SPV1050: Ultra Low Power Energy Harvester and Battery Charger with embedded MPPT and LDOs.

Alessandro Nicosia
Photovoltaic and Metering Technical Marketing Manager
STMicroelectronics Catania, Italy
alessandro.nicosia@st.com

EnSsys – Roma
Università La Sapienza - 14/11/2013
Agenda

- STMicroelectronics: Some Facts…
- SPV1050: Response to New Market Requirements
- Wireless Sensor Nodes Expected Worldwide Market Growth
- SPV1050: ULP Energy Harvester and Battery Charger
  - Market Focus
  - MPPT algorithm benefits for PV cells and TEG
  - DC-DC Converter Architecture and features
  - Conversion Efficiency
  - Energy Harvester Evaluation Tool and GUI
  - Self Powered Intelligent Distributed Environment MonitoR (SPIDEr)
About ST

- A global semiconductor leader
  - The largest European semiconductor company
- 2011 revenues of $9.73B\(^{(1)}\)
- Approx. 50,000 employees worldwide\(^{(1)}\)
  - 12,000 people working in R&D
- 12 manufacturing sites
- Listed on New York Stock Exchange, Euronext Paris and Borsa Italiana, Milano

\(^{(1)}\) Including ST-Ericsson, a 50:50 joint venture with Ericsson
The Focus of our Wholly-owned Business

Target Markets
- Automotive
- Communications
- Computer & Peripherals
- Consumer
- Industrial & Other

Target Growth Applications
- Energy Management & Saving
- Trust & Data Security
- Healthcare & Wellness
- Smart Consumer Devices

Product Portfolio
- Multimedia Convergence Platforms
- Discrete & Integrated Power Devices
- Analog ICs & MEMS
- Microcontrollers (MCUs)
- ASICs
Market Megatrends

- Energy efficiency and cost
- Renewable energies
- Growing energy demand
- Environmental technology and sustainability
- IPC
- Building automation
- Factory automation
- LED lighting
- Hybrid and electric vehicles
Factory, home and building automation markets are more and more requiring the widespread adoption of sensors and actuators, but:

- **Cables** are becoming difficult and costly to draw in some places
- **Battery replacement** becomes a burden if widely used (e.g. large factory)
- **Manufacturing line down time** for sensors networks maintenance impacts factory efficiency

**SPV1050** overcomes current limitations by enabling **Autonomous Wireless Sensor Networks**
SPV1050: An ULP Power Manager to MAKE a Wireless Sensor Node autonomous

- Take a small portion of an otherwise lost flow of ambient energy and convert it into a small flow of USEFUL electrical energy
“Smart” Home Expected Market Growth

TAM of WSN based on energy harvesting can be roughly estimated in about 40% of the total, i.e. ~ 36M units on 2017.

Figure 2.5
World Market for All 'Smart Home' Nodes - By Application
Units Shipped - 000s Units

- Energy Management: Smart thermostats, HVAC controls, Environmental sensors, In-home displays, Smart plugs and appliances, water heaters, air conditioners and load control switches.
- Others: Smoke, CO detectors and alarms, alarm monitoring systems.
TAM of WSN based on energy harvesting can be roughly estimated in about 30% of the total, i.e. ~ 90M units on 2016.

*Source: IHS IMS Research, October 2012*
SPV1050: Market Focus

Remote monitoring:
- Air / climate
- Water / soil
- Indoor monitoring

Body monitoring:
- Healthcare
- Fitness
- Body Area Network

Industrial / Building Automation:
- Structural health monitoring
- Access Control
- Process monitoring
Maximum Power Point Tracking

- For **PV cells** the voltage at maximum power stays between 70% and 80% of open circuit voltage.

- For **TEG** the voltage at maximum power stays is half of open circuit voltage ($V_{oc}/2$).
MPPT Benefit vs Standard Solution

MPPT control allows to gain up to 30% of power from PV module during the charging process.
SPV1050: Boost Configuration
SPV1050: Buck-Boost Configuration
SPV1050 Features (1/2)

- Two harvesting front-end (PV Cells and TEG) with following input voltage ranges:
  - 180mV up to 8V (Buck-Boost Configuration)
  - 180mV up to 5V (Boost Configuration)
- Embedded MPPT algorithm with disable option
- Very accurate and programmable End of Charge voltage monitoring (± 1% accuracy max.) from 2.5V up to 5.3V
- Very accurate and programmable battery Under Voltage Protection (± 1% accuracy max.) from 2.1V up to 3.8V
- “Battery Disconnect” Function for disconnecting the battery to avoid battery depletion and shortening life time
- Embedded LDOs for regulated output capability with:
  - 1.8V and 3.3V voltage output
  - Output current up to 50mA
  - Independent Enable pins
SPV1050 Features (2/2)

• **Static Current Consumption:**
  - 1nA typ. in **Shutdown** *(Device switched OFF or battery in under-voltage protection)*
  - 1uA typ. in **Trickle charge** *(Continuous charging between EOC and EOC-Hysteresis)*
  - 1uA typ. in **Standby mode** *(source not connected)*
  - 1.9uA typ. with #1 **LDO** ON in open load *(no switching)*
  - 2.5uA typ. with #2 **LDOs** ON in open load *(no switching)*

• **Battery Status Flags/pins:**
  - **Battery Charging (BATT_CHG)**
  - **Battery Connected (BATT_CONN)**

• **MPPT Efficiency:**
  - ≥ 90% in any working condition

• **QFN 20 leads 3x3 package or die form**
Boost Mode: Conversion Efficiency Highlights…

For $I_{IN} = 1 \text{mA}$:

- Supports VSTORE = 3.0V, 3.7V, and 4.2V.

For $I_{IN} = 2.5 \text{mA}$:

- Supports VSTORE = 3.0V, 3.7V, and 4.2V.
Buck Mode: Conversion Efficiency Highlights…

Figure 13: Power Efficiency @ Tamb = 25°C, Imp = 100μA

Figure 14: Power Efficiency @ Tamb = 25°C, Imp = 1mA
Energy Harvester Evaluation Tool & GUI (1/2)

- SPV1050 based Evaluation Board including:
  - Photovoltaic module soldered on the back
  - Solid State Thin-Film battery with 700uAh cap.
  - Interface to the Power Monitoring board for measuring:
    - PV Voltage and Current
    - Battery Voltage and Current
    - Conversion Efficiency
    - Power extracted from Energy Harvesting Source
    - Power flowing into the battery
    - Irradiance and MPPT Accuracy
Energy Harvester Evaluation Tool & GUI (2/2)

MPPT

Efficiency, MPPT, Voc, # of Lux, Power budget

Power Monitoring
Self Powered Intelligent Distributed Environment Monitor

Autonomous Wireless Multi-Sensor based on SPV1050
SPIDER Overview (1/3)

Real-Time Orientation, Environmental Monitoring

Multiple Source Energy Harvesting

Temperature, Pressure

SUB-GIGA WIRELESS CONNECTION

MPPT, Efficiency, Battery Monitoring

Fully Configurable via PC

Fully Configurable via PC

STI
SPIDEr Overview (2/3)

Components only

Down to 10 µA avg. power consumption

PC Interface, TEG and PV Cells power source

All devices can be switched off by software
SPIDEr Overview (3/3)

Fully Configurable SW GUI for Sensor Data Graphical Visualization

- Air Pressure
- Harvesting & Power Monitoring
- RF Multi-Sensor Node
- Receiver Hub

Sensors Data Visualization Frequency Set-Up:
- 3-Axis Acceleration
- Ambient Temperature
- Air Pressure
- Harvesting & Power Monitoring
- RF Multi-Sensor Node
- Receiver Hub
## Energy Balance and Autonomy Time

- **Solid State thin-film battery**
  - Capacity: 700 µAh
- **PV Cell**
  - Output: $V_{oc} = 7.94$ V @ 350 lux
  - Setting: 915 MHz, 250 kb/s, 0 dBm
- **SPIRIT radio**

<table>
<thead>
<tr>
<th>Test case (*)</th>
<th>Energy Consumption</th>
<th>Energy harvesting</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$Tx$ period (s)</td>
<td>Avg. current (µA)</td>
<td>Avg. power (µW)</td>
</tr>
<tr>
<td><strong>Case A</strong></td>
<td>20</td>
<td>19.1</td>
<td>47.5</td>
</tr>
<tr>
<td>Measuring temperature, air pressure, acceleration (@ 1 Hz)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0h/24</td>
</tr>
<tr>
<td><strong>Case B</strong></td>
<td>180</td>
<td>10.0</td>
<td>25.1</td>
</tr>
<tr>
<td>Measuring temperature, air pressure (no acc, fewer transmissions)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0h/24</td>
</tr>
</tbody>
</table>

(*) 70% conversion efficiency assumed for SPV1050
Thanks for Your attention