

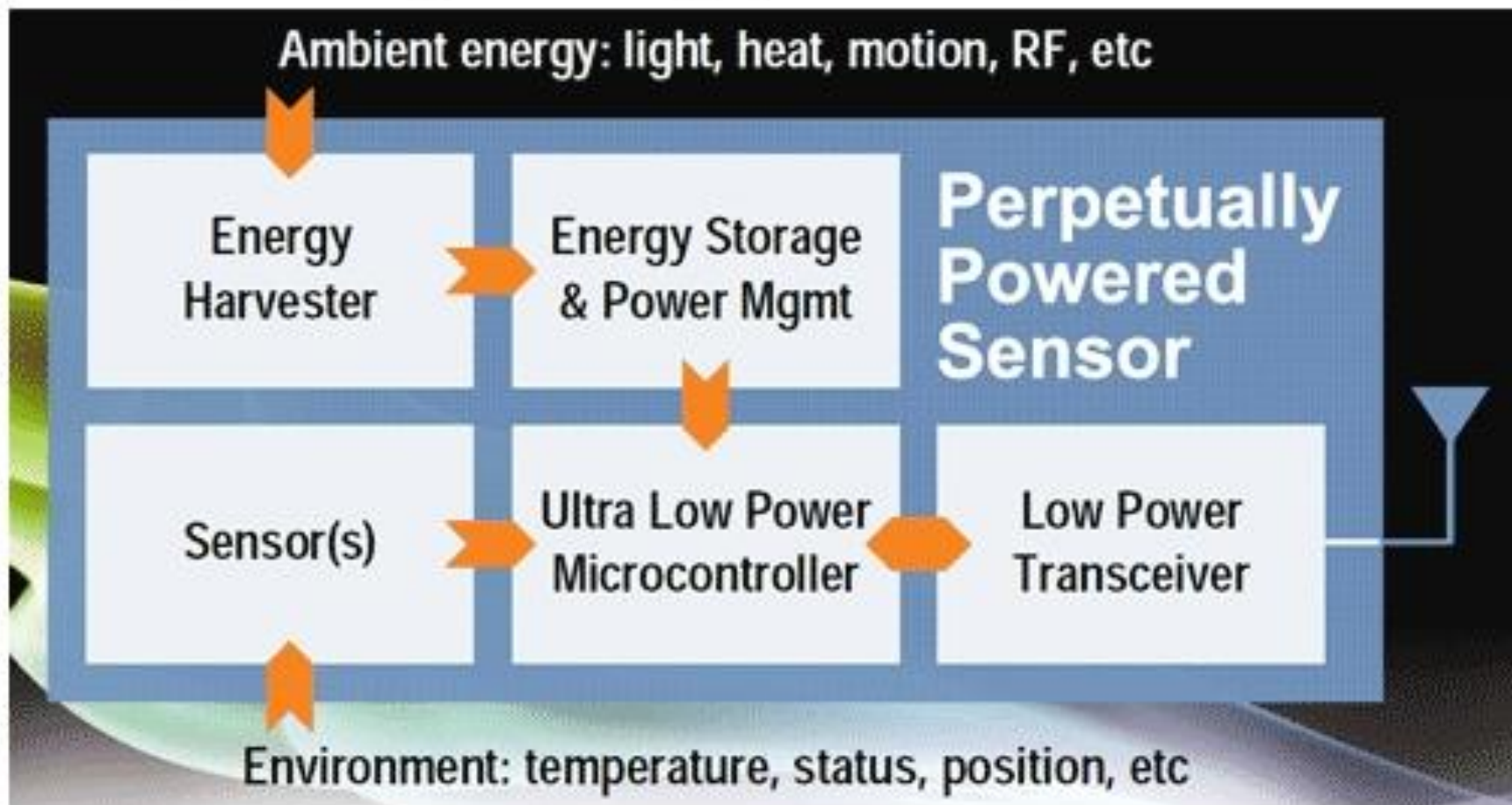
Ultra-Low Power Sensor Communications using Energy Harvesting

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Typical Energy Harvesting Architecture

Anatomy of an Energy Harvesting System



What's Interesting? SiLabs Dev Kit for \$45!



Features:

- The system can operate and Transmit using indoor lighting (@200 lux)
- Tiny Solid Battery is the Infinite Power Solutions THINERGY™ thin-film battery
- Sensor node operates at 919.84 MHz
- Wireless Sensor Distance is 100-300ft
- 15 Years Continuous Reporting
- SiLabs Si1012 Transceiver and CPU+

What's Interesting? SiLabs Dev Kit for \$45!

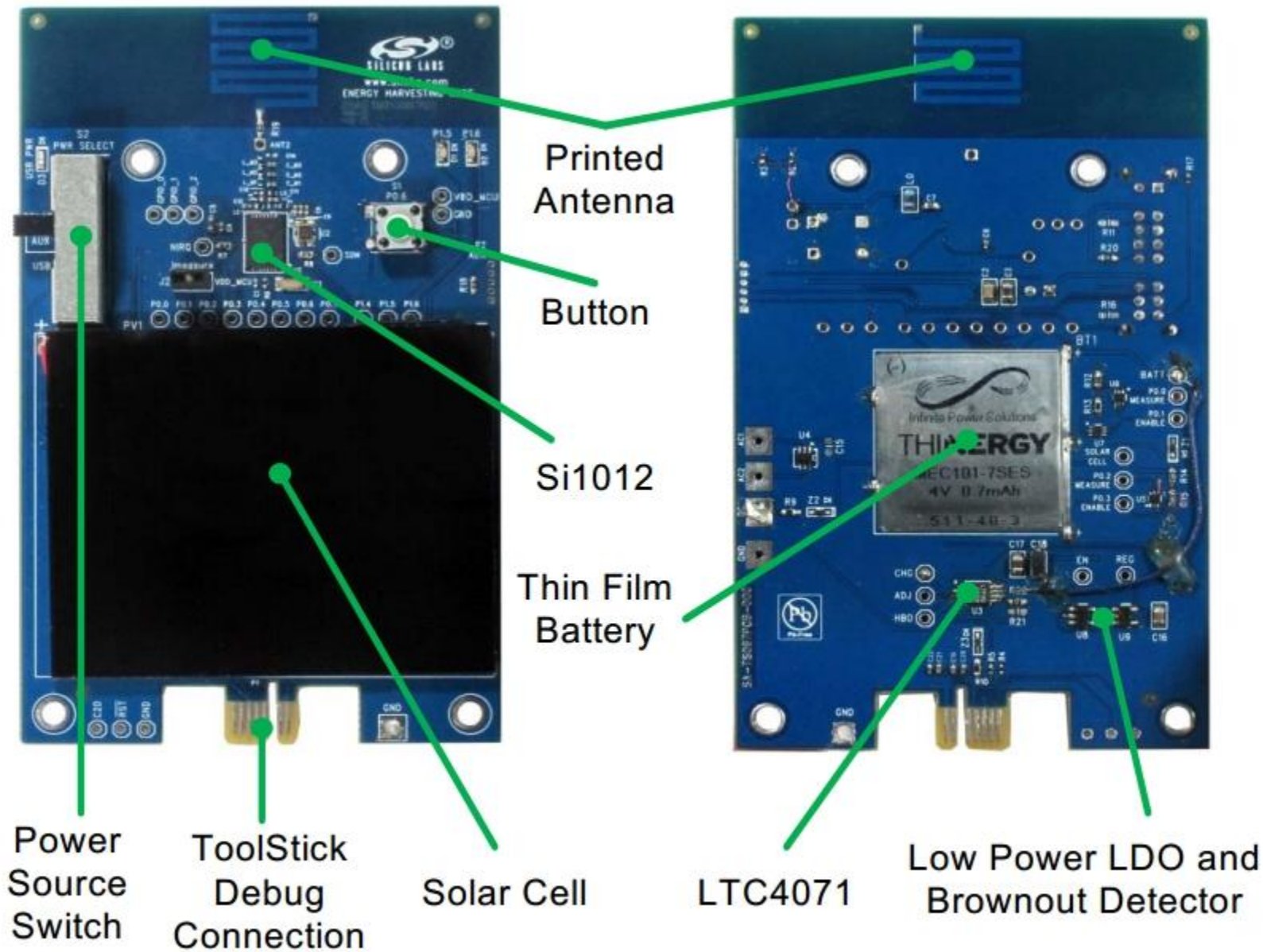
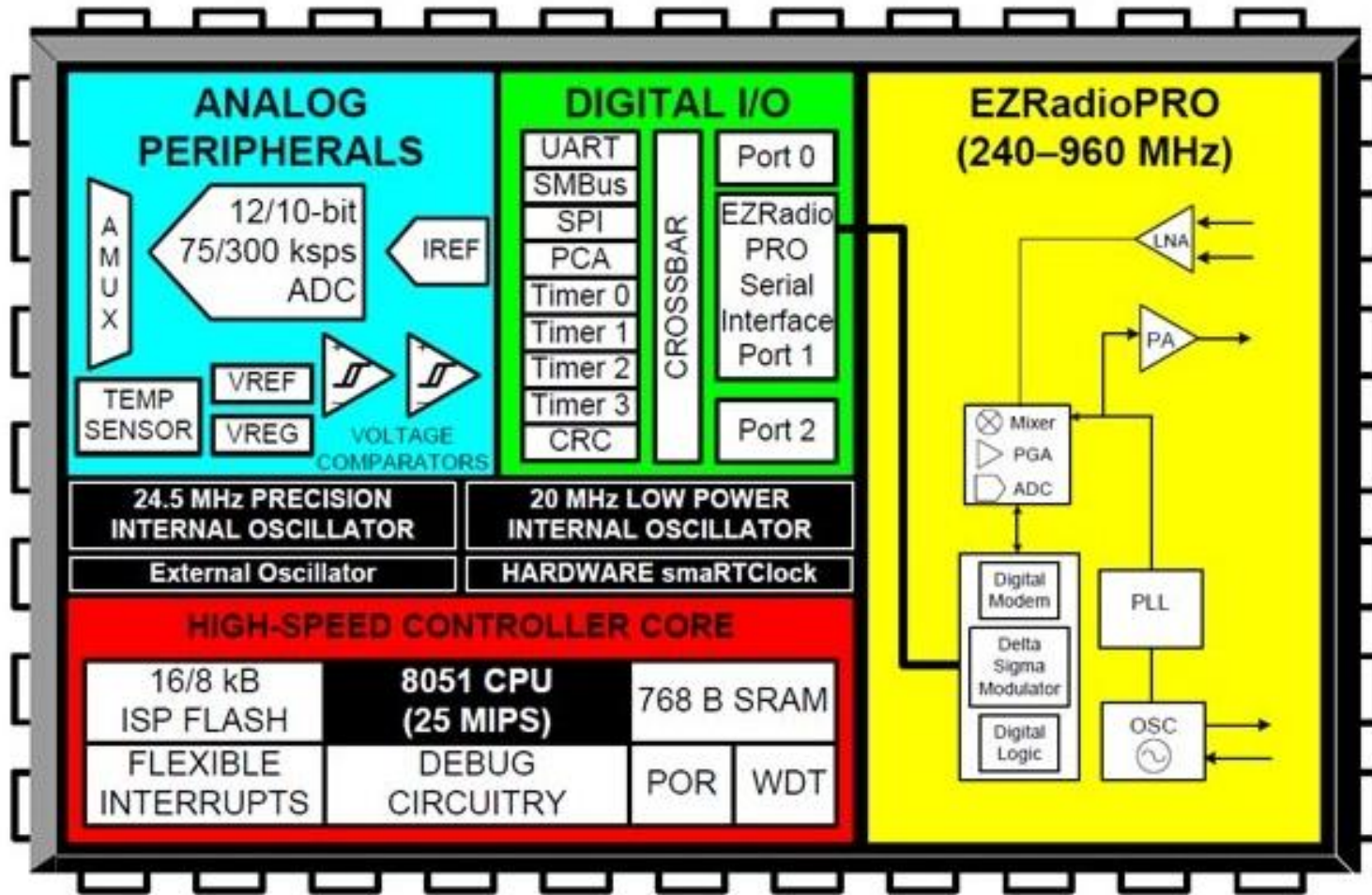


Figure 2. Si1012 Sensor Node

SiLab Si1012 Integrated Low-Power Single-Chip CPU, I/O, A/D ports and 240-960 MHz Transceiver!

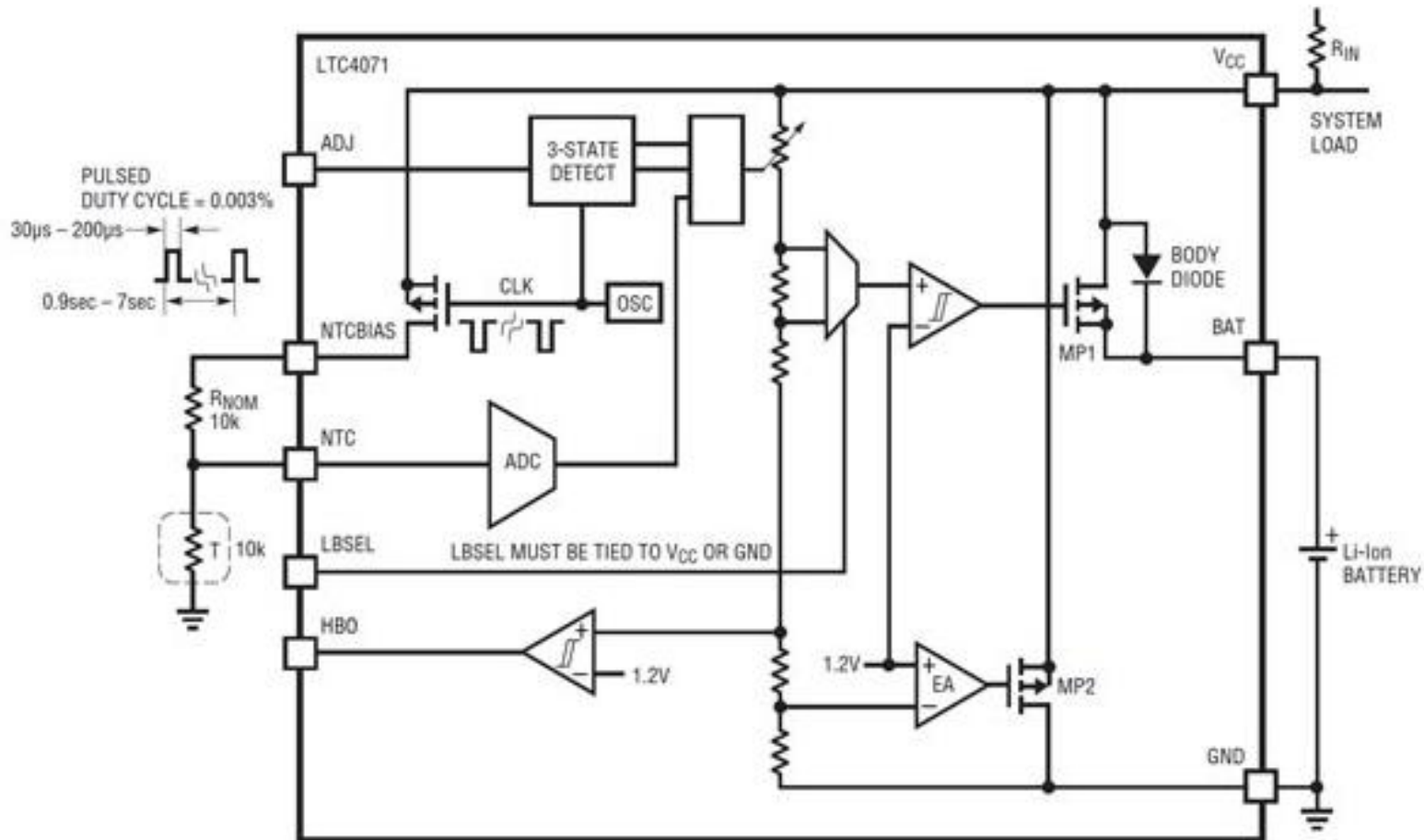


Hams – How about a Transverter for a Tiny Beacon?

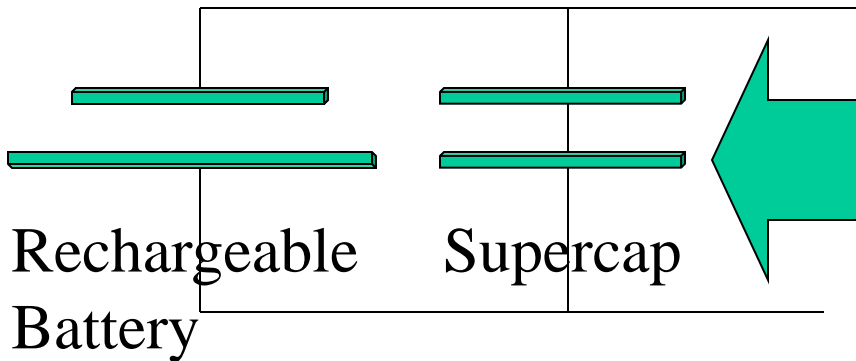
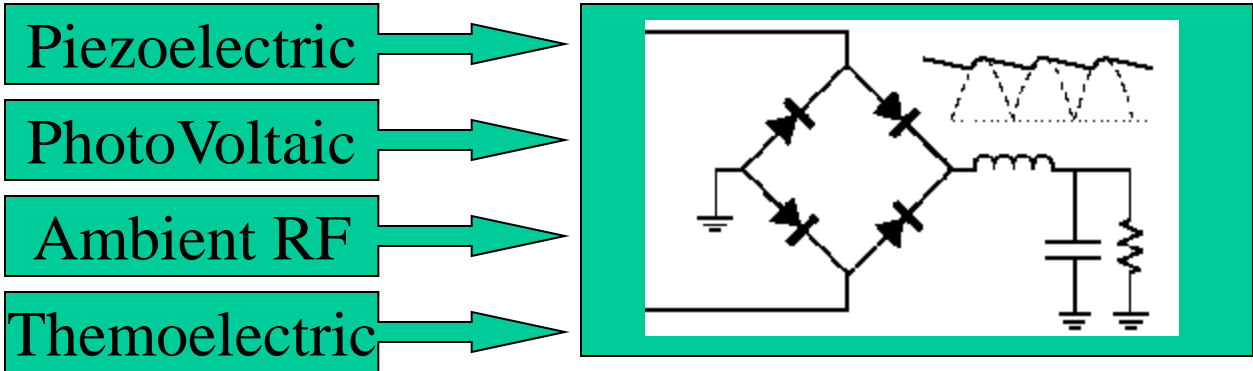
Technology LTC4071 Thin-Film Battery Charger

Features:

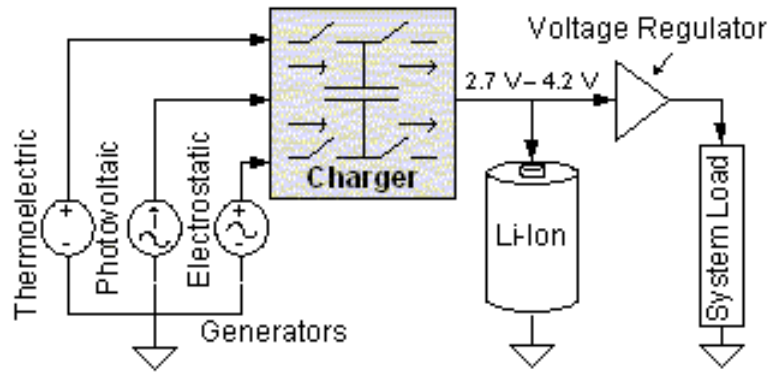
- Low-Voltage Boost Charger
- Constant 4.1 Voltage Output
- Compatible with Thin Film Battery
- Supplies Ultra-low power LDO, Analog Devices ADP162 Supply



Architecture of a Parasitic Power Supply

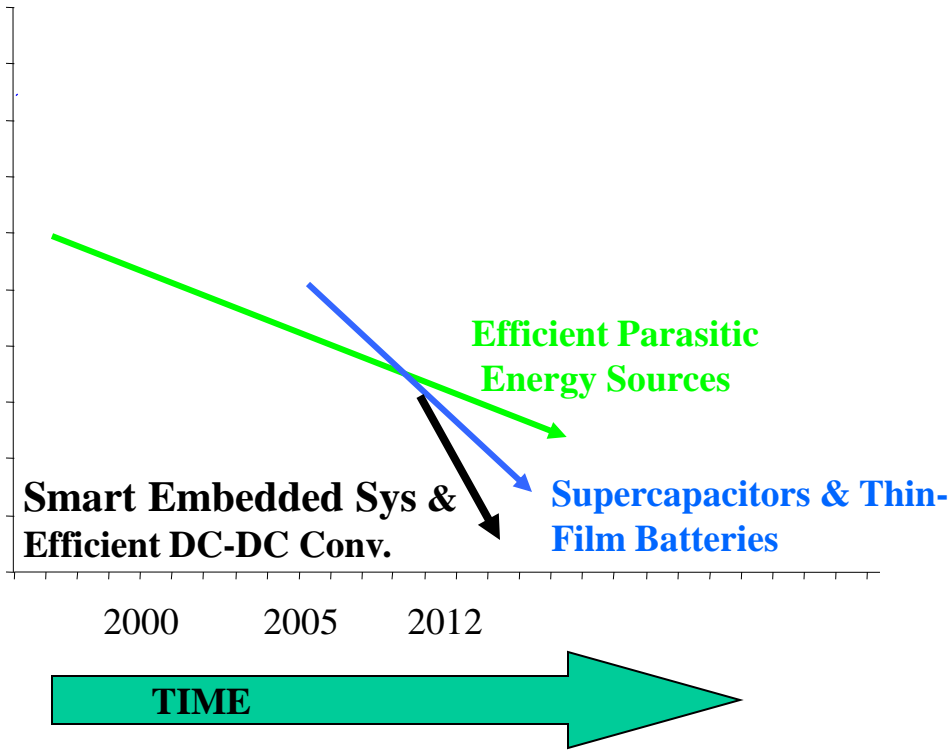
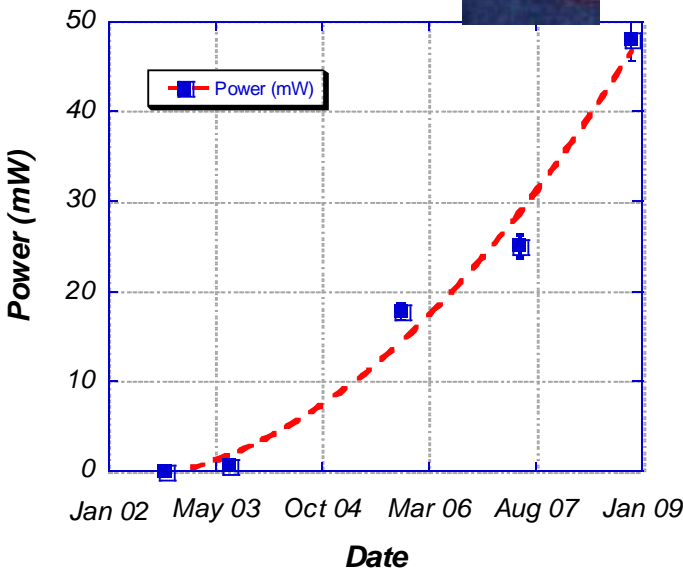


> 90%
EFFICIENT
DC-DC
Buck/Boost
Converter

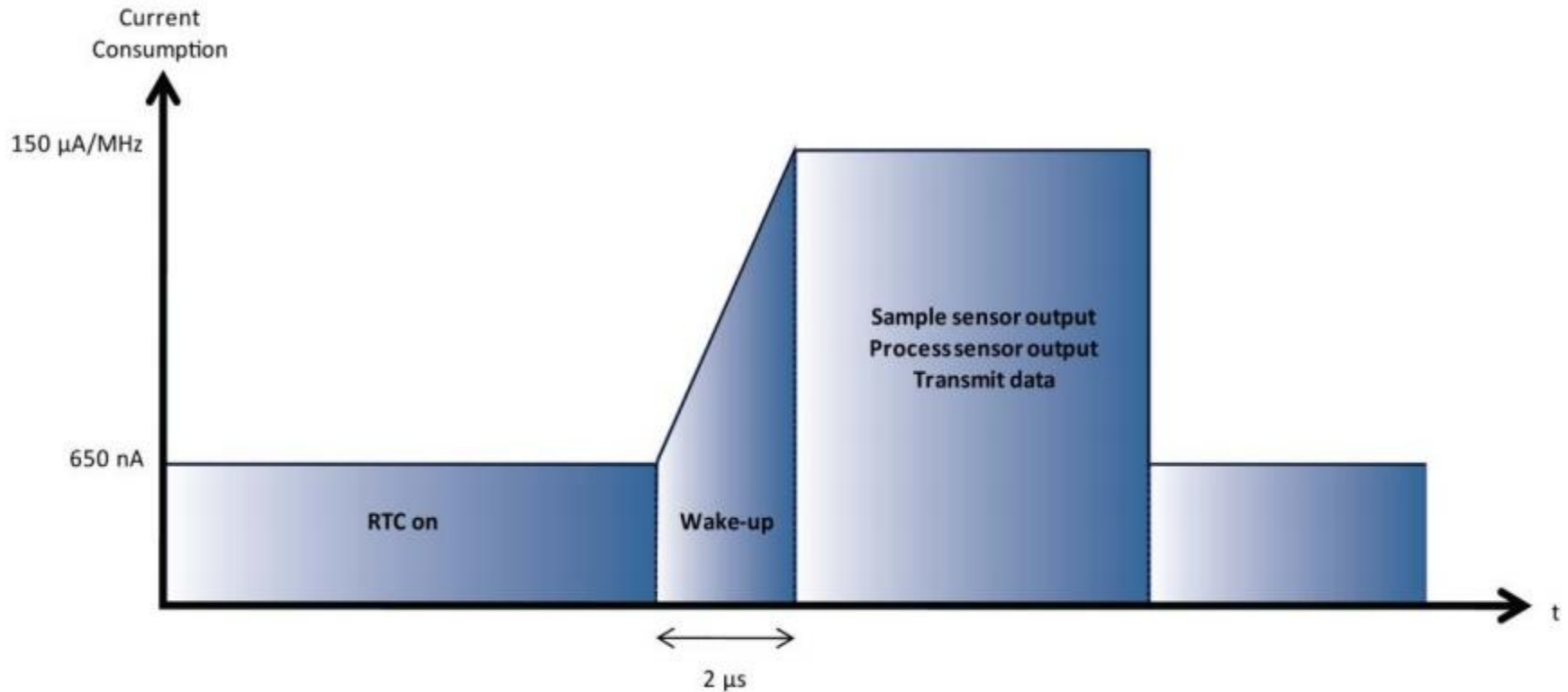
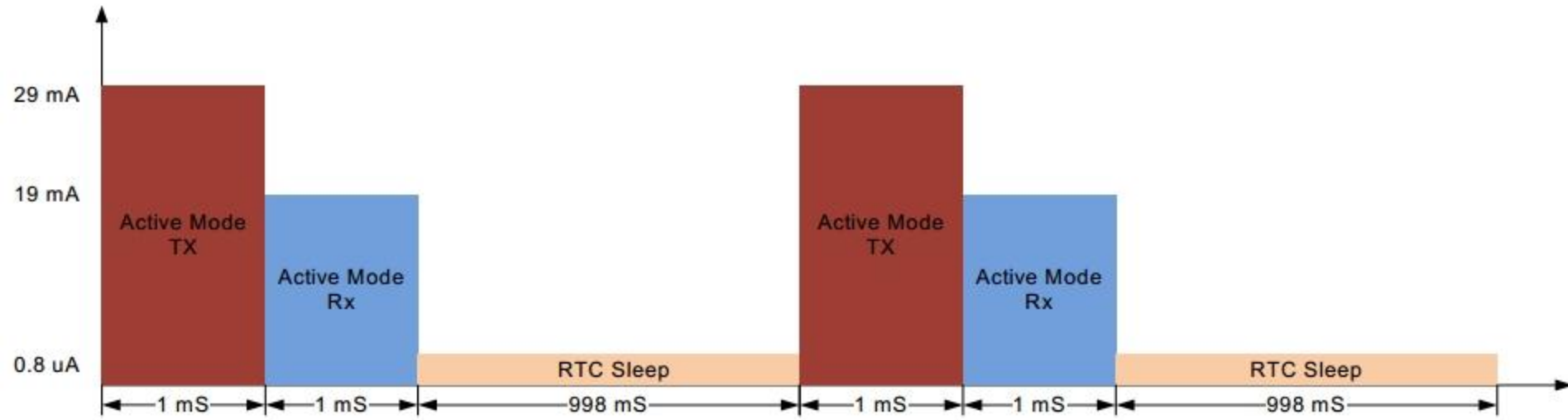


Why Solar or Energy Harvesting?

Three Intersecting Technologies in Time:



Secret of Lowest Power => Maximize RTC Sleep



Supercaps are Key - Enerchip Construction:

Single 6-Pin or 16-Pin SMT DFN/QFN Package

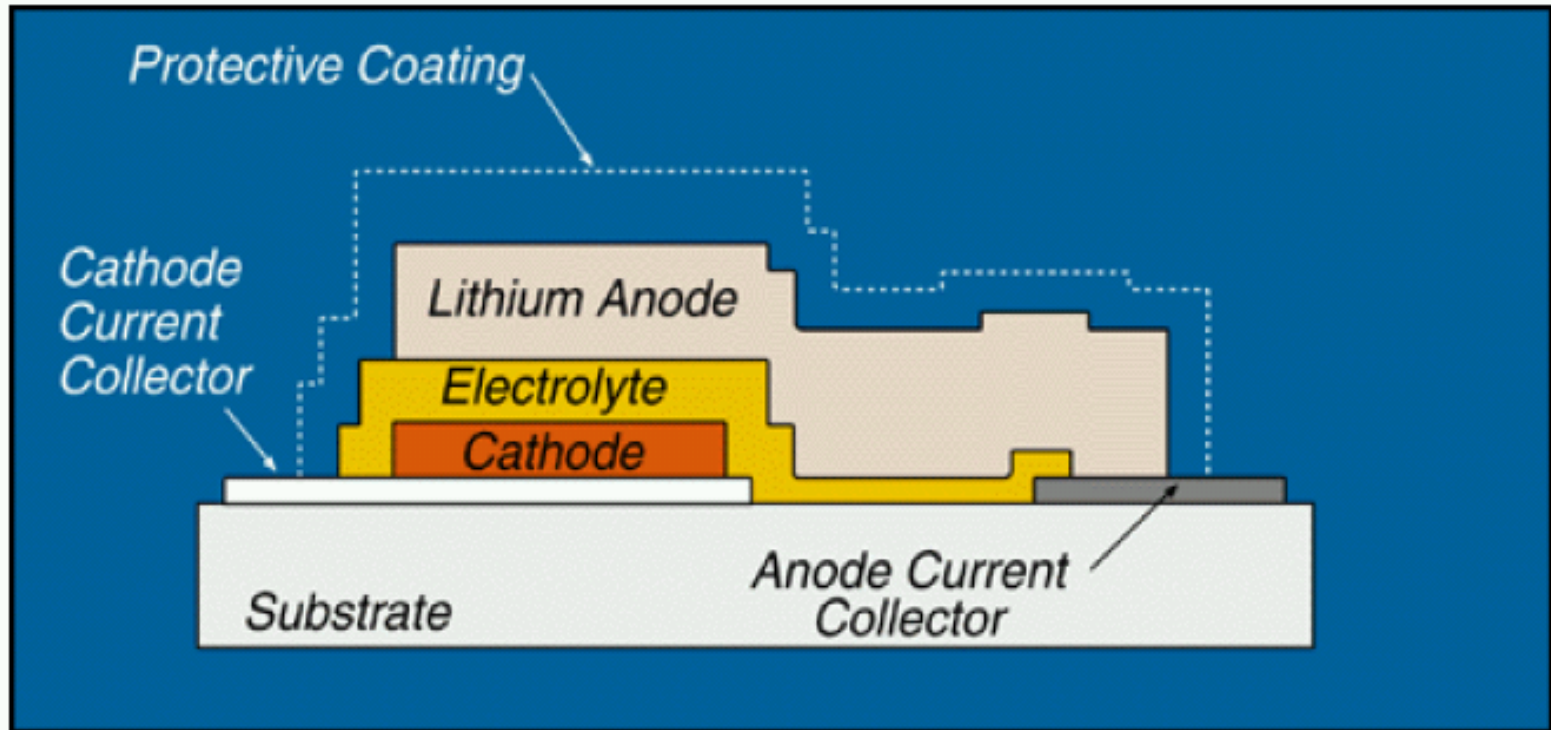


Image Courtesy DOE-ORNL

Low-Voltage, Efficient DC-DC Boost Converter



The TPS61200 boasts extremely low 0.5V start-up capability in any load condition and operates with more than 90 percent efficiency. In contrast, today's best step-up converters can only support an input voltage beginning at 0.7V with start-up at 0.9V—good for primary rechargeable battery cells or main supplies, but not low enough to support new applications using energy-harvesting power sources such as solar cells or fuel cells.

The TPS61200's ability to operate from a single solar cell eliminates the need for multiple solar cells in series, and eliminates the required protection circuitry associated with the series connection. This opens the door to new potential innovative designs, such as built-in solar-powered cell phone chargers that use indoor ambient lighting to help provide an infinite amount of stand-by time.

Extends the Operating Range of Single-Cell Alkaline, NiCd, and NiMH Batteries

The extremely low operating voltage of the integrated circuits also eliminates many of the design challenges that occur when operating single-cell alkaline, nickel-cadmium (NiCd), and nickel-metal hydride (NiMH) batteries to power anything from toys to portable medical devices. The TPS61200 extends the operating time of many pulsed-load applications.

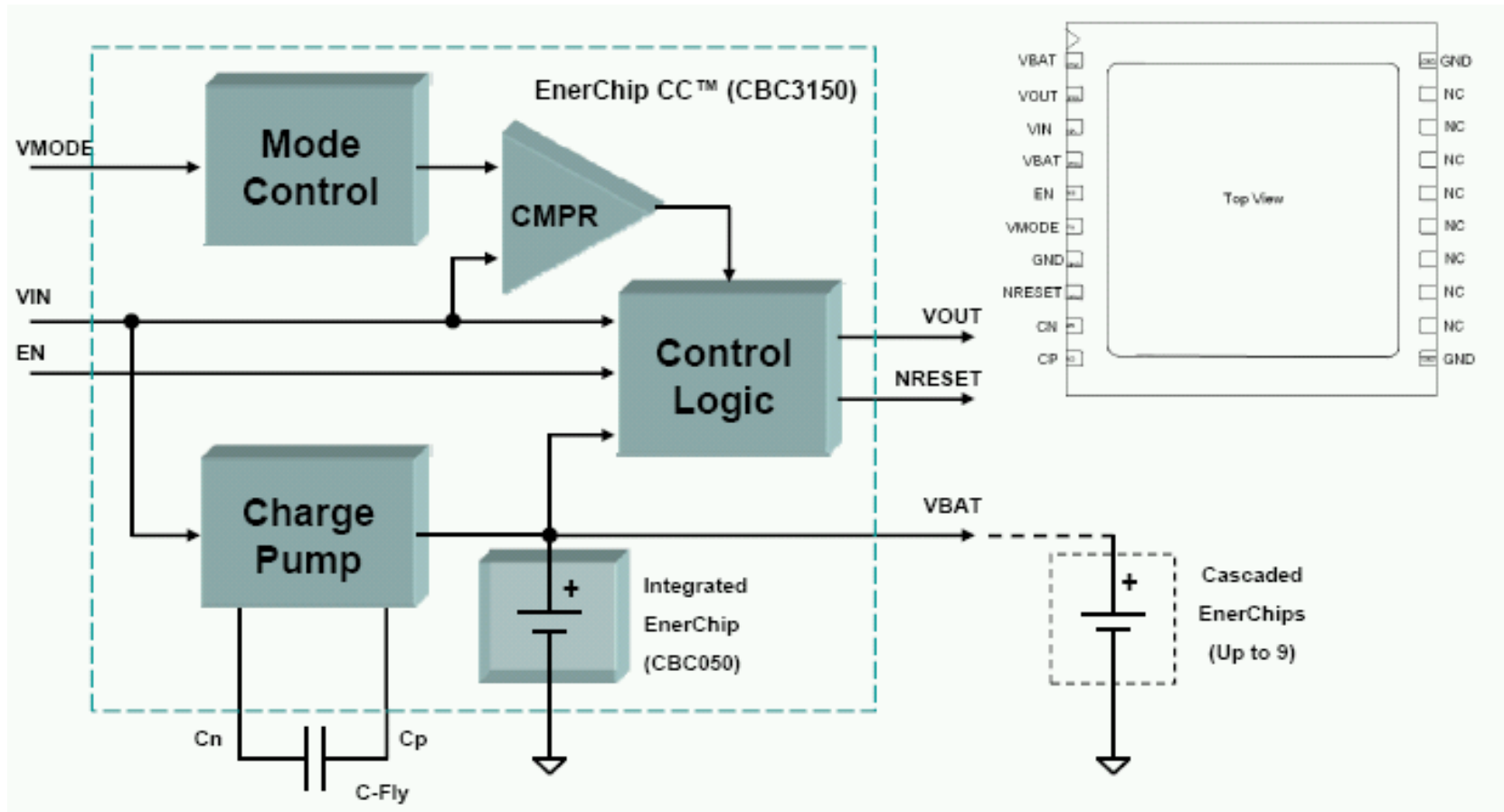
APPLICATIONS:

- All single-cell, 2-cell, and 3-cell alkaline, NiCd or NiMH, and single-cell Li-Ion battery-powered products
- Fuel- and solar-cell powered products
- Portable audio players
- PDAs
- Cellular phones
- Personal medical devices
- White LED drivers

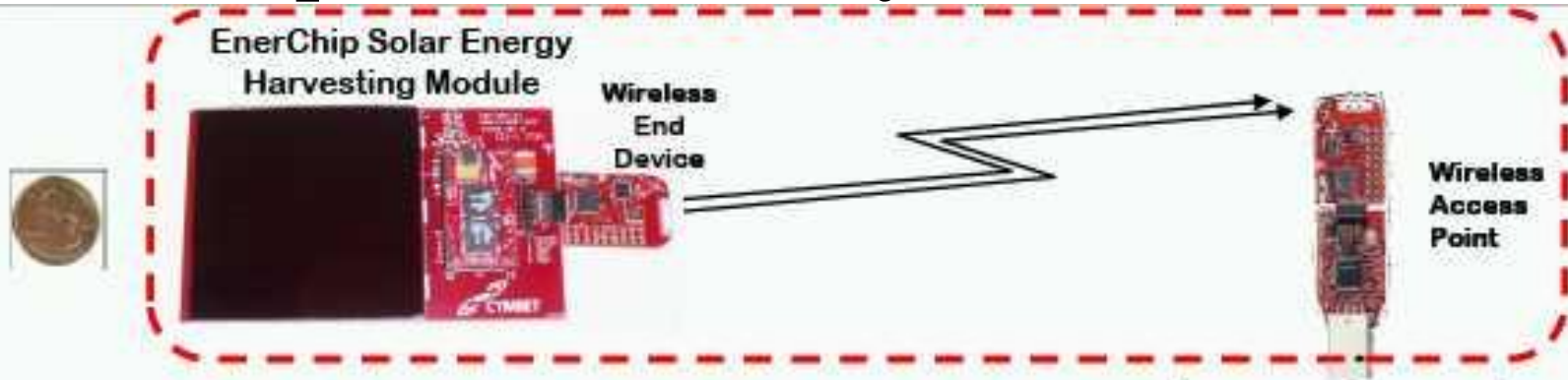
FEATURES:

- 0.3V-5.5V input operation
- Start-up into full load at 0.5V input voltage
- Up to 90% efficiency
- Automatic transition between boost and down conversion modes

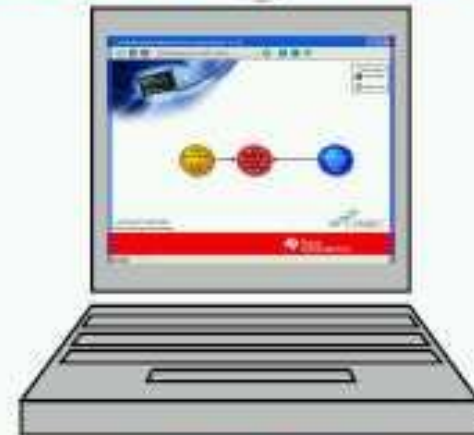
EnerChip Architecture:



TI & Chipcon Radio & Cymbet Evaluation Board:



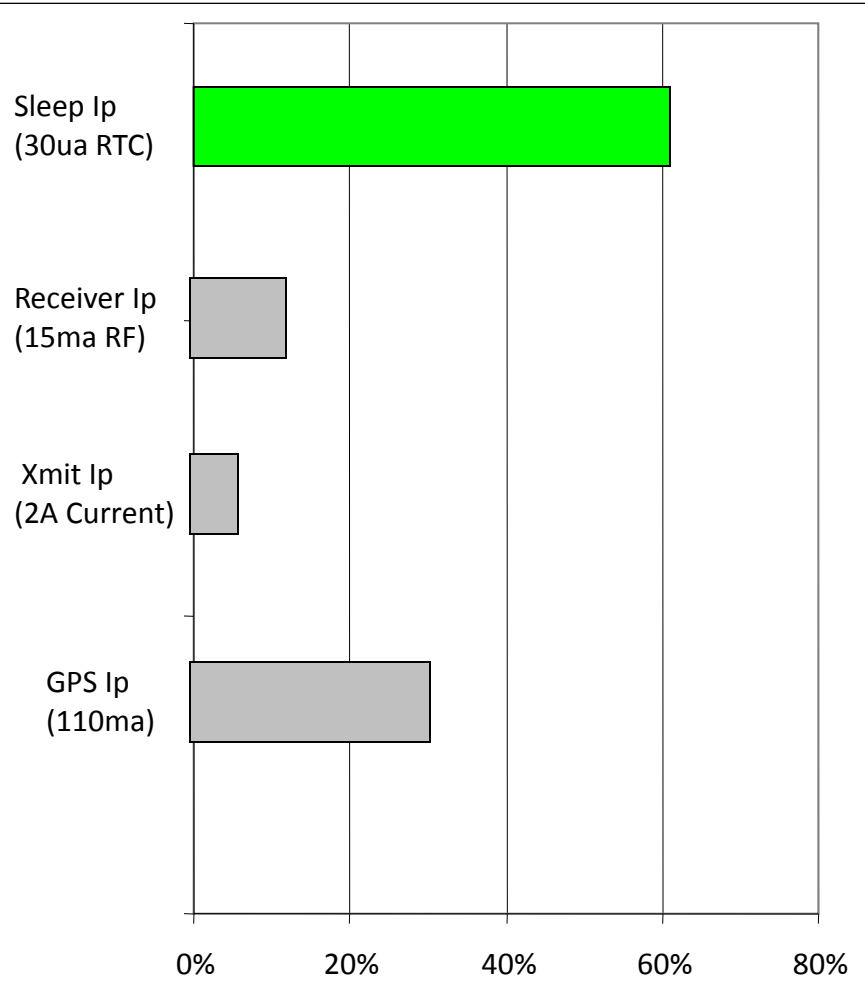
- Available as the TI eZ430-RF2500-SEH Evaluation Kit in January 2009
- Compact module with integrated solar cell
- Works in low light – down to 150Lux
- Low self-discharge enables high-efficiency
- No battery replacement or disposal; 10-year life
- Uses the EnerChip EH CBC5300 – Energy Harvesting Module
- CBC-EVAL-08 is Cymbet's version of Solar EH Board for generic Energy Harvesting designs



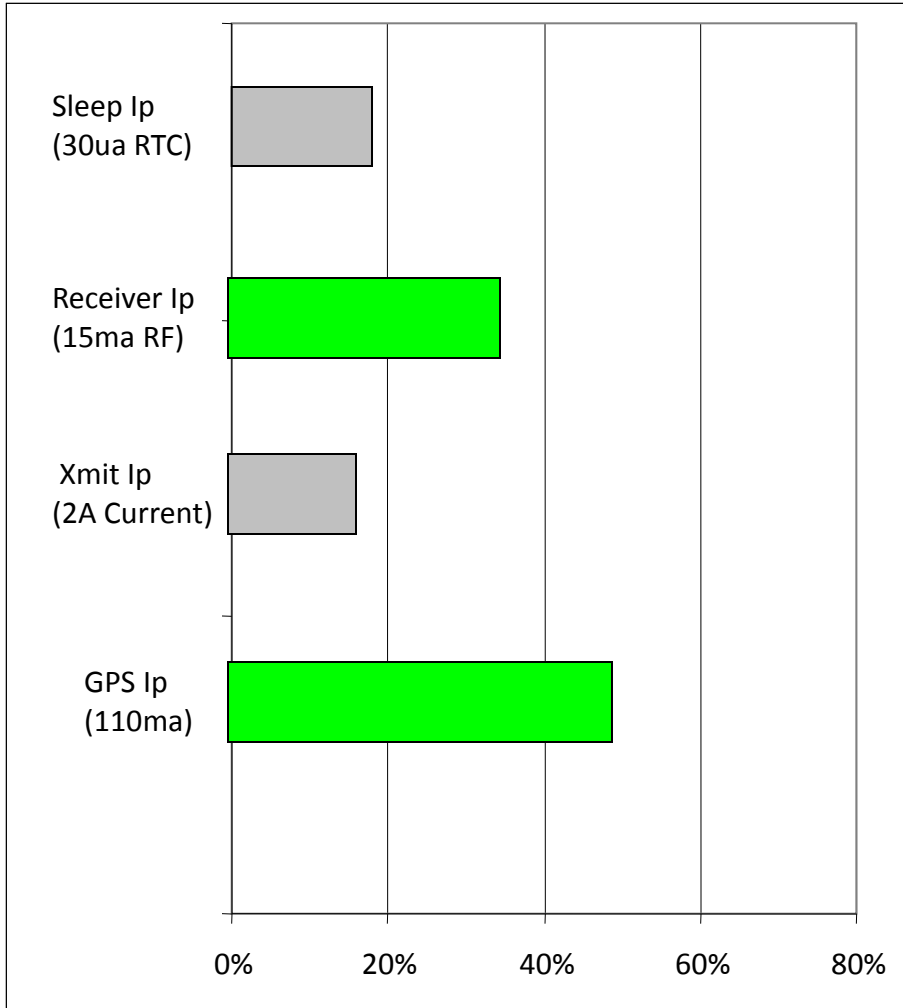
**TI's eZ430-RF2500-SEH
Evaluation Kit Contents**

Typical Percent Power by Subsystem

Infrequent Location Reports (2x Day):



Frequent Location Reports (12x Day):



Solar Energy Harvester Power Supply

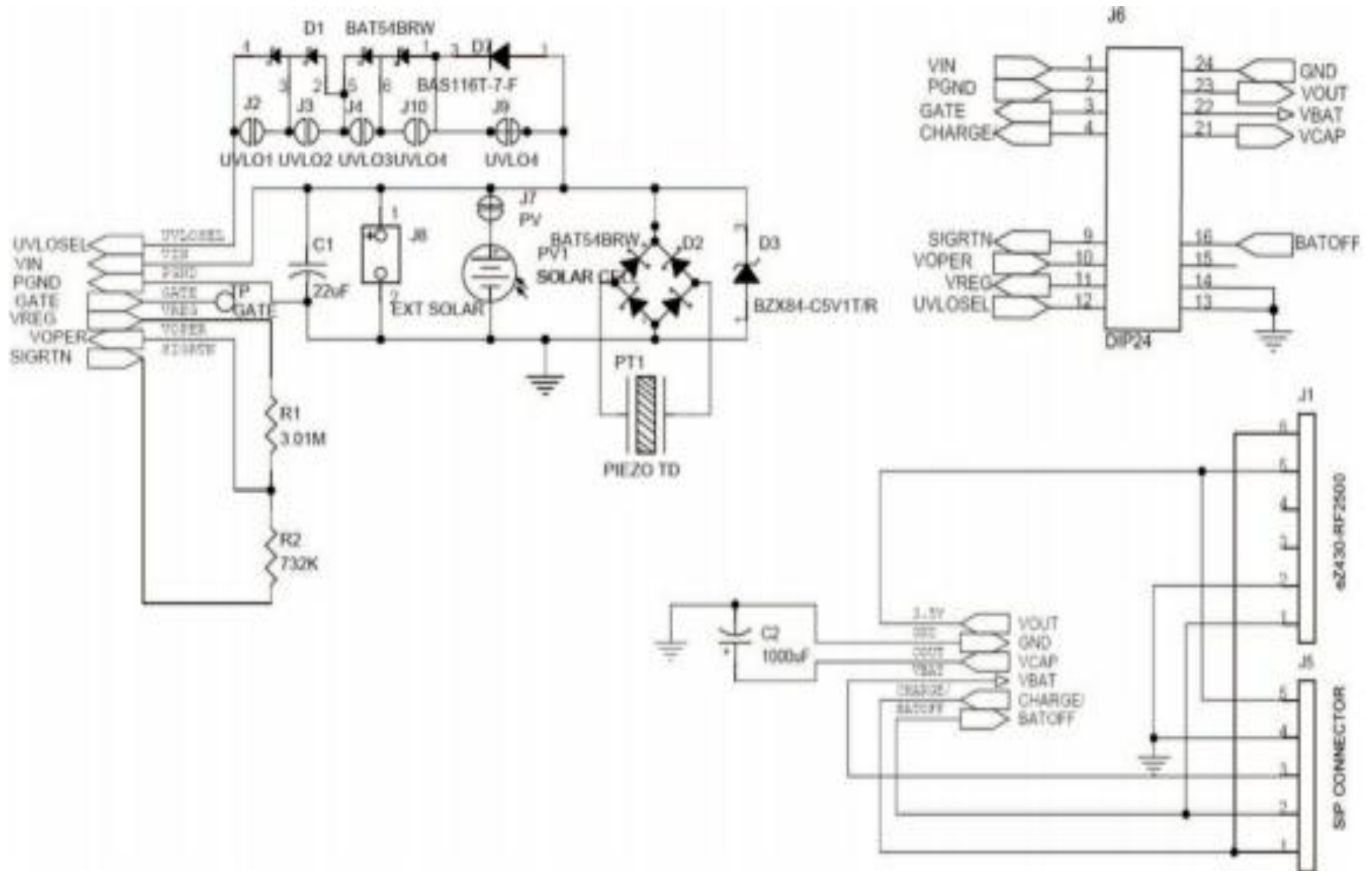


Figure 3-3. Solar Energy Harvester Module Schematic

Self-Powered SiLab Wireless Sensor Demo

Figure 6. Energy Harvesting Demo (Packet View)

10. On the Packet tab, a list of all received packets is displayed. Selecting a packet will decode the raw data and display the extracted information in the VBAT, TEMP, and LIGHT_LEVEL fields.

The screenshot displays the 'Energy Harvesting Demo Application' window. The interface is divided into two main sections. On the left, there are four node status cards labeled 'Node #1' through 'Node #4'. Node #1 is active, showing a battery icon at 100%, a sun icon, and a temperature of 25.2°C and light level of 1370 lux. Nodes #2, #3, and #4 are inactive, showing a greyed-out scene with a house and tree. On the right, the 'NodeInfo' tab is selected, showing a detailed view of the selected node's data. The data is organized into four sections, one for each node. Node #1 data is populated: Battery Voltage (100%), Temperature (25.2°C), and Light Level (1370 lux). Nodes #2, #3, and #4 have empty input fields for their respective data.

Node	Battery Voltage	Temperature	Light Level
Node #1	100%	25.2°C	1370 lux
Node #2			
Node #3			
Node #4			

Figure 7. Energy Harvesting Demo (NodeInfo View)

Ambient Thermal Generator, Nextreme



Features:

- Regulated Vout of 3.3V, 4.1V or 5.0V
- Pout up to 1mW depending on ΔT
- Compatible with thin film batteries
- Small form factor ($\sim 2 \text{ in}^3$)
- Leverages LTC®3108 UDO
- Wide range of load resistances (15k Ω or higher)



Shown with available TI EZ430 SEH transmitter

http://www.nextreme.com/media/pdf/techspecs/Nextreme_Thermobility_WPG-1_Data_Sheet.pdf

Relative Power Availability by Parasitic Source:

Energy Source	Challenge	Estimated Power (in 1 cm ³ or 1 cm ²)
Light	Conform to small surface area Wide input voltage range	10μW-15mW (Outdoors: 0.15mW-15mW) (Indoors: <10μW)
Vibrations	Variability of vibration	1μW-200μW (Electrostatic: 50μW-100μW) (Electromagnetic: <1μW)
Thermal	Small thermal gradients	15μW (10°C gradient)
Piezoelectric	Capturing pressure or motion	~ 200μW
RF & Inductive	Coupling & rectification	Various

Source: EE Times

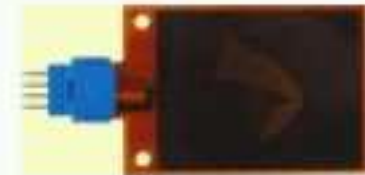


AdaptivEnergy – JouleThief™

Solar - Various



Peltier - Thermo Life



MIDE – Volture™ Piezo

Commercialized Solar-Powered M2M/IoT



- **TRAILERS, >60,000 on Wal-Mart Trailers!**
 - 1 x PVs, Solar Augmented
 - 2 x PVs, 100% Solar w/o Sensors

• RAIL

4 x PVs, 100% Solar

Solar PV Specifications

Weight (typical)	9 oz.
Size	8.2" x 3.4" x 47"
Rated Current	120 ma (9V OC)
Service Life	>10 years
Panel Impact	1" hailstones @ b50 mph
Rated Power	1.25 Watts
Rated Temperature	-40C to +85C



* SLA Battery Pack Life Extended with Solar Trickle Charging

Why Solar or Energy Harvesting?

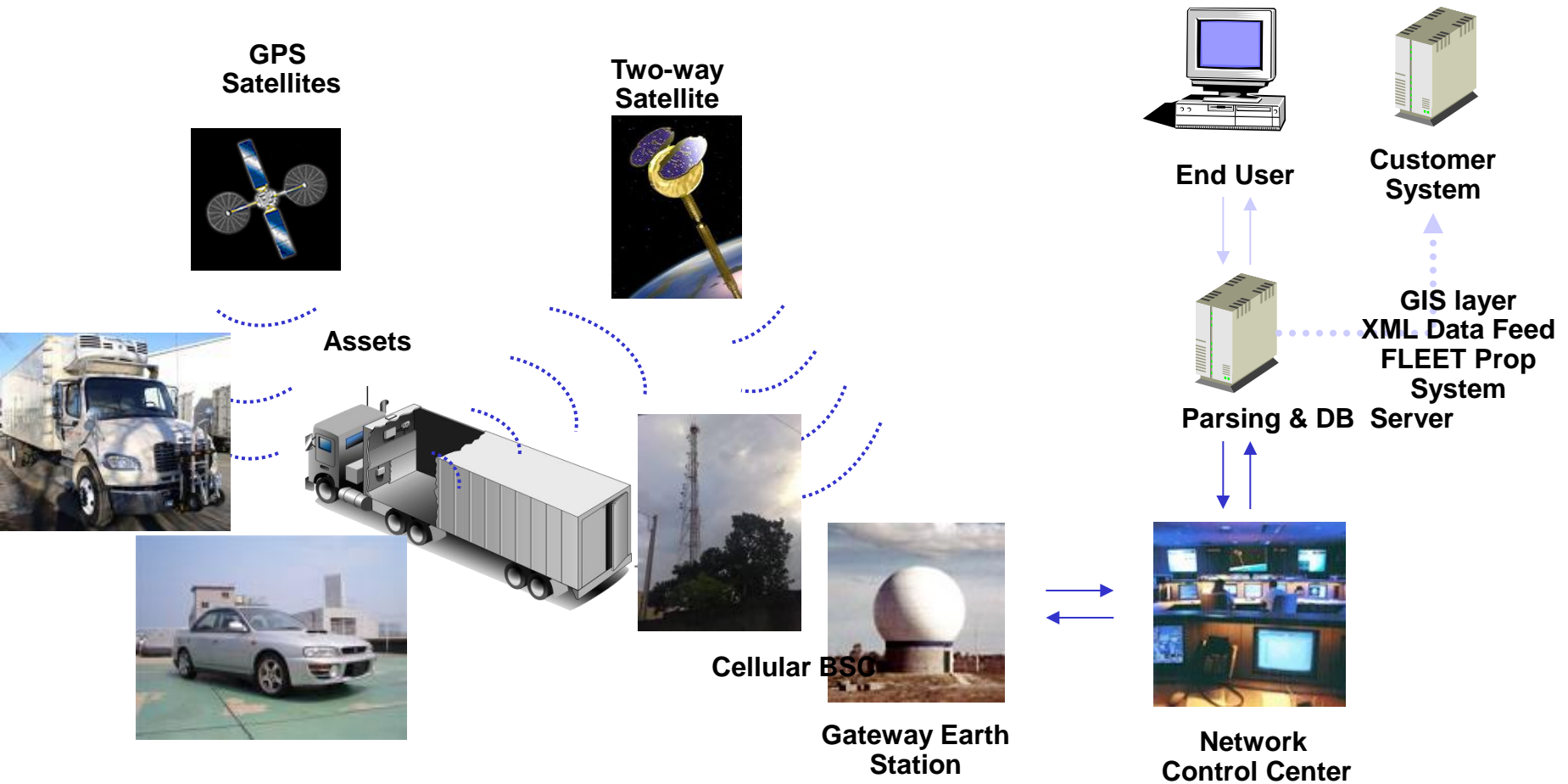


Clear M2M/Iot Business Benefits:

- ✓ Pricing Inflection Point
- ✓ Improved Reliability
- ✓ Reduction in Fuel
- ✓ Quicker Installation
- ✓ Improved Covert Mtg (Motion)
- ✓ Longer Battery Life



Typical M2M/IoT Architecture



**Standard Telematics Architecture
installed on Powered and Unpowered Assets**

TI & Chipcon Radio & Cymbet Evaluation Board:

- EnerChip EH Module – CBC5300:
 - Capacity = 100uAh, uses 2 CBC050s
 - Compatible with solar, inductive, piezo & thermoelectric transducers
 - No battery replacement or disposal; 10-year life
 - Provides control signals to enable “Energy Aware” sensor nodes
 - Low self-discharge enables high-efficiency
 - Order P/N: CBC5300-24C
- Solar Evaluation Board – EVAL-08:
 - Solar Energy Harvesting Demo Kit
 - Compact module with integrated solar cell array
 - Works in low ambient light:
 - Down to 100Lux
 - Uses the EnerChip CBC5300
 - Adaptable to many sensors and wireless networks via Interface Header
 - Order P/N: CBC-EVAL-08



CBC5300
Module

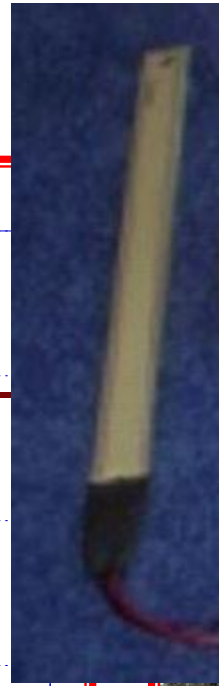
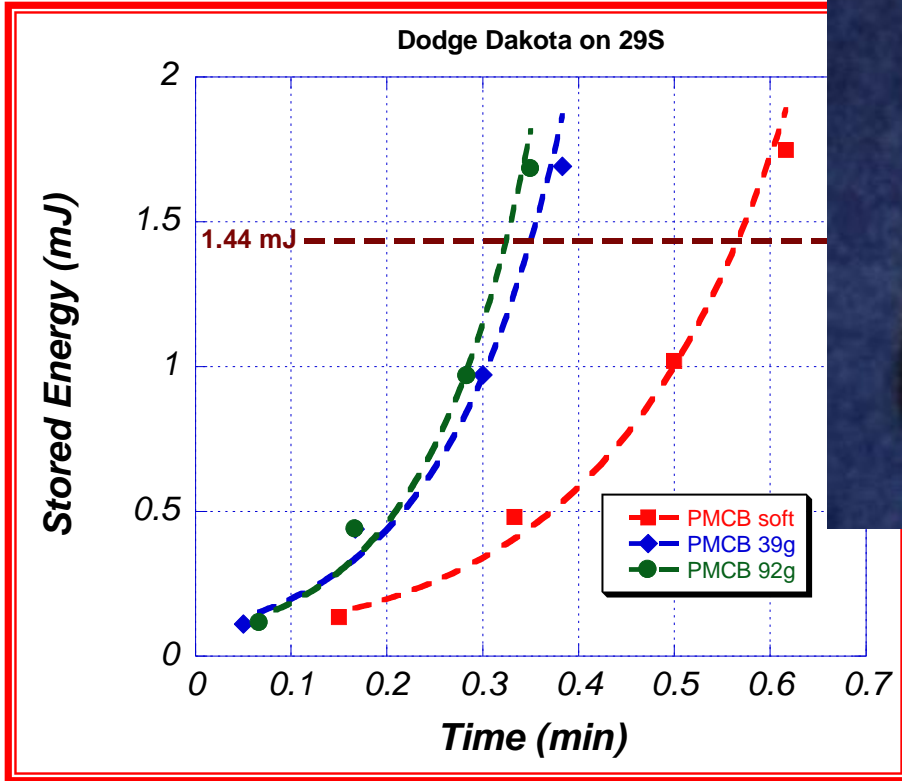


Interface
Header

TI Evaluation Board Power for 802.15.4 Protocol:

Parameter	Min	Typical	Units
Min input Lux	200		Lux
Full charge Lux	700		Lux
Load current (charging)		20	uA
Load Current (not charging)		800	nA
Battery Charge Voltage		4.06	Volts
Battery Cutoff Voltage	3.0	3.3	Volts
UVLO Trip Select Voltage		0.7	Volts

Other Energy Sources: ACI Piezo (PFCB) Source



- ❑ ACI Tested cars: Honda Civic, Dodge Dakota
- ❑ All vehicles produced sufficient energy in less than minute for wireless transmission.

Other Energy Sources: Intel WISP, Wireless identification and Sensing Platform:

Features:

- Capture Ambient TV/Radio Energy
- Wireless Energy to Power Transmitter
- Nikola Tesla would be Very Pleased!

