Demo Abstract: TEG Data Collection Platform for Wearable Applications

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ABSTRACT

Wearable systems have become popular in recent years, especially in health sensing applications where they enable long-term monitoring of patients. However, the majority of these devices are powered by batteries and regularly need to be recharged, creating not only issues of user compliance but also the potential for missing critical sensing events. Energy harvesting presents a promising solution to extend the lifetime of the batteries or even completely replace them for continuous self-powered operation. Thermoelectric generators (TEGs) provide the potential for self-powered wearables by harvesting the heat generated by the human body. However, environmental dynamics and human behavior - specifically airflow around the TEG - affects the harvestable energy, resulting in a highly dynamic energy source that can affect the potential for self-powered operation. In this project, we designed a wearable data collection platform that records environmental and behavioral data with a concentration on airflow around the wrist. This platform collects traces based on real-world environmental and behavioral dynamics, enabling exploration of energy harvesting dynamics and the potential for TEG-powered wearable applications.

CCS CONCEPTS

• **Computer systems organization → Embedded systems**; *Sensors and actuators*; • **Hardware → Sensors and actuators**; **Renewable energy**; **Impact on the environment**; **Power estimation and optimization**.

KEYWORDS

Energy Harvesting, Thermoelectric Generators, Wearable Devices

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1 INTRODUCTION

A variety of wearable sensing and computing systems have emerged in recent years for applications ranging from gaming to health monitoring. Enabling long-time operation of these systems is one of the most important challenges for designers. Although extensive progress has been made in ultra-low-power circuits and dynamic power management techniques, battery life remains a critical limiting factor in many systems. This can affect usability in all applications, but it is especially critical in systems that demand continuous operation, such as some health monitoring applications in which critical events cannot be missed.

Energy harvesting presents a viable solution to extend the battery life of wearable systems or to completely replace the batteries by achieving self-powered operation. In the last few decades, researchers have used light and kinetic energy to power wearable devices. Given the human body's continuous generation of heat, thermoelectric generators (TEGs) have recently become of interest for wearables [2]. They are robust, reliable, and easy to use, generating power as soon as they make contact with the body. Also, there are times when thermal energy is the only energy available to harvest, such as during the night when lights are off.

TEGs generate electrical energy from the temperature difference between their two surfaces. Studies show these harvesters can produce hundreds of micro-watts of power [1]. However, for wearable applications, this power depends on multiple factors, including skin temperature, ambient temperature, TEG material and device characteristics, and air rejection at the cold side of the TEG. Recent research showed that even small human activity and the resulting airflow around TEGs significantly increases their performance[3].

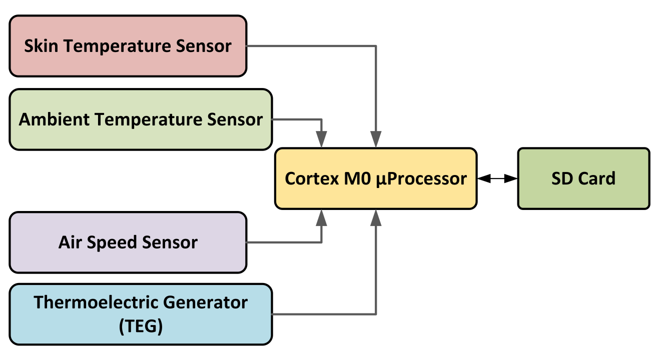

Figure 1: Overview of the data collection platform. The microprocessor collects the temperatures, airflow and TEG output and writes to the SD card.

In this work, we designed a wearable data collection platform to study TEG harvesting for wearable applications with a focus on the effects of human activity and environmental dynamics on the harvester output. This platform enables the collection of harvesting traces in a variety of real-world conditions. In addition, to generalize the output power of a specific TEG to other TEGs, we use the RC model of thermal energy transfer from human skin all the way to ambient air developed in [3]. Although extensive research has been conducted on modeling TEGs, to the best of our knowledge there has not been any work on real-world validation of TEG models in wearable applications.

2 DATA COLLECTION PLATFORM

Designing a wearable device requires considerable effort in order to make it comfortable and easy to use. While there are several spots on the human body that usually are not covered by clothing (e.g., neck, lower arms, and forehead) and are therefore exposed to airflow, we decided to collect data around the wrist based on user comfort, familiarity (many wearables are worn on the wrist) and maximal airflow.

Figure 1 shows an overview of the data collection platform. The microprocessor collects the temperatures, airflow and TEG output and writes them to the SD card along with the timestamp. The building blocks of the system are described below.

2.1 Microprocessor

The processing unit of the data collector is a Cortex© M0 compatible microprocessor clocked at 48 MHz powered by a 3.7V lithium-ion polymer battery. The microprocessor reads sensors raw values with a sampling frequency of 1Hz. Then the raw values are processed and written to the SD card along with the time stamp coming from the connected real-time clock.

2.2 Air Speed Sensor

Although some designers use accelerometer and gyroscope to measure speed, it's not a viable solution for this application because it does not take into account the ambient airflow. Therefore, we used the wind sensor Rev. C from Modern Device, which works based on hot-wire technique. It involves heating an element to a constant temperature and then measuring the electrical power that is required to maintain the heated element at that temperature as the airflow changes.

2.3 Temperature Sensors

We used the LMT70 temperature sensor because of its precision and low power dissipation. To measure the skin temperature as accurately as possible, the mechanical components should be carefully designed to conduct as much heat that goes into the LMT70 as possible. While the ambient temperature sensor resides on the main PCB, the skin temperature sensor is mounted on a separate small PCB under which a copper pad is located. This copper pad will be attached on the skin, heated by the skin and then conducts it to LMT70 die through the vias on the PCB and sensor's solder balls. Nickel wire was used to connect the temperature sensor's output to the A/D because of its low thermal conductivity.

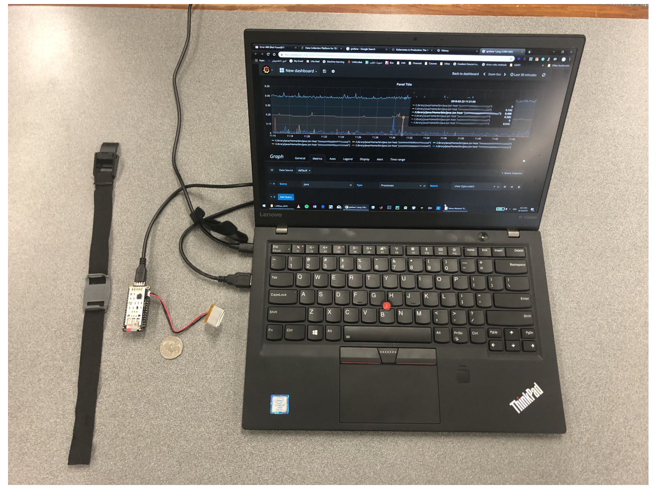

Figure 2: The system that will be used for the demo deployment (the devices is shown without the final package)

2.4 TEG

A custom TEG designed by [3] is used to correlate the output power of the harvester with the environmental data and characteristics of the harvester. When the harvester is connected to a load, electrical current flows and implies Peltier heating which decreases the TEG's output power. To take that into account, a load of 1.3 times the TEG's internal resistance is connected to extract the maximum power. The microprocessor disconnects and reconnects this load to measure open-circuit voltage along with maximum power of the TEG.

3 DEMONSTRATION

This platform is self-contained and can be worn by the user for extended periods, with the data offloaded from the SD card after use. However, for the proposed demonstration, the platform will be connected to a computer by a USB cable to stream real-time data. Software running on the computer will plot skin temperature, ambient temperature, sensed airflow around the wrist **caused by user's movement**, TEG open-circuit voltage, and TEG output power measured on the load.

4 ACKNOWLEDGEMENT

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