

Next-Generation Energy- Harvesting Electronics: Holistic Approach

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Project Overview

- £1.6M, three-year, EPSRC-funded project
- Kicked off in Q4 2009
- Over 25 people at four UK institutions:

EPSRC

UNIVERSITY OF
Southampton



**Imperial College
London**



- Industrial advisory board:

DIODES
INCORPORATED

ARM

dialog
SEMICONDUCTOR

**Mentor
Graphics**

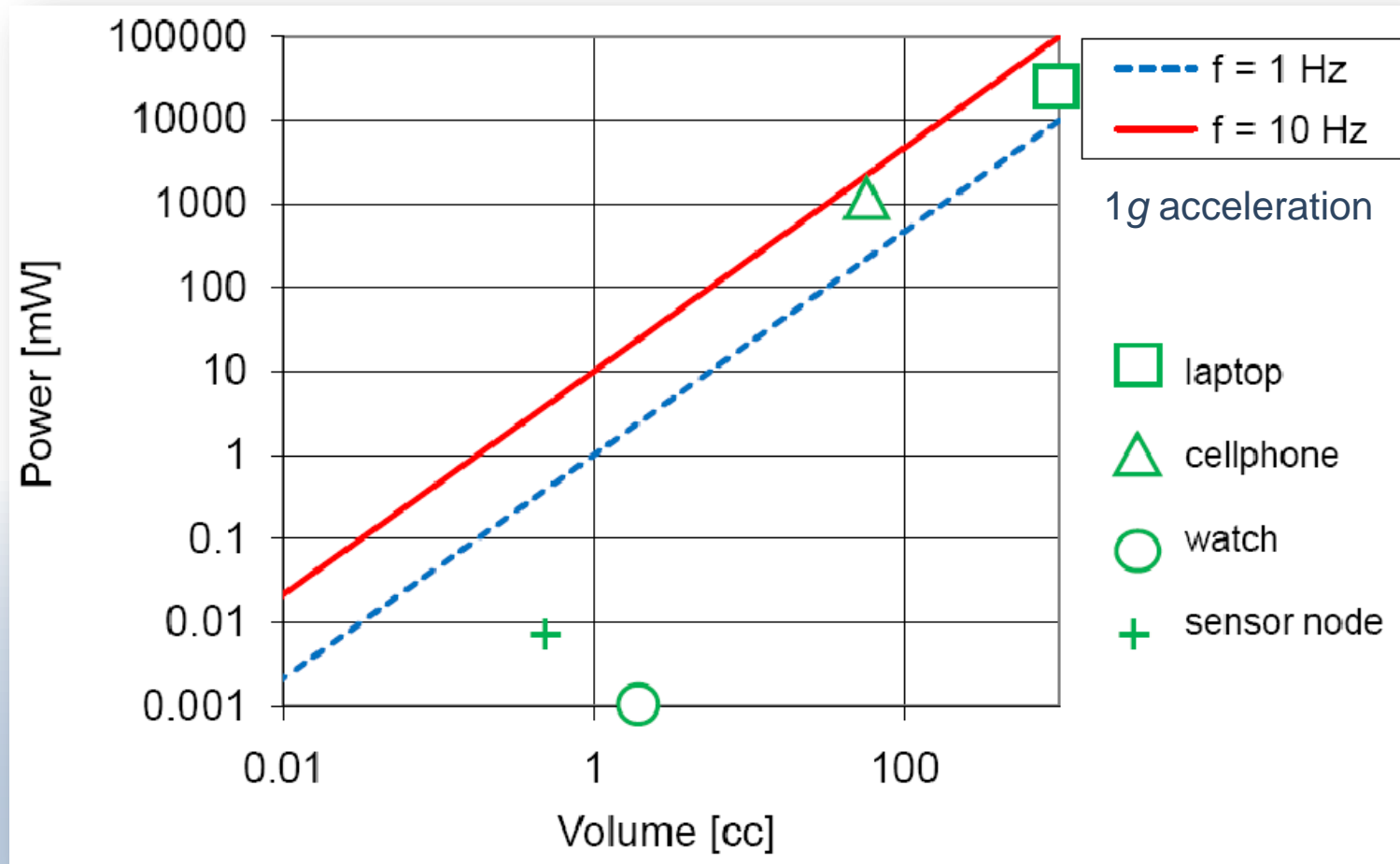
Applications of Vibration EH

- Typically condition monitoring, using wireless sensors
 - Sensors can be retro-fitted without electrician/batteries



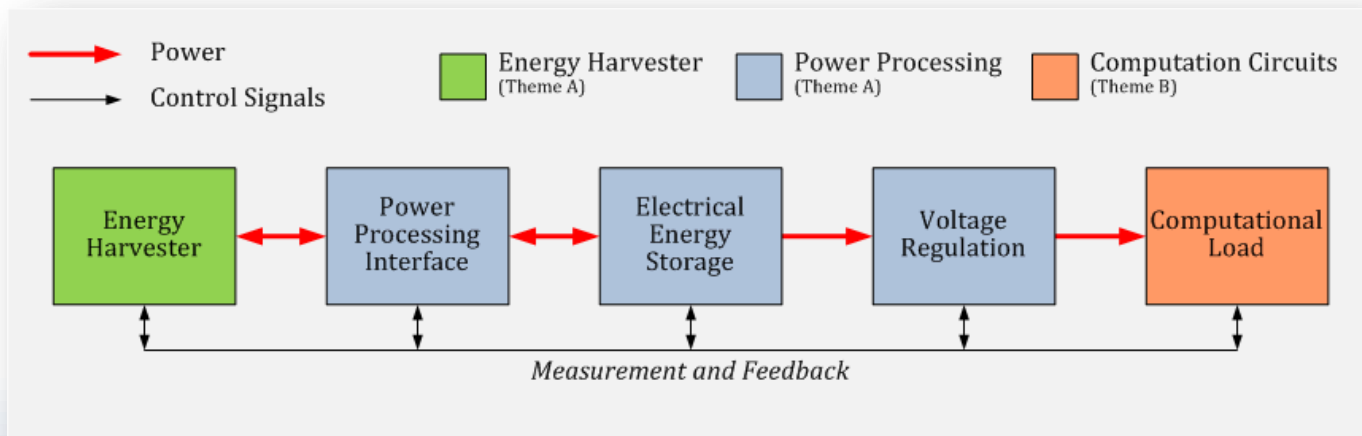
- Also applications in asset tracking, monitoring of rotating machinery, even human health monitoring

Limitations of Vibration EH



Taking a 'Holistic' Approach

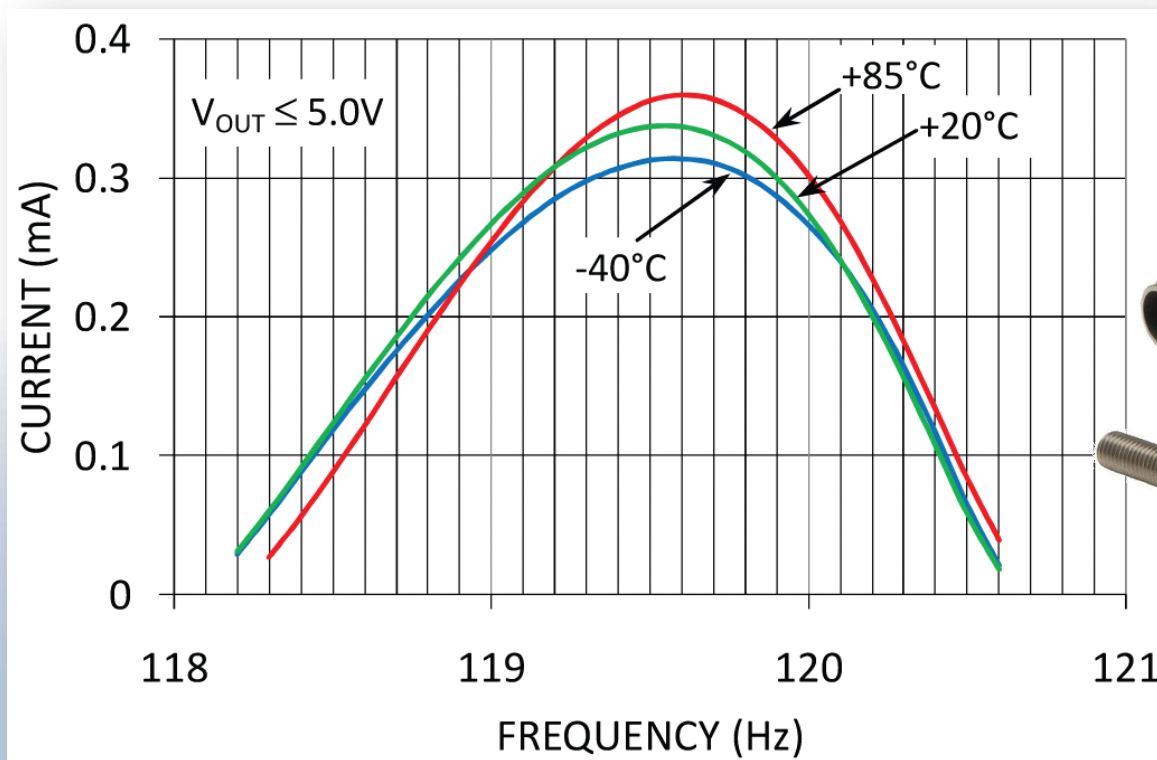
- Two-way interactions between each part



- To achieve good efficiency, simulate complete system
- Must adapt to changes to maintain efficiency

The First Problem...

- Vibration amplitude and dominant frequency vary
- Harvesters are tuned to fixed frequencies



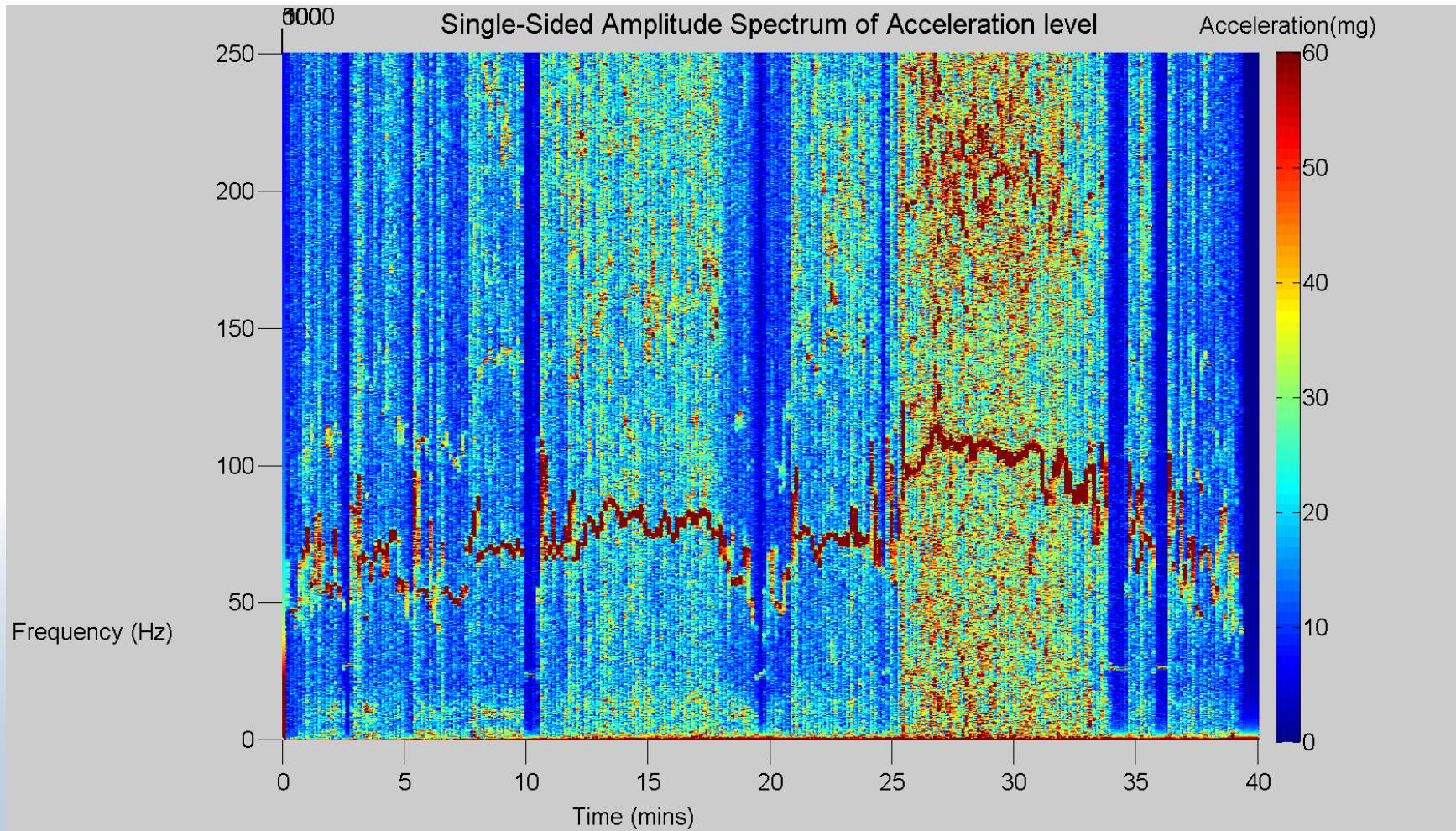
Car Engine

Monitored vibration on engine block, while driving on a variety of roads



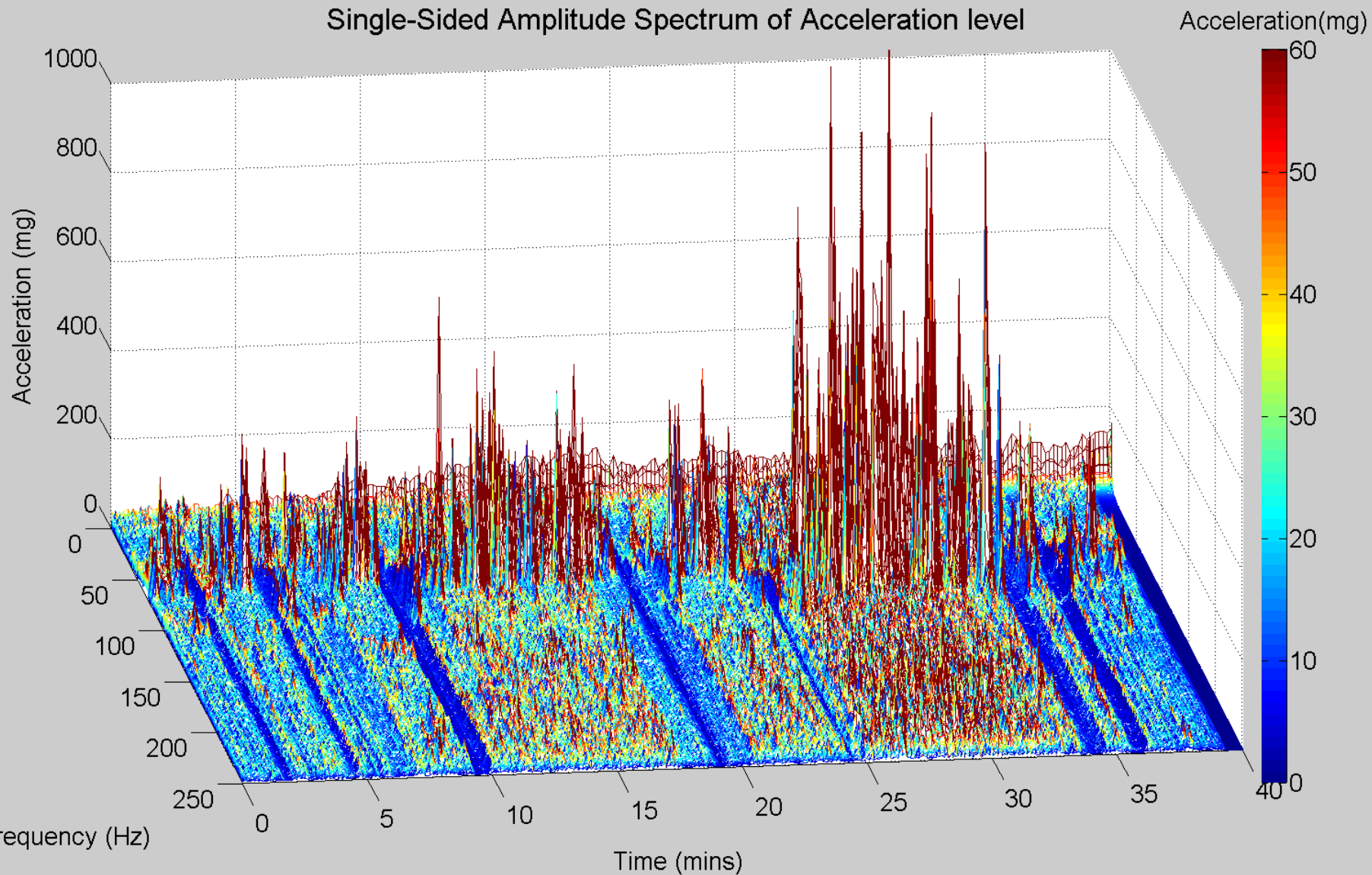


Engine Test (0-250Hz)



Speed(mph)	30	60	20	60	70	30
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Single-Sided Amplitude Spectrum of Acceleration level



Speed(mph)

30

60

20

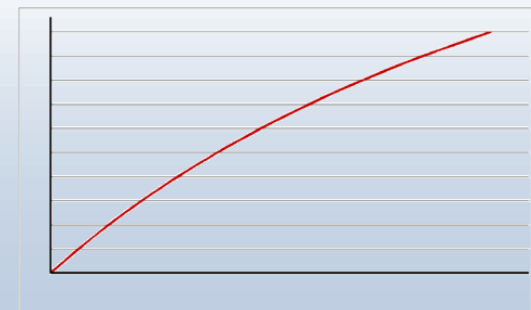
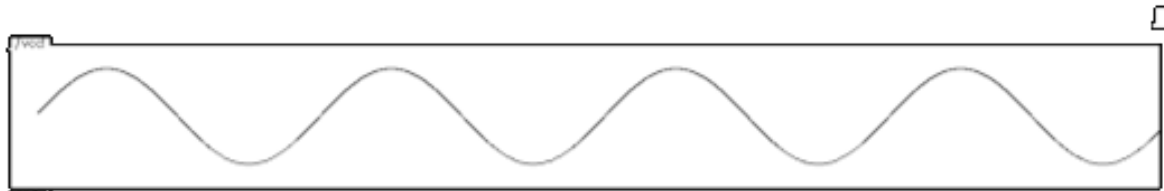
60

70

30

The Second Problem...

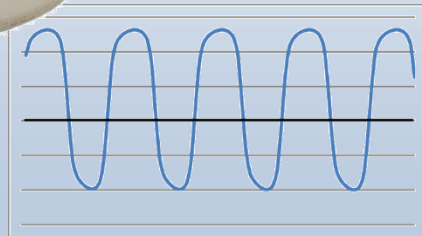
- Conventional electronics operate at a fixed voltage
- Takes a long time to charge, voltage varies
- How will systems work with varying input voltages?



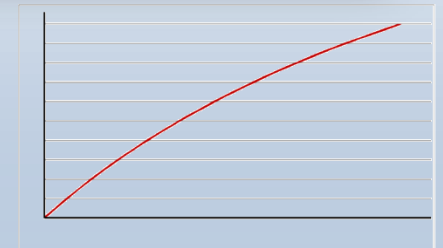
←Time (hours)→

The Third (and final) Problem...

- Systems are complex and can't be simulated easily
 - Design in isolation results in poor efficiency ($\sim 2\%$)
- Mix of long and short times make simulation difficult



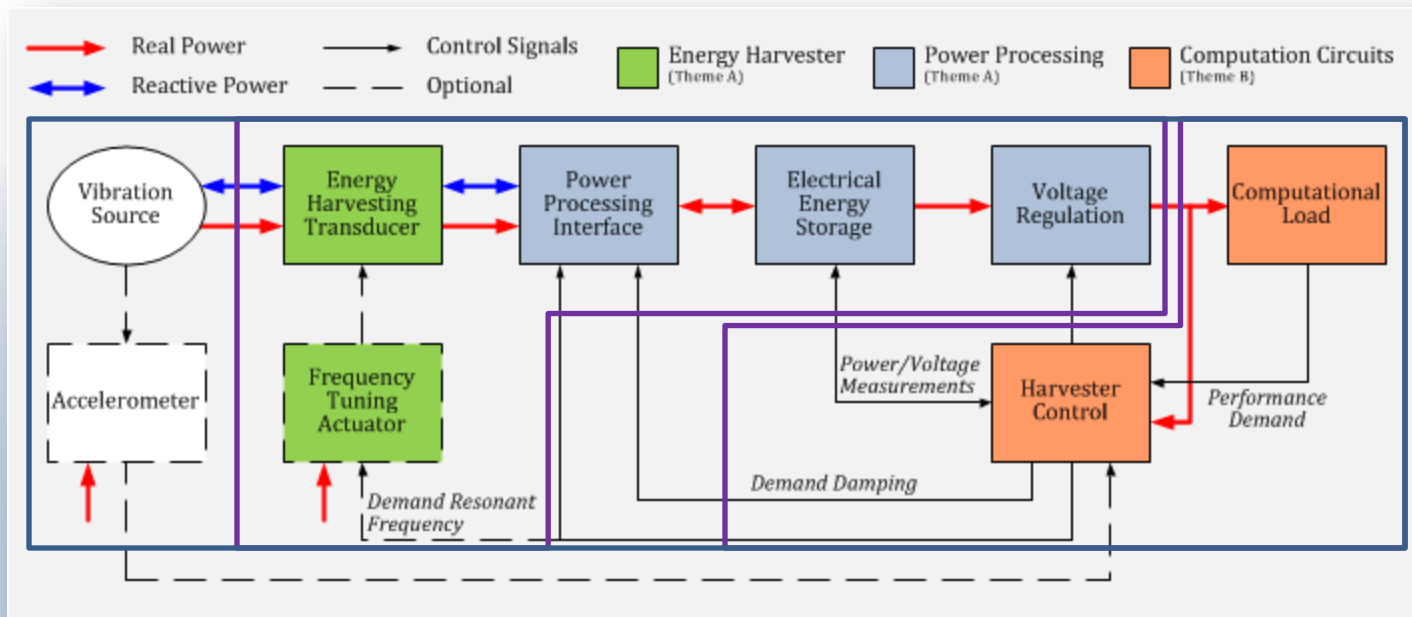
←Time (ms)→



←Time (hours)→

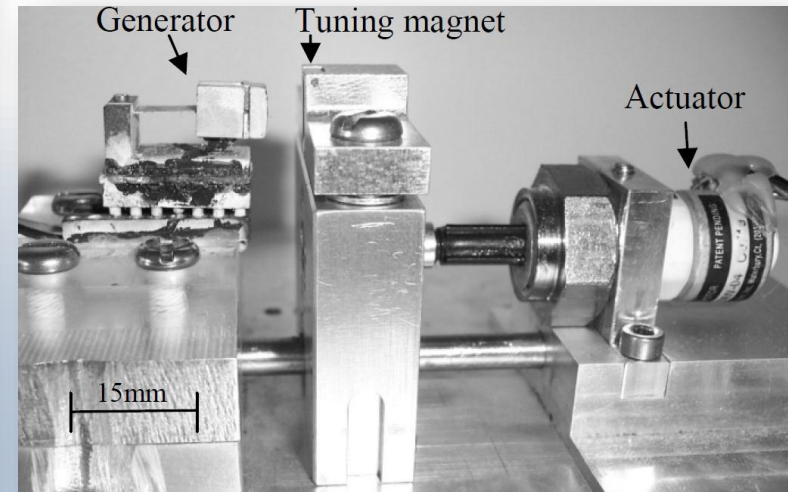
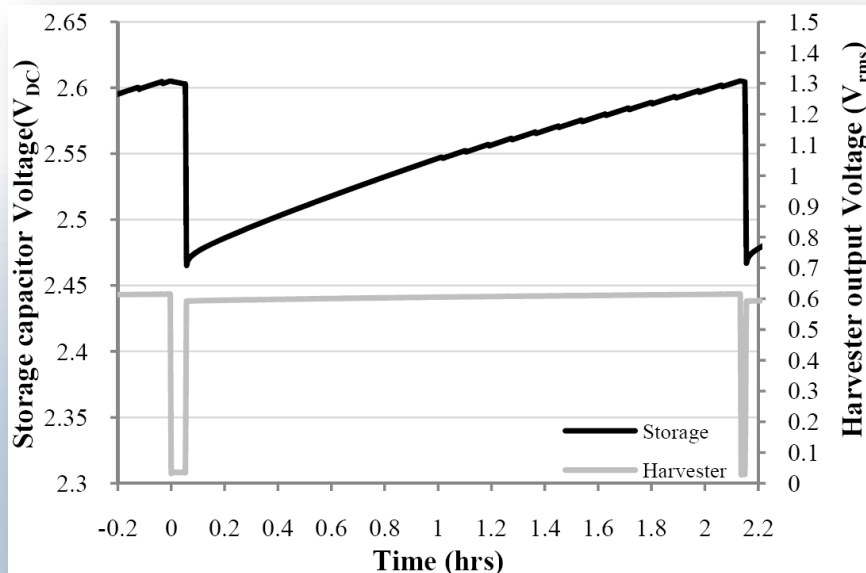
Project Themes

- A: Adaptive, High-Efficiency Micro Generators
- B: Energy Harvesting-Aware Computation Circuits
- C: Integrated Modelling & Performance Optimisation for Energy Harvesting Systems



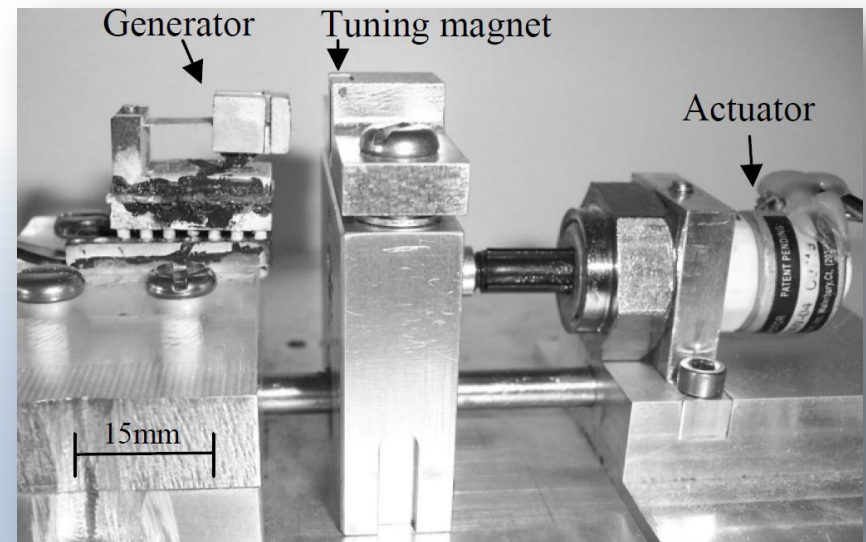
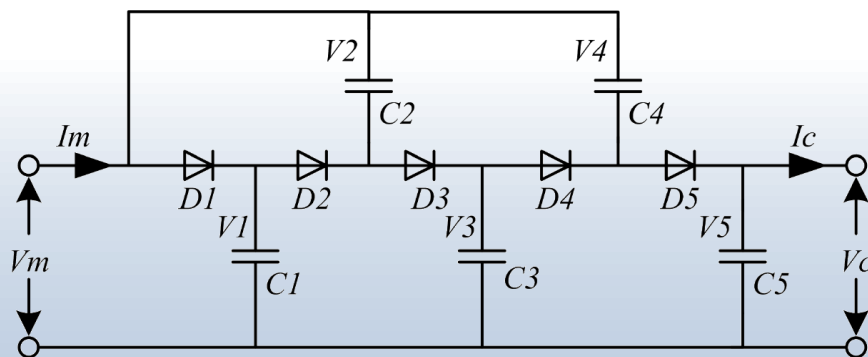
Case Study

- Existing tuneable EM vibration energy harvester
- Tuning range 64-78Hz, and is energy-intensive
- Not designed in a 'Holistic' way



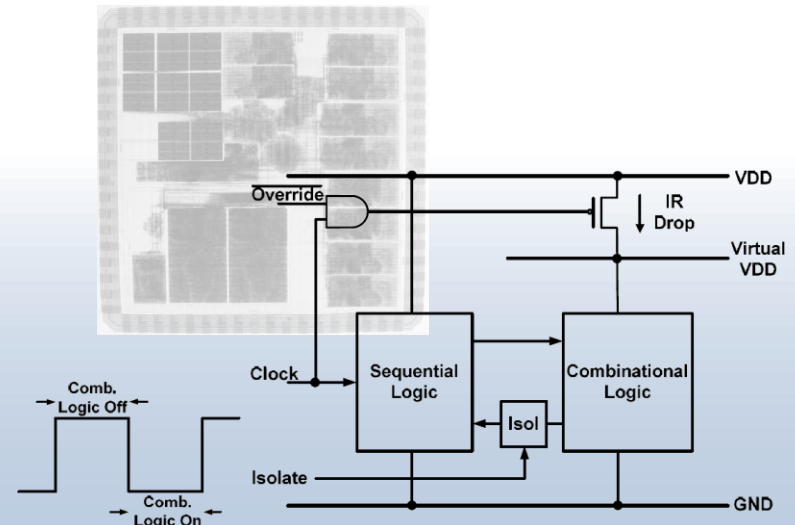
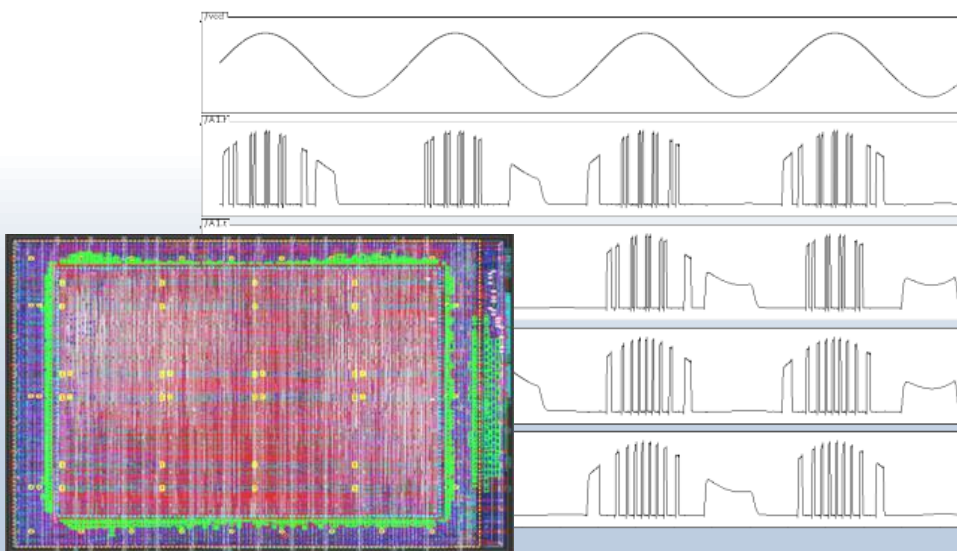
Theme A

- Novel tuning mechanisms for electromagnetic vibration EH – replacing large systems with MEMS
- Highly-efficient power conversion circuits (inc. boost converters) for tuneable EH



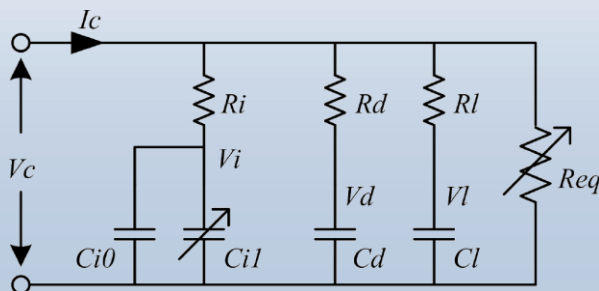
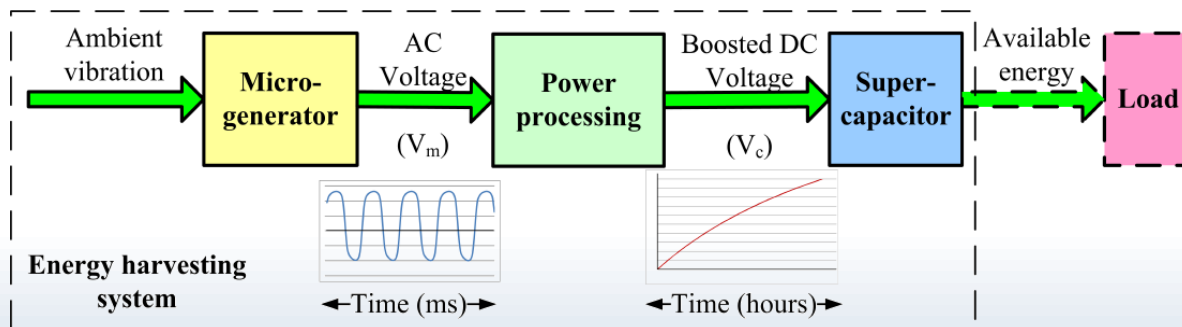
Theme B

- “Energy-modulate”, and reduce active power
 - Asynchronous digital circuits capable of operating from variable sources
 - An ultra-low-power synchronous digital processor



Theme C

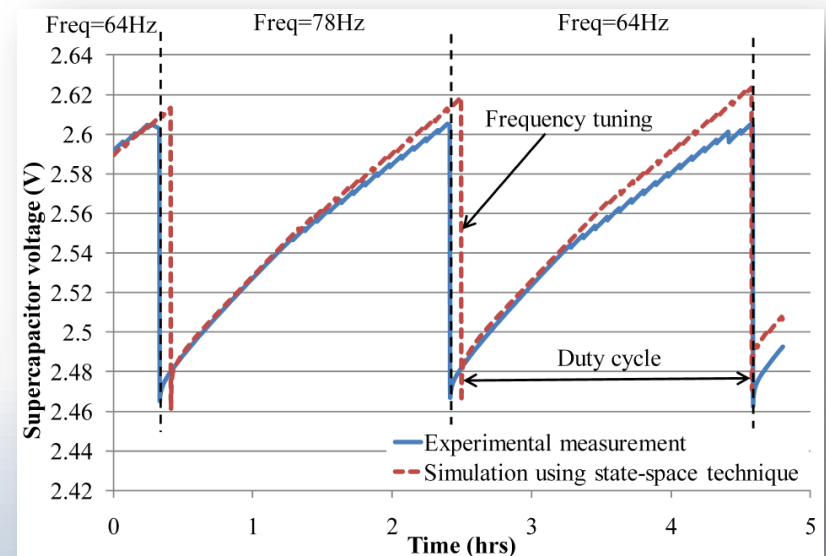
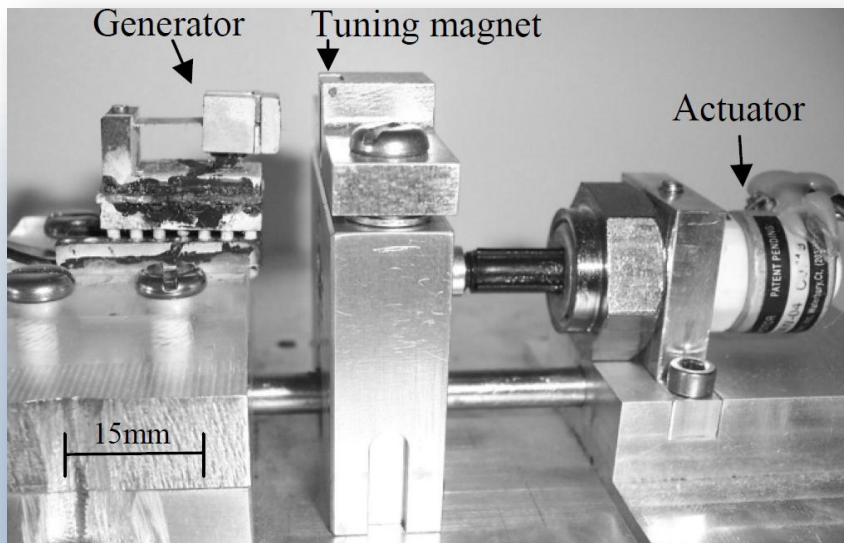
- Simulation techniques for complete systems
- Modelling of system components (e.g. supercapacitor)
- Already 100x faster simulation, enabling optimisation



	Existing technique	Proposed technique
Simulator	SystemVision	MS Visual C++
HDL	VHDL-AMS	SystemC-A
Integration method	Newton-Raphson	Adams-Bashforth
CPU time for Scenario 1	2185 sec	20.3 sec
CPU time for Scenario 2	7 hours	228 sec

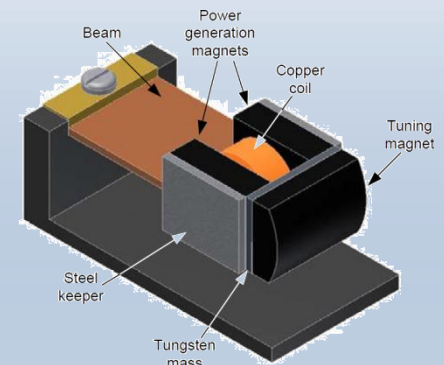
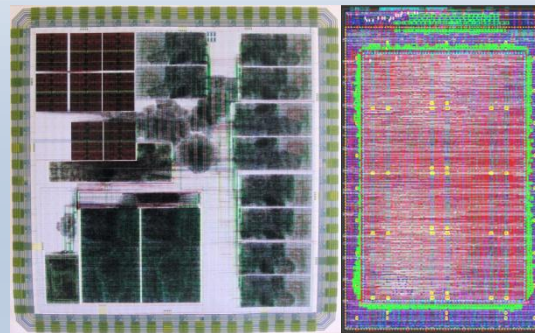
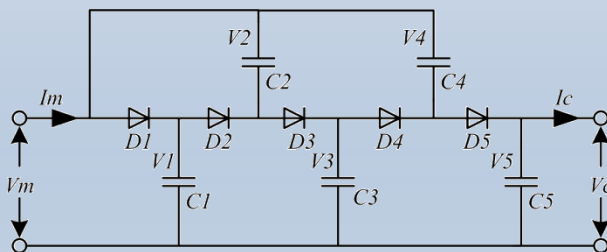
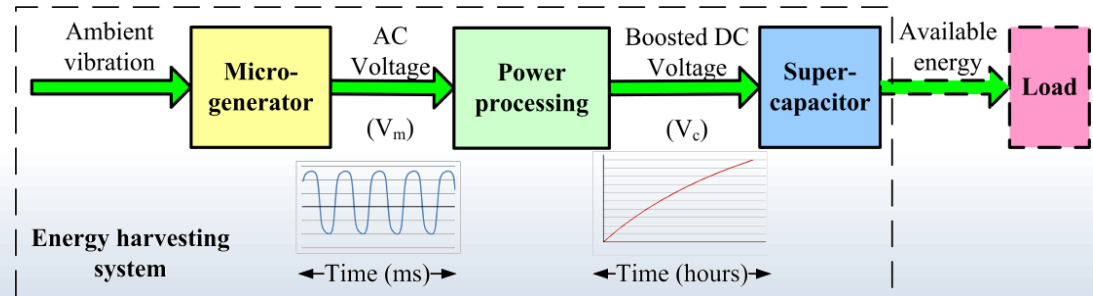
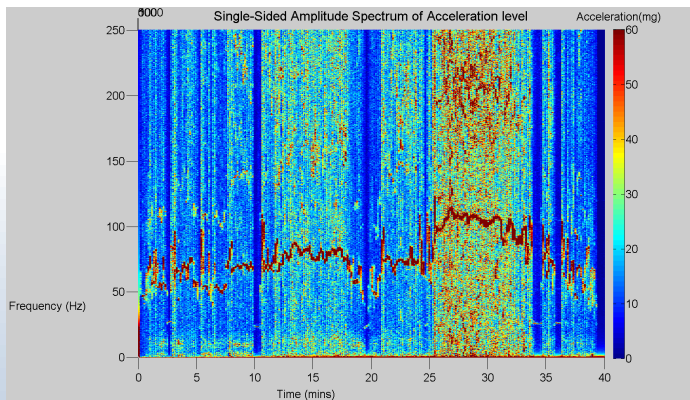
Complete System Simulation

- Able to simulate complete tuneable EH systems, including load
- Good levels of accuracy, and simulations complete much faster than previous methods



Next Steps

- Project ending in Q4 2012
 - System design targeted at real application
 - Complete system simulation
 - Deliver a real-world 'Holistic' demonstrator



To Learn More...

- Project Website – www.holistic.ecs.soton.ac.uk [or just search for “holistic energy harvesting”]



The screenshot shows the website's layout, including the header with logos for EPSRC, Southampton, Newcastle, Imperial College, and Bristol. The main content area features a navigation bar (Themes, People, Resources, Members' Area) and a section titled "Harvesting Electronics: A Holistic Approach".

Harvesting Electronics: A Holistic Approach

The era of electronics powered, or at least augmented by, energy harvesters. Future self-powered are more complex and more compact but also intelligent, adaptive and able to perform more...

...project, which is developing ultra energy-efficient electronic systems for emerging applications wireless monitoring in environmental and industrial settings. The project involves four universities (Imperial College, the University of Bristol) which will undertake the three-year industrial companies: QinetiQ, Diodes Incorporated, ARM, NXP and Mentor Graphics.

...ds, including energy harvesting and MEMS processing methods, low-power embedded computing design methodology will be incorporated into a novel mixed-technology domain modelling and design approach is fundamental to ultra energy-efficient design and to the miniaturisation of...

...es (microgenerator design, computation circuits, and system optimisation), and involves over 20 of the project and the advisory board may access the members' area of the site. The advisory Furber.

Latest News

DATE11: four and simulator Resources.

...amping. This forms the basis of Theme A. Our aim is to advance the state-of-the-art in micro-generator design by developing devices capable of adapting their resonant frequency and damping to achieve the first time broadband and resonant energy harvesting. Instead of making a single change in average power density, we aim to achieve a 1.0 generator optimised to work in the middle range of typical harvester frequencies (100-1000 Hz) which consistently operates at resonance but tracks the source frequency over a large fractional bandwidth. We will also investigate dynamic adaptation of transducer damping strength to match varying source characteristics. The availability of such dynamic adaptations creates the opportunity for closed loop control, which will be part of the interface circuit and subsystem design tasks within this theme.

Theme B: Energy Harvesting-Aware Computation Circuits

The need of Theme B is to investigate energy harvesting aware design methods for...



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Thank You



www.holistic.ecs.soton.ac.uk

EPSRC

Engineering and Physical Sciences Research Council (EPSRC) grant numbers EP/G067740/1 (Southampton), EP/G066728/1 (Newcastle), EP/G06881X/1 (Bristol), and EP/G070180/1 (Imperial) "Next Generation Energy-Harvesting Electronics: Holistic Approach"