# Self-sustainable Wearable IoT Devices: Energy Harvesting, Management and Consumption

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## 1: Energy Harvesting

### Motivation
- Flexible and stretchable wearable devices open up novel and attractive applications!
- Patient rehabilitation
- Fall detection
- Physical activity promotion
- Human activity recognition
- Wearable devices collect LOTS of data!
- Data is the new oil!
- Strong and immediate need to develop open-source devices
- Open source will enable many researchers to contribute easily

### Applications
- Human Activity Recognition  
  - [ACM TEC'19]: Identifies activities (e.g. walking, sitting, jogging ...)
- Gait Analysis [ACM TIOT'21]: Evaluates metrics, such as step length, stride length, and gait velocity
- Freezing of Gait (FoG) Prediction in PD [BioCAS'21]: Predicts potential FoG episodes using ML techniques
- Home-based Assistive Rehabilitation: Assists patients with motor disorders
- Vital Signal Monitoring: Collects electrophysiological signals (e.g., ECG, Galvanic Skin Response)

### Challenge
- Widespread adoption is hindered!
- IoT Devices have limited battery life
  - Bulky batteries are inflexible, while flexible batteries have low capacity
  - Small form factor limits the battery capacity
  - E.g. Oura Ring: 22 mAh @ 3.7V battery → 7 days
- Compliance: Users do not want yet another device to manage and maintain!

### Aim
Address the compliance challenge with self-sustainability

### 1- Energy Harvesting

#### Wearable Energy Harvesting (EH) Modalities
- Flexible Piezoelectric Transduction (PZT) Modeling (ISLPED'20)

#### Daily Energy Predictions [ISLPED'21]
- **Choose the output capacitance carefully!**
  - 150μF: 35μA at 1.7V - 20% ripple - 8.84s turn-on
  - 620μF: 35μA at 1.8V - 4% ripple - 26.37s turn-on
- **Daily EH potential using activity/location data from the American Time Use Survey**
  - Close to 0.6mAH @ 3.6V in a day

### 2- Energy Management

#### Allocate the energy in the battery such that
- Device utilization is maximized
- Device is energy-neutral

### 3- Energy Consumption

#### System-On-Chip Design for Wearable Devices [Submitted]
- Integrate them in a RISC-V based SoC (PULPissimo)

#### Design HW accelerators for these tasks

#### Evaluate the performance on three apps on FPGA

### References