SDDEC9-21
http://sddec19-21.sd.ece.iastate.edu

Battery-less IoT Device

Introduction

Problem

- Computational tasks are frequently performed in areas where it is difficult to provide power via conventional means
  - Infrastructure for wired power transfer is expensive
  - Batteries are bulky and expensive, and pose an environmental risk
  - Solar and wind energy harvesting is impractical for certain environments

Our solution

- Create a device powered by ambient radiofrequency energy
  - RF energy is harvested and stored in a capacitor bank
  - A connected device performs periodic computational tasks

Intended Users & Uses

- Proof-of-concept device to test the feasibility of harvesting local Wi-Fi energy
- For professors and grad students conducting research
- Commercial use for low-power IoT applications

Design Requirements

Functional Requirements :

- Harvest radio frequency signal from Wi-Fi router
- Store charge long-term without a battery
- Perform basic operations in sensing and computation
- Transmit computational data

Non-functional Requirements:

- Reasonable cost - under $200
- Efficiency - reasonable operation intensity and small charge time
- Data security and data privacy
- Portability and small size

Engineering Constraints:

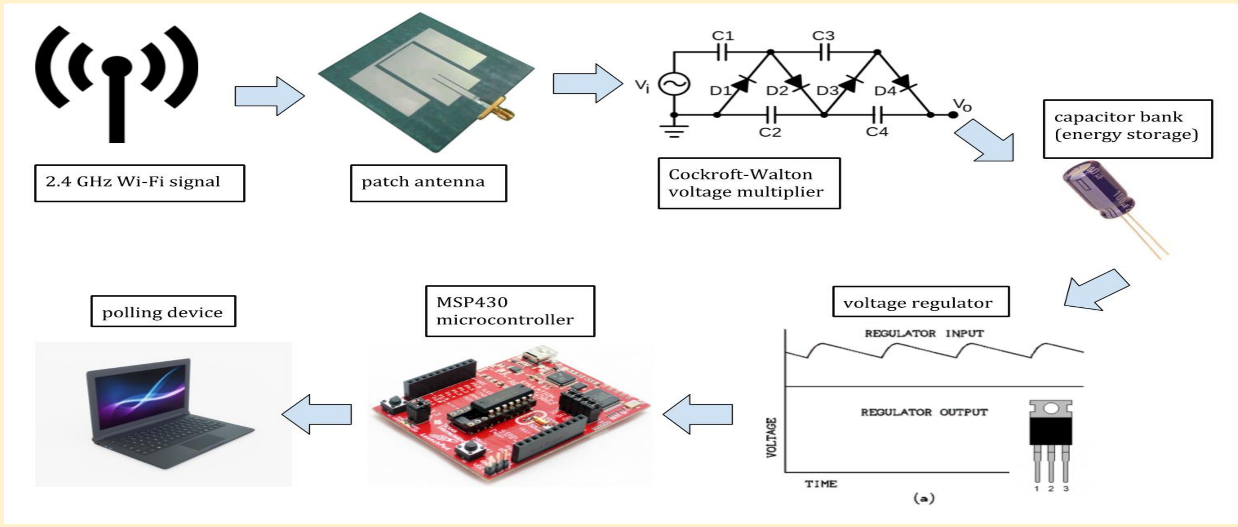
- Distance from RF source
- Losses in energy harvesting and storage
- Power-hungry computation requirements
- Small size requirement

Operating Environment:

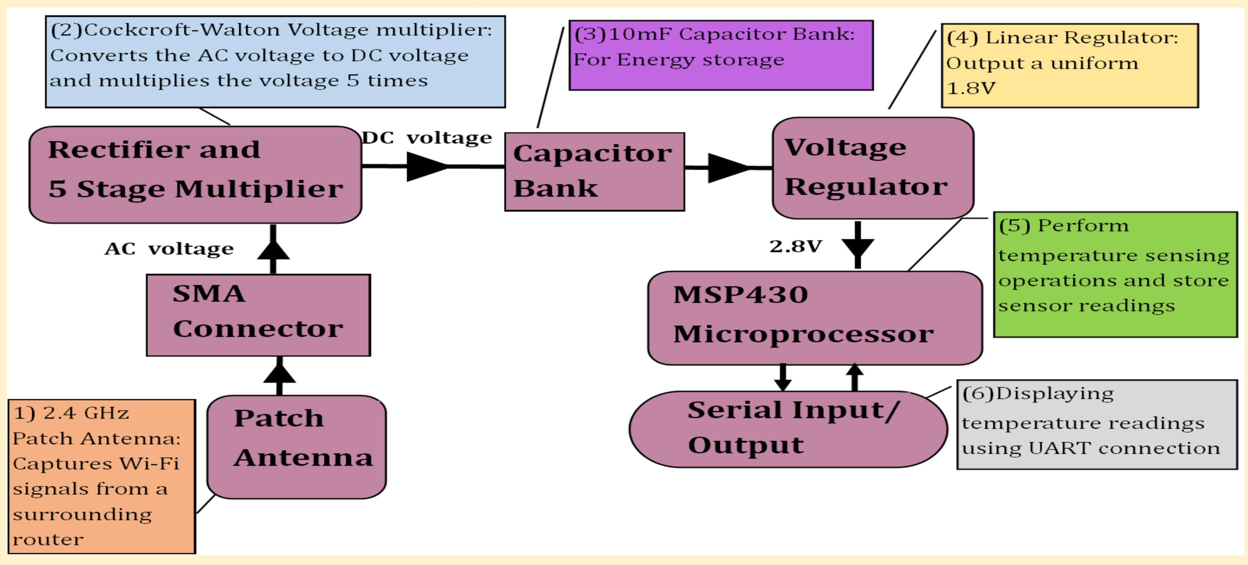
- Device placed indoors near router.
- Wi-Fi router under constant use (high traffic)
- Temperature within acceptable measuring range for microcontroller

Design Approach

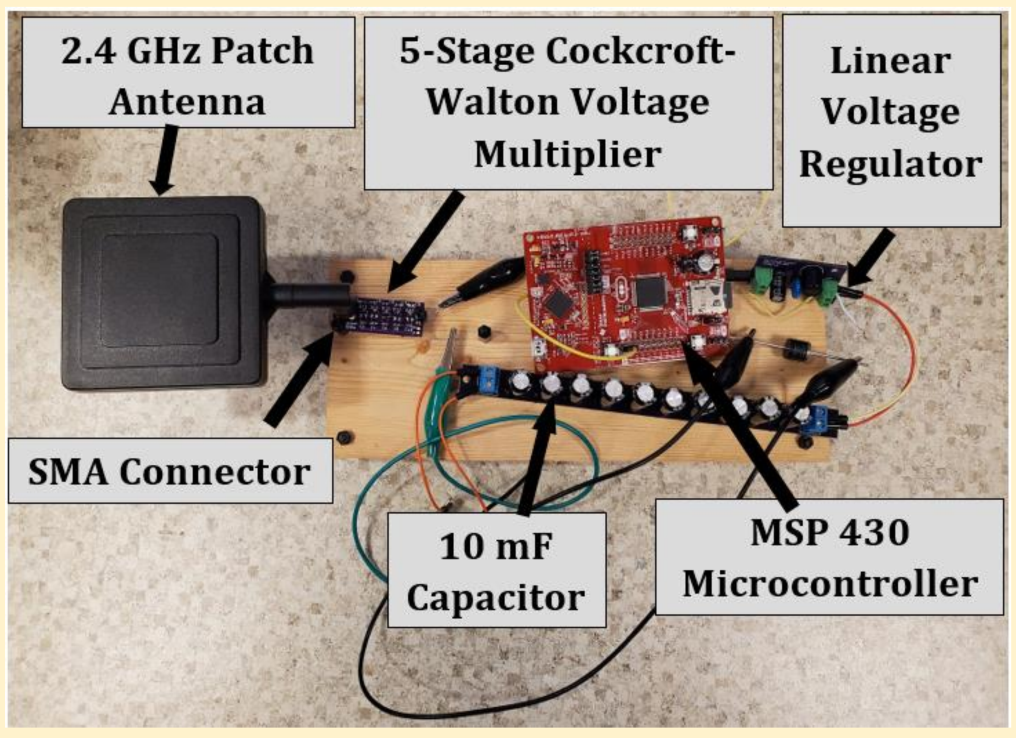
Concept Sketch



System Flow



Test Prototype



Technical Details

Development Tools

- Keysight Advanced Design System
- Ansys HFSS
- TI Code Composer Studio
- Eagle PCB Design
- Energia

Software Library

- MSP430-GCC

Embedded Hardware

- MSP-EXP430FR5994 - Embedded development platform
- MSP430FR5994 MCU

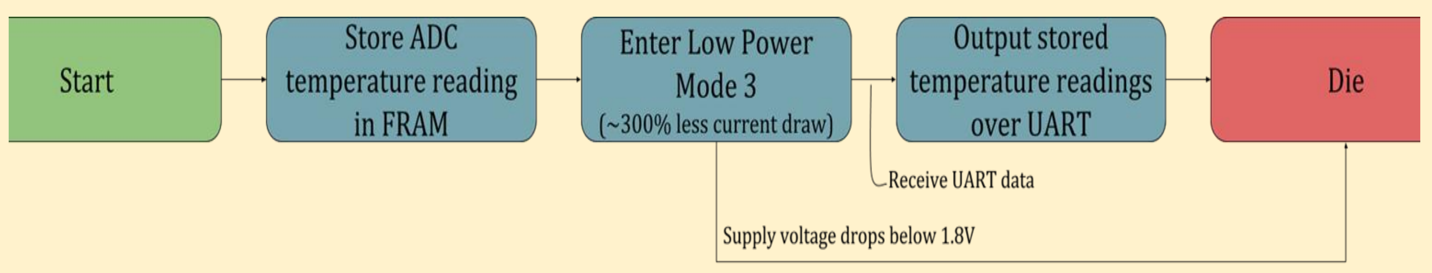
Antenna

- EMRSS 2.4GHz 8dBi Articulated Patch Antenna

Standards

- IEEE 802.11 - WLAN transmission specifications for antenna design.
- IEEE 149-1965 -Antenna characterization

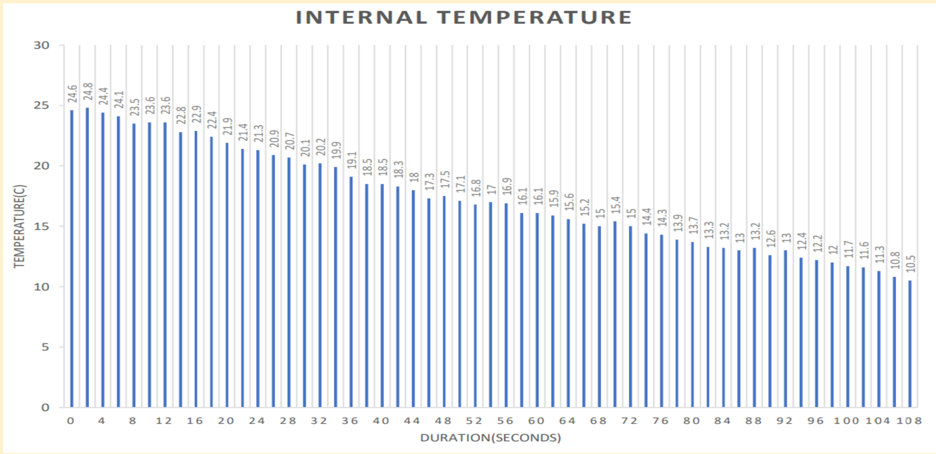
Software Implementation



Testing

MSP430 temperature sensing operation

- Readings were monitored while ambient temperature was manipulated



MSP430 Power consumption analysis

- Using an energy-based analysis tool to measure and display our application's power consumption

EnergyTrace™ Profile (Relative Measurement)

Name	Live
System	
Time	0 sec
Energy	0.401 mJ
Power	
Mean	1.7956 mW
Min	0.0000 mW
Max	2.0714 mW
Voltage	
Mean	3.2763 V
Current	
Mean	0.5481 mA
Min	0.0000 mA
Max	0.6321 mA
Battery Life	Custom: 0.0 day (est.)

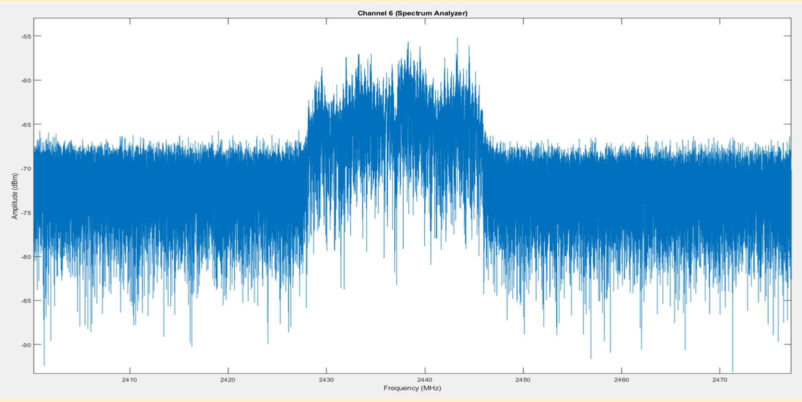
Power harvester tests

- Measured power output of the rectifier circuit with Wi-Fi router.

Board used: 5 stage with 10uF with load 100uf at 6.35cm				
with no load= 10V				
Load resistance(ohm)	volt(v)	power(w)	power(mW)	max power(mW)
100	0.09	0.000081	0.081	1.296
1000	0.7	0.00049	0.49	
10000	3.6	0.001296	1.296	
50000	5.9	0.0006962	0.6962	
100000	7.8	0.0006084	0.6084	
1000000	9.8	0.00009604	0.09604	

RF Measurements

- Antenna power measurements using spectrum analyzer
- Component characterization for RF simulations



Conclusion & Improvements

- Adding stages to Cockcroft-Walton voltage multiplier did not incur huge losses
  - possible problem of Wi-Fi intermittency with too many stages
- Impedance-matching implemented on future rectifier boards to increase efficiency
- Larger capacitors on the Cockcroft-Walton aid in harvesting but increase leakage current
- Additional Schottky diode on the output of Cockcroft-Walton stabilizes the output
- Integrating voltage supervisor into power supply aid in controlling the enable operation of the voltage regulator

Team Members: Mohammed Al-Mukhaini, Adithya Basnayake, Mohamed Gesalla, Matt Goetzman, Derek Nash, Bradley Rhein **Advisor:** Dr. Henry Duwe **Clients:** Dr. Henry Duwe, Dr. Nathan Neihart, Dr. Daji Qiao