FLOW

For **LO**wering Household **W**ater Usage

SDP Team 9

MDR

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Problem Statement

According to the United States Geological Survey, each person uses about 80-100 gallons of water per day for indoor home uses [1]. The majority of the households cannot monitor which home fixture or water outlet dispenses the most amount of water. **The system we aim to create will measure the quantity of water flowing out of each water outlet**. Users can view their water consumption behavior from an app to which the devices are connected. The data will allow users to learn which appliance/faucets use the most amount of water. Moreover, users will also be notified if leaking is detected.

MDR Deliverables (from PDR)

- Sensor selection and design
- Wireless Network selection and design
- Prototype of a set of sensors (at least 3)
    - Measure the flow
    - Relay their data to the cloud via a wireless access point
- Sensors measure the volume of water used for each sensor placement with at least <tbd> percent accuracy.
- Functional web app that can display water usage information

MDR Deliverables (for MDR)

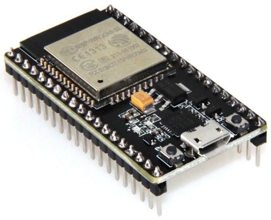
- Flow rate sensor selection and design
- Wireless Network selection and design
- Prototype of a set of sensor nodes (3 nodes)
    - Measure the flow rate from three different water outlets
    - Relay flow rate data to the cloud via a wireless access point
- Sensors measure the flow rate with at least <tbd> percent accuracy
- Functional web app that can display water usage information

MDR Deliverables

- Flow rate sensor selection and design
- Wireless Network selection and design

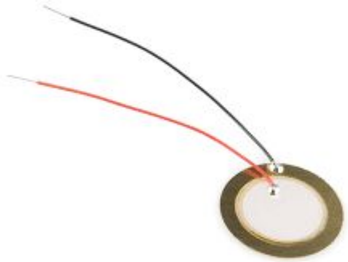
Primary Hardware Components

- ESP-32S Development Board
- Hall effect flow rate sensor
- Piezo-electric vibration sensor (Future use)



[1]

[2]



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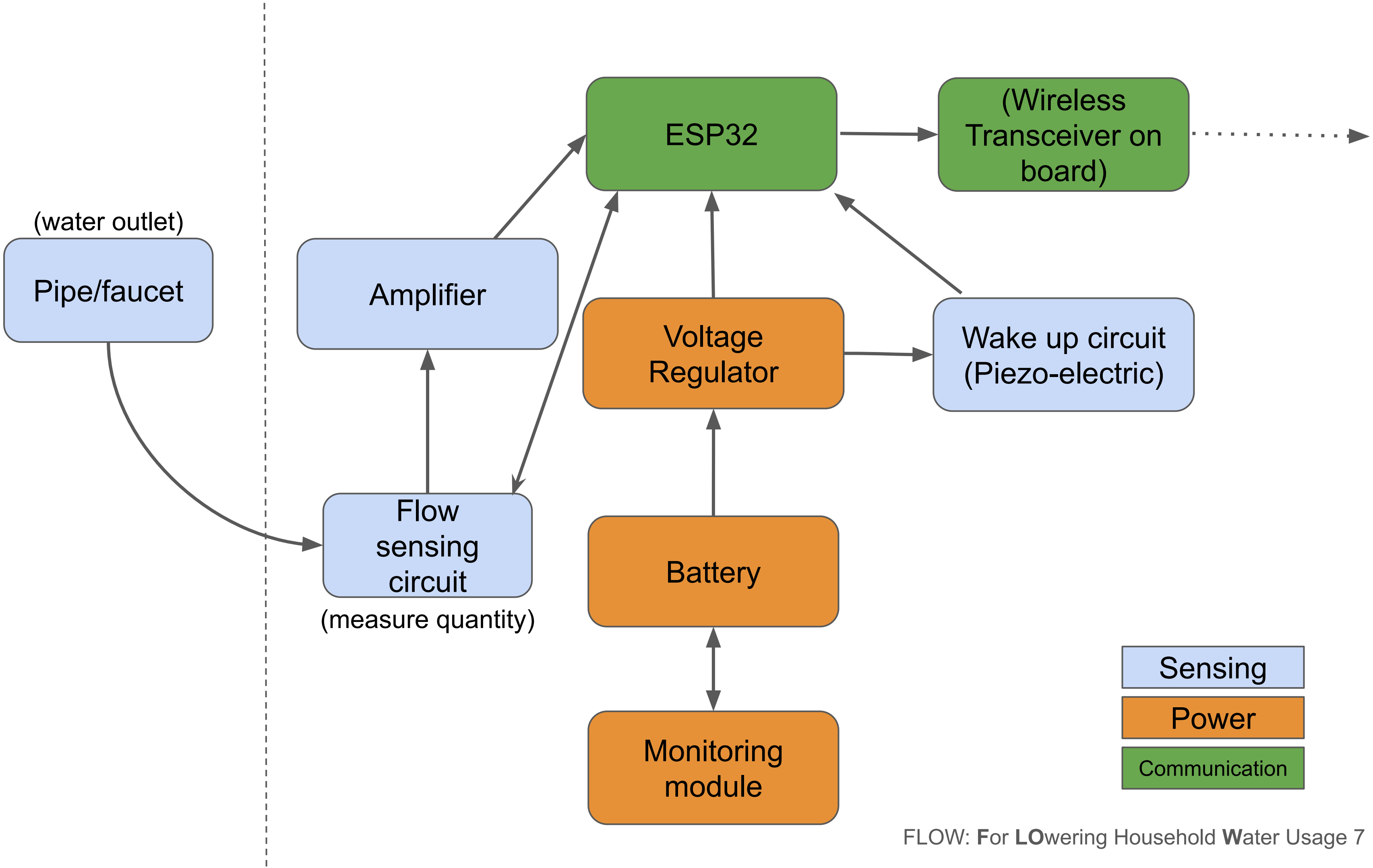
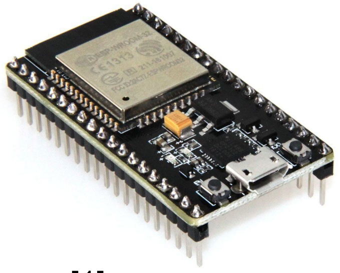

(water outlet)
Pipe/faucet
Amplifier
ESP32
(Wireless Transceiver on board)
Voltage Regulator
Wake up circuit (Piezo-electric)
Flow sensing circuit
(measure quantity)
Battery
Monitoring module
Sensing
Power
Communication

Preliminary Concept: 1 PCB per node

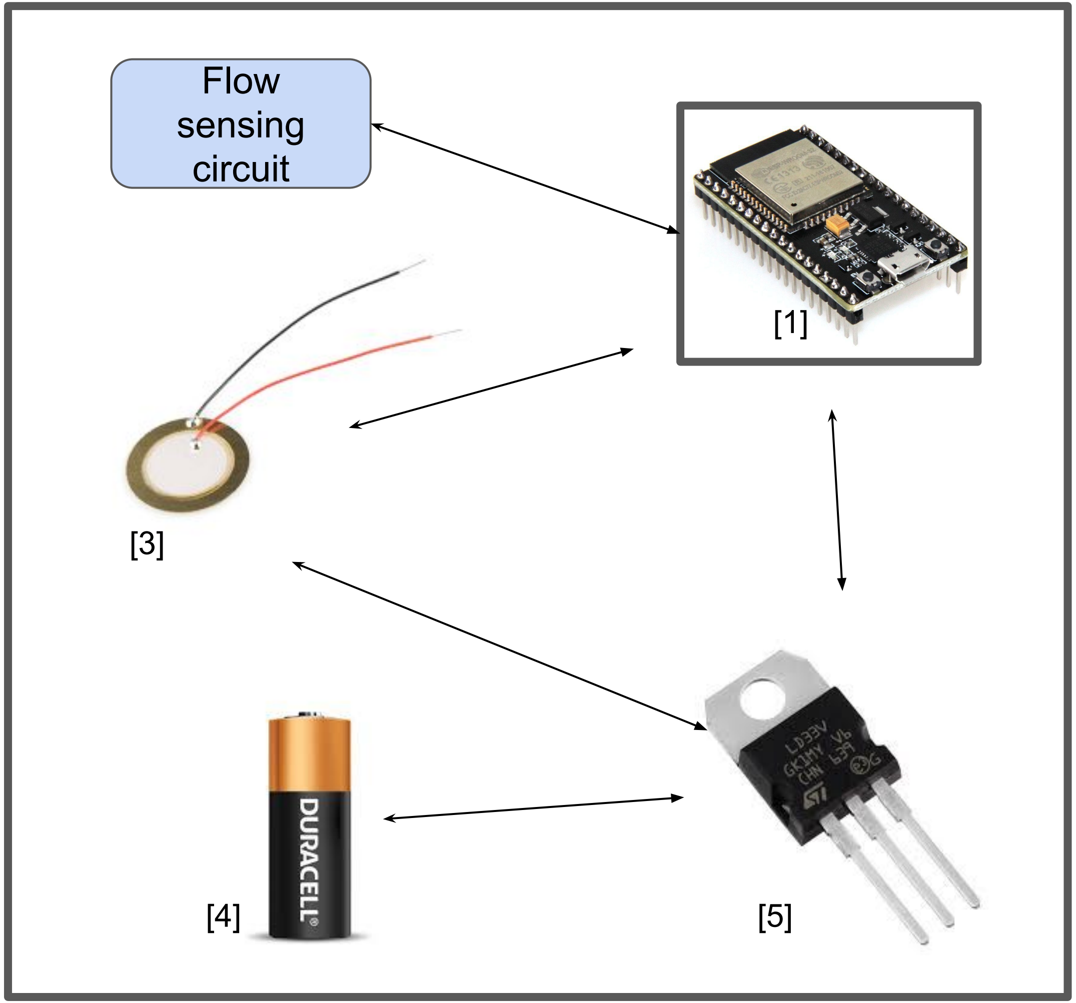
- ESP32S Development board
  - Wireless Transceiver
  - Microcontroller
  - USB->UART Bridge
- Power circuitry
  - Voltage Regulator
- Flow rate sensor interface
- Piezo-electric sensor “wake up” circuit

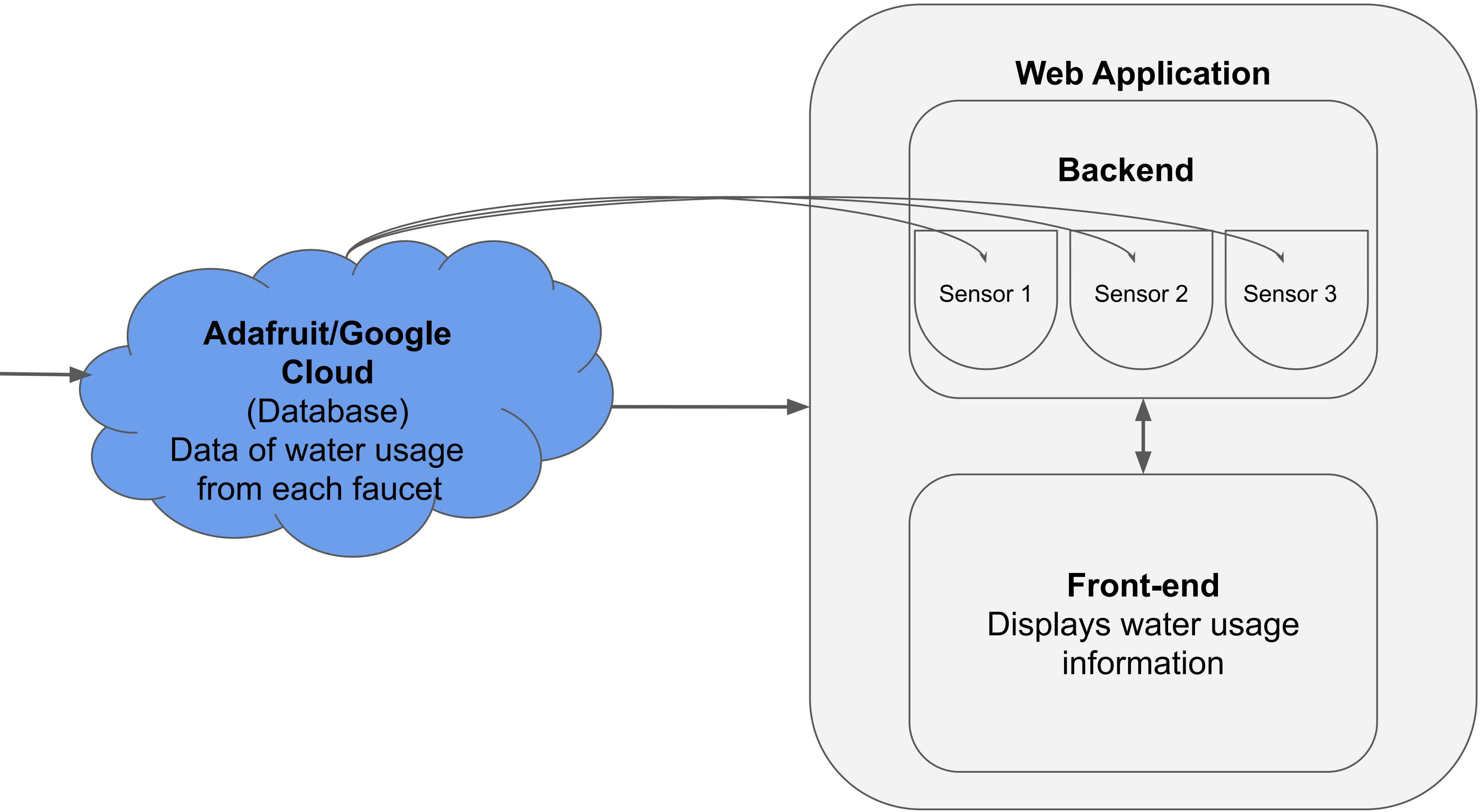


[1]

We will develop a set of 3 PCBs, 1 for each sensor node. We request a hardware exclusion to use the ESP32-WROOM module on these PCBs. This allows us to concentrate on overall functionality (power, communication, control, sensing) without needing to replicate subsystems contained within the ESP32-WROOM module.

- ESP32S Development board
    - Wireless Transceiver
    - Microcontroller
    - USB->UART Bridge
- Power circuitry
    - Voltage Regulator
- Flow rate sensor interface
- Piezo-electric sensor “wake up” circuit




Web Application
Backend
Sensor 1
Sensor 2
Sensor 3
Adafruit/Google Cloud
(Database)
Data of water usage from each faucet
Front-end
Displays water usage information

System Specifications (PDR)

Functional Specification	Characteristic Specification	Performance Requirement	*Design Goal*
• Measure the **quantity** of water coming out of each water outlet • Web App to display information to user showing water usage for each outlet in real time	• Installation of the sensor by the homeowner, without requiring a plumber • Low voltage battery operated system • Sensor output is communicated wirelessly through the house • Data transfer via home WIFI and internet access point to the cloud	• Sensors measure quantity of water with an accuracy of <tbd> • Sensor lifetime exceeds <tbd> months • System capability is up to 15 sensors per house • Sensors capable of detecting dripping at water outlets, down to a flow rate of <tbd>	• Installation on the outside of the pipe and out of view of the user

System Specifications (MDR: modified)

Functional Specification	Characteristic Specification	Performance Requirement	*Design Goal*
• Measure the **quantity** of water coming out of each water outlet • Web App to display information to user showing water usage for each outlet in real time	• Installation of the flow sensor nodes by the homeowner, without requiring a plumber • Low voltage battery operated system • Flow sensor nodes output is communicated wirelessly through the house • Data transfer via home WIFI and internet access point to the cloud	• Flow sensor nodes measure quantity of water with an accuracy of **90%** • Flow sensor node lifetime exceeds **<tbd>** months • System capability is up to 15 flow sensor nodes per house • flow sensor nodes capable of detecting dripping at water outlets, down to a flow rate of **<tbd>**	• Installation on the outside of the pipe and out of view of the user

Fittings and Fixtures

- Pipe adapters: PVC fittings, $1-$2
- Wrench: ~$5
- Thread sealant tape: ~$1

[6]

[7]

[8]

Explanation of Accuracy

Known Container Volume	Volume derived from sensor node	% error	Average % error
Sensor 1			Average
1300	1384	6.5	8.5
1200	1286	7.2	
1100	1195	8.6	
1000	1095	9.5	
900	968	7.6	
700	742	6	
600	629	4.8	
500	563	12.6	
400	438	9.5	
300	338	12.7	

Known Container Volume	Volume derived from sensor node	% error	Average % error
Sensor 2			
1300	1284	1.2	1.7
1200	1211	0.9	
1100	1098	0.2	
1000	960	4	
900	885	1.7	
700	697	0.4	
600	620	3.3	
500	498	0.4	
400	396	1	
300	288	4	

Known Container Volume	Volume derived from sensor node	% error	Average % error
Sensor 3			
1300	1362	4.8	5.9
1200	1229	2.4	
1100	1172	6.5	
1100	1132	2.9	
900	925	2.8	
700	755	7.9	
600	654	9	
500	542	8.4	
400	425	6.3	
300	277	7.7	

Dripping Problem

- The minimum flow rate measured by our current flow rate sensor is 2 mL/s
- Not sensitive enough to detect dripping
  - A fast drip of 1 drop per second will results in a flow rate of 0.33 mL/s [9]
- Will work on solving that problem

Power Management: Preliminary concept

- The sensor nodes will consume battery energy when sensing and communicating to the wireless access point.
- Our concept is to put the system to sleep to save battery energy, waking it up when flow is detected by using an interrupt detection circuit, then sleeping again after a defined time interval.
  - We may be using a piezo-electric vibration sensor as part of this, but we have not looked at that yet.
- Deep sleep mode (test results)
  - 5V: current with voltage regulator: 40mA, current without voltage regulator: 8mA
- We have not chosen a battery yet

Performance of the Integrated System (video)

- Entire system
- Volume checking

MDR Deliverables

- Flow rate sensor selection and design
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- Prototype of a set of sensor nodes (at least 3)
  - Measure the flow rate from three different water outlets
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MDR Verification Plan

Volume Checking:

- Place a container with a known volume under the tap. Place device on the tap and turn the tap on. Once the tap is turned off, check the volume of the water calculated by the flow sensing node against the amount in the container.

Real Time Monitoring:

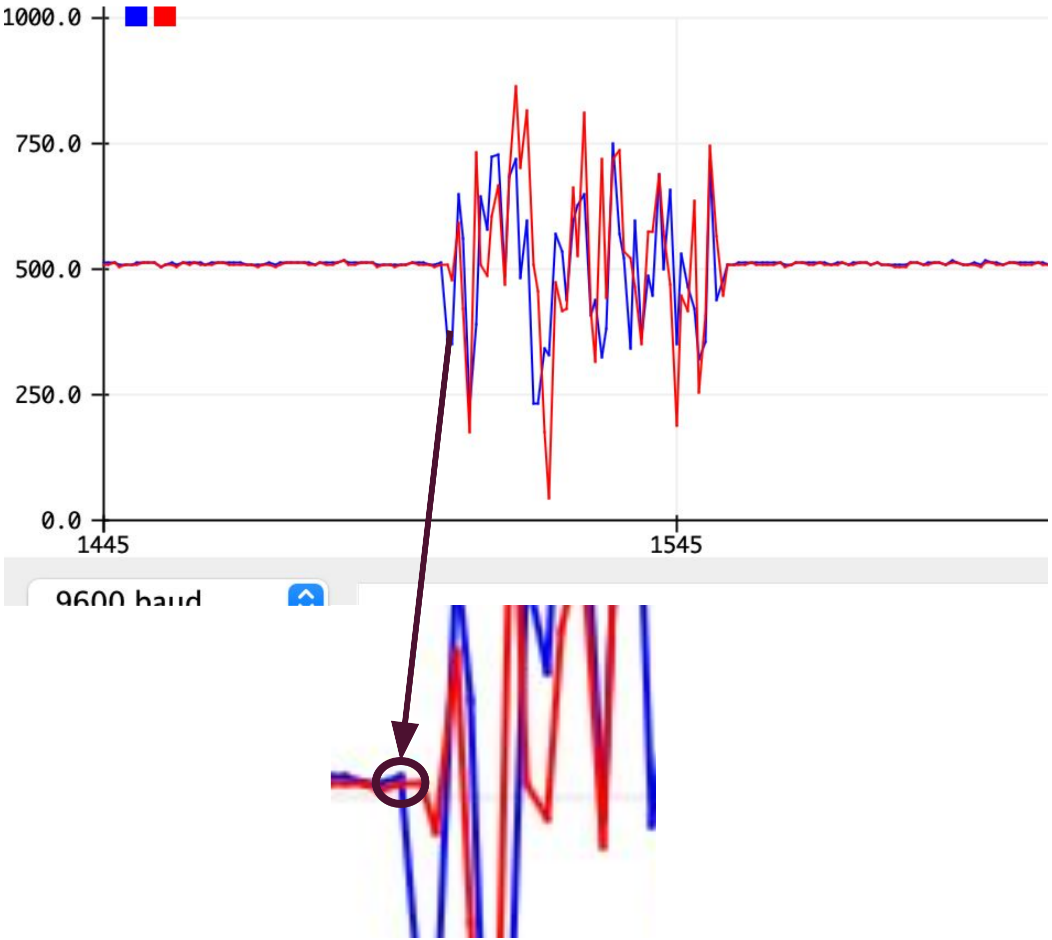
- The data generated by the sensor should be displayed on the local computer while water flows out of the faucet

Wireless Communication:

- The information in the cloud is the same as the information displayed on the local computer

Are we settled on the flow rate sensor?

- Used Hall Effect flow rate sensor to work on the rest of the system.
- Why are we not giving up on other sensors?
  - Saw encouraging results with electret microphone
  - Ultrasonic is a widely used flow rate sensor
    - 644 patents were filed between 1950 to 2016
    - Did not get much time to work on it
  - Dedicate 3 weeks time during the winter break
- Has more important components other than the sensor node
  - Sensor alone does not define the success of our project
- Only a design goal
  - Installation on the outside and out of the view


1000.0
750.0
500.0
250.0
0.0
1445
1545
9600 baud

Project Expenditures (current)

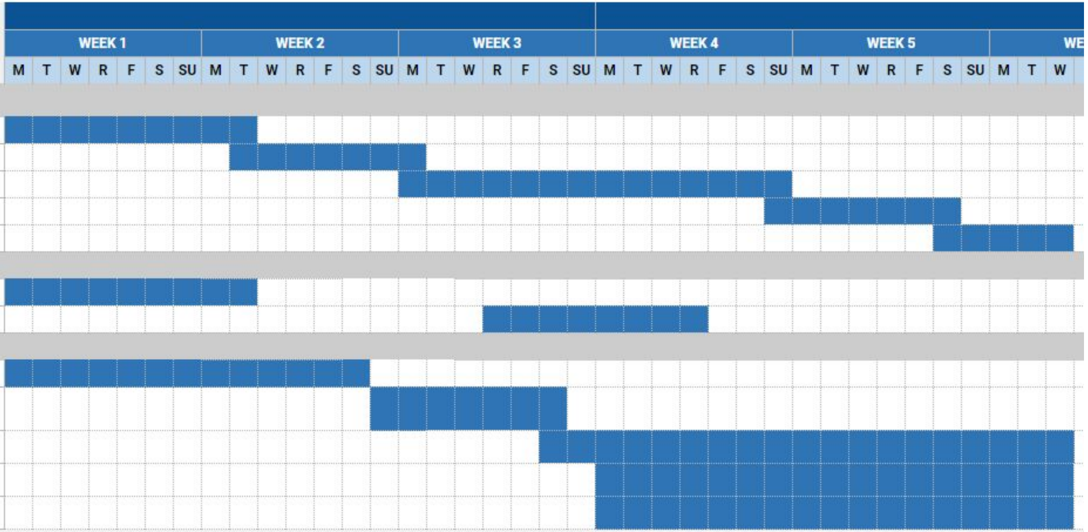
Item	Cost
Components for Flow sensing circuit	$42
Wireless Components	$40
Water prototype system	$12
Cloud service (free 12-month trial)	$0
Website Hosting	$0
Total	$94

Expected Expenditures

Item	Cost
Components for Flow sensing circuit	$100
Components	$100
Cloud service	$50
Website hosting	$50
PCB	$50
Fitting and fixtures	$56
Total	$406

Gantt Chart

TASK NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION
1	**PCB and Sensors**				
1.1	PCB Research	All	1/25/22	2/4/22	9
1.2	Learn Altium	TS & SH	2/4/22	2/11/22	7
1.3	PCB Design	SH	2/11/22	2/25/22	14
1.4	PCB Testing	SK & SH	2/25/22	3/2/22	7
1.5	PCB Design Finalization	SH	3/2/22	3/7/22	5
2	**Flow Sensing Circuit**				
2.1	Sensor development	SK & AT & TS	1/25/22	2/4/22	9
2.1	Sensor finalization	SK & AT & TS	2/13/22	2/21/22	8
3	**Application**				
3.1	Cloud migration	SK & AT & TS	1/25/22	2/8/22	13
3.2	Modify Web App (due to cloud migration) + Web-hosting	AT & SK	2/9/22	2/16/22	7
3.3	User interface design	AT & TS	2/16/22	3/7/22	21
3.4	Front-end design	TS	2/18/22	3/7/22	19
3.5	Back-end design	AT & SK	2/18/22	3/7/22	19



https://docs.google.com/spreadsheets/d/1W_RimOb7iqgFxVbxXvdJyEs-ZJ6X8mxSJoRQ8jIiOiA/edit#gid=1115838130

Team Responsibilities

- Head of Hardware: Stephanie
- Webmaster: Anjali
- Signal Processing & Sensor Development: Sanjana
- Team Coordinator: Thanathorn

Works Cited

[1] *HiLetgo ESP-WROOM-32 ESP32 ESP-32S Development Board 2.4GHz Dual-Mode WiFi + Bluetooth Dual Cores Microcontroller*. Amazon. https://www.amazon.com/HiLetgo-ESP-WROOM-32-Development-Microcontroller-Integrated/dp/B0718T232Z

[2]*Hall Effect Sensor*. Amazon. https://www.amazon.com/DIGITEN-Sensor-Effect-Flowmeter-Counter/dp/B07QNN2GRV/ref=sr_1_15?dchild=1&keywords=arduino+hall+effect+sensor&qid=1632946819&sr=8-15

[3]*Piezo Element*. Sparkfun. https://www.sparkfun.com/products/10293.

[4]*Duracell Specialty Batteries | MN21/23 Alkaline Battery.* Duracell. https://www.duracell.com/en-us/product/mn2123-alkaline-battery/

[5] *3.3V Voltage Regulator 950mA LD1117V33 (LD33V).* Addicore. https://www.addicore.com/3-3V-Voltage-Regulator-950mA-LD1117V33-LD33V-p/ad165.htm

[6] *LASCO 3/4-in x 1/2-in dia Adapter Adapter PVC Fitting*. Lowes. https://www.lowes.com/pd/LASCO-3-4-in-x-3-4-in-x-1-2-in-dia-Adapter-PVC-Fitting/3369126.

[7] *WORKPRO 8-in Steel Adjustable Wrench*. Lowes. https://www.lowes.com/pd/WORKPRO-8-in-Steel-Adjustable-Wrench-Individual/1000015771.

[8] *Thread Sealant Tape, PTFE, 0.35 to 0.5sg, 1/2 in Width, 260 in Length, White Color*. Grainger. https://www.grainger.com/product/21TF19?ef_id=Cj0KCQiAtJeNBhCVARIsANJUJ2FzBlxgISARX42cVQtu73Vd3VYrnHz7a2FRi2uVXt6626iPu20I8aMaAvBqEALw_wcB:G:s&s_kwcid=AL!2966!3!264955915658!!!g!438381471565!&gucid=N:N:PS:Paid:GGL:CSM-2295:4P7A1P:20501231&gclid=Cj0KCQiAtJeNBhCVARIsANJUJ2FzBlxgISARX42cVQtu73Vd3VYrnHz7a2FRi2uVXt6626iPu20I8aMaAvBqEALw_wcB&gclsrc=aw.ds.

Works Cited

[9] “How many drips are in a gallon?,” *How many drips are in a gallon? | City of St Helens Oregon*. [Online]. Available: https://www.sthelensoregon.gov/dwff/page/how-many-drips-are-gallon. [Accessed: 02-Dec-2021].

Thank you for your time!

Any questions?