td>Up to 23 wake sources</td>
<td>Allows MCU to stay in sleep mode as long as possible</td>
<td>Reduces system power</td>
</tr>
</tbody>
</table>
Example #3: Wireless Connected Devices for IoT

- Dedicated peripherals (DTM, AES crypto block, run-time encoder) accelerate processing of radio protocol without CPU intervention
  - Greatly reduces active-mode power
- Low-power, high-performance and small footprint
- SiM3L1xx MCUs are optimized for wireless connected devices:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Function</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIO RF power option</td>
<td>Powers RF portion of system</td>
<td>Interfaces with radio operating at a different voltage from MCU</td>
</tr>
<tr>
<td>DTM and DMA</td>
<td>Create autonomous chain of events</td>
<td>Reduces CPU overhead</td>
</tr>
<tr>
<td>dc-dc converter</td>
<td>Improves battery efficiency</td>
<td>Longer battery life and powers can power radio</td>
</tr>
<tr>
<td>Hardware encryption</td>
<td>Encrypt/decrypt data in hardware</td>
<td>Reduces CPU overhead</td>
</tr>
<tr>
<td>Dynamic voltage scaling</td>
<td>Scales voltage in response to application conditions</td>
<td>Enables longer battery life</td>
</tr>
</tbody>
</table>
SiM3L1xx Competitive Analysis

- **Silicon Labs’ value proposition**
  - Lowest power 32-bit MCU on the market, rich set of autonomous low-power peripherals including on-chip dc-dc converter and LCD controller

<table>
<thead>
<tr>
<th></th>
<th>Silicon Labs SiM3L1xx</th>
<th>Silicon Labs C8051F96x</th>
<th>Competitor1</th>
<th>Competitor2</th>
<th>Competitor3</th>
<th>Competitor4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Core</strong></td>
<td>32b - CM3</td>
<td>8b - 8051</td>
<td>16b proprietary</td>
<td>32b - CM3</td>
<td>32b - CM3</td>
<td>32b - CM3</td>
</tr>
<tr>
<td><strong>Max Speed</strong></td>
<td>50 MHz</td>
<td>25 MHz</td>
<td>25 MHz</td>
<td>32 MHz</td>
<td>32 MHz</td>
<td>72 MHz</td>
</tr>
<tr>
<td><strong>Flash (up to)</strong></td>
<td>256 kB</td>
<td>128 kB</td>
<td>128 KB</td>
<td>128 kB</td>
<td>256 kB</td>
<td>256 kB</td>
</tr>
<tr>
<td><strong>RAM (up to)</strong></td>
<td>32 kB</td>
<td>8 kB</td>
<td>8 kB</td>
<td>16 kB</td>
<td>32 kB</td>
<td>64 kB</td>
</tr>
<tr>
<td><strong>LCD</strong></td>
<td>4x40</td>
<td>4x32</td>
<td>8x40,4x44</td>
<td>4x40</td>
<td>8x40,4x44</td>
<td>4x40,8x36</td>
</tr>
<tr>
<td><strong>Pins</strong></td>
<td>40,64,80</td>
<td>40,76</td>
<td>80,100</td>
<td>100</td>
<td>64,100,132,144</td>
<td>100,104</td>
</tr>
<tr>
<td><strong>Sleep RTC @ 3 V</strong></td>
<td>200 nA</td>
<td>570 nA</td>
<td>2500 nA</td>
<td>900 nA</td>
<td>1700 nA</td>
<td>670 nA</td>
</tr>
<tr>
<td><strong>Sleep + LCD w/contrast</strong></td>
<td>950 nA</td>
<td>1500 nA</td>
<td>4100 nA</td>
<td>8950 nA</td>
<td>7800 nA</td>
<td>(not specified)</td>
</tr>
<tr>
<td><strong>Active Idd @ 3.6 V</strong></td>
<td>175 µA/MHz</td>
<td>130 µA/MHz</td>
<td>265 µA/MHz</td>
<td>180 µA/MHz</td>
<td>233 µA/MHz</td>
<td>&gt;300 µA/MHz</td>
</tr>
<tr>
<td><strong>Wakeup</strong></td>
<td>4 µsec</td>
<td>2 µsec</td>
<td>3 µsec</td>
<td>2 µsec</td>
<td>46 µsec</td>
<td>300 µsec</td>
</tr>
<tr>
<td><strong>HW AES</strong></td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><strong>Special feature</strong></td>
<td>Buck</td>
<td>Buck</td>
<td>ΔΣ ADC</td>
<td>12b DAC</td>
<td>EEPROM, USB</td>
<td>16b ADC</td>
</tr>
</tbody>
</table>
Development Tools, Software and Collateral

**Tools**
- Silicon Labs’ Precision32 development suite (**free!**)
  - Free Eclipse-based development suite including IDE, compiler and debugger
- AppBuilder GUI configuration tool
  - Updated with Power Tips and Power Estimator
  - Provides firmware configuration guidance for low power

**Development kits**
- LCD and non-LCD development kits for $99.00 USD
  - Includes target board, cables, debug adapter
  - SiM3L1XXLCD-B-DK: SiM3L1xx LCD development kit
  - SiM3L1XX-B-DK: SiM3L1xx non-LCD development kit

**Software**
- Full set of code examples including examples that achieve critical data sheet specifications

DK Part #: SiM3L1XXLCD-B-DK

The SiM3L1xx Development Kit is available for **$99.00 USD**
### Precision32 Family

#### Flash Size (RAM Size)

<table>
<thead>
<tr>
<th>Flash Size</th>
<th>1 MB (128 kB)</th>
<th>512 kB (64 kB)</th>
<th>256 kB (32 kB)</th>
<th>128 kB (32 kB)</th>
<th>64 kB (16 kB)</th>
<th>32 kB (8 kB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C186</td>
<td>C176</td>
<td>C164</td>
<td>C154</td>
<td>C144</td>
<td>C134</td>
</tr>
<tr>
<td></td>
<td>U186</td>
<td>U176</td>
<td>U164</td>
<td>U154</td>
<td>U144</td>
<td>U134</td>
</tr>
<tr>
<td></td>
<td>L186</td>
<td>L176</td>
<td>L164</td>
<td>L154</td>
<td>L144</td>
<td>L134</td>
</tr>
<tr>
<td></td>
<td>C187</td>
<td>C177</td>
<td>C166</td>
<td>C156</td>
<td>C146</td>
<td>C136</td>
</tr>
<tr>
<td></td>
<td>U187</td>
<td>U177</td>
<td>U166</td>
<td>U156</td>
<td>U146</td>
<td>U136</td>
</tr>
<tr>
<td></td>
<td>L187</td>
<td>L177</td>
<td>L166</td>
<td>L156</td>
<td>L146</td>
<td>L136</td>
</tr>
</tbody>
</table>

#### Package Options
- QFN40 (6 mm x 6 mm)
- QFN64 (9 mm x 9 mm)
- TQFP64 (10 mm x 10 mm)
- BGA80 (5.5 mm x 5.5 mm)
- TQFP80 (12 mm x 12 mm)

#### Key
- Core line
- USB
- Low power
- Coming soon

### Low power, flexible and feature-rich 32-bit MCUs
- Integrated ADC(s), DAC(s), precision osc, Vref, temp sense
- Crossbar technology allows selectable peripherals and pins
## Precision32 Family Overview

<table>
<thead>
<tr>
<th>Features</th>
<th>SiM3C1xx</th>
<th>SiM3U1xx</th>
<th>SiM3L1xx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flash (KB)</td>
<td>16-1024</td>
<td>32-1024</td>
<td>32-1024</td>
</tr>
<tr>
<td>RAM (KB)</td>
<td>4-128</td>
<td>8-128</td>
<td>8-128</td>
</tr>
<tr>
<td>Speed (MHz)</td>
<td>80</td>
<td>80</td>
<td>50</td>
</tr>
<tr>
<td>Package</td>
<td>24-81p</td>
<td>32-81p</td>
<td>24-81p</td>
</tr>
<tr>
<td>Sleep</td>
<td>85-600 nA</td>
<td>85-600 nA</td>
<td>75-350 nA</td>
</tr>
<tr>
<td>Wake up time</td>
<td>12 us</td>
<td>12 us</td>
<td>4 us</td>
</tr>
<tr>
<td>Active</td>
<td>275 uA/MHz</td>
<td>275 uA/MHz</td>
<td>175 uA/MHz</td>
</tr>
<tr>
<td>USB</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>UARTs/SPI/I2C/I2S</td>
<td>4/3/2/1</td>
<td>4/3/2/1</td>
<td>2/2/1/0</td>
</tr>
<tr>
<td>5V regulator</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Parallel i/f</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>DMA</td>
<td>16 ch</td>
<td>16 ch</td>
<td>10 ch</td>
</tr>
<tr>
<td>Timers / counters (16-bit)</td>
<td>15</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>ADC</td>
<td>2x12b</td>
<td>2x12b</td>
<td>1x12b</td>
</tr>
<tr>
<td>DAC</td>
<td>2x10b</td>
<td>2x10b</td>
<td>1x10b</td>
</tr>
<tr>
<td>Other</td>
<td>6 x 300mA IO 16ch CDC</td>
<td>6 x 300mA IO 16ch CDC USB XTAL</td>
<td>4x40 LCD DC converter Voltage scaling</td>
</tr>
</tbody>
</table>

*All Precision32 MCUs includes crossbar, dPLL, AppBuilder, 1.8-3.6V analog*
Keep these tips in mind when designing for low power

<table>
<thead>
<tr>
<th>Sleep mode</th>
<th>Active mode</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep mode peripherals</td>
<td>Fast wake (&lt;5us)</td>
<td>DC-DC converter</td>
</tr>
<tr>
<td>Power optimized RTC</td>
<td>Advanced DMA</td>
<td>Code from RAM</td>
</tr>
<tr>
<td>Power optimized LCD</td>
<td>HW accelerators</td>
<td>Interrupt driven</td>
</tr>
<tr>
<td>Memory retention w/o LDO</td>
<td>Voltage scaling</td>
<td>High-speed analog</td>
</tr>
<tr>
<td>Wake from pin, RTC, data</td>
<td>Clock gating</td>
<td>Power estimator in SW</td>
</tr>
<tr>
<td>Sleep mode charge pump</td>
<td>Clock speed flexiblity</td>
<td>Power tips</td>
</tr>
</tbody>
</table>

Sleep

Active

System