ENERGY HARVESTING IN FITNESS ELECTRONICS

GARMIN INTERNATIONAL

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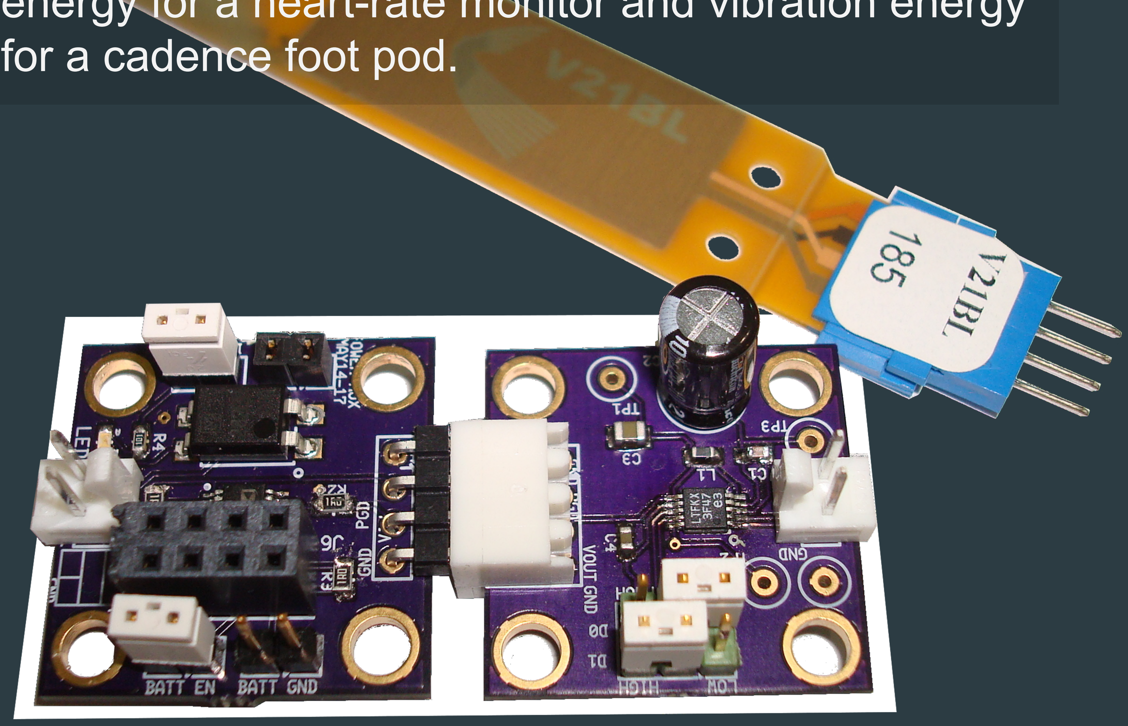
Problem Statement

Garmin International produces many fitness sensors that are limited by their battery lifespan. Our project is to increase the battery life by harvesting unused energy from the surrounding environment. The implementation includes harvesting body heat energy for a heart-rate monitor and vibration energy for a cadence foot pod.



Technical Details

Piezoelectric Materials

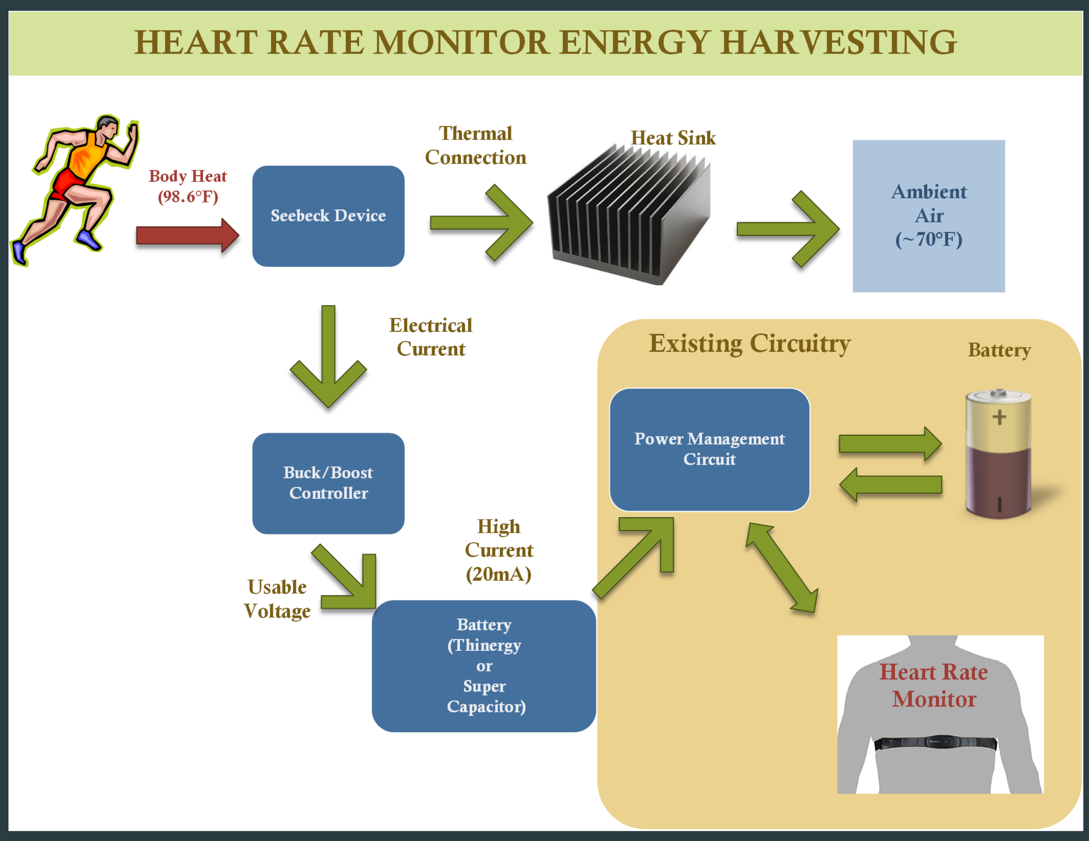
- Mechanical strain induces an AC electrical signal
- Brittle (high power output) materials or flexible (low power) materials are available
- High electrical impedance

Thermoelectric Generator

- Thermopile of many thermocouples electrically in series and thermally in parallel
- Uses the Seebeck Effect

Linear Technology ICs

- Convert harvested energy (from Piezo and Peltier) to a usable DC signal



Heart Rate Solution

- Energy is harvested from body heat
- The low voltage signal is increased with a DC-DC converter to 5.25V
- Up to 3J of energy is stored in a 220mF capacitor
- During a load spike from the heart rate monitor, energy is used from the capacitor
- The voltage is reduced from 5.25V to 3V with a second DC-DC converter
- If there is a shortage of energy harvested, energy from the battery through a power mux is used
- With 10°C temperature gradient, can supply 100% of heart rate monitor energy requirements.

Design Requirements

Functional Requirements

- The design must power any additional circuitry for the energy harvesting module in addition to 10% of the present current draw from the battery
- Must fit into the current device with minimal alterations
- Operational in many types of environments since Garmin's devices are meant for fitness

Non-Functional Requirements

- The power harvesting solutions involve minimal user interaction
- Garmin International has requested a price of under $50 for the parts in the final prototype

Design Approach

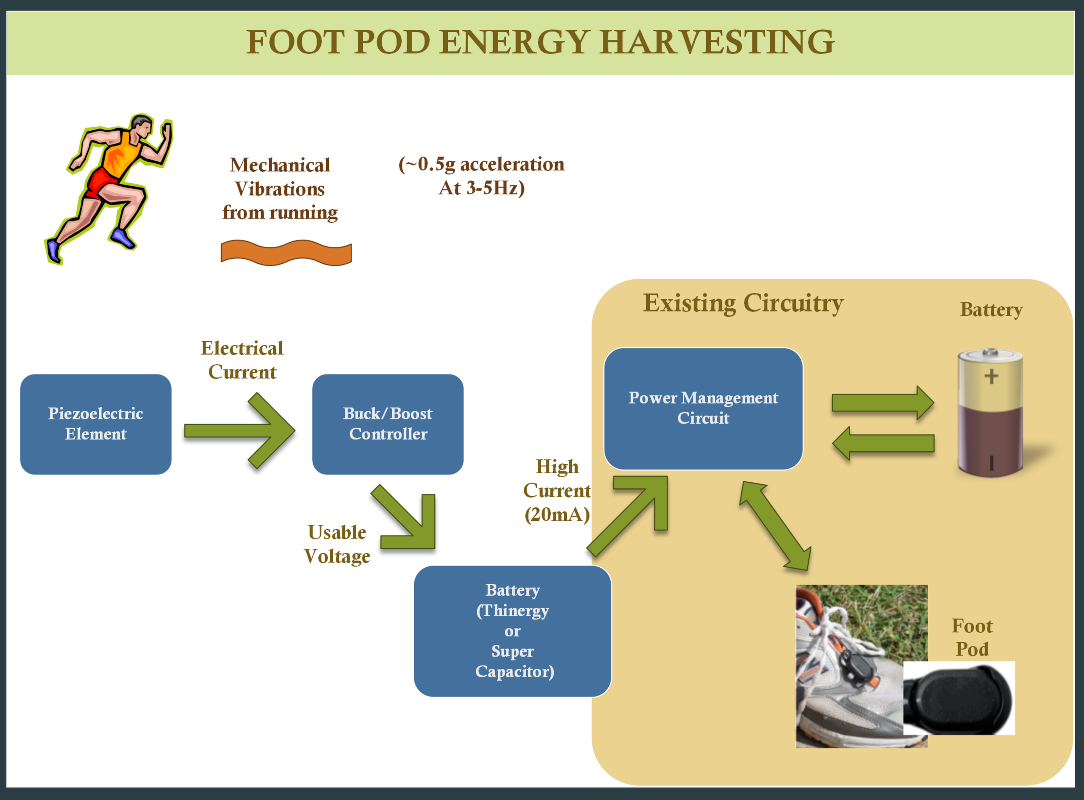
We have developed two energy harvesting solutions for this project: harnessing energy from vibrations when walking or running and from the temperature difference between the air and the wearer's skin.

Design Process

- Identified potential energy harvesting sources and researched their feasibility
- Researched available energy harvesting elements and ICs
- Performed power estimates & basic calculations before producing iterations of schematics and layouts

Risk Management

- Two independent prototypes were developed in parallel to maximize chance of a successful design
- The schedule included time for multiple board iterations



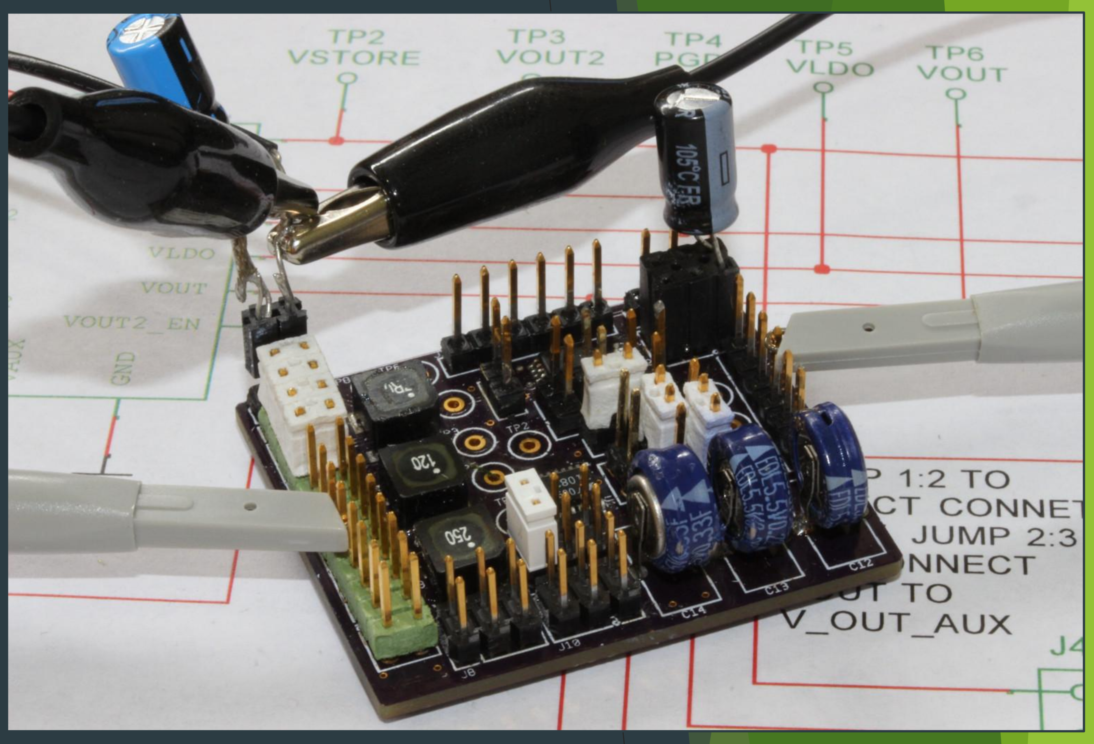
Foot Pod Solution

- Energy harvested from vibrations created when user walks or runs with foot pod mounted on shoelaces
- The high voltage from the piezo element is decreased and rectified to 3.3V
- The energy is run through a selection circuit which selects between the harvested energy and the battery energy
- If there is a shortage of harvested energy, the circuit will switch to energy from the battery
- Harvests 23% of the foot pod's energy needs

Operating Environment

The energy harvesting solution will be used in active fitness scenarios, and target consumers will wear these devices to the gym and during their workout routines.

- Devices must be water resistant in compliance with the IPX7 standard and resistant to the wearer's sweat
- Must be able to withstand physical strain of being worn in workout environment (i.g. foot pod must be able to tolerate physical strain of repeated impacts when foot lands while running)
- Devices must be durable for a wide temperature range
  - Storage: -20° C to 70° C
  - Operation: 0° C to 45° C



Testing

The prototypes developed were checked for basic operation in a lab and robustness via real-world use cases.

Initial Tests

- Measured the time domain power requirements of the Garmin devices
- Made empirical measurements of vibration frequency of a walker and runner

Functionality Tests

- Tested prototypes with simulated load at various frequencies and duty cycles
- Tested prototypes with Garmin's products to ensure they meet the requirements

Robustness Tests

- Measured power output during user tests with a variety of scenarios (different athletes, temperature, humidity, exercise terrain, etc.)
- Verified proper operation of Garmin devices when powered by the prototypes

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