European Thermodynamics Limited

Intelligent Thermal Management

EPSRC

Engineering and Physical Sciences Research Council

European Thermodynamics Limited

Thermoelectric energy harvester with integrated, robust and autonomous sensing system

Energy Harvesting 2015, 19th March 2015, London

Mr. Kevin Simpson- Technical Director

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OVERVIEW. INTRODUCTION TO ETL

- Founded in 2001. Private Ltd Co.
- Bespoke thermal management
- 26 full and part-time staff

R&D department (6 Researchers) &

Engineering (8 Engineers and 2 Technicians)

- €5m annual turnover
- R&D projects part-funded by:

esa European Space Agency

Technology Strategy Board Driving Innovation

Department of Energy & Climate Change

PRINTEG Production Innovation for ThermoElectric Generators

Prestege

POWERDRIVER

ESOT

MAXCOP

TITAN

innovteg

BESPOKE DEVELOPMENT FOR THERMAL MANAGEMENT

Mechanical and electronic design

Thermal and stress analysis

Prototyping

Production

LEADING SECTORS

Telecomm

Automotive

TV & Broadcast

Industrial

Lab & Medical

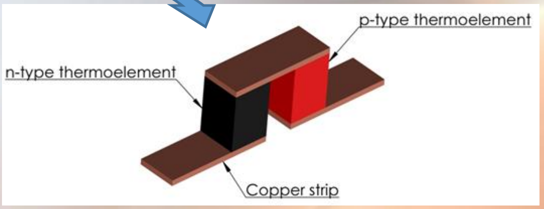
Military

BASICS ON THERMOELECTRIC DEVICES

The thermoelectric concept is a perfect solution for recovering waste heat to obtain electric energy

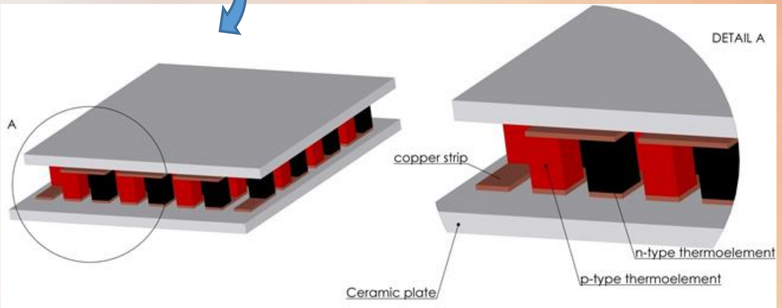
SEEBECK EFFECT

- Basic unit of a thermoelectric device is the Thermocouple
- N & p-type thermo elements connected electrically in series by a conducting strip
- Units are arranged electrically in series and thermally in parallel, Module



Key Features

- High reliability
- Relatively inexpensive and small
- Light weight
- Compact
- Quiet operation



TE MATERIALS FOR ENERGY HARVESTING. LIMITATIONS OF CURRENT MATERIALS

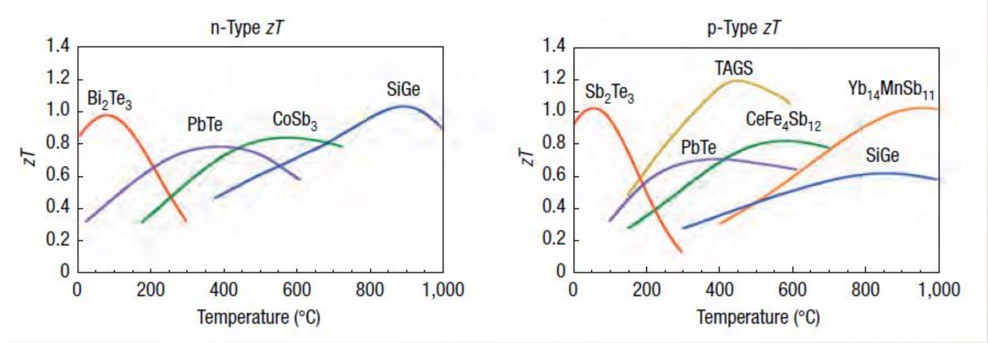
What makes a good thermoelectric,

α: Seebeck coefficient
σ : Electrical conductivity
κ: Thermal conductivity

$$ZT = \frac{S^2 \sigma T}{(\kappa_L + \kappa_e)}$$

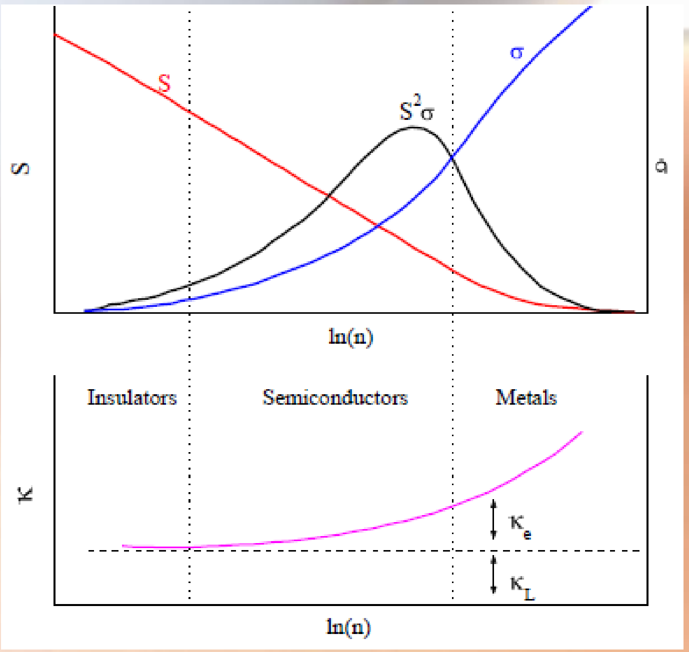
Up-to –date best Bulk Thermoelectrics: Bi_2Te_3/Sb_2Te_3, PbTe, Si-Ge

Bulk materials performance



[1]

PARAMETERS ARE ALL INTER-DEPENDENT



The ideal material should conduct electricity like a metal and heat like an insulator

[1] Nature Materials 7, 105 (2008)

Energy Thermal Harvesting System

- Autonomous battery-free wireless sensing system
- Sensor data (e.g. temperature / humidity / pressure) transmitted under normal/harsh conditions
- Low power requirements, thermoelectric power from temperature gradients
- MPPT system to maximise efficiency
- Various heat sources possible, target warm and hot water sources
- All sensor data collected, burst of data via a wireless channel to a base station/node.

Features of Adaptive Energy Harvesting System:

Input voltage range: 50mV – 1000mV

Minimum input power:1mW, min. temp diff: 5ºC

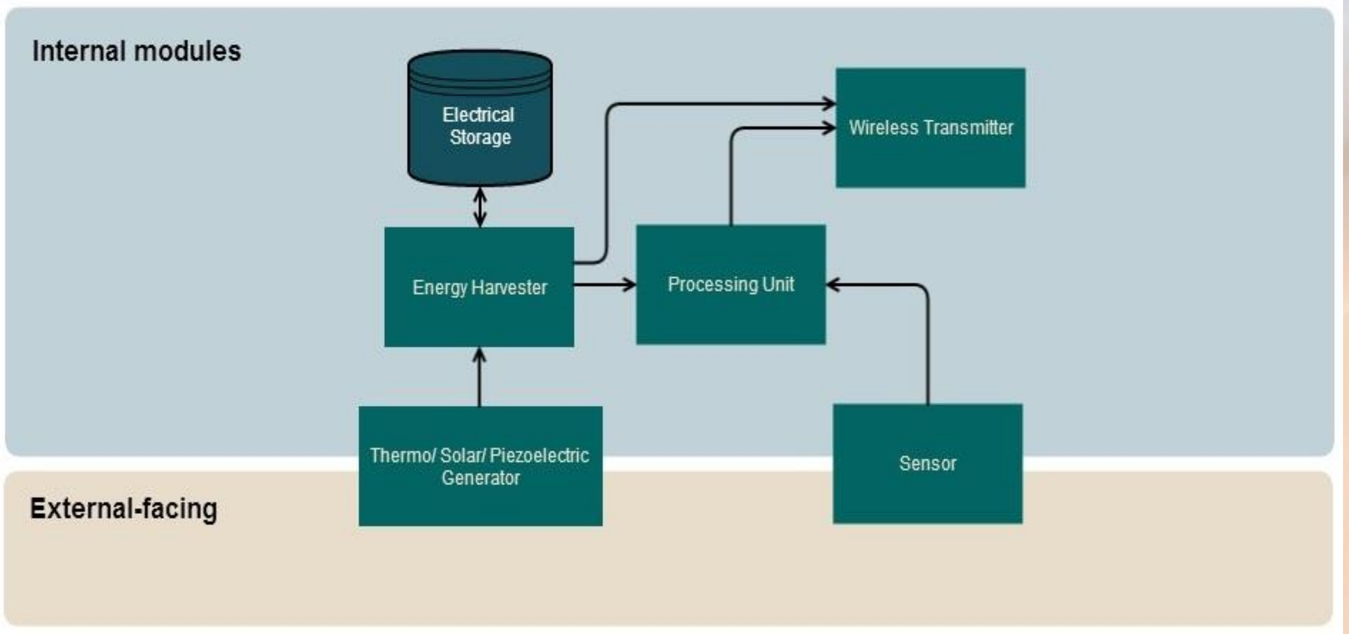
High priority “alert” capability in an “out of bounds” event

Switchable MPPT to MEffPT to keep energy storage topped up (when capacitor fully charged)

Wireless transmissions, embedded micro-processor with integrated RTC and analogue i/p , with digital I/O

Energy Thermal Harvesting System

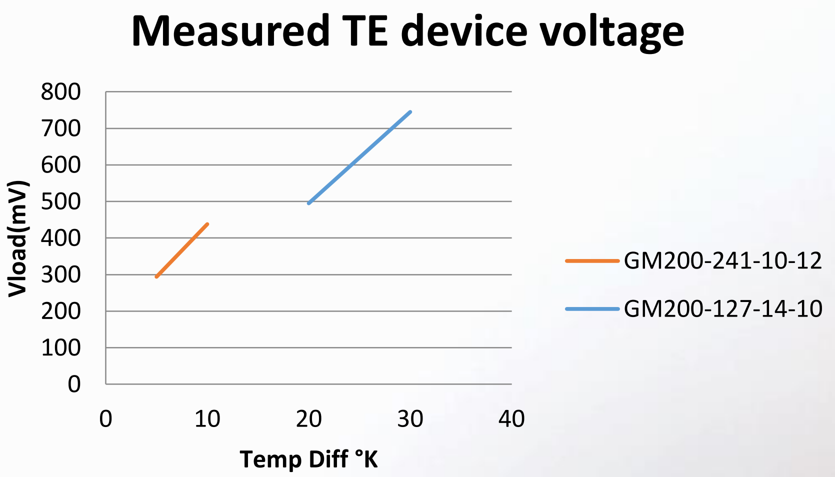
- Hardware Architecture

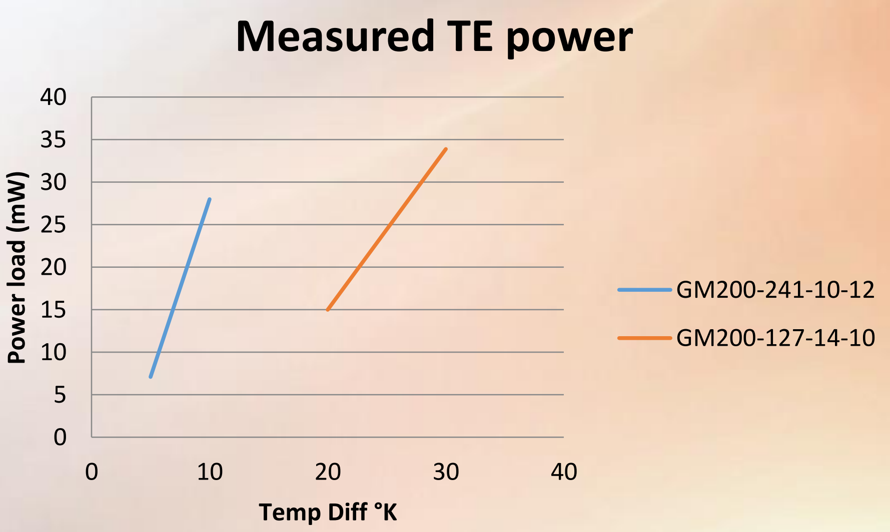


Energy Thermal Harvesting System

Thermal Harvesting potential

Table 1	°K	Measured		
Module	Temp Diff	Pload(mW)	Vload (mV)	Iload (mA)
GM200-241-10-12	5	7.1	294	24
GM200-241-10-12	10	28	438	64
GM200-127-14-10	20	15	495	30.5
GM200-127-14-10	30	33.9	745	45.5





Thermal Energy Harvesting System

MPU Selection

Table 1: Microprocessor options and features (top) and selection matrix (bottom)

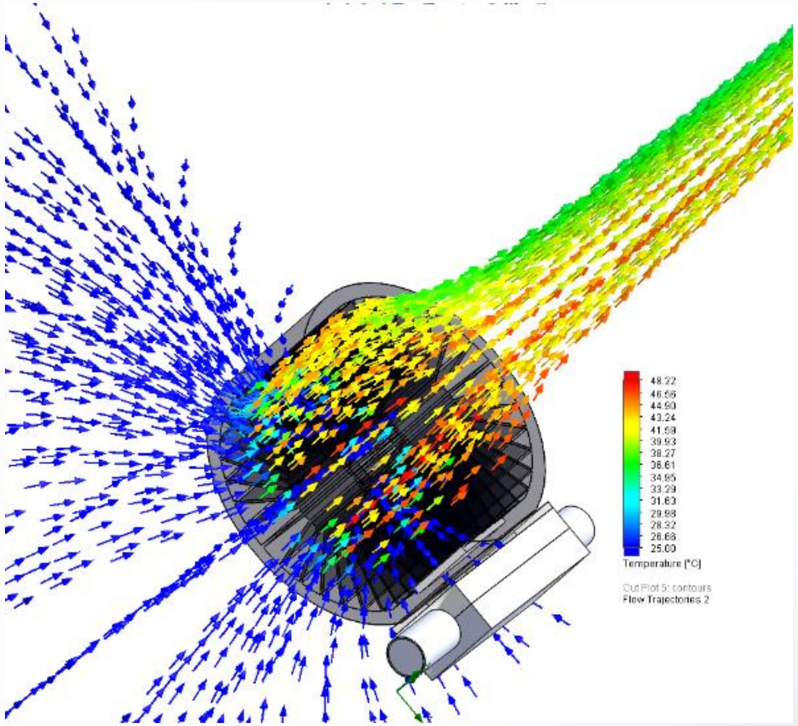
Part Selection	Features						
Part	**Manufacturer**	**Power Consumption**	**Peripheral I/O**	**ADC**	**Pins**	**Data Width**	**Real Time Clock**
MSP430FR5739	Texas Instruments	81.4µA/MHz	3 spi/1 i2c	10 x 12	38	16	Yes
PIC16LF1503	Microchip	20µA @ 31kHz	SPI or I2C	10 bit x 8	14	8	Yes
STM8L101F2	STMicroelectronics	150µA/MHz	SPI	None	20	8	No

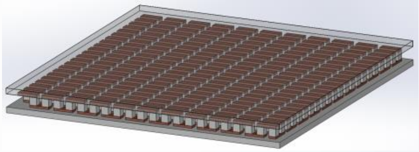
Design Criteria	Weighting	MSP430FR5739	PIC16LF1503	STM8L101F2
Power Consumption	0.8			
Peripheral IO	0.5			
ADC	0.5			
Pins	0.2			
Real Time Clock	0.8			
Score		SELECTED	B/UP	

CC430 (MSP430 with integrated radio)

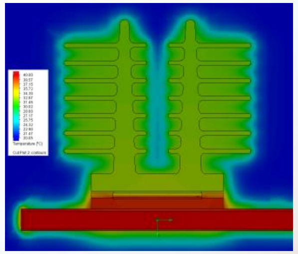
Thermal Energy Harvesting System

Mechanical / CFD Design

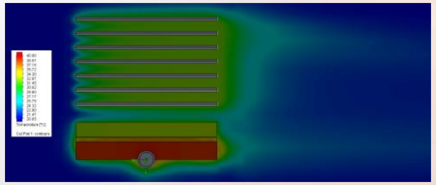




Module modelled within complete system design

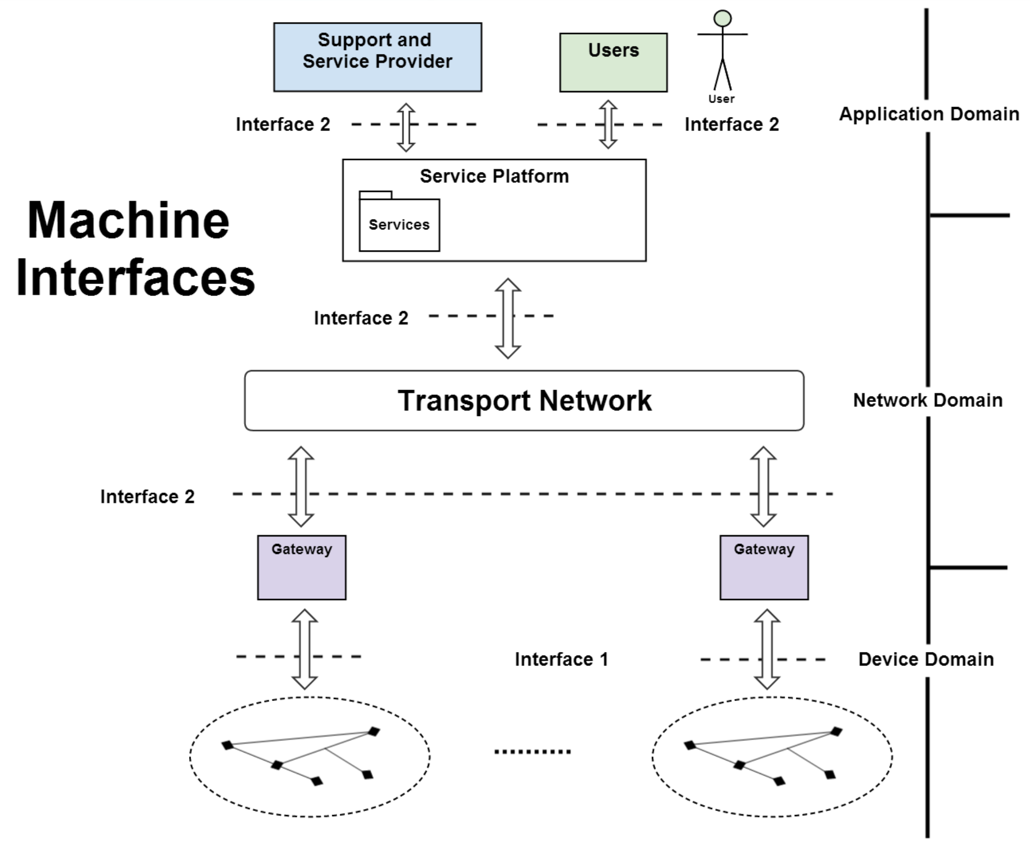


Cut sections for showing natural convection movement

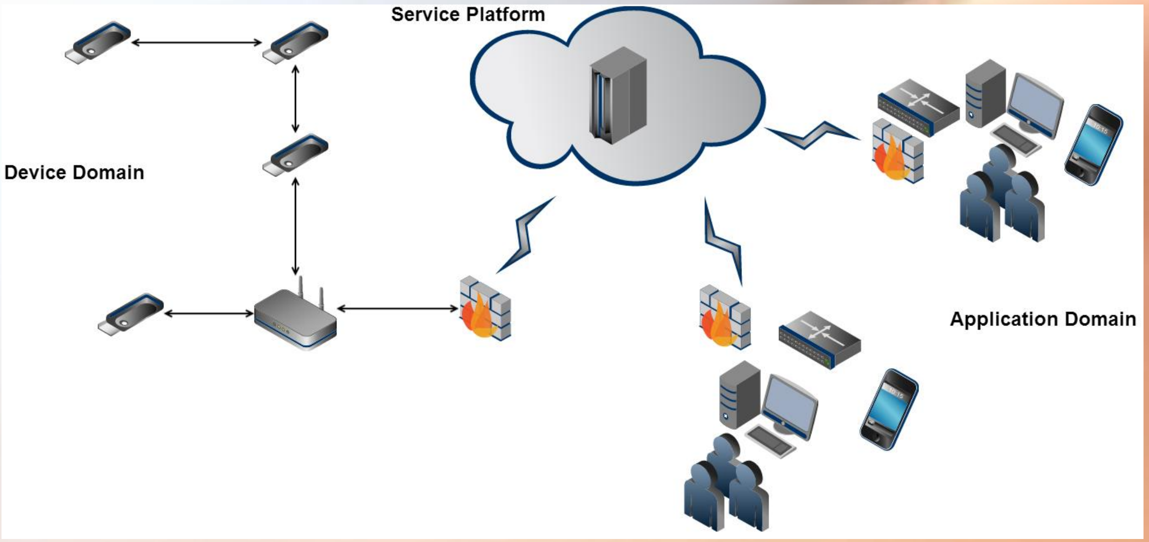


Design compromise for cost/performance/flexibility

Energy Harvesting Sensors and the IOT Ecosystem



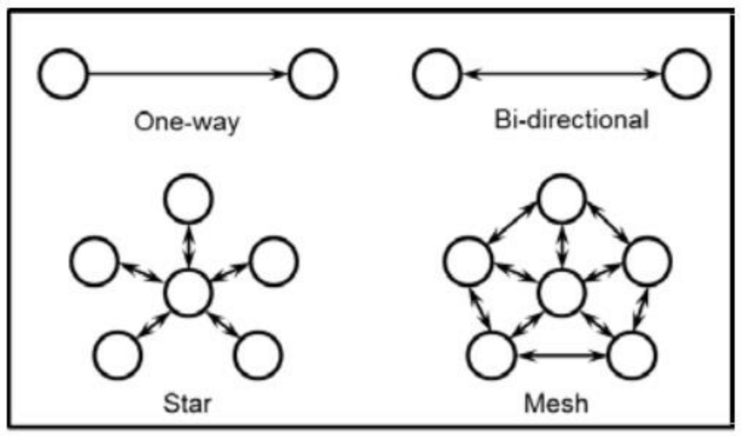
Interfaces in a Wireless Energy Harvesting Sensor Network



Wireless Energy Harvesting Sensor Network Ecosystem

Energy Harvesting Sensors and the IOT Ecosystem

- Network Topologies
  - Robust and cost effective point to point links
  - Mesh and star emerged as predominant for WiFi connected devices



Energy Harvesting Sensors and the IOT Ecosystem

- Power consideration
  - Point – Point Ultra Low Power
  - Low Power Sub GHz mesh network for data collection
  - Low Power WiFi network as a gateway and big data processor or real-time sensor
- Hardware Independent Platform within a Geo-Distributed network
  - Single board computers (eg. Arduino), PCs, Cloud
- Real time capability
  - Connection to data intensive analytics platforms (eg. AWS Cloud)

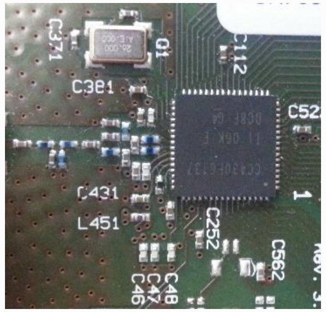
Energy Harvesting Sensors and the IOT Ecosystem

- Cost reduction challenges
  - Industrial and Harsh environment – Special Enclosures and connectors
  - Radio Interfaces - FCC/ETSI Certified modules or design your own ?
  - Adoption of low power mesh networking software
  - Standardised sensor assemblies or custom made for specific fields ?
  - 3D assembly for high volumes

Energy Harvesting Sensors and the IOT Ecosystem

Highly integrated Solutions

- Data Processing and RF transmission - Mixed Signal SoC solutions



Ultra low power – Sub GHz

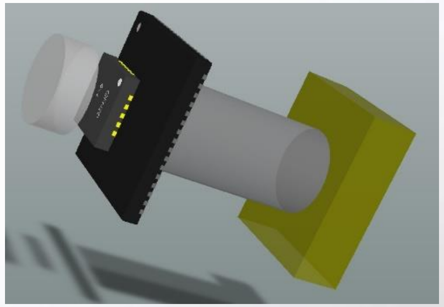
Low power WiFi

- Harvester

High ESR Capacitor

Low Voltage (<100mV) harvester

- Special applications – Extreme High temperature applications

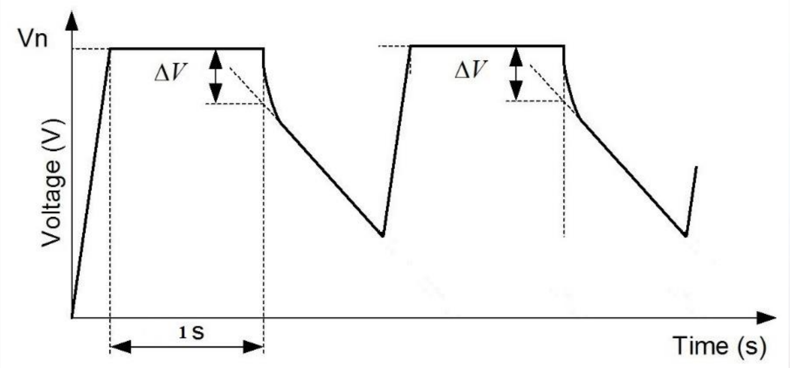


Low ESR Capacitor

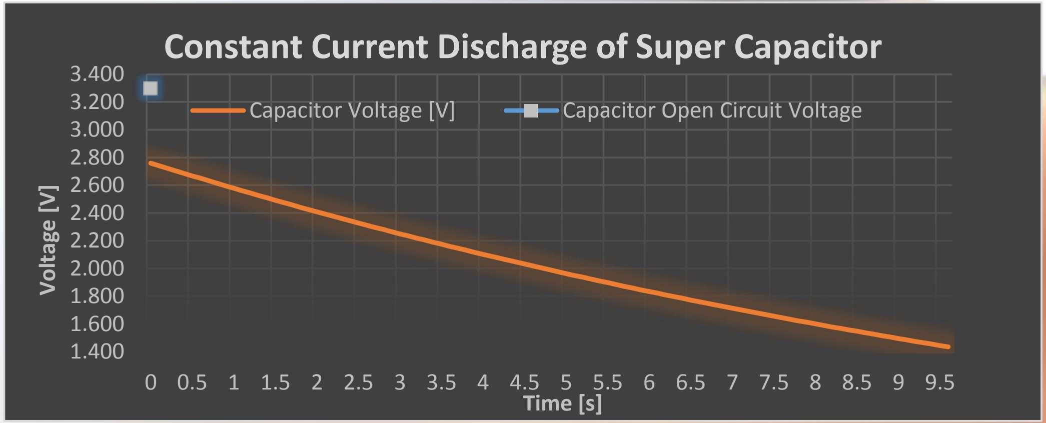
Energy Harvesting Sensors and the IOT Ecosystem

- Power Budget Considerations

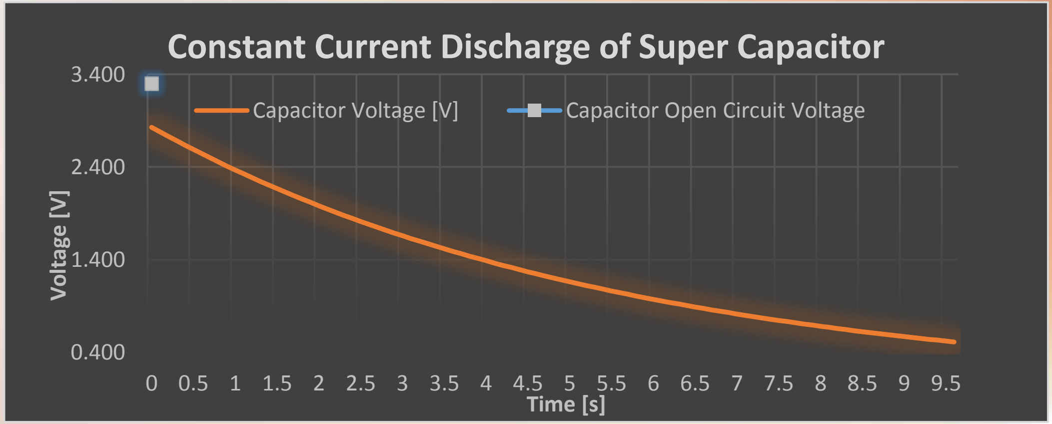
$$\text{Total Average Current} = \frac{\text{Inactive Current x Inactive Time} + \text{Active Current x Active Time}}{\text{Total Time}}$$



- Charging from intermittent sources
  - Internal resistance, size of super-capacitors
  - Duty cycle limitations



Low Power Sub GHz

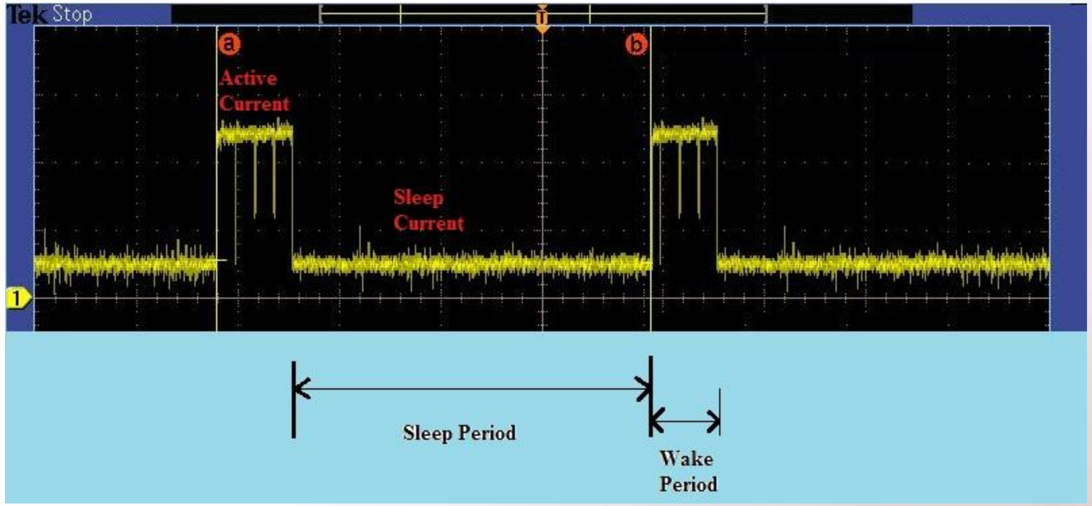


Low Power WiFi

Energy Harvesting Sensors and the IOT Ecosystem

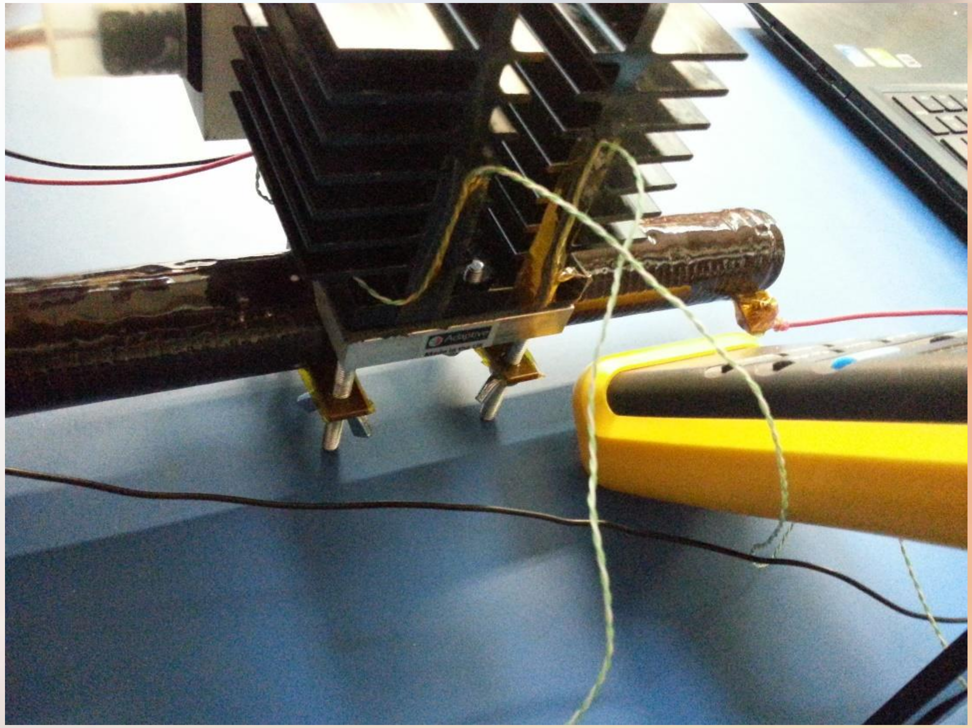
Min. Power Budget Considerations

Low Power								
Current		Time			Calculated Current			Calculated Power
Active [mA]	Sleep [mA]	Active [ms]	Sleep [ms]	Total [ms]	Peak [mA]	Average [mA]	24h [mA_ hours]	Power required [µW]
18	0.004	3	997	1000	18	0.057988	1.391712	187.88112



Thermal Energy Harvesting System

Example Use Case - Wireless Harvester



- Demo kits to be made available by Q3 ‘15

Thank you

Thankyou for listening

The Adaptive Plant Energy Harvesting project,

Project number 131189, was co-funded by Innovate UK.

Project partners: ETL and University of Glasgow

Lead PI from UoG: Professor Andy Knox – Electronics and Nanoscale Eng.

University of Glasgow

Innovate UK
Technology Strategy Board