

Data Logger Subsystems

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February 2012



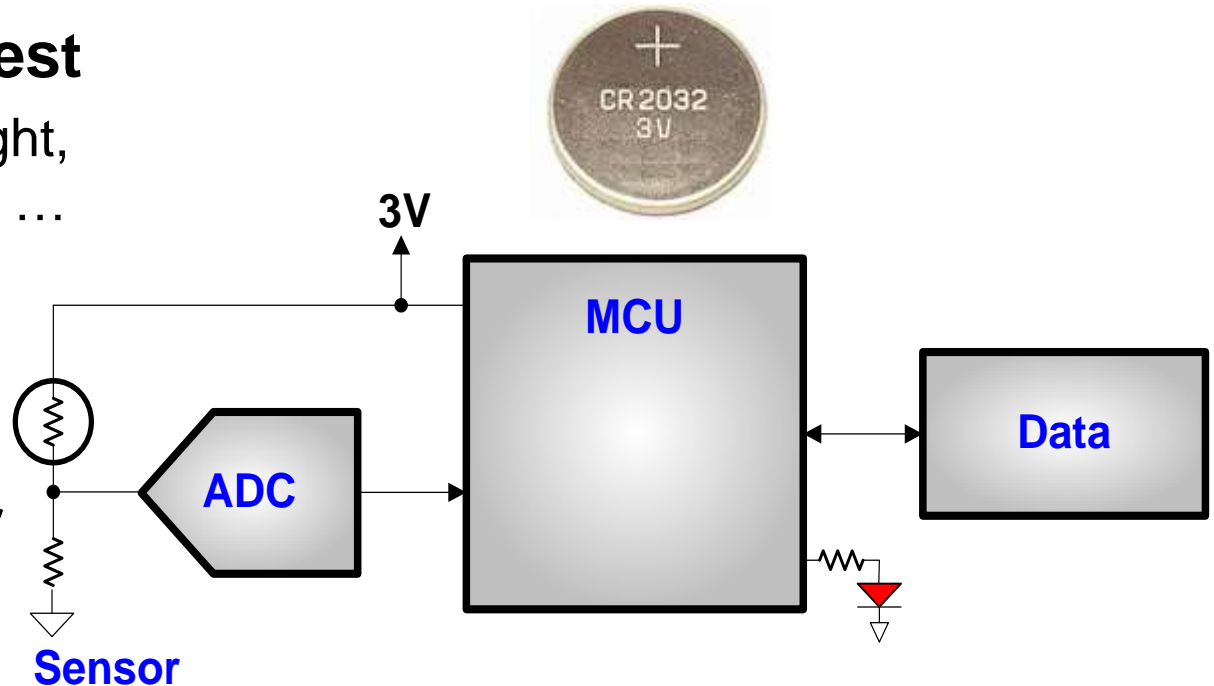
Full Disclosure

- **Mark E. Buccini**
- **ULP Staff at TI**
- **25+ years strategy, applications, marketing, sales, and management experience**
- **Lead MSP430 worldwide introduction from 1995**
- **An MCU fan**
- **Promise to try and not oversell TI products**
(I will lie today)



Typical Data Logger Subsystems

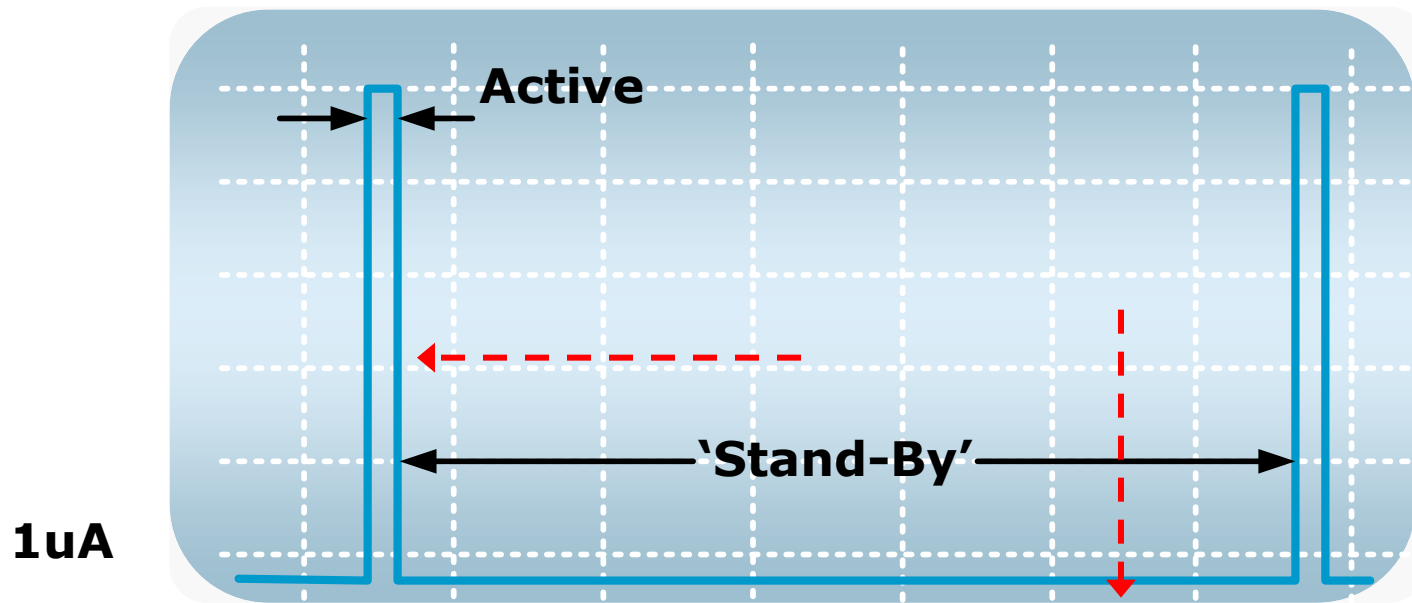
- **Sensor of interest**
 - Temperature, light, sound, vibration ...
- **Interface**
 - Analog/Digital Convertor
- **Microcontroller**
 - Processing
- **Data storage**
 - Non-volatile
- **Ultra-low power**
 - Days, weeks, months, years autonomous operation



Reducing Power Consumption

- **Importance of extended standby duty cycling**
- **Power manage sensor**
- **Power aware software**
- **Efficient non-volatile data storage**

Ultra-low Power System Profile

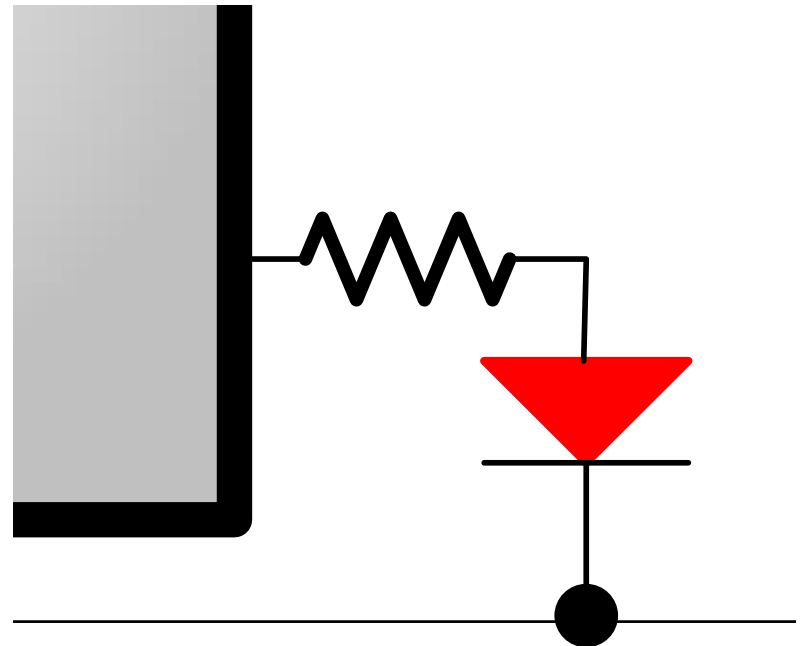


- Extended **Ultra-Low Power** standby mode
- Minimum active duty cycle
- Interrupt driven performance on-demand

A Starting Point: Flashing LED

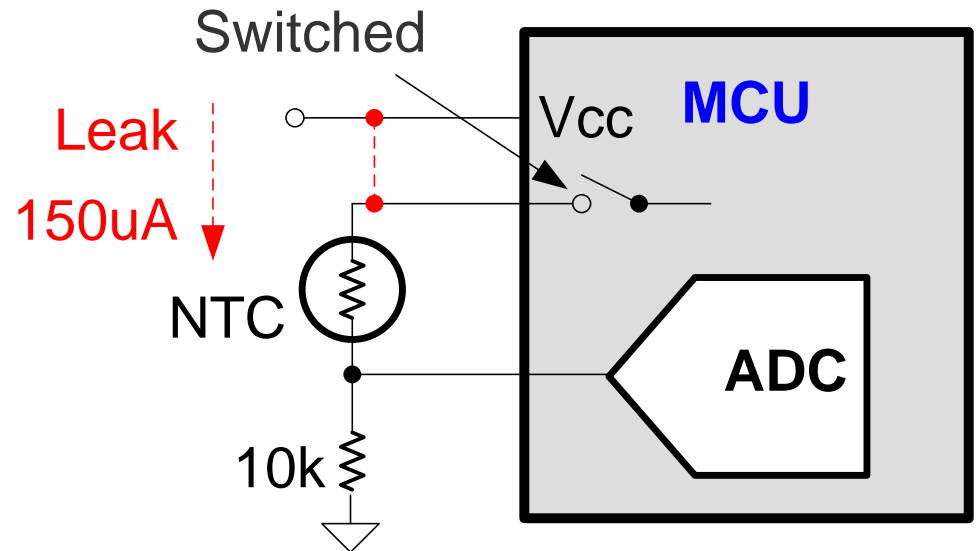
- Marketing must-have electronic system-functioning-properly indicator
- ~5mA pulse for 1ms
- 1/second
 - 0.1% duty cycle
 - 5uA adder on average

- **1/5 second**
 - 0.02% duty cycle
 - **1uA adder**



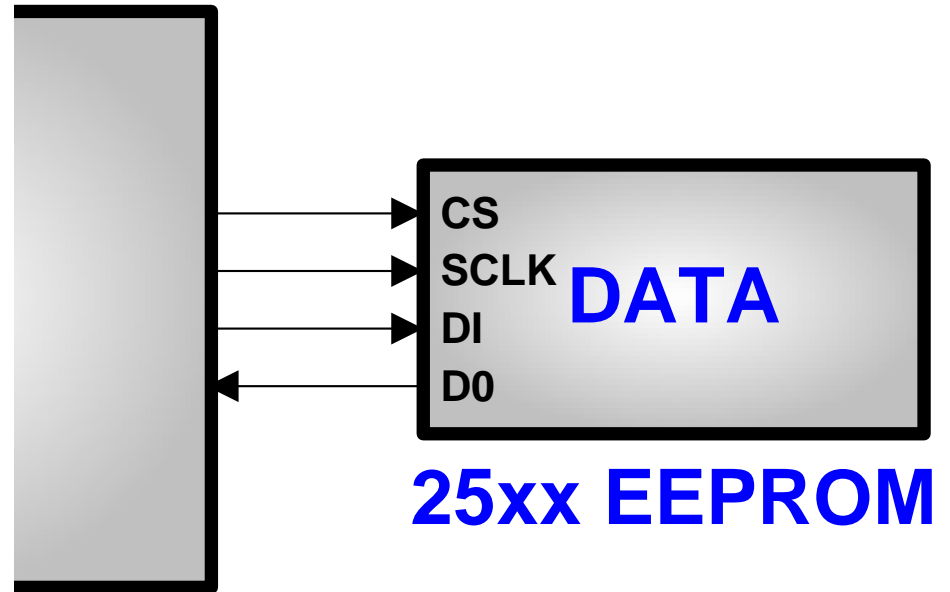
Power Manage External Devices

- **Switched sensor**
 - Eliminate static drain
- **Measure_Sensor () ;**
 - 50us/5s (0.01%)
- **All measurements and calculations**
 - <500us at 200uA
- **1/5 second**
 - 0.01% duty cycle
 - **0.2uA adder**

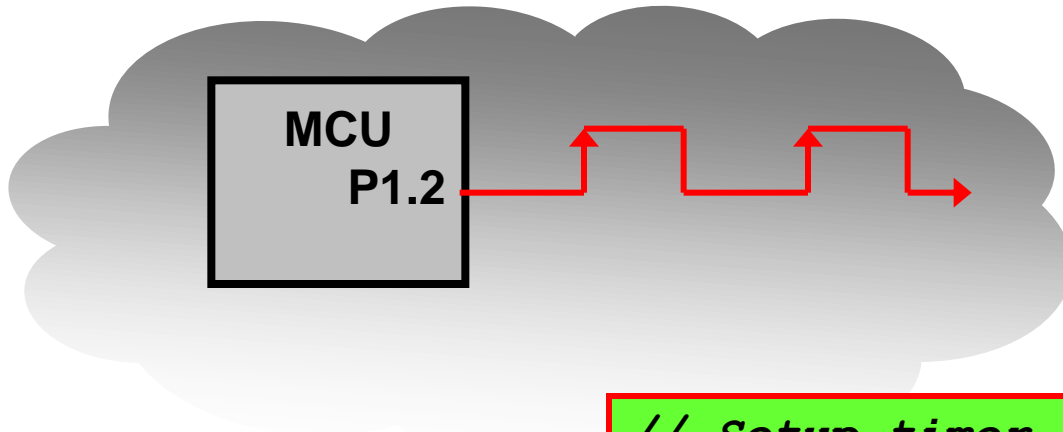


Non Volatile Memory

- Write to external 25xx EEPROM
- 5mA for 5ms
- 1/second
 - 0.1% duty cycle
 - 25uA adder
- 1/5 second
 - 0.02% duty cycle
 - 5uA adder



Power Wise Firmware



```
// Endless Loop  
for (;;)   
{  
    P1OUT ^= 0x04; // Toggle  
    for (i = 10000; i>0; i--);  
}
```

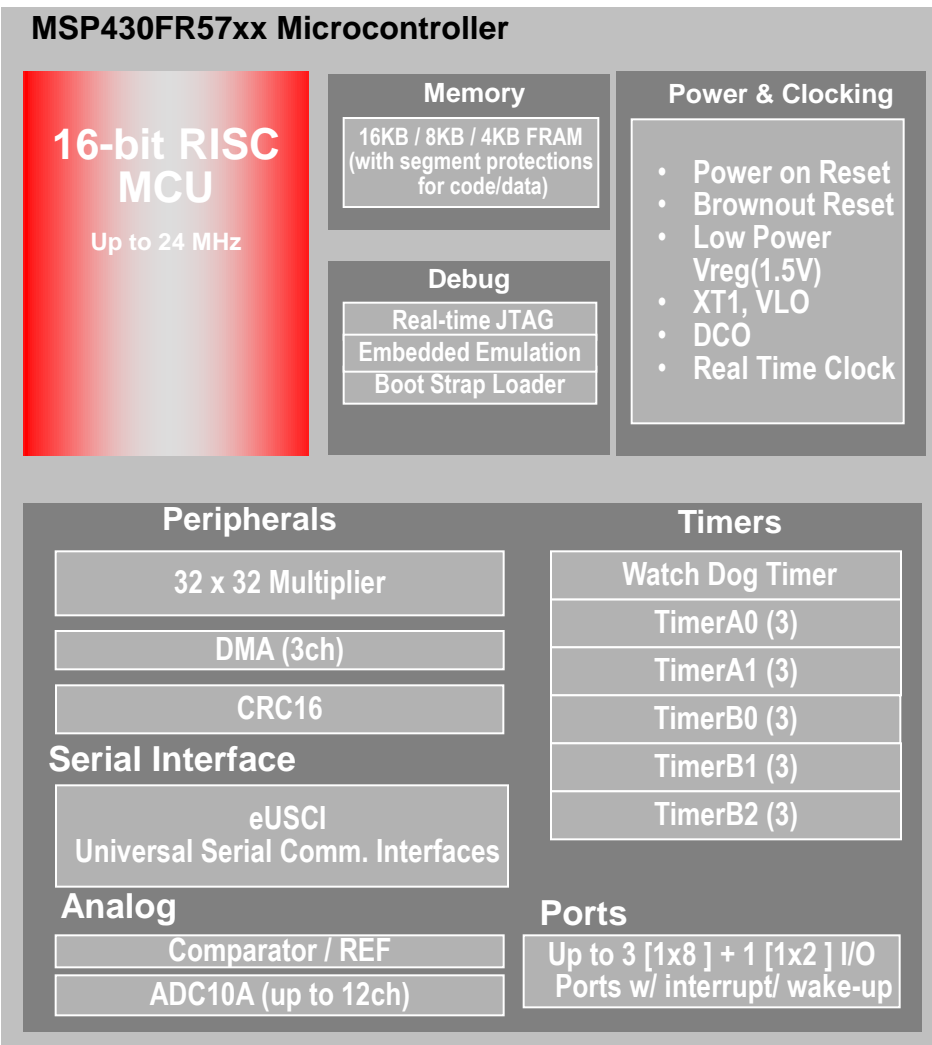
100% CPU Load!

```
// Setup timer output unit  
CCTL1 = OUTMOD0_1;  
_BIS_SR(CPUOFF);
```

0% CPU Load!

'FR5739 - Worlds First ULP FRAM MCU

- **Performance**
 - Up to 24MHz
 - FRAM @ 8MHz
- **Power Numbers**
 - Active Mode: <110 μ A/MHz
 - Standby Mode: (LPM3): <7 μ A
 - RTC mode (LPM3.5): ~1.5 μ A
 - Shutdown Mode (LPM4.5): ~0.3 μ A
- **Flexible Unified Memory**
 - Up to 16 KB FRAM
 - Configurable memory partitioning
 - Memory Protection Unit
- **Package**
 - 40/38/28/24-Pin options
 - Temp Range -40°C to 85°C



What is FRAM?

FRAM, an acronym for ferroelectric random access memory, is a non-volatile memory that can hold data even after it is powered off. In spite of the name, FRAM is a ferroelectric memory and is not affected by magnetic fields as there is no ferrous material (iron) in the chip. Ferroelectric materials switch polarity in an electric field, but are not affected by magnetic fields.

Advantages

Write Speed

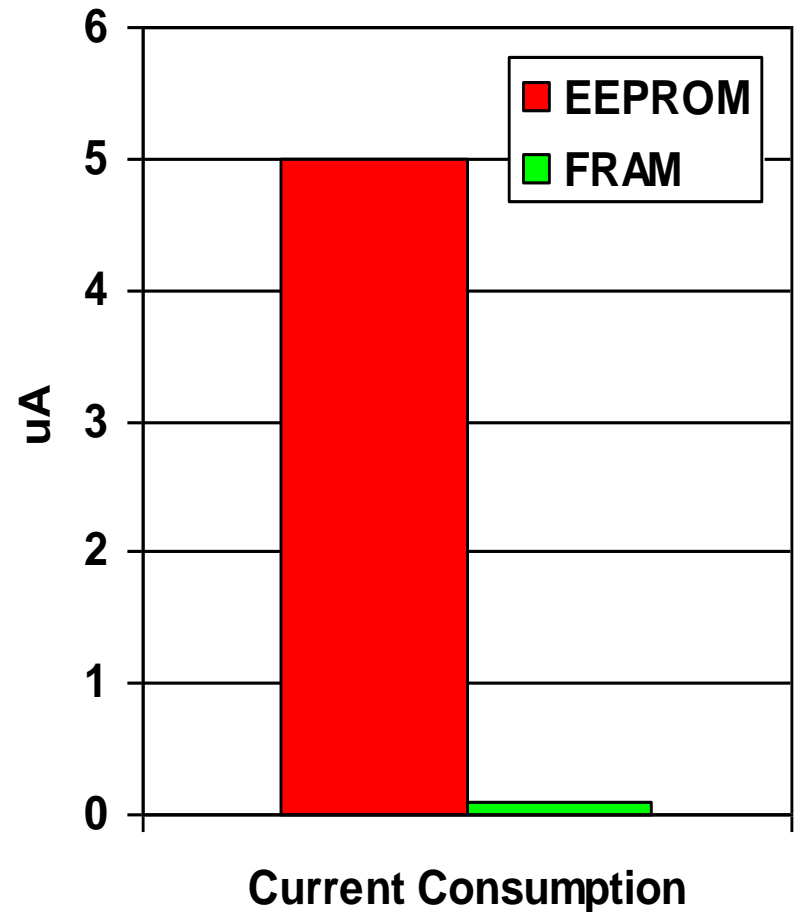
Ultra-low power

Unified

Reliable $10^{14}+$... literally trillions of writes cycles

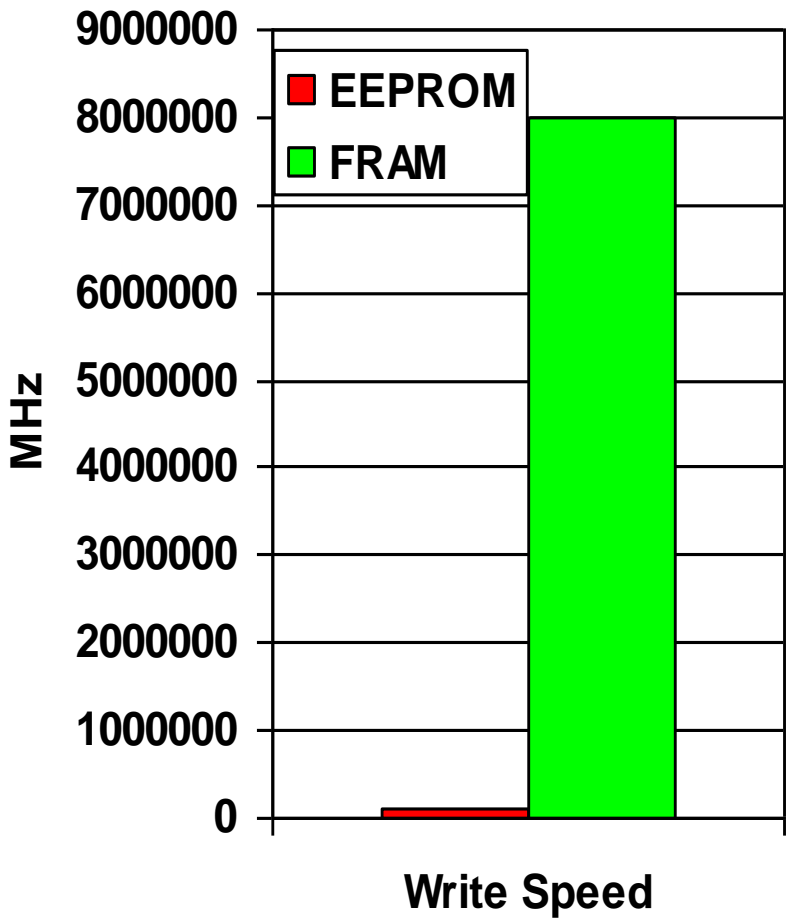
FRAM Power Compared to EEPROM

- **Write 1 bytes 1/5 sec.**
- **With FRAM**
 - 125ns/byte (or word)
 - 100uA
- **With EEPROM**
 - 5ms
 - 5mA
 - EEPROM software overhead not show

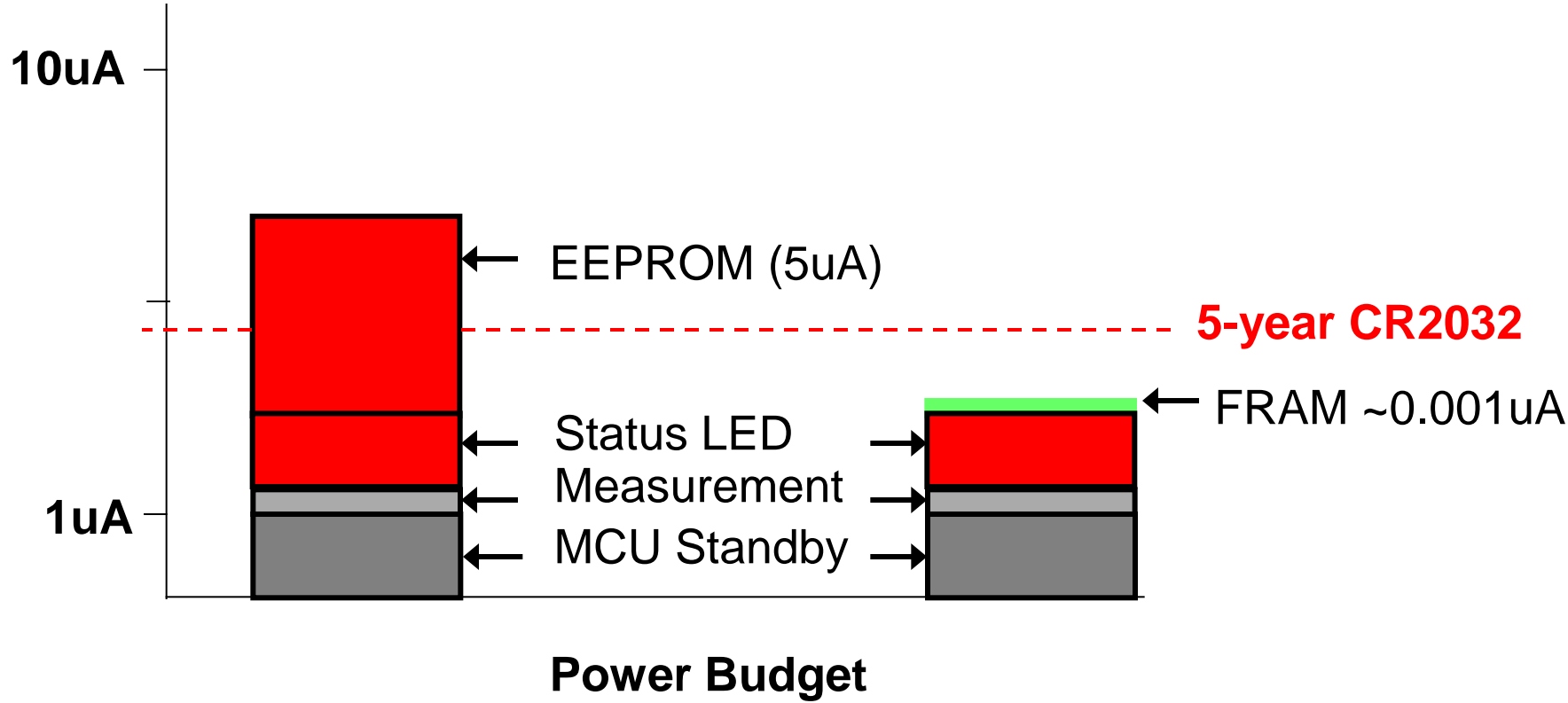


FRAM Write Speed Versus EEPROM

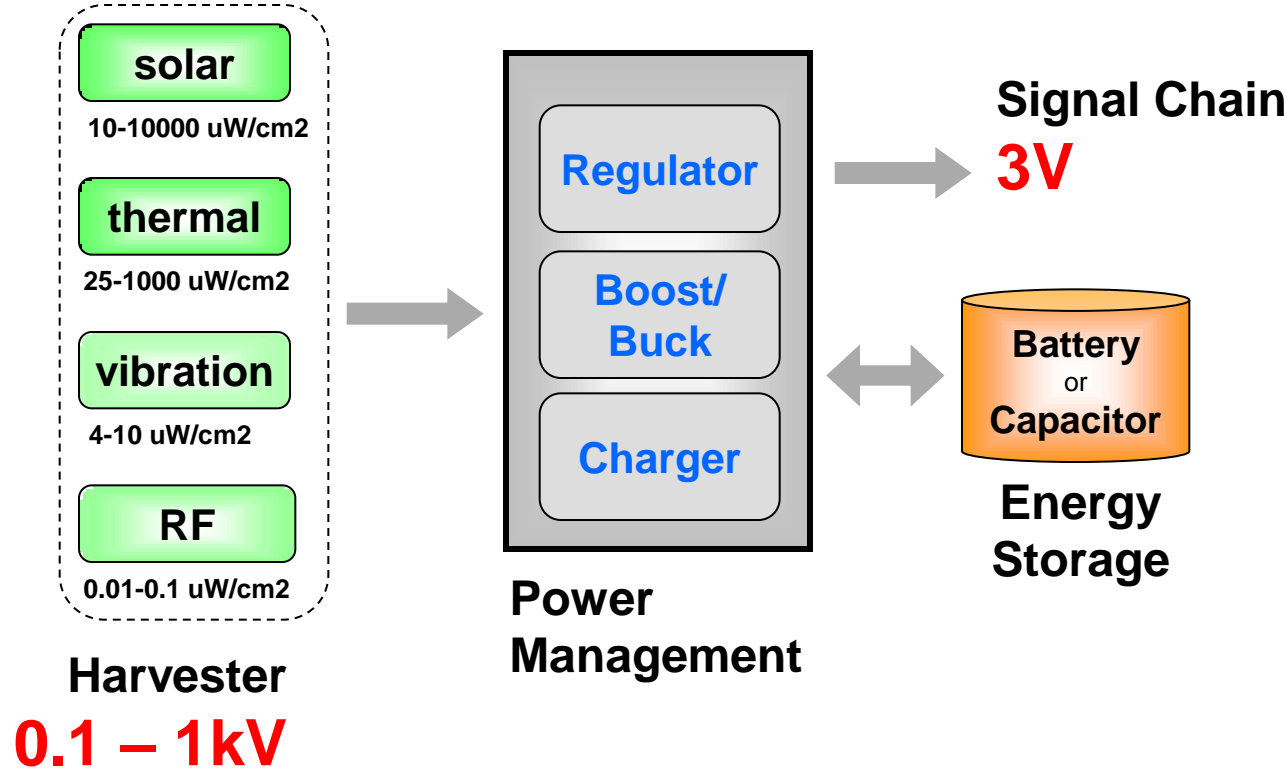
- **Write as fast as possible**
- **With FRAM**
 - 125ns/byte (or word)
 - 100uA
- **With EEPROM**
 - 5ms
 - 5mA
- **Maximum FRAM access**
 - 16,000,000 bytes/sec
 - 8M DMA word transfers/sec



Data Logger Power Budget



Energy Harvester Optional Subsystem



Significant mismatch in Harvester/Signal-Chain

bq25504 For Energy Harvesting

- **Ultra-low Power Boost Converter / Charger**

- Ultra-low quiescent 330nA
- Harvests from $V_{in} > 100\text{mV}$
- Cold Start Unit $V_{in} > 330\text{mV}$.
- Efficiency $> 80\%$ for $V_{in} > 500\text{mV}$
- Supports single cell solar cells
- Supports TEG harvesting
- Maximum Power Point Tracking

- **Energy storage**

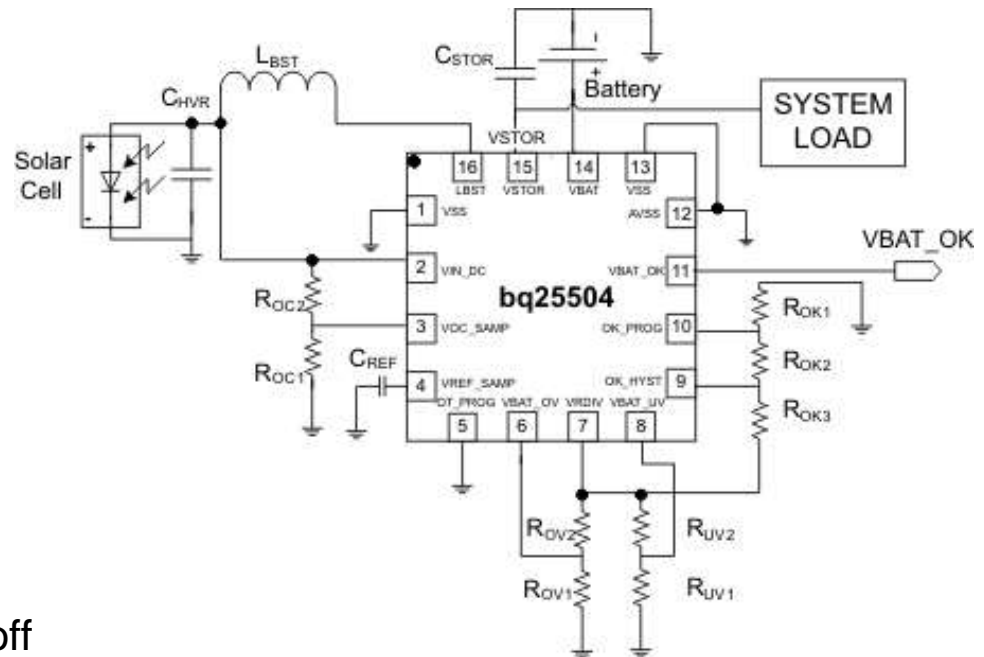
- Conventional / super-capacitors
- Re-chargeable Li-ion

- **Battery protection**

- Programmable UV / OV levels
- On-chip temp sensor for OT shutoff

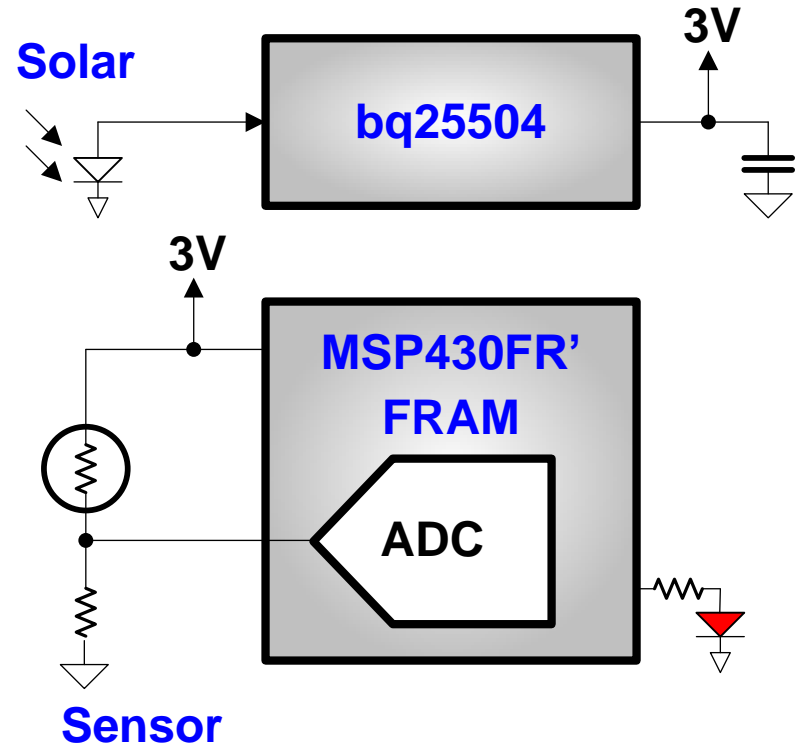
- **Battery status output**

- Programmable level and hysteresis



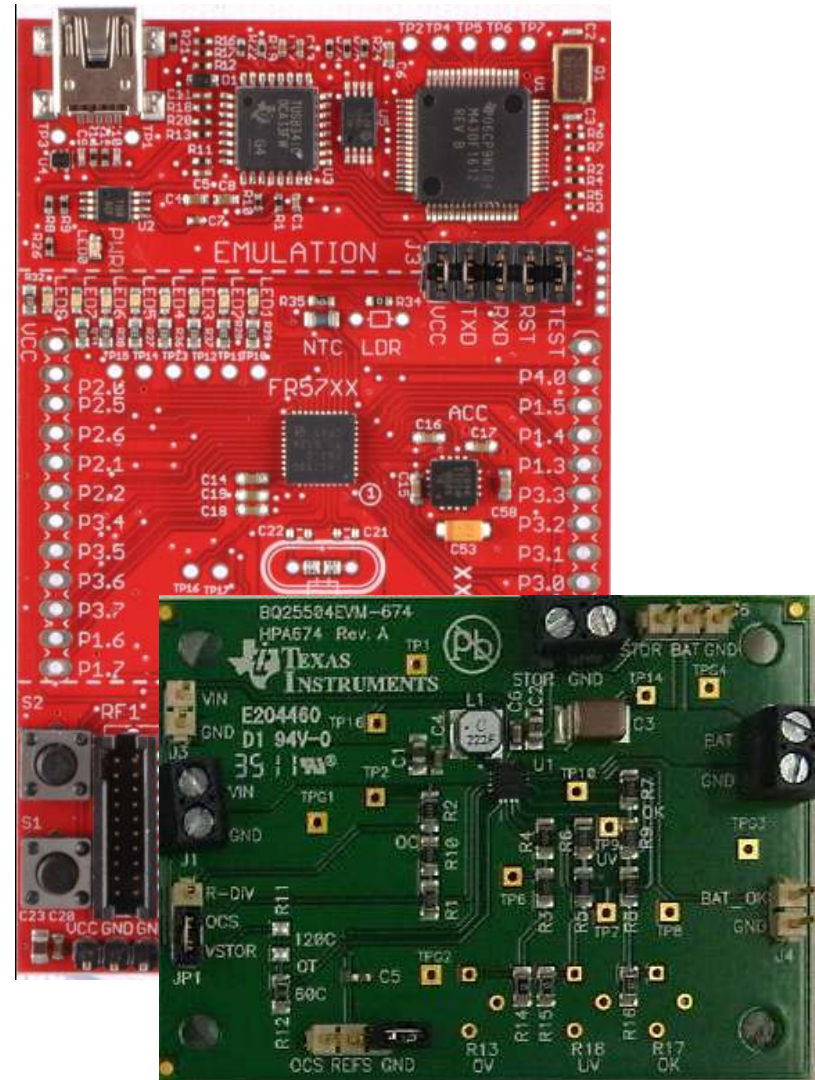
EH Optimized Data Logger

- **MSP430FR5739 MCU**
 - ADC for direct sensor interface
 - FRAM enables embedded logging
- **bq25504**
 - Ultra-low Power Boost Converter
 - Harvest solar energy
- **Externally low power 3uA**
- **Simpler and lower cost**
- **Permanently powered!**



MSP-EXP430FR5739 - BQ25504-EVM

- **MSP Experimenter's Board**
 - On Board Emulation
 - Features
 - 8 Display LED's
 - NTC Thermister
 - 3 axis accelerometer
 - 2 User input Switches
- **BQ25504-EVM**
 - Ready for instrumentation
 - Flexible for different inputs
- **Out-of-box(s) systems demo!**



Summary

- **Data Logger Subsystems**
 - Sensor + Interface
 - Processor
 - Data storage
 - Output
- **Save Energy**
 - Duty Cycle
 - Power manage sensor
 - Power aware software a must
 - Efficient non-volatile data storage
- **MSP430FR57xx**
 - integrates sensor interface and FRAM Data storage
- **bq25504 boost converter**
 - Enables EH with for permanent power