Energy Harvesting with Thin-Film GaAs Solar Cells

Energy Harvesting Industry Session at APEC 2017
Sponsored by the PSMA Energy Efficiency Committee

Rodney Amen
Alta Devices, Inc.
www.altadevices.com
info@altadevices.com

Contents

Why Solar for IoT Devices ?

- IoT Developer's concerns:
  - Sensors, Radio, Computer, and Data.
  - Then just use a battery and declare victory.

- IoT Users' concerns:
  - Does it solve my functional need?
  - How much does it cost to maintain ?
- Why Solar energy ?

  …until recently, existing solar technologies have been too bulky, too rigid, or not power efficient enough to use in IoT devices.
- High Performance Gallium Arsenide (GaAs) solar cells
  - World record single junction power conversion efficiency 28.8%
  - Lightweight, flexible, thin-film GaAs solar cells are being produced today

Which Solar?

Lighting Environments

Gallium Arsenide (GaAs) Solar Technology

SOLAR FOR SENSORS

Which Solar?

a-Si
- •Flexible
- •Low cost
- •Low efficiency

μc-Si
- •Rigid
- •Cost competitive
- •Very common material

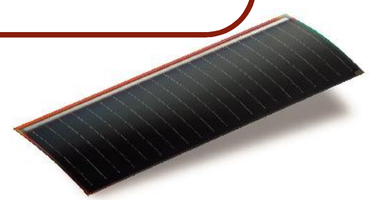
Depends on the application

CdTe
- •Rigid
- •Established thin-film technology
- •Cost competitive

Organic
- •Flexible
- •Moisture sensitive
- •Low cost (theory)
- •Low efficiency

GaAs
- •Thin-film technology
- •Flexible
- •World record efficiency
- •Higher cost (today)

c-Si
- •Rigid
- •Industry standard solar material



CIGS
- •Flexible
- •Emerging thin-film technology
- •Moisture sensitive
- •Low cost (theory)

Lighting Environments

Outdoor (Sun)

- Solar irradiance or "insolation"
  - 1 sun = 1000 W/m^2
- Wide spectral distribution
  - 300-2500nm
  - Spectrum varies through day
- Varying angle (sun moves!)
- Varying intensity
  - sunny, clear 600 - 1000 W/m^2
  - cloudy, fog 100 - 300 W/m^2
- Varies around the globe and with the season

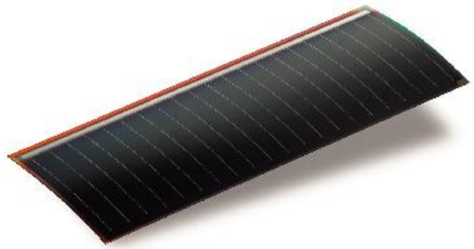
Indoor (artificial lighting)

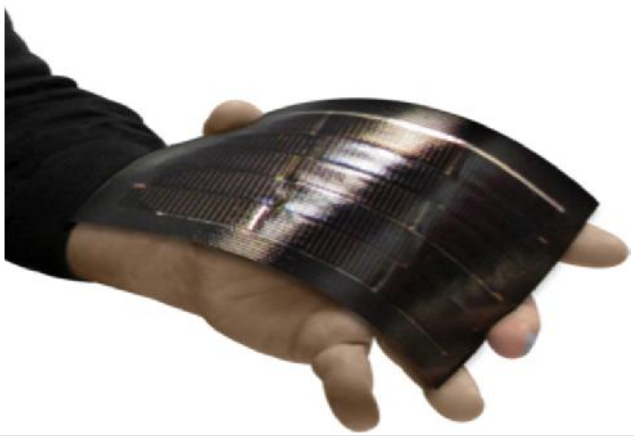
- Typically measured in lux
  - Lux = $lumens/m^2$
- Narrow spectral distribution
  - 400-700nm (visible light)
  - Depends on light source
- Typical values are
  - Office: 500-1000 lux
  - Warehouse: 200 lux

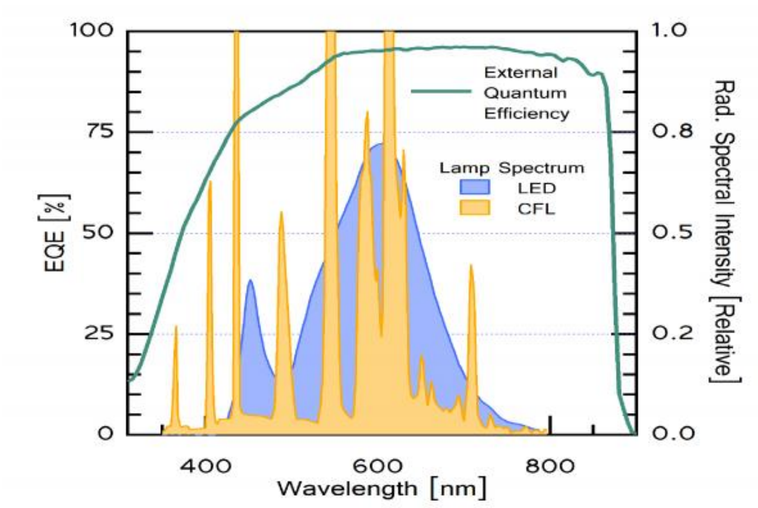
- 200 lux ≈ 0.06 mW/cm^2 (LED)
  - Roughly 0.1% of the power of the sun
- Usually constant but subject to "turning off the lights"!

Thin-Film GaAs Solar Cells

- Highest Efficiency
  - single junction cell: 28.8%
- Highest power
  - 26 mW/cm^2 outdoor in bright sun
  - 15 $\mu W/cm^2$ indoor in 200 lux
- Lightweight and thin
  - Cells are 110 µm thick and 1 W/g
- Flexible
- Full sun to artificial and low light







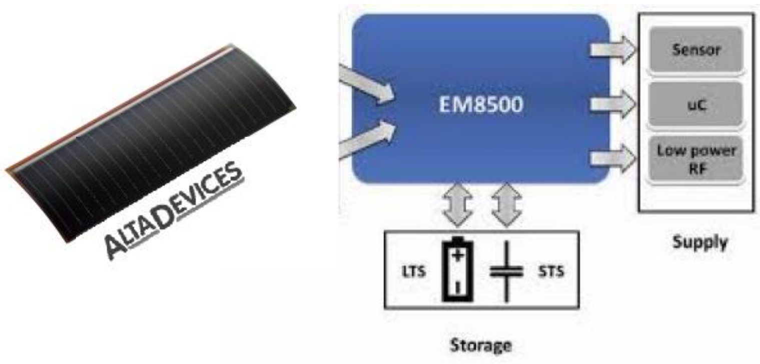
Solar Powered Beacon

In Very Low Light Environments

SMALL 5 CM² 100 µW GALLIUM ARSENIDE SOLAR CELL
EXTREMELY LOW POWER ENERGY HARVESTING

Extremely low power Energy Harvesting

- One example of an extremely low power energy harvester is the EM Microelectronics EM8500.
  - Designed to harvest sources as low as 3 microwatts.
  - Ideal for mating with a tiny solar cell to create an ultra low light energy harvester.



EM MICROELECTRONIC
A COMPANY OF THE SWATCH GROUP

Beacons

- iBeacon is a commonly used protocol developed by Apple.
  - Bluetooth low energy broadcasted identifier and minimal data used to determine the Beacon’s physical location relative to the smart device (ie. smart phone)
    - EM Microelectronics EMBC01 is an example of a BLE proximity Beacon
  - Extremely low power but is often used in remote locations where battery replacement is costly and causes down time.
  - Solar power can eliminate changing batteries in Beacons or other low power mobile/remote device.

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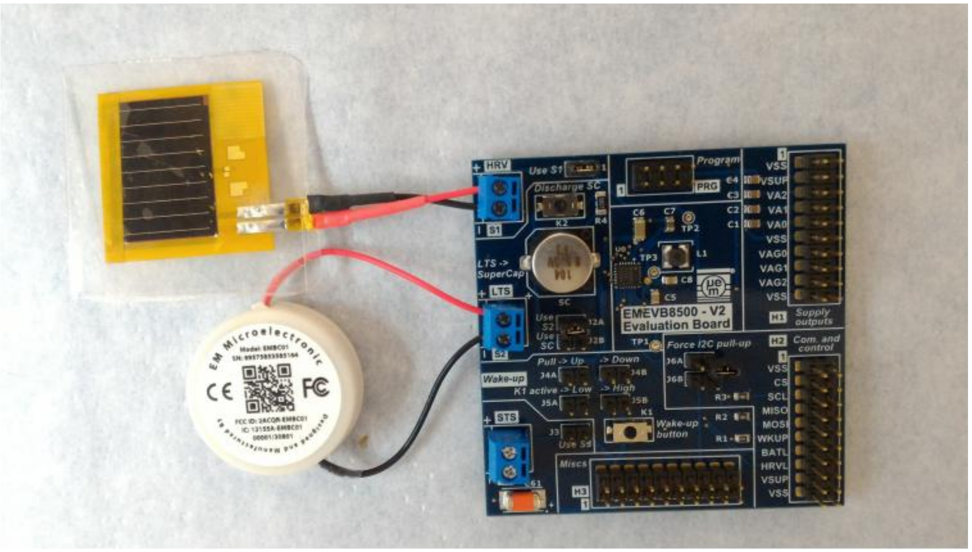
Solar Powered Beacon

- Power density of GaAs solar cell harvests 100 µW in artificial light in a small area 5 cm²
- EM Microelectronic EMEVB8500 evaluation board
- EM Microelectronic EMBC01 Beacon



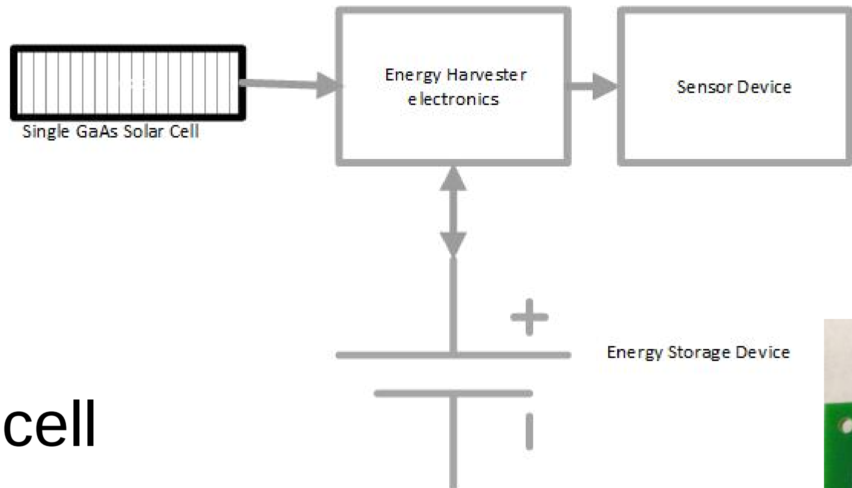
Solar Beacon in a tiny package operates forever as long as there is a few hours of daily light

Develop a Solar Powered IoT Device

HOW MUCH SOLAR?
COMMERCIALLY AVAILABLE SENSORS, SUPERCAP, AND SOLAR CELL
OPTIMIZING POWER CONSUMPTION
PRODUCT DESIGN INTEGRATION

Develop a Solar Powered BLE Sensor

Architect the simple design



- Solar cell
- Energy harvesting IC
- Energy Storage
- Sensors and other electronics

How Much Solar?

1. Calculate the load's average energy consumption in a 24 hour day in Watt-Hours
2. Divide by the battery efficiency (about 80%)
3. Divide by the energy harvesting electronics efficiency (about 80%)
4. Estimate the number of hours of light (ie. how long the lights are turned on)
5. Divide solar energy needed by the lighted hours

1. Example 1 mW-Hrs.
2. 1 mW-Hrs / 80% = 1.25 mW-Hrs.
3. 1.25 mW-Hrs / 80% = 1.56 mW-Hrs.

   Result is the solar energy needed in one day in W-Hrs.
4. Example 12 Hrs.
5. 1.56 mW-Hrs. / 12 Hrs. = 130 µW

   Result is the solar power needed

A single 10 cm² GaAs solar cell can harvest 130 µW in 100-200 Lux

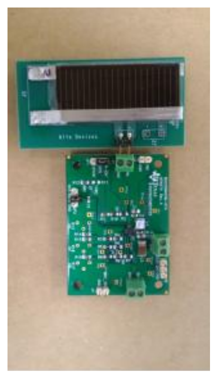
Choose an Energy Harvesting Device

Analog Devices

- Analog Devices ADP5090 is an ultra-low power, boost dc-to-dc converter.
- The ADP5091 is a newer device with faster startup

Texas Instruments

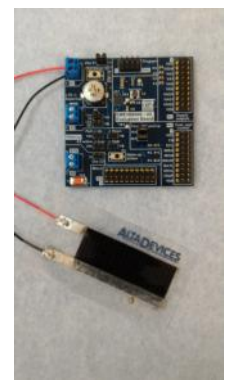
- BQ25504 ultralow power energy harvesters and charger
- BQ25505 for primary battery extension designs
- BQ25570 adds an integrated buck regulator.



ST Microelectronics

- The SPV1050 is an ultra-low power and high-efficiency energy harvester and battery charger
- The SPV1040 is a low power, step-up converter with embedded Perturb and Observe MPPT algorithm,

EM Microelectronics



- EM8500 is an integrated power management solution for ultra-low power applications in the µW to mW range.

Choose Some Sensor Electronics

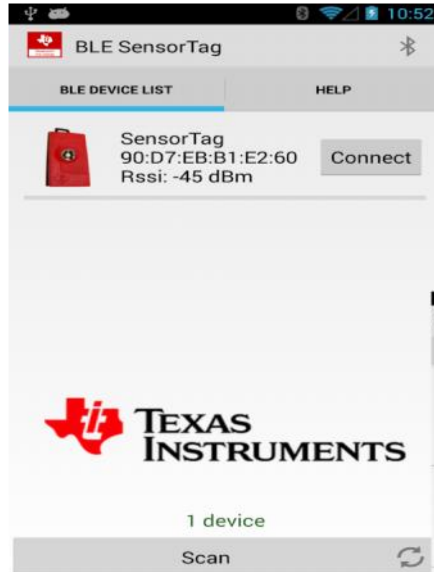
- There are many commercially available BT-BLE Sensors
  - Environmental Sensors
    - myBlue temperature sensor
  - Texas Instruments Sensor Tag
    - Development kit with many sensors
    - CC2650 Microcontroller with built-in BLE

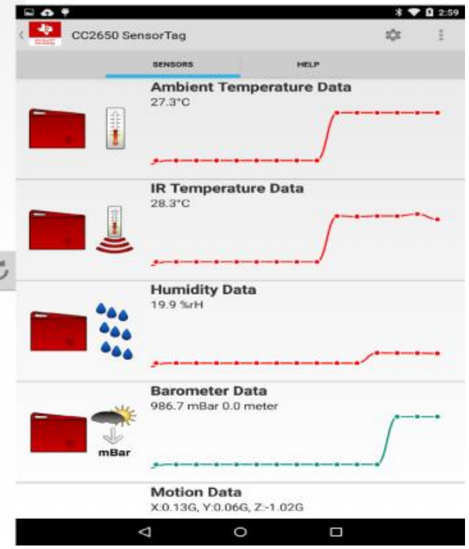
Or use your own microcontroller, radio, and sensors

Add More Sensors

- Texas Instruments *CC2650STK* Bluetooth BLE Sensor Tag Development Kit

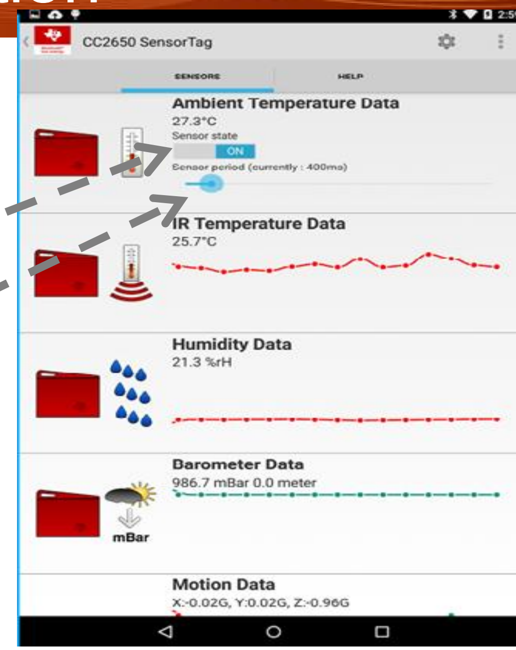
- TI sensor tag include several sensors – although it is not optimized for low power





Optimizing Power Consumption

- Troubleshooting
  - If the supercap/battery is too small - needs to be fully charged before plugging in the sensor tag
  - The sensor tag default settings use too much power
- Use the App to lower the power consumption
  - Turn off unused sensors
  - Change BLE broadcast interval
  - Monitor power and optimize
- Further optimize to reduce power by modifying the sensor tag firmware
  - Use the TI *CC-DEVPACK-DEBUG* development and debug pack
  - Comes with Code Composer dev environment



Integrating Solar into Product Design

- Many mounting options
  - Product enclosure surface
  - PCB
  - Flex circuit
- Protection from elements
  - Lamination or encapsulation
- Flexible cell allows mounting on curved surfaces.

Takeaways

- For further information
  - Alta Devices Thin-Film GaAs Solar cells
    http://www.altadevices.com
  - Analog Devices energy harvesting
    http://www.analog.com
  - Texas Instruments Sensor Tag and energy harvesting
    http://www.ti.com
  - EM Microelectronics energy harvesting and Beacon
    http://www.emmicroelectronic.com
  - ST Microelectronics energy harvesting
    http://www.st.com/

Smart Devices

Smart Home

Smart Cities

Smart Agriculture

Questions?

For further information see www.altadevices.com
Or email info@altadevices.com