ECEN 5833
Low Power Embedded Design Techniques
Final Project Proposal

Team Name: Vega

Project Name: Vega – A bike computer

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University of Colorado Boulder

Date: 9/7/2024

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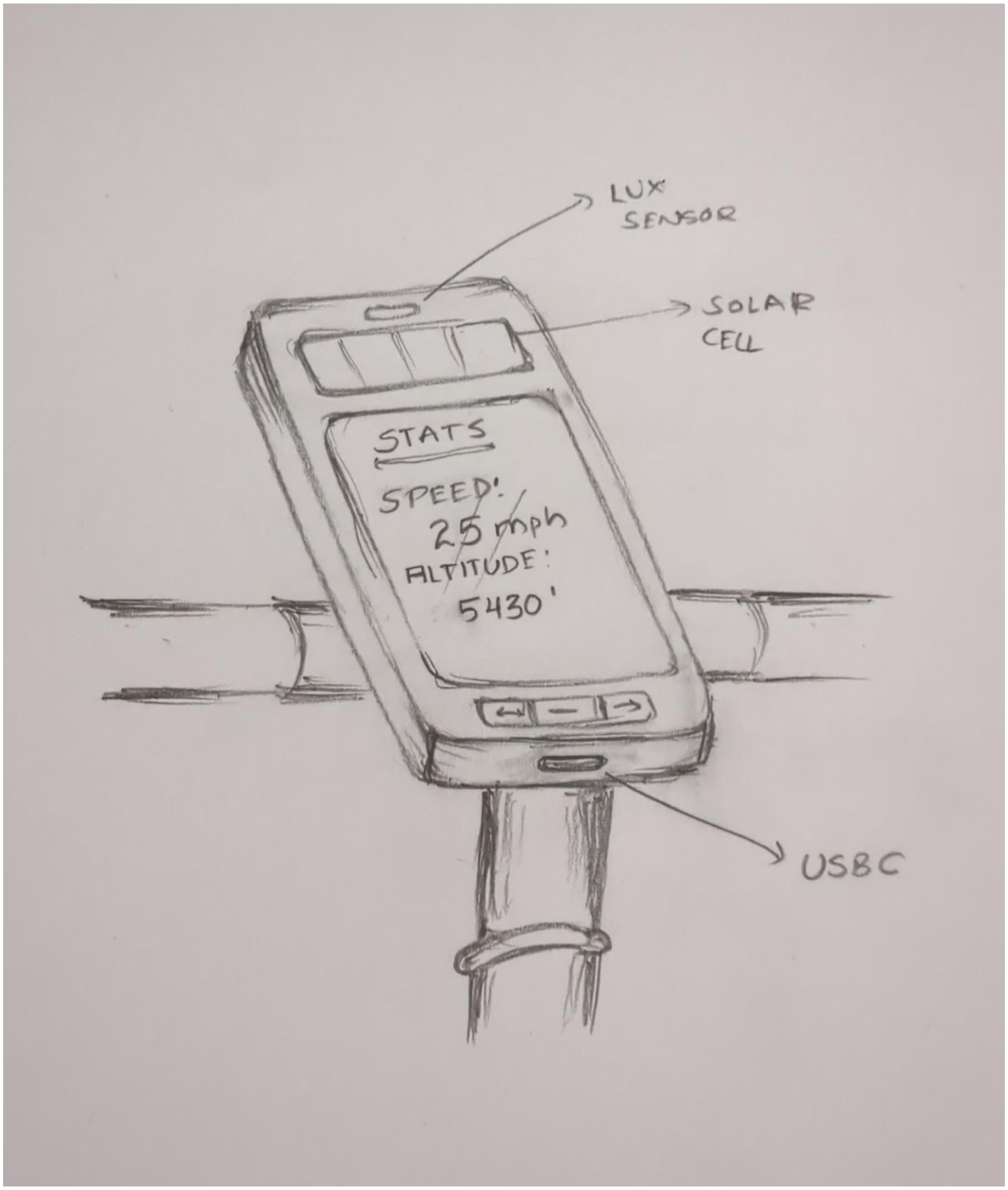
Section 1: Project Proposal

1.1 Device Illustration



1.2 Project Overview

A bike computer powered by low power BLE chip from silicon labs and will do following basic functionalities

1. Odometer
2. Cadence meter
3. Navigation assistance using a connected phone
4. Elevation gain
5. Ambient Temperature
6. Luminous Intensity
7. Road quality assessment using IMU

Device will consist of a low power display which can show basic statistics such as speed, cadence, distance travelled and elevation gain

What problem does it solve?

This is an added advantage for cyclists and fitness enthusiasts to get to know more about their performance and track progress to improve. Road quality assessment can help the authorities to improve the road conditions.

Power and Energy harvesting:

The entire system will be powered by a lithium-ion battery with USB C charging and Solar based energy harvesting for longevity. The expected battery life of the device is 12 weeks.

Sensors:

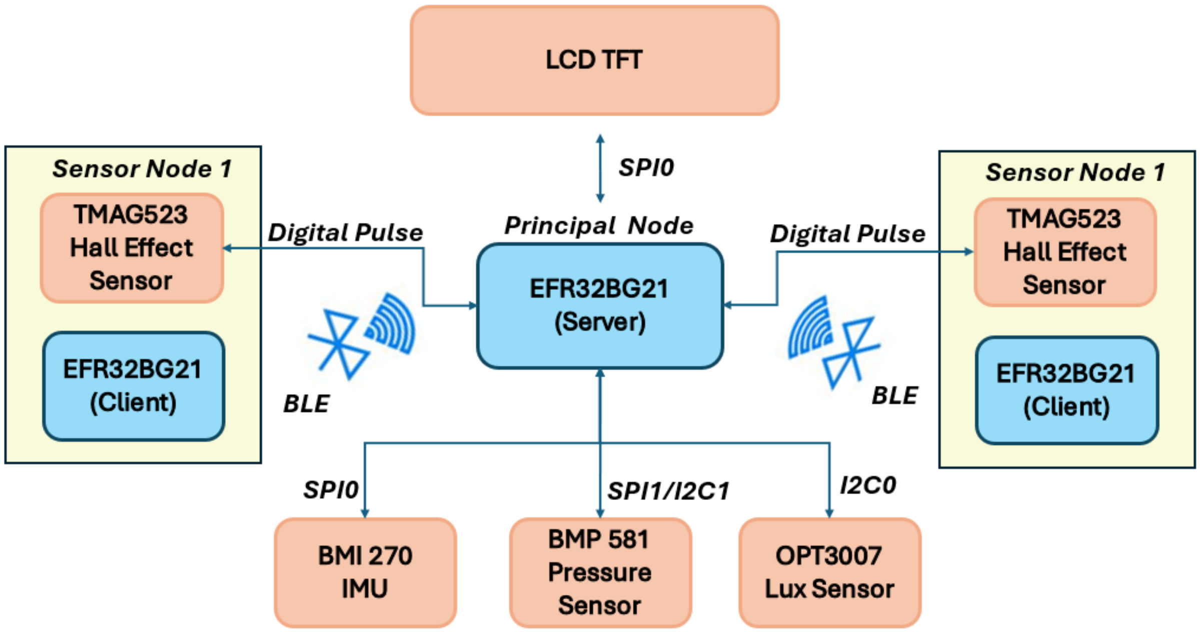
Following sensors will be used in this device

Sensor name	Functionality
Hall effect sensor 1	Cadence
Hall effect sensor 2	Odometer/Speed/Distance
IMU	Road Quality Assessment
MEMS pressure sensor	Elevation gain, Ambient Temperature
Photo Lux sensor	Luminous Intensity for auto brightness

Connectivity:

Planned connectivity will be Bluetooth Low Energy between 2 sensor nodes [agents] to principal and from principal to a smartphone. The current plan is to keep both wired and wireless options for the hall effect sensor nodes so that if wireless option does not pan out, we can still use the same PCBs (Printed Circuit Boards) without populating the agent microcontrollers.

1.3 Connectivity block diagram



Protocols used:

BLE between sensor node [agents] to Principal

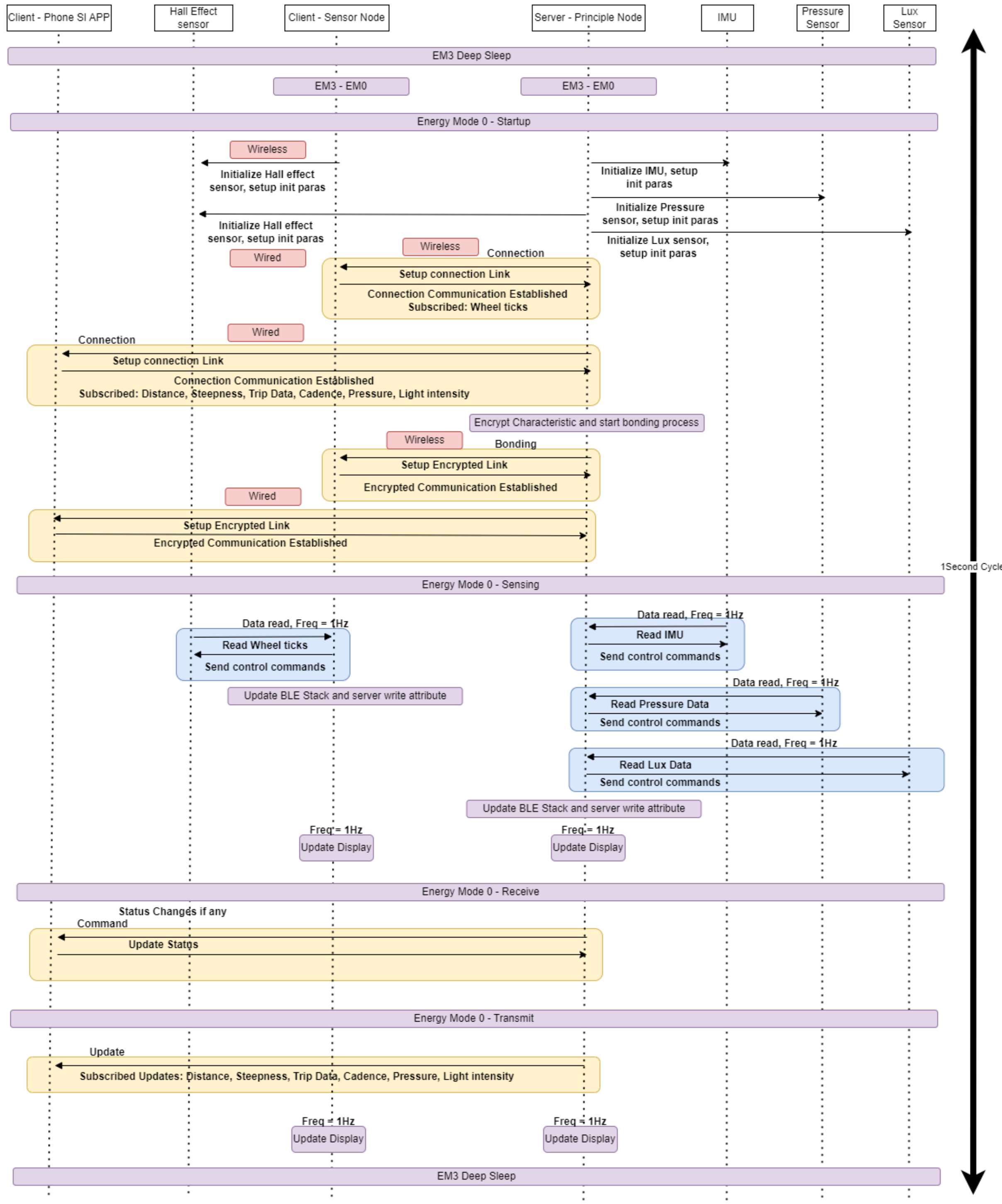
BLE between principal to a smartphone

SPI from pressure sensor to Principal [Main device]

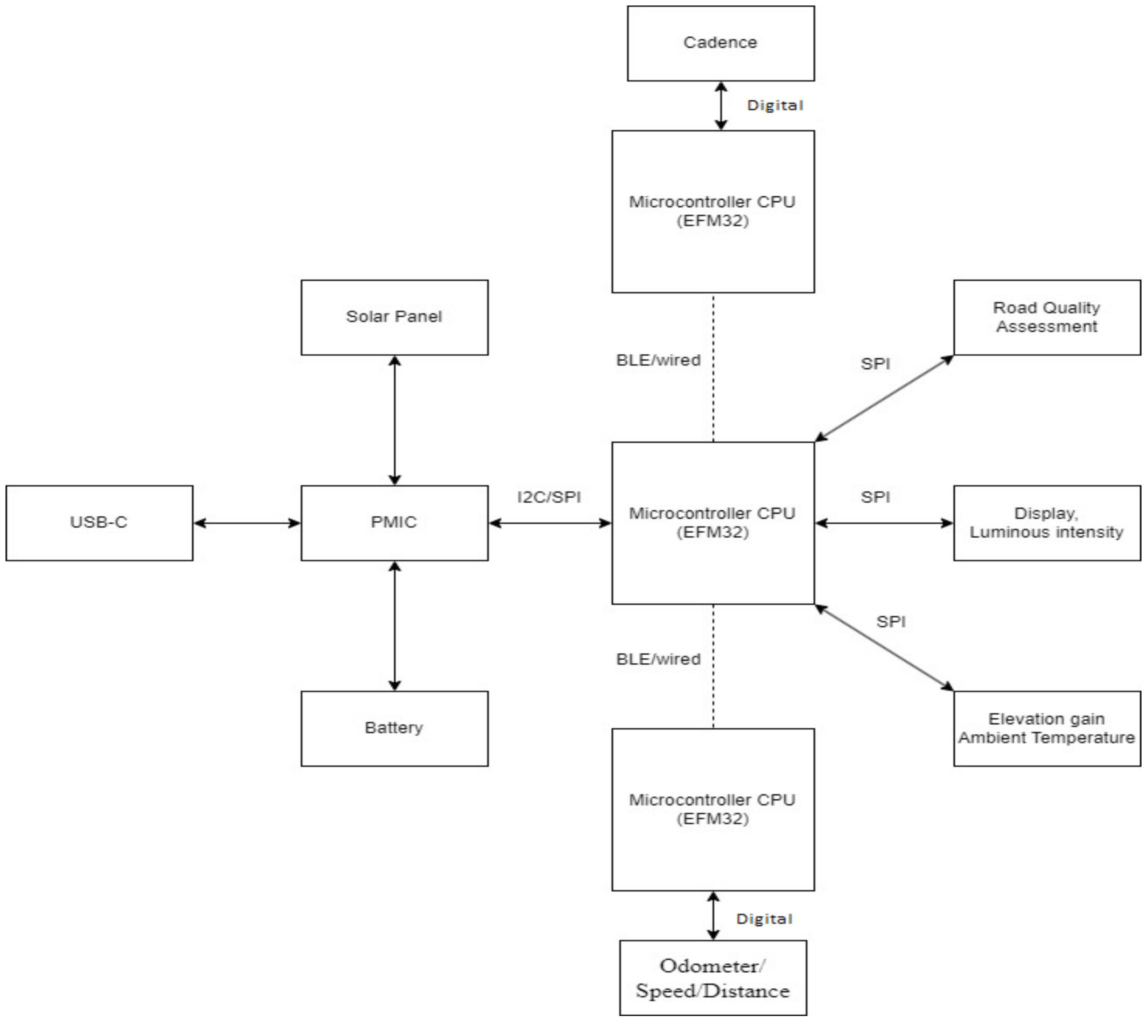
Analog read from Lux sensor to Principal [Main device]

SPI from IMU to Principal [Main device]

1.4 Use Case Model:



1.5 System overview block diagram:



1.6 Components List

Component	Purpose	Approximate cost [$]	Quantity	Total Price
EFR32BG21A010F1024IM32-BR	BLE MCU [Principal]	4.27	1	4.27
EFR32MG22C224F512IM32-C	BLE MCU [Agent]	3.00	2	6
BMI 270	IMU	5.88	1	5.88
BMP581	Pressure sensor	4.12	1	4.12
OPT3007	Lux sensor	2.22	1	2.22
LS027B7DH01A	Display	25.48	1	25.48
TMAG5231A2DQDBZR	Hall effect sensor	0.44	3	1.32
SM340K10L	Front Solar cell	3.27	1	3.27
BQ25570RGRT	PMIC	8.23	1	8.23
1250mah Battery	Battery	10.95	1	10.95
CR2032	Coin cell	0.41	2	0.82

Section 2: Project Status Update 1

Date: 9-14-2024

2.1 Professors review:

Hi team, first and foremost, very nice illustration of your intended final design. What are the expected dimensions of your final product? Overall, very good proposal as you address all major points. I like the system design and fallback plans for your sensor nodes being BLE or wired. Is there a particular reason you are moving to an EFR32MG22 series for the agent instead of using the same EFR32BG21 your principal is using? I would consider some sort of load power management for your display as it's fairly large. This is well put together and should be a fun project to put together. If you are looking at three blue geckos per design, you may run over budget, just something to keep in mind. If these agent modules will be running wirelessly, you need to consider how they will be powered. Will they have their own energy harvesting and battery?

2.2 Team's response

Projected dimensions of the product:

This factor depends on things like display active area, solar cell dimensions, navigation button area and battery dimensions. By considering all the above here's our projected dimensions.

Component	Dimension [LxBxH]
Display active area	58.8mm x 38.28mmx1.8mm
Solar cell dimensions	16mmx34mmx2mm
Navigation button	6.5mmx6.5mmx4mm
Battery	50.8mm x 33.5mm x 5.9 mm
PCB [Projected]	90mmx 60mmx1.6mm
Overall dimensions for main device [Projected]	95mmx65mmx15mm

Agent device projected dimensions

CR2032 Cell	22mmx16mmx3.2mm
PCB [Projected]	28mmx20mmx1.6mm
BLE+Passives+ Hall sensor	1.5mm height max
Overall dimensions	30mmx24mmx8mm

Reason for choosing 2 different MCUs

While narrowing down the requirements it was decided that the main device MCU should have enough RAM and flash size for storing information about logs of at least the last 3 trips and some icon images to show on the screen. Upon compilation of the code with basic BLE stack [100KB] + sensors [200KB] + icons [100KB] which comes to around 400KB flash, as an area for future development it was decided to keep another 200KB of flash headroom, that is why EFR32MG21 was chosen as a principal controller. [1024KB flash 96KB RAM]

The agent controller was chosen as EFR32MG22 as the design did not require much RAM and flash size and it was cost effective [30% less than EFR32MG21] compared to the principal microcontroller.

2.3 Sensor selection Criteria

Major criterion considered for choosing the sensor were,

1. Energy consumption (Especially sleep current)
2. Sensor resolution
3. Communication: Whether it supports SPI (so that energy per byte would be lesser) or digital

2.4 Energy harvester selection

As the device is a cyclo-computer and mostly used for outside purposes choosing solar cells would be more appropriate as it has higher energy density compared to thermal or vibration-based energy harvesting method.

2.5 Power management for sensors and display

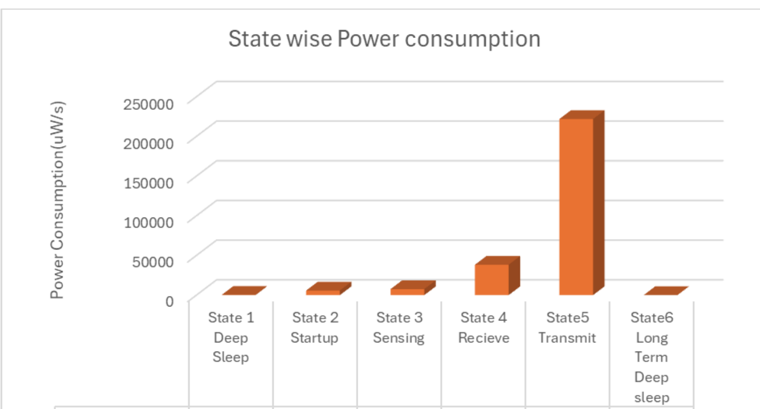
1. Sensor power: Sensors have built-in deep sleep modes which help in saving battery when not in use.
2. MOSFET based control for sensors and display: MOSFET as a load switch will be used to control the power to devices such as sensors [without sleep mode] and displays by using the lux sensor and IMU data [for motion detection] i.e. turn off after 5 minutes if there is no motion detected
3. IMU based auto switching between energy harvesting solar cells: Based on the orientation of the device Solar cell can be switched between front and back.

2. 6 Use Case Model Updates: Has been updated on **Page 5**

2.7 Power mode master sheet: Link

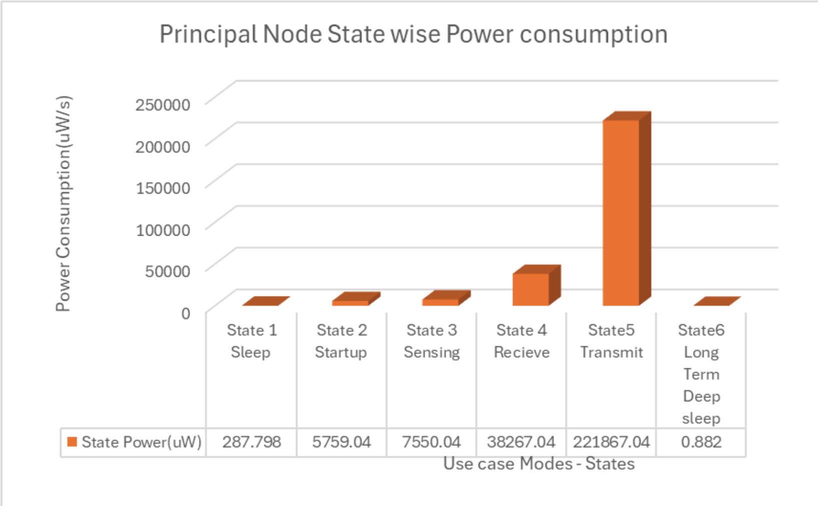
2.8 Energy Models for Projected Modes:

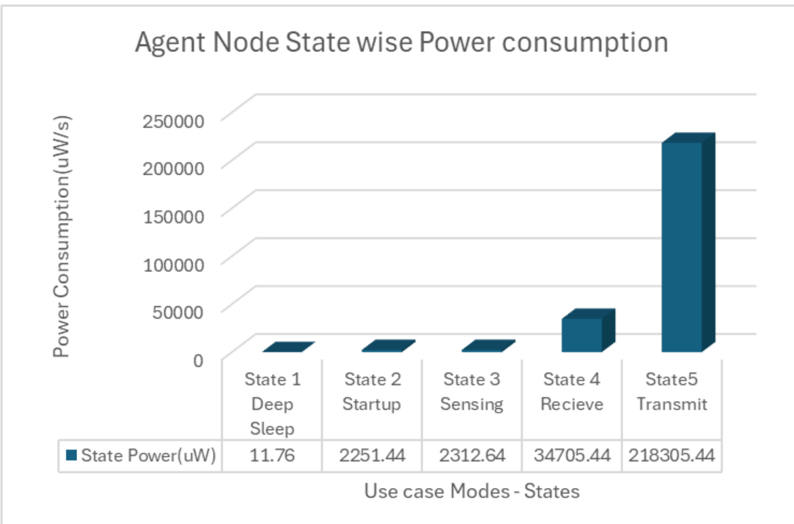
2.8.1 Energy Models Wired Mode Bar Chart:



	State 1 Deep Sleep	State 2 Startup	State 3 Sensing	State 4 Recieve	State5 Transmit	State6 Long Term Deep sleep
State Power(uW)	299.558	5759.04	7556.916	38267.04	221867.04	0.882

2.8.2 Energy Models Wireless Mode Bar Chart:





2.9 Energy Harvesting (Latest Update: 2)
Our project mainly consists of 1 Principal, and 2 client nodes connecting over wired or wireless. The solar energy harvested from the solar panel on the principal can recharge its battery. The client nodes are of smaller size and might not get exposure to solar energy due to its placement angle on the bike. So, planning to design client nodes such a way that it works with both wired from principal and independent coin cell mounted on it. If we go for a wired connection, we will have an extra pair of wires between principal and client.

2.10 Over budget:

We looked for cost-effective sensors and microcontrollers without compromising the features and capabilities. Currently our budget stands at ~$77(Used to be $70). To cut down costs, we are planning to design principal and client nodes on same layout and separating them once assembled. So that way we can save some money from PCB manufacturing and use it for components. Also we can reduce costs by ordering just a single solar panel [back] instead of the per board requirement.

2.11 Plan for next week:

1. Interfacing sensors on an eval board or existing thunderboard to get an idea over the challenge
2. Exploring app interface options
3. Planning PMIC operation and power sequencing

2.12 Project Schedule Proposed

S.No	Task	Target Start Date	Plan Duration	Percentage Completed	Status
1	Project Ideation	27-08-2024	7	100%	On Track
2	Component Selection	27-08-2024	21	100%	On Track
3	Block Diagrams	02-09-2024	7	100%	On Track
4	System UML Diagram	02-09-2024	7	100%	On Track
5	Initial Proposal Documentation	02-09-2024	7	100%	On Track
6	GD & T [Physical Dimension Estimation]	02-09-2024	7	100%	On Track
7	Firmware memory requirement analysis	02-09-2024	7	100%	On Track
8	Power Analysis for client nodes	09-09-2024	7	100%	On Track
9	Component Budgeting	09-09-2024	7	100%	On Track
10	Power calculation sheet	09-09-2024	7	50%	On going
11	Use Case model and Energy Modes	09-09-2024	7	0%	Not Started
12	Footprint Creation - Power Block	16-09-2024	14	0%	Not Started
13	Footprint Creation - Control Block	16-09-2024	14	0%	Not Started
14	Footprint Creation - Sensor Block	16-09-2024	14	0%	Not Started
15	Schematic Design - Power Block	16-09-2024	14	0%	Not Started
16	Schematic Design - Control Block	16-09-2024	14	0%	Not Started
17	Schematic Design - Sensor Block	16-09-2024	14	0%	Not Started
18	Firmware Demo of sensors - Eval Boards	30-09-2024	7	0%	Not Started

Section 3: Project Status Update 2

3.1 Professors review:

Hi team, please be sure to include what you have accomplished in the past week, and if you are on schedule (also if you have any blockers). I see you have included tasks for next week. For your power calculations, are you estimating your principal node will be able to run forever off of energy harvesting and your agent node will run for 700+ days? I believe you are underestimating your energy usage. For example, how are you getting 35uA for your display usage? I am looking at the datasheet and at a 1Hz data update @ 5V VDD, it looks like a typical consumption of 175uA with a maximum of 350uA. If you are going to go down to EM4 (hibernation), you need to have an external wake-up (such as a GPIO interrupt). Is there a plan for this? Otherwise, I would stick with EM3 as your lowest state. The coin cell battery you have selected is a primary non-rechargeable battery. I assume this is intentional and meant to be replaced by the user?

3.2 Team Response:

Question	Answer from team
For your power calculations, are you estimating your principal node will be able to run forever off of energy harvesting and your agent node will run for 700+ days? I believe you are underestimating your energy usage.	This has been corrected, there was a factor of 100 being divided to total energy being consumed and this resulted in a very large number of days
For example, how are you getting 35uA for your display usage? I am looking at the datasheet and at a 1Hz data update @ 5V VDD, it looks like a typical consumption of 175uA with a maximum of 350uA.	The current required for the display is 35uA and 175uW at 5V (35uA*5).
If you are going to go down to EM4 (hibernation), you need to have an external wake-up (such as a GPIO interrupt). Is there a plan for this? Otherwise, I would stick with EM3 as your lowest state.	We are planning to use EM4 mode for the principal node so that we can save power when the device is not in use. We will have physical button to wake up from sleep. For agent node we are planning to use hall sensor interrupt as the wake up and enter EM4 when not in use.
The coin cell battery you have selected is a primary non-rechargeable battery. I assume this is intentional and meant to be replaced by the user?	Yes. We are currently planning to use the non-rechargeable version of the battery so that it will be field replaceable by user

3.3 Project Schedule Status

S.No	Task	Target Start Date	Plan Duration	Percentage Completed	Status
1	Project Ideation	27-08-2024	7	100%	On Track
2	Component Selection	27-08-2024	21	100%	On Track
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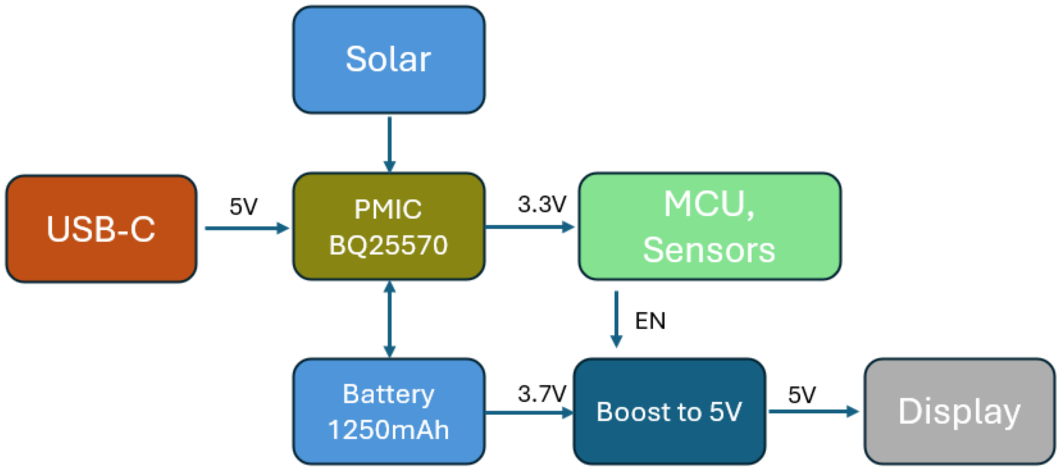
10	Power calculation sheet	09-09-2024	7	100%	On Track
11	Use Case model and Energy Modes	09-09-2024	7	100%	On Track
12	Footprint Creation - Power Block	16-09-2024	14	100%	On Track
13	Footprint Creation - Control Block	16-09-2024	14	100%	On Track
14	Footprint Creation - Sensor Block	16-09-2024	14	25%	On going
15	Schematic Design - Power Block	16-09-2024	14	10%	On going
16	Schematic Design - Control Block	16-09-2024	14	10%	On going
17	Schematic Design - Sensor Block	16-09-2024	14	10%	On going
18	Firmware Demo of sensors - Eval Boards	30-09-2024	7	0%	Not Started

We are on track for the next week. For the past week, we have completed the footprint creation for the power block and the control block. This week we will look at completing the footprint library and as a stretch goal, we aim to complete the initial draft schematic. We are still working on the android app development using MIT app inventor. Footprints for IMU and pressure sensor has been created.

3.4 Final Component Selection:

The final Component list is updated in Project Proposal section 1.6. That is the finalized component list as of Update 2.

3.5 PMIC Selection and Justification



Power tree diagram for the principal device

Note: Updated block diagram based on the inputs from the professor after project update 2.

Change: USB-C directly connects to PMIC and avoids the need for one more component i.e. Li-ion charger

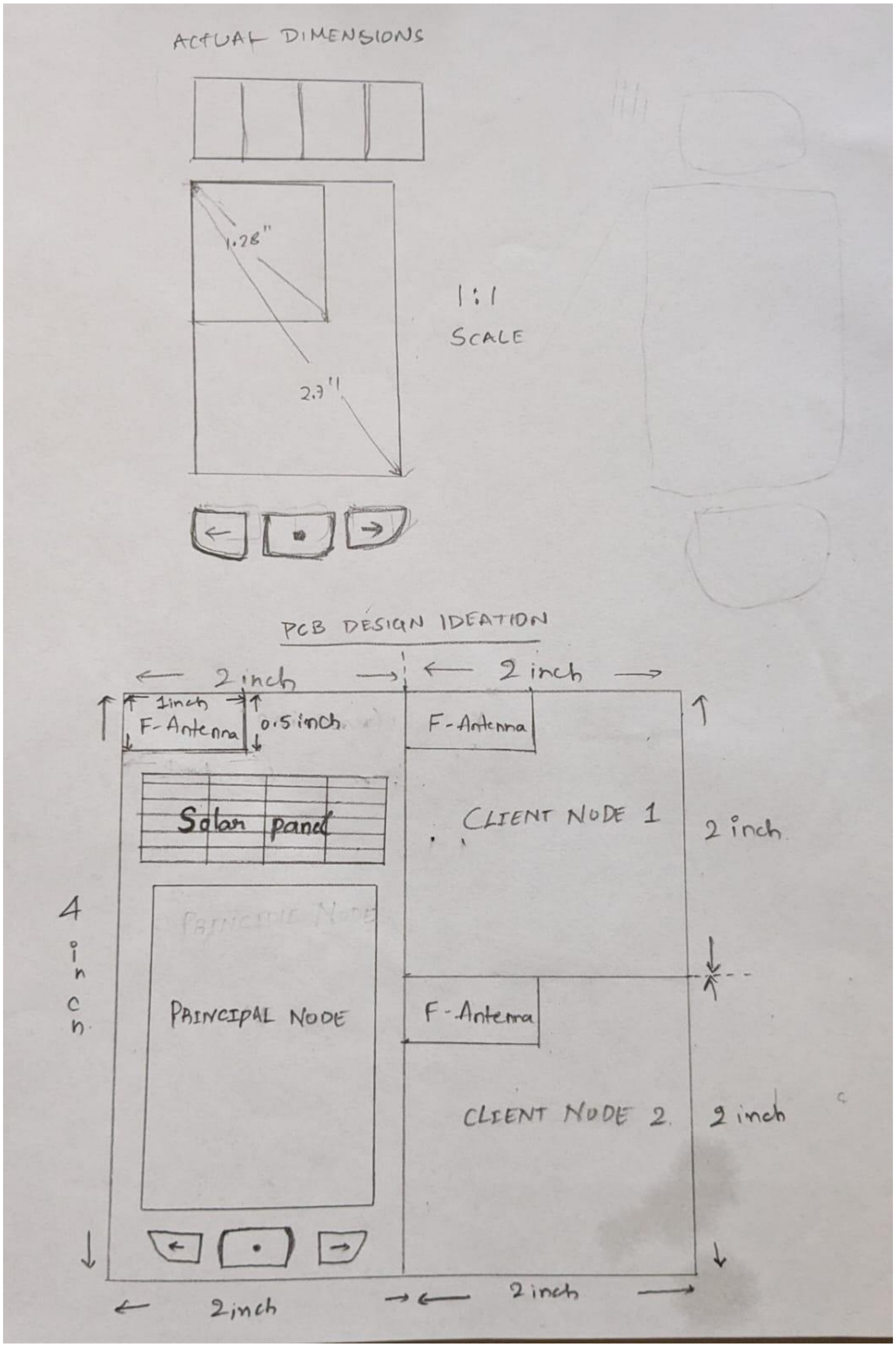
Power tree diagram for the agent device

PMIC Selection:

PMIC [Power Management Integrated Circuit] is an IC used for the basic power management of the product when there is a need for multiple features such as battery charging, regulated buck output, energy harvesting etc. IC BQ25570 provides a unified solution for this by providing solar energy harvesting solution, Li-ion battery charging and regulated buck output of 3.3V for the nominal operation of the circuit.

Boost converter:

There is a requirement of the boost converter for boosting the voltage to 5V as minimum operating voltage for the display is 5V. This display is essential as other displays which are low power are smaller in size and hence it will be hard to display all the information we want to display. Refer actual dimension comparison image below.


ACTUAL DIMENSIONS
1.28"
2.7"
1:1
SCALE
PCB DESIGN IDEATION
2 inch
2 inch
1inch
F-Antenna
0.5inch
F-Antenna
Solar panel
CLIENT NODE 1
2 inch
4
inch.
PRINCIPAL NODE
F-Antenna
CLIENT NODE 2.
2 inch
2inch
2inch

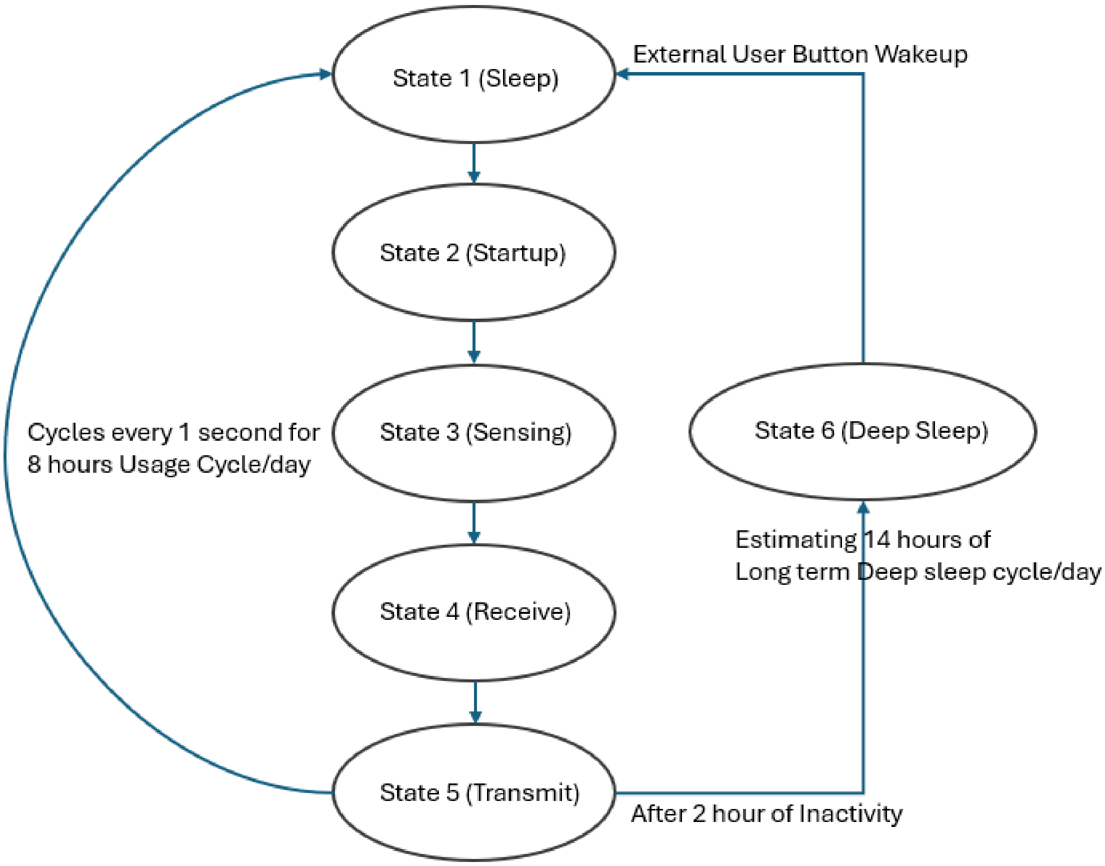
Part Number	Vin_Min (V)	Vin Typical (V)	Vin_max (V)	Absolute Min (V)	Absolute Max (V)
EFR32BG21A010F1024IM32-BR	1.71	3	3.8	-0.3	3.8
EFR32MG22C224F512IM32-C	1.71	3	3.8	-0.3	3.8
BMI 270	1.71	1.8	3.6	-0.3	4
BMP581	1.71	1.8/3.3	3.6	-0.3	4.3
OPT3007	1.6	-	3.6	-0.5	6
LS027B7DH01A	4.8	5	5.5	-0.3	5.8
TMAG5231A2DQDBZR	1.65	-	5.5	-0.3	5.5
BQ25570RGRT	0.1	-	5.1	-0.3	5.5

3.6 Use Case Energy Considerations

Our proposed use case model has 6 states, in which these 6 states are used by 2 models, one being the Usage Cycle and the other being long term Deep sleep Cycle.

We estimate that an average user of this device will use this device for 10 hours a day and the 14 hours remaining in that day, the device will be in long term deep sleep Cycle. Every day, the user must wake up the device from a deep sleep cycle by pressing a power button we will provide on the mechanical housing. This essentially is an external wakeup to the MCU to move from EM4 to EM3 and then the usage cycle takes over.

Usage Cycle: This Cycle is intended to be executed by the MCU when device is being actively used by the user. In this cycle, the MCU switches from State 1 (sleep) to State 2 (Startup) where initial device configuration and setup takes place. After this the device switches from State 2 (startup) to State 3 (Sensing) where the sensor values are read by the MCU and stored. Then the MCU switches from State3(Sensing) to State4 (Receive) where all the sensor reading is sent via Bluetooth to the Phone and data from the agent nodes will be also sent to the Phone and the Principal Node.



Long term Deep sleep Cycle: After 2 hours of Inactivity device will be sent into long term deep sleep state, from where only an external button can wake the device and start usage again

3.7 Average Power Calculation

Wired Mode: In this mode, our principal node and agent node are connected by physical wires and there will not be a separate coin cell battery for the agent nodes. Agent nodes and the Hall Effect sensor on the agent node will be powered using the main battery on the principal node.

Principal Node (Per day: 10 hours Usage Cycle, 14 hours Long term Deep sleep Cycle)

	Current (uA)	Voltage (V)	Power(uW)	Sleep Current (uA)	Power in sleep mode(uW) (#)	State 1 (Deep Sleep)	State 2 (Startu	State 3 (Sensing)	State 4 (Reci	State5 (Transı	State 6 (Long term Sleep)
Power Supply Quiescent (EM3) (Full RAM retention and RTC on)	4.8	3	14.4			x	x	x	x	x	
Microcontroller Deep Sleep (EM4) (No BURTC, no LF oscillator)	0.21	3	0.63								x
Microcontroller Run Mode (EM0 - 26 MHz HFRCO, CPU runningwhil	1536.6	3	4609.8				x	x	x	x	
Microcontroller Peripherals (SPI - 1Mhz, I2C - 1MHz)	30	3	90					x	x	x	
IMU - BMI270 (Accel+Gyro - Low power mode at 25Hz)	420	3.3	1386	3.5	11.55	#		x			
Pressure Sensor - BMP581 (Low power mode, ODR at 1Hz)	1.3	3.3	4.29	1	3.3	#		x			
Lux Sensor - OPT3007 (At 1Hz)	1.8	3.3	5.94	0.4	1.32	#		x			
Hall Effect Sensor 1 - TMAG5231A2DQDBZR (1Hz)	2	3	6	1.4	4.2	#		x			
Hall Effect Sensor 2 - TMAG5231A2DQDBZR (1 Hz)	2	3	6	1.4	4.2	#		x			
Display - LS027B7DH01A (1 Hz Update Rate)	35	5	175			x	x	x	x	x	
Bluetooth Low Energy Receive	9000	3	27000						x		
Bluetooth Low Energy Transmit	60000	3	180000							x	
Efficiency 60%						x					x
Efficiency 80%							x	x	x	x	

	State 1	State 2	State 3	State 4	State 5	State 6
State Power(uW)	299.558	5759.04	7556.916	38267.04	221867.04	0.882
%Time (Estimate 20 bytes for SPI and I2C at 1MHz)	0.999956	0.000002	0.000002	0.00002	0.00002	
Weighted Avergae Power (uW)	7861.675021					
Energy Required for 4 Hours (J)	113.2081203					
Total Energy Required for 10 hrs usage and 14 hours deep sleep per day (J)	113.2652739					
Solar Panel Power (mW) (Front panel)	65					
Pessimistic 10% Efficiency (mW)	6.5					
Energy Generated in 8 Hours (J)	93.6					
Energy of battery (J)	3600					
Predicted Battery life (days)	31.79983901					

Weighted Average Power (uW) for 1 Cycle (Deep sleep	0.882
Energy Required for 18 Hours (J) in deep sleep	0.0571536

As seen in the above picture from the power calculation sheet, in wired mode, for our device total Energy Required for 4hrs usage and 18 hours deep sleep per day is 113.2 Joules. Our usable battery capacity is 3600 Joules.

Case 1: If we don't use energy harvesting at all, the device will run for 32 days (about 1 month) on the battery in a scenario where the user utilizes this device for 4 hours a day.

Case 2: Whenever the device is in use, the battery will also be charging when exposed to sunlight (maybe not during night times). If we assume that the user will use it for 4 hours a day, the front solar panel produces 93.6 Joules for that 4-hour window. As discussed above the usage is 113.2 Joules, so it will be using 113.2 Joules, but 93.6 Joules is recharged back. In this way, the solar panel will let the device last much longer than 32 days (about 1 month).

Wireless Mode: In this mode, our principal node and agent node are not connected physically but using Bluetooth connectivity. The agent node will have a coin cell battery of usable energy of 810 Joules. The agent node will have a coin cell battery, and Hall Effect sensor, MCU and a BLE PCB antenna. The principal node will host the rest of the sensors and will communicate with the phone and the agent nodes.

As seen in the below picture from the power calculation sheet, in wireless mode, for our device principal node total Energy Required for 4hrs usage and 18 hours deep sleep per day is 112.9 Joules. Our usable battery capacity is 3600 Joules.

Case 1: If we don't use energy harvesting at all, the device principal node will run for 32 days on the battery in a scenario where the user utilizes this device for 4 hours a day. The agent node will run on coin cell battery for 24 Days and after which the user is expected to replace this coin cell.

Case 2: Whenever the device is in use, the battery will also be charging when exposed to sunlight (maybe not during night times). If we assume that the user will use it for 4 hours a day, the front solar panel produces 93.6 Joules for that 4-hour window. As discussed above the usage is 113.2 Joules, so it will be using 112.9 Joules, but 93.6 Joules is recharged back. In this way, the solar panel will let the device last much longer than 32 days (about 1 month).

Since their agent node is not connected to the principal node physically, we will not be able to charge the coin cell battery.

Principal Node (Per day: 10 hours Usage Cycle, 14 hours Long term Deep sleep Cycle)

	Current (uA) (I	Voltage (V) (:	Power(uW) (	Sleep Current (	Power in sleep mode(uW) (#)	State 1 (Sleep)	State 2 (Startu	State 3 (Sen	State 4 (Re	State5 (Transmit	State 6 (Long term Deep Sleep)
Power Supply Quiescent (EM3) (Full RAM retention and RTC on)	4.8	3	14.4			x	x	x	x	x	
Microcontroller Deep Sleep (EM4) (No BURTC, no LF oscillator)	0.21	3	0.63								x
Microcontroller Run Mode (26 MHz HFRCO, CPU runningwhile loop	1536.6	3	4609.8				x	x	x	x	
Microcontroller Peripherals (SPI - 1Mhz, I2C - 1MHz)	30	3	90					x	x	x	
IMU - BMI270 (Accel+Gyro - Low power mode at 25Hz)	420	3.3	1386	3.5	11.55	#		x			
Pressure Sensor - BMP581 (Low power mode, ODR at 1Hz)	1.3	3.3	4.29	1	3.3	#		x			
Lux Sensor - OPT3007 (At 1Hz)	3.7	3.3	12.21	0.4	1.32	#		x			
Display - LS027B7DH01A (1 Hz Update Rate)	35	5	175			x	x	x	x	x	
Bluetooth Low Energy Receive	9000	3	27000						x		
Bluetooth Low Energy Transmit	60000	3	180000							x	
Efficiency 60%						x					x
Efficiency 80%							x	x	x	x	

	State 1 (Sleep)	State 2 (Startu	State 3 (Sen	State 4 (Re	State5 (Transmit	State 6 (Long term Deep Sleep)
State Power(uW)	287.798	5759.04	7550.04	38267.04	221867.04	0.882
%Time (Estimate 20 bytes for SPI and I2C at 1MHz)	0.999956	0.000002	0.000002	0.00002	0.00002	
Weighted Average Power (uW) for 1 Cycle (Usage Cycle)	7843.039539					
Energy Required for 4 Hours (J)	112.9397694					
Total Energy Required for 4 hrs usage and 18 hours deep sleep per day (J)	112.996923					
Solar Panel Power (mW) (Front panel)	65					
Pessimistic 10% Efficiency (mW)	6.5					
Energy Generated in 4 Hours (J) during device usage	93.6					
Usable Energy of main battery (J)	3600					
Predicted Battery life (days) for 1 full charge	31.85927462					

Weighted Average Power (uW) for 1 Cycle (Deep sleep Cycle)	0.882
Energy Required for 18 Hours (J) in deep sleep	0.0571536

Agent Node

	Current (uA)	Voltage (V)	Power(uW)	Sleep Current (	Power in sleep mode(uW) (#)	State 1 (Deep Sl	State 2 (Startu	State 3 (Sen	State 4 (Re	State5 (Transmit	State 6 (Long term Deep Sleep)	
Power Supply Quiescent (EM3) (Full RAM retention and RTC on)	1.4	3	4.2			x	x	x	x	x		
Microcontroller Deep Sleep (EM4) (No BURTC, no LF oscillator)	0.21	3	0.63								x	
Microcontroller Run Mode (26 MHz HFRCO, CPU runningwhile loop	624	3	1872				x	x	x	x		
Microcontroller Peripherals (SPI - 1Mhz)	15	3	45					x	x	x		
Hall Effect Sensor 1 - TMAG5231A2DQDBZR (1Hz)	2	3	6	1.4	4.2	#		x				
Bluetooth Low Energy Receive	9000	3	27000						x			
Bluetooth Low Energy Transmit	60000	3	180000							x		
Efficiency 60%						x						
Efficiency 80%							x	x	x	x		
					State Power(uW)	11.76	2251.44	2312.64	34705.44	218305.44	0.882	
					%Time (Estimate 20 bytes for SPI and I2C at 1MHz)	0.99997	0.00001	0.00001	0.000005	0.000005		
					Weighted Avergae Power (uW)	2325.687226					Weighted Average Power (uW) for 1 Cycle (Deep sleep Cycle)	0.882
					Energy Required for 4 Hours (J)	33.48989605					Energy Required for 18 Hours (J) in deep sleep	0.0571536
					Energy Required for 24 Hours (J)	33.54704965						
					Energy of battery (J)	810						
					Predicted Battery life (days)	24.14519334						

3.8 Energy Storage Element Justification:

We have selected a Li-ion battery of 1250mAh battery. Calculating usable battery capacity is (4V-3.2V) *1250mAh = 1000mWh, converting to Joules, 3600 Joules. This gives us approximately 32 days of function on a single charge.

For the agent node, we have selected a coin cell battery of 810 Joules which will provide us with 24 days of charge. These numbers are relative to the scenarios discussed above in section 3.7. Thus, these battery choices were made based on this suitability.

3.9 Wireless Range Requirement of the Product:

Currently we do not have a requirement for the long range as we are planning to communicate data back to a smartphone in a cyclist's pocket or bag. The wireless range required between the principal and agent would be 1.5 to 2 meters, as agent nodes will be on the bicycle frame.

3.10 Expected Operating Temperature and Humidity Range for the Product

Our device will be mostly used in outdoor conditions, usually riders bike at temperature 10°C at winter up to 50°C in summer. So, our device should operate in this range. Since the most intricate element in our device is the Li-ion battery, our entire operating range will be based off that. Since the temperature range for the battery is 10°C to 45°C, we will be making a mechanical slot in the housing to protect this, and we presume operating temperature range of 10°C to 45°C with housing. Humidity range is the same as the cell which is 65±20% RH.

Component	Max Temperature(°C)	Min Temperature (°C)	Remarks
EFR32BG21A010F1024IM32-BR	125	-40	
EFR32MG22C224F512IM32-C	125	-40	
OPT3007YMFR	85	-40	
LS027B7DH01A	70	-20	
TMAG5231A2DQDBZR	125	-40	
SM340K10L	90	-40	
BQ25570RGRT	125	-40	
Battery	45	10	Concerning

CR2032	80	-30	

3.11 Warranty time/ End of Life of the Product

Usually, warranty of the entire device depends on End-of-life calculations based on the device environmental conditions. In a more direct way, the least life cycle element in the device is directly affecting the warranty of the product. In our device, the Li-ion cell has the least life cycle of 6 months, so our product warranty time is also 6 months.

Section 4: Project Status Update 3

Project name: Vega

Date: 28th September 2024

Team Members: Vishwas Navada Benagere, Prudhvi Kondapalli, Jithendra Halenahalli Somashekharaih

Major links:

1. **Power sheet: Link**
2. **Gantt chart: Link**

4.1 Professors review:

Hi team, thank you for addressing all my feedback from the previous week. Well done on this update. Instead of having a BQ21040, have you considered inputting 5V into your PMIC BQ25570 in conjunction with your solar? The BQ25570 is capable of this and has a max input voltage of 5.1V. This would greatly simplify your PMIC schematic. Also, when including screenshots of you excel sheet, please attach the excel sheet as well. It is hard for me to read and turns out blurry when using Canvas. I have not deducted for this. Well done applying your energy use cases to your power calculations into your energy storage element justifications. Keep in mind your peak use case current.

4.2 Team Response:

Question	Answer from team
Instead of having a BQ21040, have you considered inputting 5V into your PMIC BQ25570 in conjunction with your solar? The BQ25570 is capable of this and has a max input voltage of 5.1V. This would greatly simplify your PMIC schematic.	We have decided to edit the proposed power tree in line with these comments. We will be using a MOSFET Switch circuit to automatically switch between USB-C input and the solar cell. The following has been updated in section 3.5
Keep in mind your peak use case current.	Peak use case current is 61mA which can be generated by the power components.

4.3 Project Status Schedule

Tasks accomplished for this update:

We have successfully completed the Altium footprint and schematic symbol creation for all our IC components including the MCU's. We are on track to start schematic design.

Tasks planned for next update:

We will be completing our design and review of our schematic Design of the entire Product in Altium and will have a paper sketch for component layout ready for our future updates.

S.No	Task	Target Start Date	Plan Duration	Percentage Completed	Status
1	Project Ideation	27-08-2024	7	100%	On Track
2	Component Selection	27-08-2024	21	100%	On Track
3	Block Diagrams	02-09-2024	7	100%	On Track
4	System UML Diagram	02-09-2024	7	100%	On Track
5	Initial Proposal Documentation	02-09-2024	7	100%	On Track
6	GD & T [Physical Dimension Estimation]	02-09-2024	7	100%	On Track
7	Firmware memory requirement analysis	02-09-2024	7	100%	On Track
8	Power Analysis for client nodes	09-09-2024	7	100%	On Track
9	Component Budgeting	09-09-2024	7	100%	On Track
10	Power calculation sheet	09-09-2024	7	100%	On Track
11	Use Case model and Energy Modes	09-09-2024	7	100%	On Track
12	Footprint Creation - Power Block	16-09-2024	14	100%	On Track
13	Footprint Creation - Control Block	16-09-2024	14	100%	On Track
14	Footprint Creation - Sensor Block	16-09-2024	14	100%	On Track
15	Schematic Design - Power Block	16-09-2024	14	20%	On going
16	Schematic Design - Control Block	16-09-2024	14	10%	On going
17	Schematic Design - Sensor Block	16-09-2024	14	20%	On going
18	Firmware Demo of sensors - Eval Boards	30-09-2024	7	0%	Not Started

4.4 Sizing Storage based on Recharge Requirements

Based on the required current for the principal device [2mA average] it has been decided to use a battery with a decent energy density and with the available size of around 70mmx50mmx8mm. Chosen battery has a good temperature tolerance and excellent long-term self-discharge rates (<8% per month) with a maximum life of 400 cycles. As per the current usage and self-discharge the battery should last for 25-26 days. Chosen battery dimensions are 50.8mmx33mmx5.9mm which is well within the limit. Since the principal device also has an energy harvester it should last for even longer and harvester charging current will be well withing the maximum charging C rating of 1.0C

The agent device needs around 0.3mA average current and should last about 31 days with CR2032 225mAh battery.

4.5 Tolerance Issues

Tolerance issues in the value of resistors will not affect most of the voltage and power settings as the components are chosen in such a way that it is well within the margin. [1% tolerant resistors]

Tolerance issues in temperature will not affect much to other devices and sensors as the accuracy of sensors due to temperature change is minimal and intended use case doesn't necessarily need that level of accuracy.

Battery is tolerant to temperature change -20C to +60C which is well within our product's operating range.

4.6 Battery solution and C rating

Chosen battery is 3.7V Lithium-Ion battery with a capacity of 1250mAh [As tested by spark fun, manufacturer claims 1300mAh] This is because our consumption is less, the chosen battery has excellent long-term self-discharge rates (<8% per month) and is IEC certified.

The maximum charge and discharge rating of the battery is 1.0C which means we can safely draw about 1.25A of current without any issues.

C rating of the CR2032 is very low as they are designed for low C rating applications. In our application the required max current will go up to 61mA which is about 0.25C.

4.6.1 Calculate Maximum Discharge rate of the battery

As per the datasheet maximum discharge C rate is 1.0 and hence our maximum current that can be drawn from the battery is 1250mA or 1.25A. During normal operation the principal device needs 2mA for regular operation. Considering the nominal voltage of the battery to be at 3.6V, battery should last about 625 hours or 26 days. [Note that the voltage is considered as an average value].

With 0.3mA in the agent the battery should last about 31 days. Which is easily field replaceable.

4.6.2 Lowest Nominal Voltage

3.7V is the nominal voltage but since all the devices in the principal takes less than 3.0V we should be able to operate till the cutoff voltage

3.0V is the nominal voltage but since all the devices in the client takes less than 2.2V we should be able to operate till the cutoff voltage

4.6.3 Battery Cutoff voltage of the device

As per the datasheet cut off voltage is 3.0V [Li-ion 1250mAh], As per the datasheet cut off voltage is 2.2V [CR2032]

4..6.4 Will Nominal Voltage work using a buck only solution or is buck boost needed

Yes. It will work in the case of both principal and agent as both work well below that voltage**.**

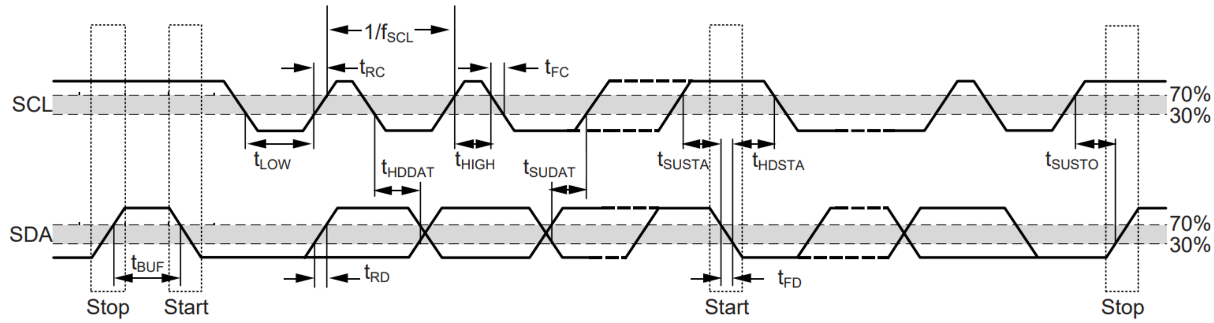
4.6.5 Does PMIC support a low battery discharge cut off voltage, if yes what will be the cutoff voltage that will be set

Battery itself also has a cut off voltage which will be set to 2.80V so we will be setting the PMIC to 2.90V battery OK voltage. PMIC not used in the case of Agent.

4.7 Worst Case Timing Information - Based on Worst Case Device on comm bus

According to the present configuration, the worst-case device on the bus is the OPT3007 Ultra-Thin Ambient Light Sensor, because it is on a I2C bus which is generally slower than SPI. Even though the plan is to use I2C at 1MHz, the shutdown current at 1MHz due to the I2C lines always being pulled up is around 10uA for this component. So as a backup strategy, we will be reducing the I2C speed to 400Khz. The worst-case timing info is as shown in the below table.

Parameter	**Description**	**MIN**	**TYP**	**MAX**	**UNIT**
fSCL	SCL operating frequency		0.01	0.4	MHz
tBUF	Bus free time between stop and start	1300			ns
tHDSTA	Hold time after repeated start	600			ns
tSUSTA	Setup time for repeated start	600			ns
tSUSTO	Setup time for stop	600			ns
tHDDAT	Data hold time	20		900	ns
tSUDAT	Data setup time	100			ns
tLOW	SCL clock low period	1300			ns
tHIGH	SCL clock high period	600			ns
tRC and tFC	Clock rise and fall time			300	ns
tRD and tFD	Data rise and fall time			300	ns
tTIMEO	Bus timeout period. If the SCL line is held low for this duration of time, the bus state machine is reset		28		ms



Citation: Texas Instruments. (2024). OPT3007 Ultra-Thin Ambient Light Sensor. Retrieved from https://www.ti.com/lit/ds/symlink/opt3007.pdf

4.7.1 Parameters to look out for and measure
SCL Clock Frequency (fSCL), Data Setup Time (tSUDAT), Data Hold Time (tHDDAT), Clock Low Period (tLOW), Bus Free Time (tBUF) as these directly contribute to signal latching and power consumption of the bus and the peripherals on it.

4.8 High Risk development Items

- Sensor interfacing and handling the data display
- How real-time the data should be?
- Storage mechanisms for the existing data? Is there a need for an external SPI flash or EEPROM?
- A backlight option needed for display. If yes, is it easy to implement using a single LED front lit mechanism so that the loss due to the translucence of the display can be eliminated
- Graphics and icons storage

4.9 Planned Mitigation Plans

- After interfacing the sensor, we will get to know more about the polling frequency and display update frequency. It is not necessary for us to display the information super real-time in terms of milliseconds as the rider will get distracted. Once the interfacing of sensors and displays is working, we can try to decide on the update and display the information.
- Once we start gathering the data we can clean the data through some digital filtering algorithms and then we can reduce the number of data points that can be stored based on the requirements.
- If required, an external I2C EEPROM with sleep will be used for storing the data.
- Once the display is accessible, controlling the contrast and brightness will be tried then we will have to decide whether to add an external light for the display as lights consume more power.
- Graphics and icons should be able to fit in the given size of 1MB flash of the BG21 we will implement flash mechanism if required.

Section 5: Project Status Update 4

Project name: Vega

Date: 7th October 2024

Team Members: **Vishwas Navada Benagere, Prudhvi Kondapalli, Jithendra Halenahalli Somashekharaih**

Major links:

1. **Power sheet: Link**
2. **Gantt chart: Link**

5.1 Professors review:

Hi team, please give me access to your Gantt Chart (chch4948@colorado.edu). Well, done considering both resistor tolerances and temperature tolerances. Also, well done on recognizing your high-risk development items and implementing specific mitigation plans. A minor logistical note: you mention updating the power topology in section 3.5, but if you have multiple 3.5's, I will add a note saying the diagram is in section 3.5 of update 2. Not a showstopper, just a minor note. Not mentioned in your update but be aware of the BQ25570's maximum boost charge current (there are two values given in the datasheet, a cycle-by-cycle max current, and an average current. Please reference the average current). Well, done on this update.

5.2 Team Response:

Question	Answer from team
A minor logistical note: you mention updating the power topology in section 3.5, but if you have multiple 3.5's, I would add a note saying the diagram is in section 3.5 of update 2.	The document has been updated clearly to avoid confusion.
Not mentioned in your update, but be aware of the BQ25570's maximum boost charge current (there are two values given in the datasheet, a cycle-by-cycle max current, and an average current. Please reference the average current)	Peak use case current is 61mA which can be generated by the power components. The cycle-by-cycle current max is 230mA, but the average is 100mA according to the data sheet. So, we are under the limit.

5.3 Project Status Schedule

Tasks accomplished for this update:

We have successfully completed the Altium schematic for the principal node and the sensor node. We have also completed the bulk capacitance simulation for our power tree.

Tasks planned for next update:

We will be completing our board layout of the entire Product in Altium and will have a review among our team to identify any improvements.

S.No	Task	Target Start Date	Plan Duration	Percentage Completed	Status
1	Project Ideation	27-08-2024	7	100%	On Track
2	Component Selection	27-08-2024	21	100%	On Track
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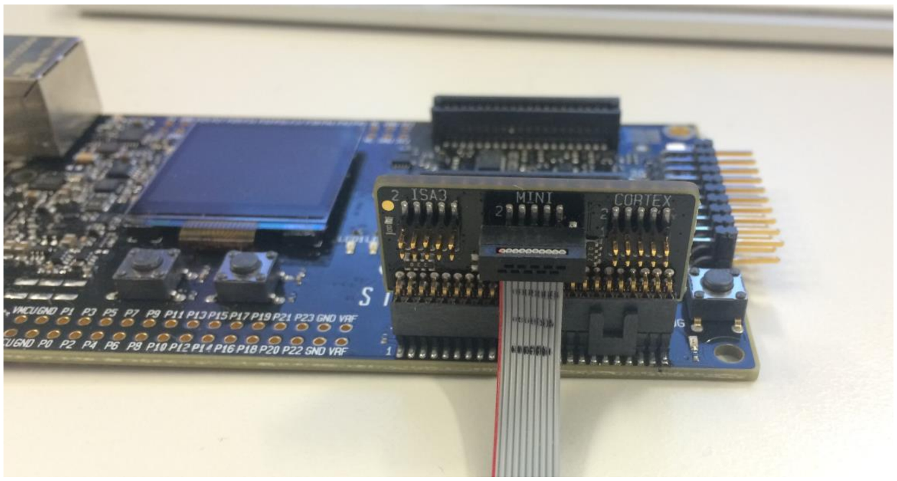
11	Use Case model and Energy Modes	09-09-2024	7	100%	On Track
12	Footprint Creation - Power Block	16-09-2024	14	100%	On Track
13	Footprint Creation - Control Block	16-09-2024	14	100%	On Track
14	Footprint Creation - Sensor Block	16-09-2024	14	100%	On Track
15	Schematic Design - Power Block	16-09-2024	14	100%	On Track
16	Schematic Design - Control Block	16-09-2024	14	100%	On Track
17	Schematic Design - Sensor Block	16-09-2024	14	100%	On Track
18	Board Layout – Principal Node	07-10-2024	7	10%	On going
19	Board Layout – Sensor Node	07-10-2024	7	10%	On going
20	Firmware Demo of sensors - Eval Boards	30-09-2024	7	30%	On going

5.4 Features to enable programming the MCU

We will be using an xG24-PK6009A EFR32xG24 Pro Kit to flash and debug our product. Since the dev kits have an on board EFM32 debugger & flasher and allows us the capability to run energy profiler of our product via this connector. We will be using the simplicity connector on the dev kit and the board which allows us to use the AEM and other advanced debugging features.

5.5 Process of Compile and Download code to the target Board

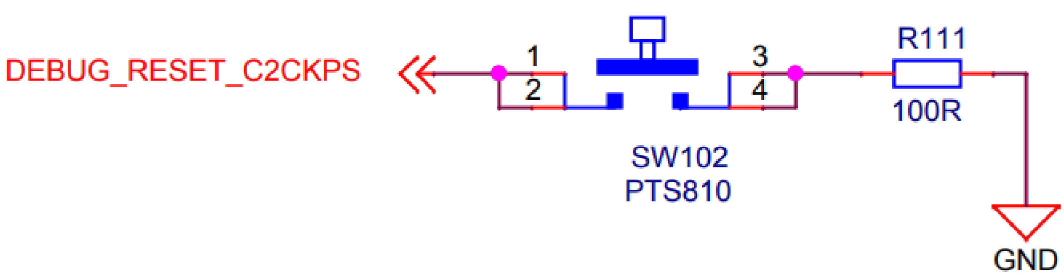
To compile and download code, we will be using the Simplicity Connector of an xG24-PK6009A EFR32xG24 Pro Kit. We will connect a Simplicity Debug Adapter Board as seen in the below image and the MINI connector will be connected to our board to flash over JATG.



5.6 Which signals will have test points

All I2C lines will have test points. Main power branches, enable signals will have test points.

5.7 Reset Circuit Description



This is the reset circuit present on the dev kit, this is also connected via the MINI connector to our board. We will be using this button if reset is required during flash.

Our principal node has a dedicated reset circuit as shown below which will also do a similar function when the product is working standalone.

5.8 Clock Generation Description

Both EFR32BG21 and EFR32MG22 board supports two crystal oscillators:

1. High Frequency Crystal Oscillator (HFXO) - 38.4 MHz
    - Primary uses:
        - Provides precise timing reference for the MCU
        - RF clocking
        - Can also use an external TCXO for extremely accurate frequency over temperature
2. Low Frequency Crystal Oscillator (LFXO) - 32.768 kHz
    - Primary use:
        - Provides accurate timing reference for low energy modes

However, we do not always need both crystals in both ICs. The EFM32MG22 also has integrated RC oscillators that can be used as alternatives:

- HFRCO (1 MHz to 76.8 MHz) can be used when crystal accuracy isn't required
- LFRCO (32.768 kHz) can be used for low power operation without an external crystal
- FSRCO (fixed 20 MHz) for fast start-up
- ULFRCO (1 kHz) for lowest energy consumption in low energy modes

5.9 Alternative Energy source other than Solar Panel (USB)

The alternate energy source other than solar panel is USB C port which is used for charging the battery in the case of main node. In the case of client node there won't be any other source of energy apart from the coin cell

5.10 What Jump start method will be used to charge the energy storage element

USB based charging will be used to charge the battery quickly. We are planning to charge the battery using PMICs output only, if required we will use a separate battery charger for fast charging.

5.11 Max charging current allowed by PMIC

Typical charging current [cycle to cycle] is 230mA and absolute maximum is 285mA, but we will be considering the average current which is 100mA typical.

5.12 Max charging current allowed by Battery

Maximum charging current allowed by the battery is at 1C i.e. 1.25A

5.12.1 What will the maximum current of jump start power source be set to?

Jump start in our case is by USB and hence the maximum current is set to 230mA with existing PMIC as a charger.

5.12.2 Where will the jump start power and ground signals connect to?

Jumpstart pins are connected to PMIC's input and common ground

5.13 Ensure enough energy to program flash of the MCU

Since we will be flashing using the dev pro kit, we have USB also as a backup option to battery.

5.13.1 How much current will the programming of the MCU flash require?

For EFR32BG21, the program flash current is 2.73mA.

For EFR32MG22, the program flash current is 1.45mA.

5.13.2 How much current will the energy storage element and the PMU provide?

The energy storage element and PMU will be able to provide 60mA when the battery is fully charged, so we will not be having any issues while flashing since we also have USB as a backup option.

5.13.3 What are the connection points to enable external power to MCU if required?

External power can be enabled by connecting a USB C source to an external power source. This will power it if battery is not charged.

Section 6: Project Status Update 5

Project name: Vega

Date: 12th October 2024

Team Members: Vishwas Navada Benagere, Prudhvi Kondapalli, Jithendra Halenahalli Somashekharaih

Major links:

1. **Power sheet: Link**
2. **Gantt chart: Link**

6.1 Professors review:

No Comments.

6.2 Project Status Schedule
Tasks accomplished for this update:

We have successfully completed the Altium schematic review by the SA and component layout for the principal node and the sensor node. We have also completed the bulk capacitance simulation for our power tree.

Tasks planned for next update:

We will be completing our board layout of the entire Product in Altium and will have a review among our team to identify any improvements.

S.No	Task	Target Start Date	Plan Duration	Percentage Completed	Status
1	Project Ideation	27-08-2024	7	100%	On Track
2	Component Selection	27-08-2024	21	100%	On Track
3	Block Diagrams	02-09-2024	7	100%	On Track
4	System UML Diagram	02-09-2024	7	100%	On Track
5	Initial Proposal Documentation	02-09-2024	7	100%	On Track
6	GD & T [Physical Dimension Estimation]	02-09-2024	7	100%	On Track
7	Firmware memory requirement analysis	02-09-2024	7	100%	On Track
8	Power Analysis for client nodes	09-09-2024	7	100%	On Track
9	Component Budgeting	09-09-2024	7	100%	On Track
10	Power calculation sheet	09-09-2024	7	100%	On Track
11	Use Case model and Energy Modes	09-09-2024	7	100%	On Track
12	Footprint Creation - Power Block	16-09-2024	14	100%	On Track
13	Footprint Creation - Control Block	16-09-2024	14	100%	On Track
14	Footprint Creation - Sensor Block	16-09-2024	14	100%	On Track
15	Schematic Design - Power Block	16-09-2024	14	100%	On Track
16	Schematic Design - Control Block	16-09-2024	14	100%	On Track
17	Schematic Design - Sensor Block	16-09-2024	14	100%	On Track
18	Component Layout	12-10-2024	7	100%	On Track
18	Board Layout – Principal Node	12-10-2024	7	10%	On going

19	Board Layout – Sensor Node	12-10-2024	7	10%	On going
20	Firmware Demo of sensors - Eval Boards	15-10-2024	7	30%	On going

6.3 High Risk development Items

- Sensor interfacing and handling the data display
- How real-time the data should be?
- Storage mechanisms for the existing data? Is there a need for an external SPI flash or EEPROM?
- A backlight option needed for display. If yes, is it easy to implement using a single LED front lit mechanism so that the loss due to the translucence of the display can be eliminated
- Graphics and icons storage

6.4 Planned Mitigation Plans

- After interfacing the sensor, we will get to know more about the polling frequency and display update frequency. It is not necessary for us to display the information super real-time in terms of milliseconds as the rider will get distracted. Once the interfacing of sensors and displays is working, we can try to decide on the update and display the information.
- Once we start gathering the data we can clean the data through some digital filtering algorithms and then we can reduce the number of data points that can be stored based on the requirements.
- If required, an external I2C EEPROM with sleep will be used for storing the data.
- Once the display is accessible, controlling the contrast and brightness will be tried then we will have to decide whether to add an external light for the display as lights consume more power.
- Graphics and icons should be able to fit in the given size of 1MB flash of the BG21 we will implement flash mechanism if required.

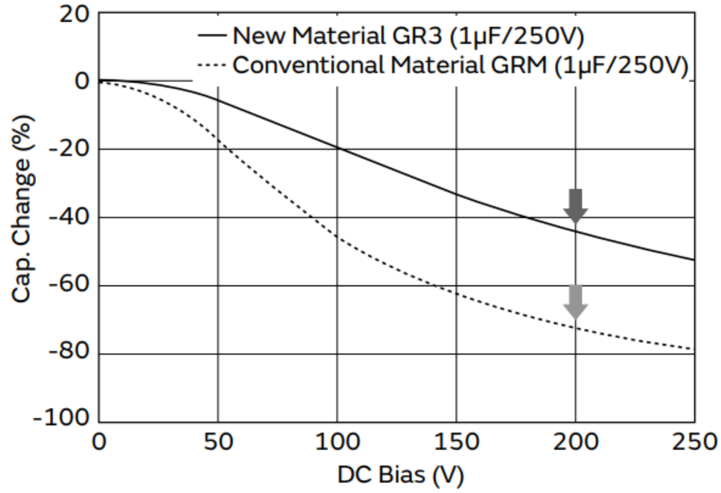
6.6 Bulk capacitance Requirements

Based on the bulk capacitance simulation, we are going to use a 47uF bulk capacitance. We have verified none of the sensors or the PMIC has a on (rise) time requirement, so we decided to have a bigger capacitance.

6.6 Bulk capacitance Part Requirement and DC bias

Part Number: GRM21BR61A476ME15K

Operating Voltage: 3.3V. 47 µF ±20% 10V Ceramic Capacitor X5R 0805 (2012 Metric)



<Comparison between Capacitance - DC Bias Characteristics>

According to the datasheet, there is not much change at 3.3V. So we can use this part.

6.7 I/O in our design

Principal Node- USB C, Solar Cell, Lithium Ion Battery, three push buttons for user control, MINI flash interface and DNP Wired connected to Agent Node

Agent Node – MINI flash interface, Coin Cell battery and DNP wired connector to Principal Node.

6.6 ESD Protection on these IO ports.

We will be having ESD protection on the MINI connector. We wont be placing the ESD connector anywhere else as user interaction with the rest of the interface is very limited/none.

Part Number: PUSB3AB4.

Detailed Description: 5V (Typ) Clamp 7A (8/20µs) Ipp Tvs Diode Surface Mount DFN2510A-10

Section 7: Project Status Update 6

Project name: **Vega**

Date: 26th October 2024

Team Members: **Vishwas Navada Benagere, Prudhvi Kondapalli, Jithendra Halenahalli Somashekharaih**

Major links:

1. **Power sheet: Link**
2. **Gantt chart: Link**

7.1 Professors review:

Hi team, when considering the bulk capacitance added to your circuit, also account for the tolerances of the capacitor and the degredation over time. Good job considering the DC bias characteristics of the cap. The image you have provided is for a DC bias chart for a 1uF/250V cap and not the part you selected. There will be a different DC bias characteristic for the 47uF cap vs the 1uF cap. As far as adding ESD protection to your IO ports, you should consider any IO ports in which the user will interact with. Will the user be plugging in a USB C cable? There are user buttons they will interact with. The recommended strategy for ESD protection is to add protection to any IOs the user will interact with and ignore the IO only used for testing purposes. For your application, I would add ESD protection to USB C, the push buttons at a minimum. You do not need to add ESD protection to the MINI connector as it is only used for programming/debugging by the engineer.

7.2 Team Response:

Question	Answer from team
Hi team, when considering the bulk capacitance added to your circuit, also account for the tolerances of the capacitor and the degradation over time. Good job considering the DC bias characteristics of the cap. The image you have provided is for a DC bias chart for a 1uF/250V cap and not the part you selected. There will be a different DC bias characteristic for the 47uF cap vs the 1uF cap	This issue has been communicated that all the cap in the selected cap family has the same DC bias graph. Since the selected cap has a higher voltage rating, at 3.3V, they are able to have 47uF capacitance with a tolerance of 1%.
As far as adding ESD protection to your IO ports, you should consider any IO ports in which the user will interact with. Will the user be plugging in a USB C cable? There are user buttons they will interact with. The recommended strategy for ESD protection is to add protection to any IOs the user will interact with and ignore the IO only used for testing purposes. For your application, I would add ESD protection to USB C, the push buttons at a minimum. You do not need to add ESD protection to the MINI connector as it is only used for programming/debugging by the engineer.	We already have ESD diodes on our USB lines. We will add ESD diodes on our push button lines. But we would like to reconfirm this with you because push button lines are shared with some other lines.

7.3 Project Status Schedule

Tasks accomplished for this update:

We have successfully completed Altium schematic, placement and layout review with TAs.

Tasks planned for next update:

We will be working on working on and fixing some layout comments and also some component selection issues due to their minute footprint. We will be updating Gantt chart as well with all other tasks related to PCB bring up.

S.No	Task	Target Start Date	Plan Duration	Percentage Completed	Status
1	Project Ideation	27-08-2024	7	100%	On Track
2	Component Selection	27-08-2024	21	100%	On Track
3	Block Diagrams	02-09-2024	7	100%	On Track
4	System UML Diagram	02-09-2024	7	100%	On Track
5	Initial Proposal Documentation	02-09-2024	7	100%	On Track
6	GD & T [Physical Dimension Estimation]	02-09-2024	7	100%	On Track
7	Firmware memory requirement analysis	02-09-2024	7	100%	On Track
8	Power Analysis for client nodes	09-09-2024	7	100%	On Track
9	Component Budgeting	09-09-2024	7	100%	On Track
10	Power calculation sheet	09-09-2024	7	100%	On Track
11	Use Case model and Energy Modes	09-09-2024	7	100%	On Track
12	Footprint Creation - Power Block	16-09-2024	14	100%	On Track
13	Footprint Creation - Control Block	16-09-2024	14	100%	On Track
14	Footprint Creation - Sensor Block	16-09-2024	14	100%	On Track
15	Schematic Design - Power Block	16-09-2024	14	100%	On Track
16	Schematic Design - Control Block	16-09-2024	14	100%	On Track
17	Schematic Design - Sensor Block	16-09-2024	14	100%	On Track
18	Board Layout – Principal Node	07-10-2024	7	100%	On Track
19	Board Layout – Sensor Node	07-10-2024	7	100%	On Track
20	Firmware Demo of sensors - Eval Boards	30-09-2024	7	100%	On Track
21	Product Full layout - Panelized	10-26-2024	14	100%	On Track
22	Finalizing layout based on layout comments	11-1-2024	7	50%	On Track

23	Board Assembly	11-10-2024	3	0%	Not started
24	Bring up	11-20-2024	7	0%	Not started
25	Board Final Test	11-24-2024	14	0%	Not started

7.4 Other Project Updates

Layout Comments:

We are done with one full review of the board layout. We will be addressing the below issues based on review comments:

1. Large Ground discontinuity forming in the middle of the board due to multiple cross-unders.
2. Improving better pour at the PMIC portion
3. Keep out layers for each section of the board
4. Finalizing the panel design
5. PMIC Symbol integration issue

Other than this we received good feedback, and we will try to improve our design as time permits.

Project Struggles:

We will approach the TAs for the library integration issue we are facing. We are trying to replace the footprint of the PMIC, but it's already routed on the PCB. When we try to import it, it throws an error saying that pads are not matching, and class members cannot be added.

Section 8: Project Status Update 7

Project name: Vega

Date: 11th November 2024

Team Members: Vishwas Navada Benagere, Prudhvi Kondapalli, Jithendra Halenahalli Somashekharaih

Major links:

1. **Power sheet: Link**
2. **Gantt chart: Link**
3. **Verification Plan: Link**

8.1 Professors review:

No comments were provided for the previous update as previous weeks were comprised of board review and comment addressing

8.2 Team Response:

The team has addressed layout comments and submitted boards for manufacturing.

8.3 **Project Status Schedule**

Tasks accomplished for this update:

We have successfully completed the layout for the board and submitted for manufacturing. This week we have completed i2c comms between all sensor to the BG21 dev board. We are working on the Bluetooth connection between the BG21 and MG22. BLE connection between BG21 and phone is established.

Tasks planned for next update:

Once BLE connection is established between MG22 and BG22, we will work on developing the application code and develop individual features based on sensor data.

Roadblocks: We don't have a fixed LCD display ordered yet. We are awaiting instructions on this aspect but at the same time we are done with developing lcd driver for the BG and MG chips.

S.No	Task	Target Start Date	Plan Duration	Percentage Completed	Status
1	Project Ideation	27-08-2024	7	100%	On Track
2	Component Selection	27-08-2024	21	100%	On Track
3	Block Diagrams	02-09-2024	7	100%	On Track
4	System UML Diagram	02-09-2024	7	100%	On Track
5	Initial Proposal Documentation	02-09-2024	7	100%	On Track
6	GD & T [Physical Dimension Estimation]	02-09-2024	7	100%	On Track
7	Firmware memory requirement analysis	02-09-2024	7	100%	On Track
8	Power Analysis for client nodes	09-09-2024	7	100%	On Track
9	Component Budgeting	09-09-2024	7	100%	On Track
10	Power calculation sheet	09-09-2024	7	100%	On Track
11	Use Case model and Energy Modes	09-09-2024	7	100%	On Track
12	Footprint Creation - Power Block	16-09-2024	14	100%	On Track
13	Footprint Creation - Control Block	16-09-2024	14	100%	On Track

14	Footprint Creation - Sensor Block	16-09-2024	14	100%	On Track
15	Schematic Design - Power Block	16-09-2024	14	100%	On Track
16	Schematic Design - Control Block	16-09-2024	14	100%	On Track
17	Schematic Design - Sensor Block	16-09-2024	14	100%	On Track
18	Board Layout – Principal Node	07-10-2024	7	100%	On Track
19	Board Layout – Sensor Node	07-10-2024	7	100%	On Track
20	Firmware Demo of sensors - Eval Boards	30-09-2024	7	100%	On Track
21	Product Full layout - Panelized	10-26-2024	14	100%	On Track
22	Finalizing layout based on layout comments	11-1-2024	7	100%	On Track
23	Board Assembly	11-10-2024	3	0%	Not started
24	Bring up	11-20-2024	7	0%	Not started
25	Board Final Test	11-24-2024	14	0%	Not started
26	Application code design	11-11-2024	14	35%	Ongoing

Section 8: Project Status Update 8

Project name: Vega

Date: 23rd November 2024

Team Members: Vishwas Navada Benagere, Prudhvi Kondapalli, Jithendra Halenahalli Somashekharaiah

Major links:

4. **Power sheet: Link**
5. **Gantt chart: Link**
6. **Verification Plan: Link**

8.1 Professors review:

No comments were provided for the previous update as previous weeks were comprised of board review and comment addressing

8.2 Team Response:

The team worked on the board bring up and was successful in boot loading and accessing sensors

8.3 **Project Status Schedule**
Tasks accomplished for this update:

The application code for the principal agent interfacing the BG21 and MG22 was developed successfully, allowing all I2C sensor data to be retrieved.

The SMT parts were soldered using a pick-and-place machine and an oven. A cold test was performed both before and after soldering the board, confirming the absence of short circuits. The board was powered up, and the principal node was detected on Simplicity Studio. Initially, the agent was not detected on the IDE, but the issue was debugged successfully. A disconnected net in the schematics was identified and manually wired. Following this, the hall effect sensor was boot-loaded and tested. The I2C bus was scanned, successfully detecting all sensors on the principal agent, ensuring that the sensors were properly soldered.

Tasks planned for next update:

To work on the features for showing the information on the display.
To 3D print a case for the whole system

Roadblocks: To implement a graphics scheme and graphs, if possible, for elevation gain.

S.No	Task	Target Start Date	Plan Duration	Percentage Completed	Status
1	Project Ideation	27-08-2024	7	100%	On Track
2	Component Selection	27-08-2024	21	100%	On Track
3	Block Diagrams	02-09-2024	7	100%	On Track
4	System UML Diagram	02-09-2024	7	100%	On Track
5	Initial Proposal Documentation	02-09-2024	7	100%	On Track
6	GD & T [Physical Dimension Estimation]	02-09-2024	7	100%	On Track
7	Firmware memory requirement analysis	02-09-2024	7	100%	On Track
8	Power Analysis for client nodes	09-09-2024	7	100%	On Track
9	Component Budgeting	09-09-2024	7	100%	On Track
10	Power calculation sheet	09-09-2024	7	100%	On Track
11	Use Case model and Energy Modes	09-09-2024	7	100%	On Track
12	Footprint Creation - Power Block	16-09-2024	14	100%	On Track
13	Footprint Creation - Control Block	16-09-2024	14	100%	On Track
14	Footprint Creation - Sensor Block	16-09-2024	14	100%	On Track
15	Schematic Design - Power Block	16-09-2024	14	100%	On Track
16	Schematic Design - Control Block	16-09-2024	14	100%	On Track
17	Schematic Design - Sensor Block	16-09-2024	14	100%	On Track
18	Board Layout – Principal Node	07-10-2024	7	100%	On Track
19	Board Layout – Sensor Node	07-10-2024	7	100%	On Track
20	Firmware Demo of sensors - Eval Boards	30-09-2024	7	100%	On Track
21	Product Full layout - Panelized	10-26-2024	14	100%	On Track
22	Finalizing layout based on layout comments	11-1-2024	7	100%	On Track
23	Board Assembly	11-10-2024	3	100%	On Track
24	Bring up	11-20-2024	7	80%	On going
25	Board Final Test	11-24-2024	14	10%	On going
26	Application code design	11-11-2024	14	60%	Ongoing

Section 9: Project Status Final Update

Project name: Vega

Date: 16th December 2024

Team Members: **Vishwas Navada Benagere, Prudhvi Kondapalli, Jithendra Halenahalli Somashekharaiah**

Major links:

1. **Power sheet:** **Link**
2. **Gantt chart:** **Link**
3. **Verification Plan:** **Link**
4. **Code Repository:** **Link**

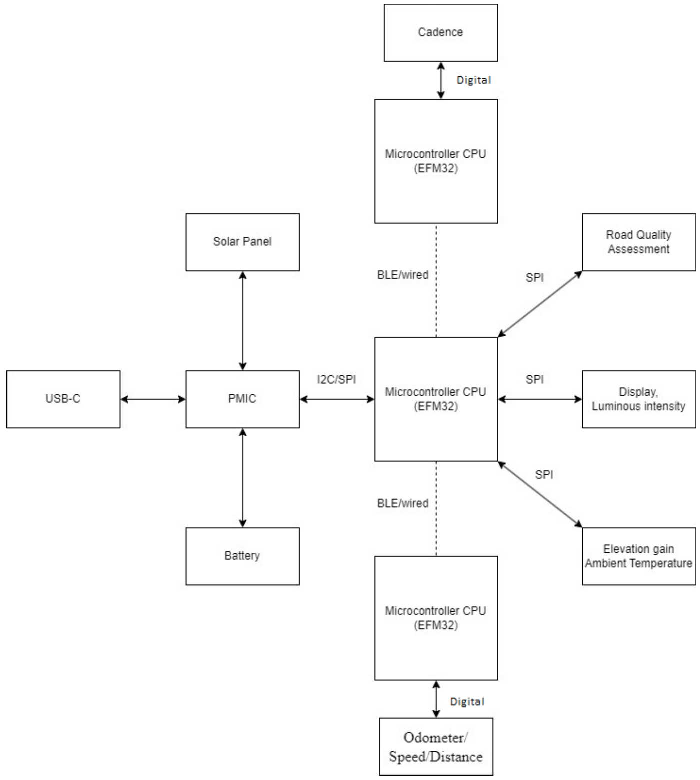
Project Overview

This bike computer, powered by a low-power BLE chip from Silicon Labs, offers a range of features to enhance the cycling experience for fitness enthusiasts and cyclists. It functions as an odometer and cadence meter, provides navigation assistance via a connected smartphone, tracks elevation gain, measures ambient temperature, assesses road quality using an IMU, and adjusts display brightness based on luminous intensity. The device includes a low-power display to show essential metrics like speed, cadence, distance, and elevation gain. Powered by a lithium-ion battery with USB-C charging and solar-based energy harvesting, it boasts an expected battery life of 12 weeks. It integrates sensors such as Hall effect sensors for cadence and speed, a MEMS pressure sensor for elevation and temperature, an IMU for road quality, and a lux sensor for brightness control. Connectivity is facilitated by Bluetooth Low Energy, linking two sensor nodes to a principal device, which then connects to a smartphone, with both wired and wireless options planned for flexibility. This device not only supports performance tracking for cyclists but also contributes to road condition monitoring for potential infrastructure improvements

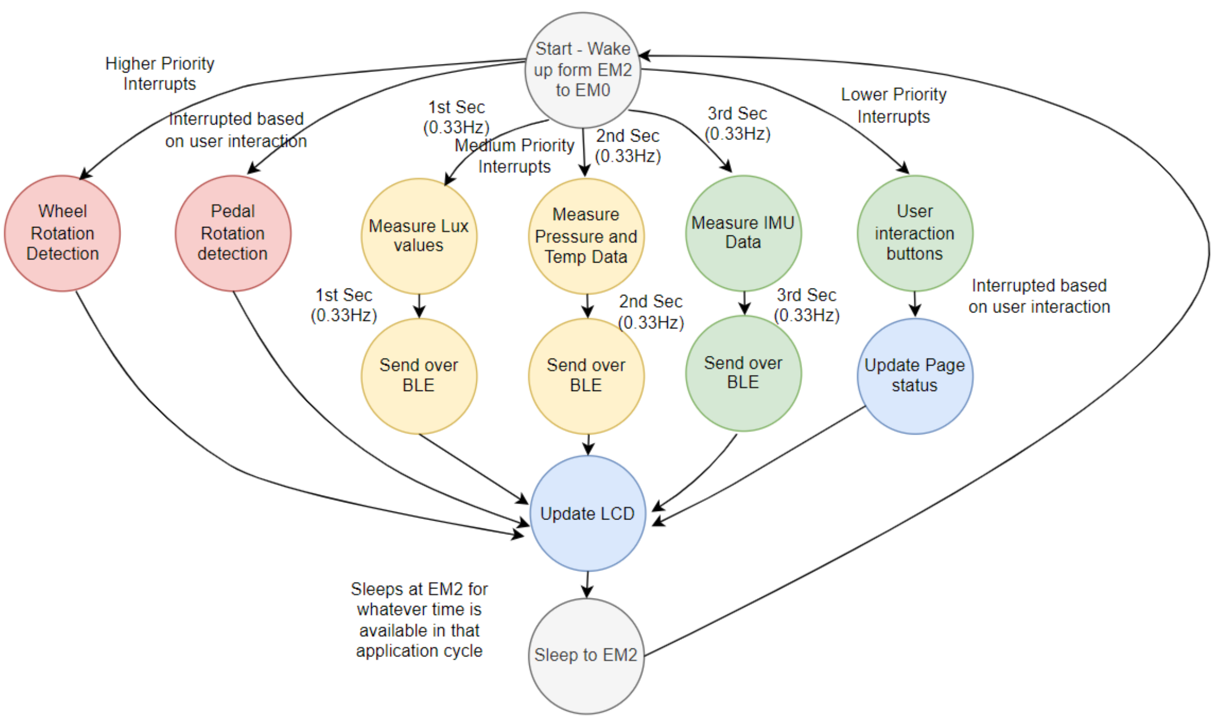
What problem does the project solve?

This project solves several problems for cyclists and fitness enthusiasts by providing an easy way to track performance, monitor progress, and stay informed while riding. It gives real-time stats like speed, cadence, distance, and elevation gain, helping users improve their efficiency and achieve their fitness goals. The road quality assessment feature adds a unique benefit by identifying rough patches, which can help authorities improve road conditions over time. With extras like temperature and light sensors, the device adapts to changing environments, making rides safer and more enjoyable. Plus, its long battery life and solar energy harvesting mean less hassle with charging, making it a practical and eco-friendly solution for everyday use.

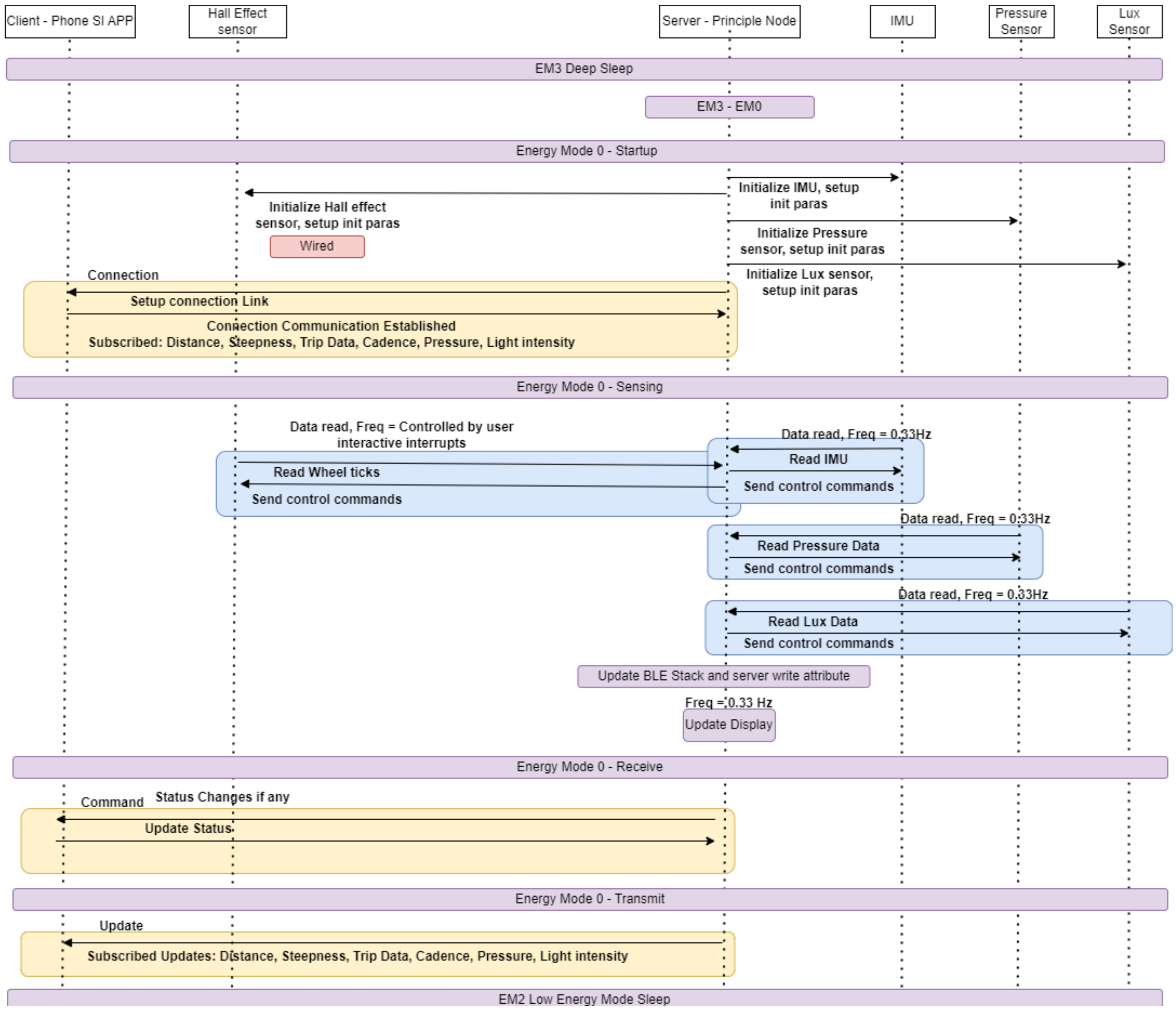
Hardware block diagram



Power Mode Timeline



Software flow organizational or block diagram chart



• List of commands

The following are the GATT (Generic Attribute Profile) Bluetooth commands being used in order to communicate with the EFR32 applications on our phones:1. sl_bt_system_get_identity_address(): Retrieves the Bluetooth device address.

2. sl_bt_advertiser_create_set(): Creates an advertising set.

3. sl_bt_advertiser_set_timing(): Sets the timing parameters for advertising packets.

4. sl_bt_advertiser_legacy_start(): Starts advertising.

5. sl_bt_advertiser_stop(): Stops advertising.

6. sl_bt_connection_set_parameters(): Sets connection parameters.

7. sl_bt_gatt_server_write_attribute_value(): Writes the value of a GATT attribute.

8. sl_bt_gatt_server_send_indication(): Sends an indication to a GATT client.

- **Planned development schedule and when tasks were completed**

S.No	Task	Target Start Date	Plan Duration	Percentage Completed	Status
1	Project Ideation	27-08-2024	7	100%	Completed
2	Component Selection	27-08-2024	21	100%	Completed
3	Block Diagrams	02-09-2024	7	100%	Completed
4	System UML Diagram	02-09-2024	7	100%	Completed
5	Initial Proposal Documentation	02-09-2024	7	100%	Completed
6	GD & T [Physical Dimension Estimation]	02-09-2024	7	100%	Completed
7	Firmware memory requirement analysis	02-09-2024	7	100%	Completed
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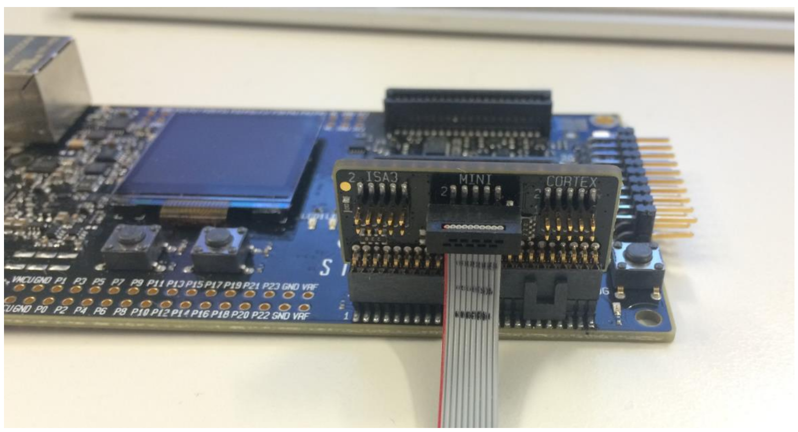
11	Use Case model and Energy Modes	09-09-2024	7	100%	Completed
12	Footprint Creation - Power Block	16-09-2024	14	100%	Completed
13	Footprint Creation - Control Block	16-09-2024	14	100%	Completed
14	Footprint Creation - Sensor Block	16-09-2024	14	100%	Completed
15	Schematic Design - Power Block	16-09-2024	14	100%	Completed
16	Schematic Design - Control Block	16-09-2024	14	100%	Completed
17	Schematic Design - Sensor Block	16-09-2024	14	100%	Completed
18	Board Layout – Principal Node	07-10-2024	7	100%	Completed
19	Board Layout – Sensor Node	07-10-2024	7	100%	Completed
20	Firmware Demo of sensors - Eval Boards	30-09-2024	7	100%	Completed
21	Product Full layout - Panelized	10-26-2024	14	100%	Completed
22	Finalizing layout based on layout comments	11-1-2024	7	100%	Completed
23	Board Assembly	11-10-2024	3	100%	Completed
24	Bring up	11-20-2024	7	100%	Completed
25	Board Final Test	11-24-2024	14	100%	Completed
26	Application code design	11-11-2024	14	100%	Completed
27	Corner Case Testing	12-01-2024	5	100%	Completed

28	Additional Feature development (Real time Ride clock on LCD)	12-01-2024	12	100%	Completed

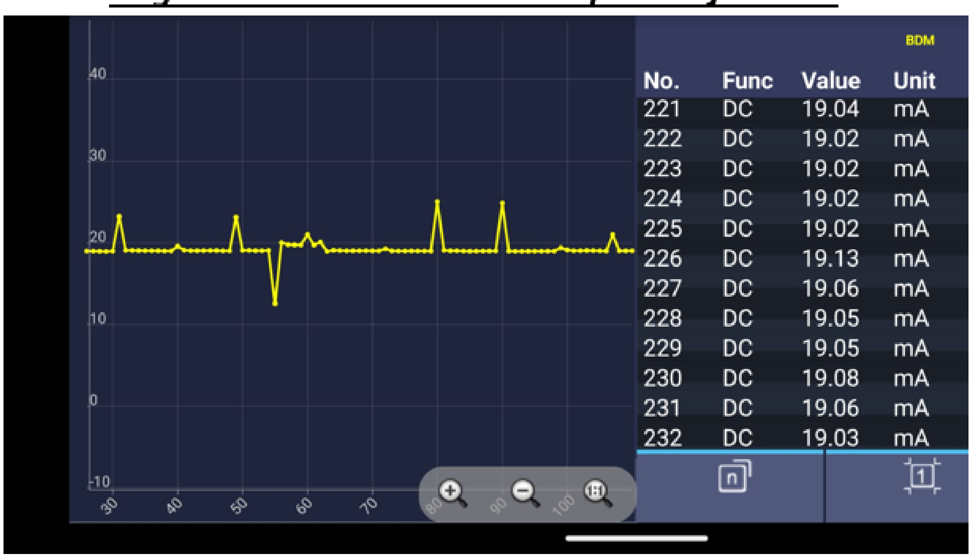
How the target microcontroller/SoC will be programmed?

The EFR32BG21 and the EFR32MG22 were programmed using a Silicon Labs Wireless Pro Kit Main Base Board via its DEBUG OUT/MINI feature. Our custom board had the SWD Debug interface connected via this MINI to the baseboard, which allows to flash and debug custom application code using Simplicity Studio IDE.

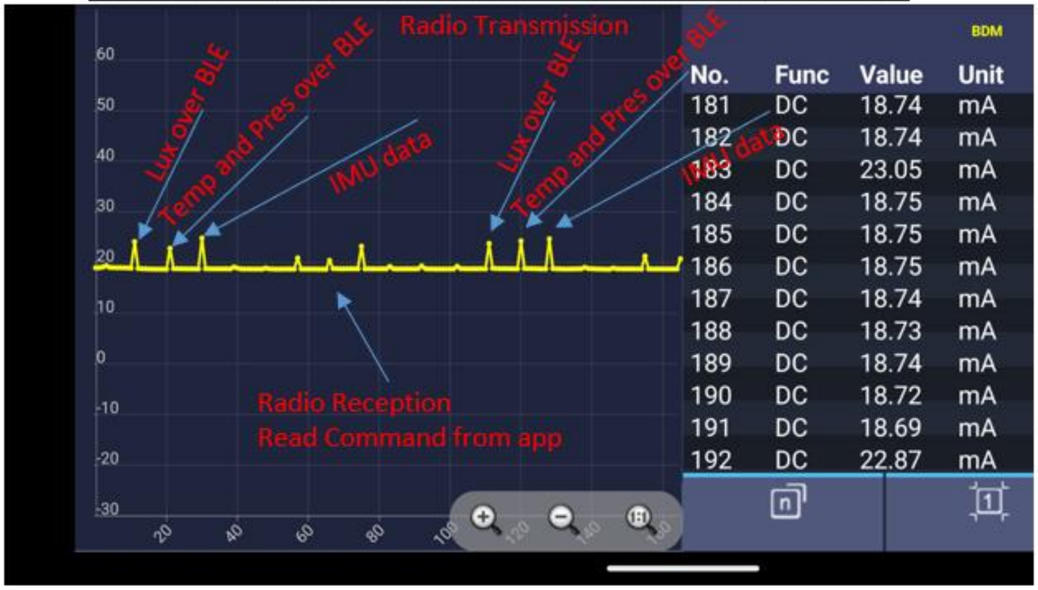


Current profile over time based on expected application usage

Avg Normal Current Consumption of device



Current consumptions during BLE Notifications



Energy Storage Element selected and selection documentation

With the available space on the front panel of the device the selected solar panel has the highest energy generation capacity of 73mW hence this solar cell is used for the device

PMU simulation results

Original PMIC: BQ25570
PMIC considered for simulation: LTC3106

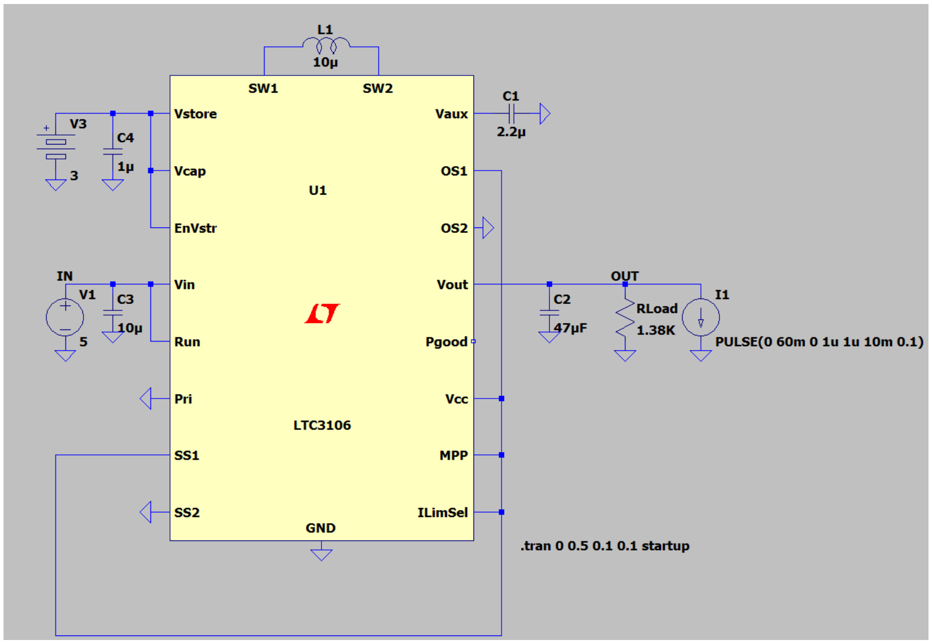
Reason: BQ25570 spice model is discontinued, and the closest part with similar architecture is LTC3106. LTC3106

Both has 2.1V to 5V Input voltage range.
Both has 5.5V as Max Output Voltage.

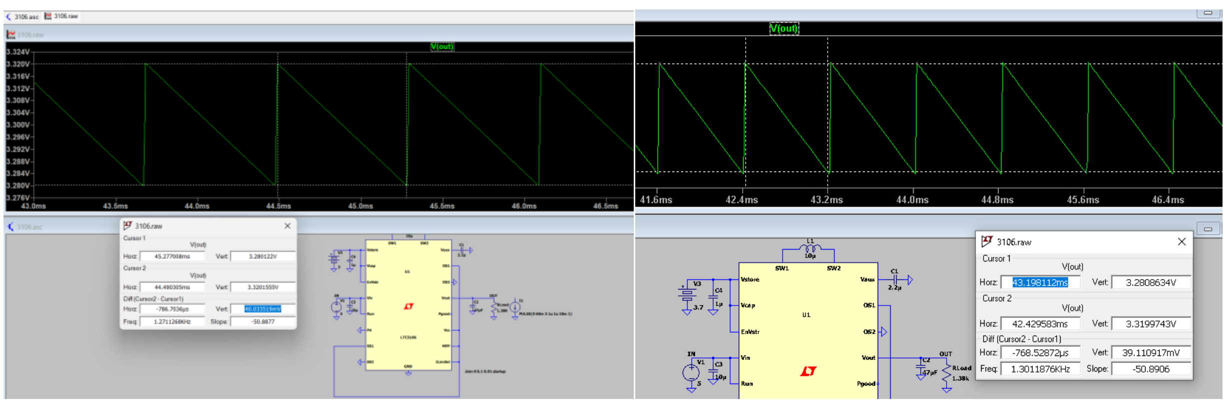
Average power requirement according to our power calculation sheet = 7843mW
Voltage = 3.3V
Average current = 7843mW/3.3V = 2.376mA.
R = 3.3V/2.376mA = 1.38Kohm – This can be considered as a constant load resistor.

Peak current requirement according to our power calculation sheet = 221867 mW
Voltage = 3.3V
Peak Current = 221867mW/3.3V = 60mA.

We will be using a current load to simulate the dynamic load and a constant R for average load. We will consider two voltages for the simulation. One is 3v which is the minimum voltage that the battery can source and max 3.7V (nominal).



At Vin = min: 3V, ripple observed is 40mV and at Vin = max: (nominal 3.7V): ripple observed is 39mV



At Vin = min(3V): The ripple is between 3.28V to 3.2v, hence it is within specs and at Vin = max (3.7V): The ripple is in between 3.28V to 3.32V , hence it will work and meets the specs. For the display we will use a boost LM2750 whose minimum requirement is 2.7V

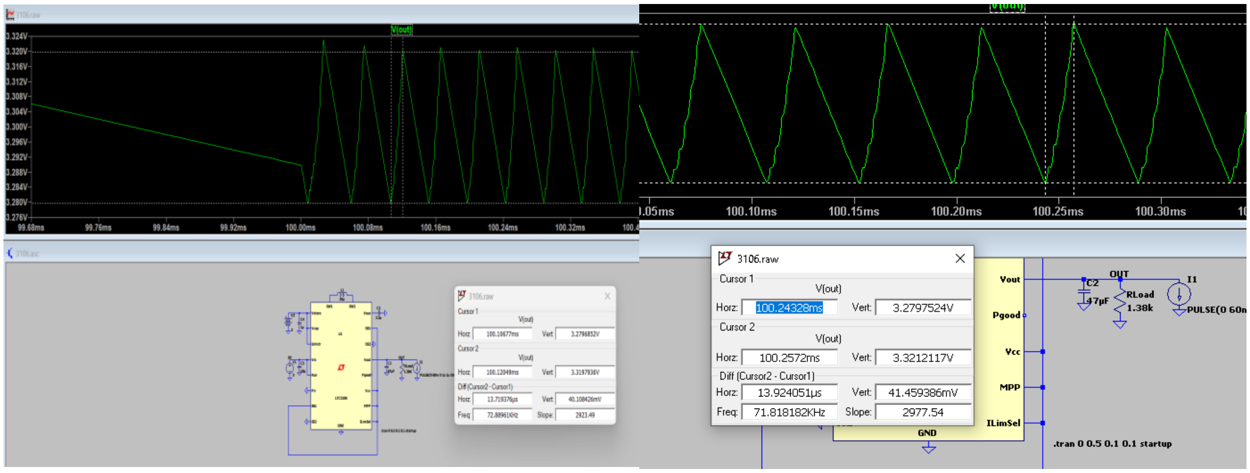
<u>Initial Power Analysis</u>

- Total Energy Required for 4 hrs usage and 18 hours deep sleep per day = 32 mWh
- Predicted battery life = 31 days

<u>Actual Power Analysis</u>

- Total Energy Required for 4 hrs usage and 18 hours deep sleep per day = 19mA*3.3V = 240 mWh
- Battery life = 20 days

- Reasons for Mismatch – Real Time Clock Display feature, continuous wheel and pedal interrupts and extra hardware on LCD module



Bulk or large decoupling capacitor selection and back up data

Based on the simulations done above, we considered a 47uF decoupling capacitor which satisfies all the specs, so we implemented it on our board.

Will an external energy source be required to program the MCU?

No, it can be programmed using just the eval board

Planned test points

SPI test points

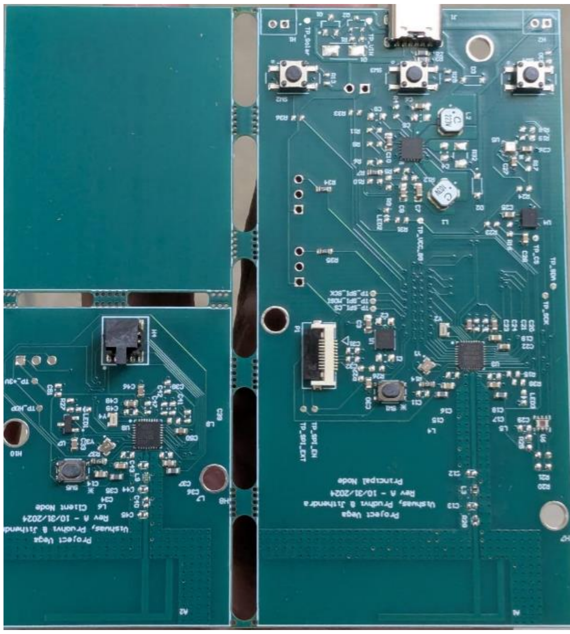
I2C test points

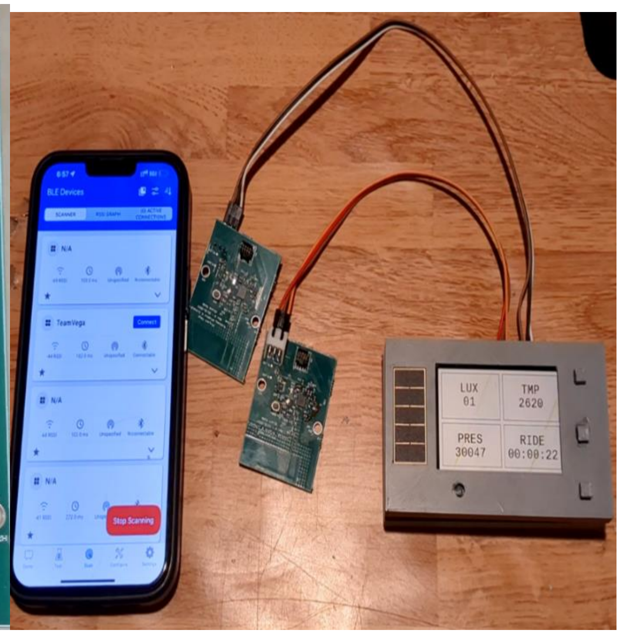
Power test points such as VCC_BG, VIN, VBAT, Solar.

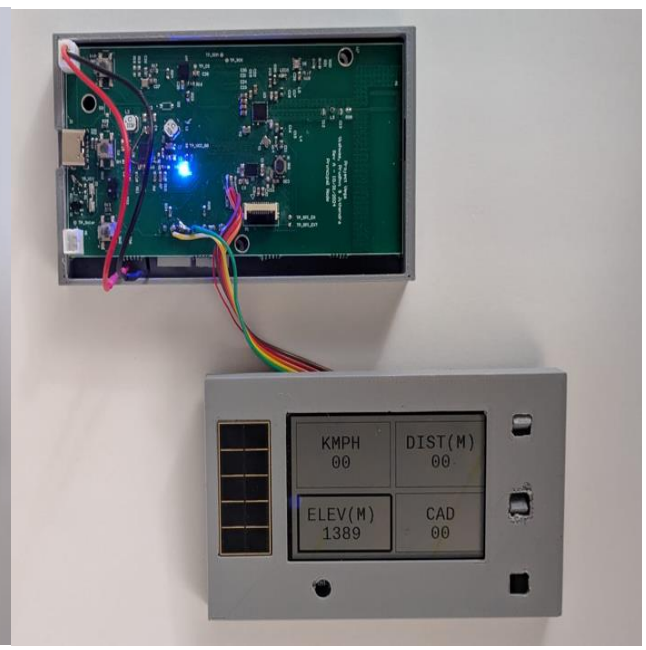
Did this work for bring up? Should there have been more test points?

The test points were enough for the bring up. Could have added a test point for 5V boost circuit output

Photos of assembled board



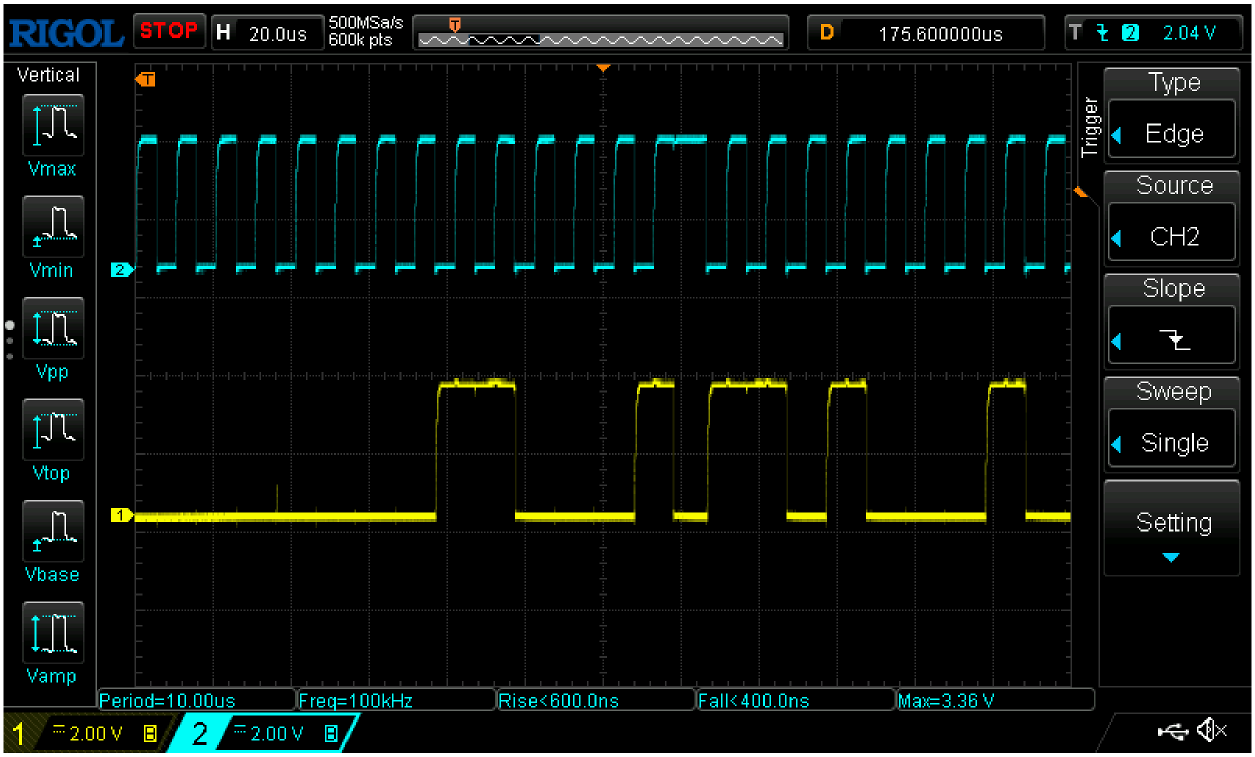




Complete detailed verification report (spread sheet)

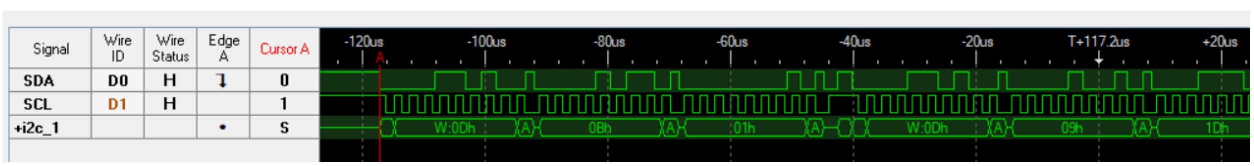
Verification Plan: [Link]

Signal quality analysis of key signals

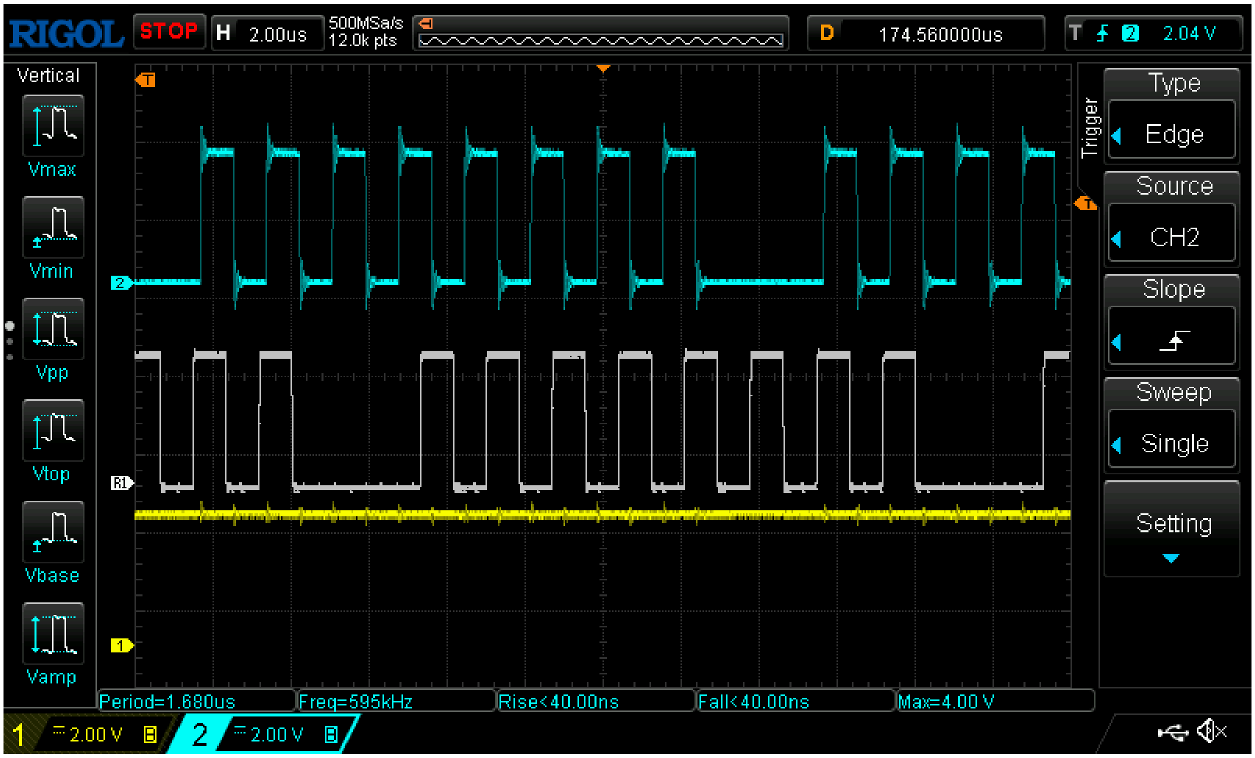


<u>I2C waveforms with SCL [Blue Ch2] and SDA [Yellow Ch1]</u>

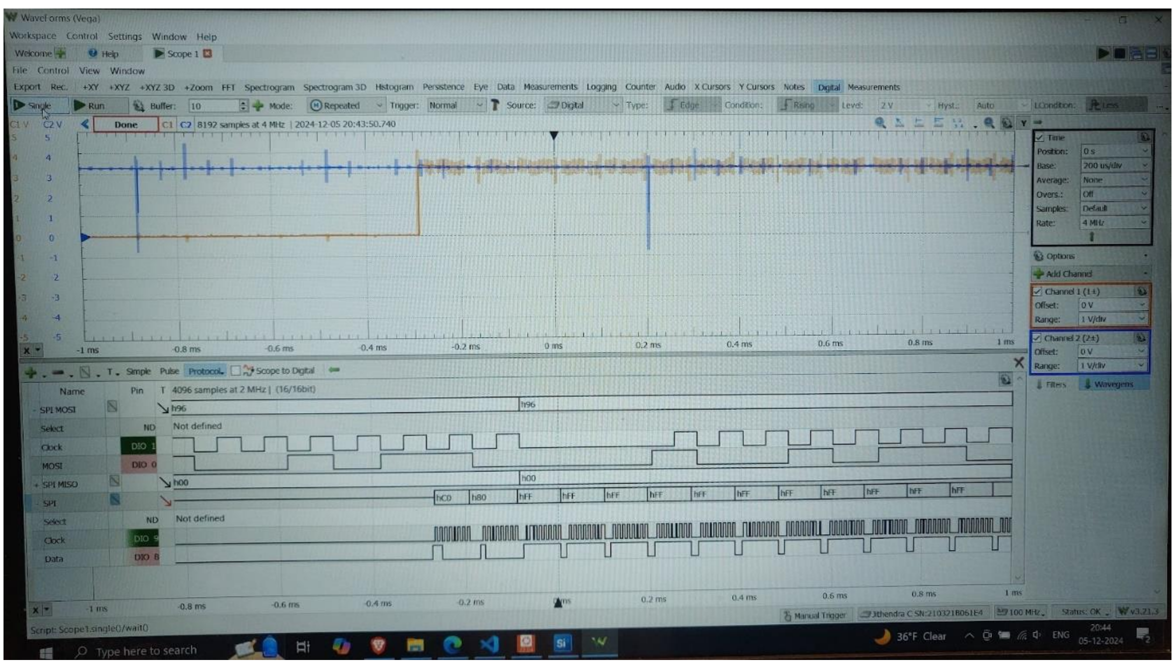
Frequency	100KHz
Period	10uS
Risetime	About 500nS
Fall time	About 200nS
Vmax	3.36V



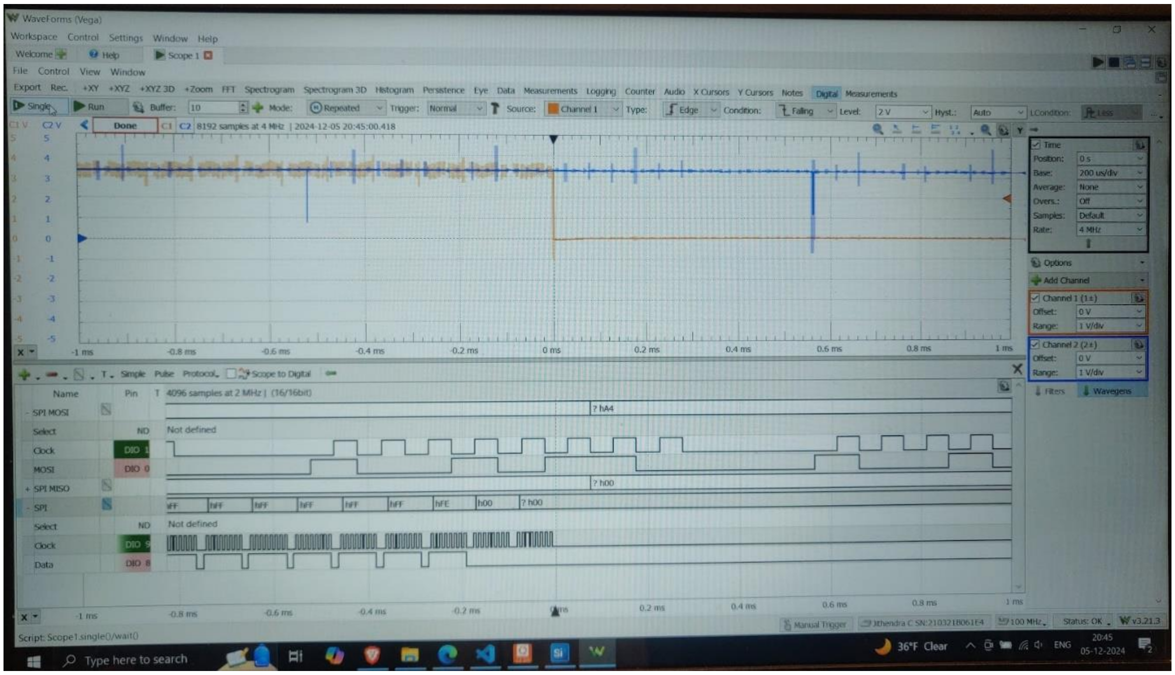
I2C Transaction – MCU Writing config flash and reading initialization status



SPI waveforms [Blue: SCK, White: MOSI, Yellow CS, active high CS]



The screen shot shows the triggering of chip select (orange trace) and respective MOSI digital data recorded. The initial mode setting byte 0xCO and address starting from 0x01 which should be send in reverse order as 0x80 and values for each pixel.



Similarly, at the end of chip select sending 0x00 to signal the end of transaction.

What were the difficulties encountered on the project?

We had a couple of issues in terms of schematics mistakes which was corrected using external wire being rigged up on the board.

1. Swap of pins in client debug adapter: Solution: We made a custom cable to program client nodes
2. Output of VREGSW was not connected to RFVDD on client nodes: Due to an error in label placement in schematics we missed out this connection which was later fixed through a wire.
3. PMIC Vout_EN: Vout_EN of PMIC buck regulator was not connected to VSTOR which was done to fix the charging of battery issue.

Summary of functionality of final project 2

Team Member Learnings

Vishwas:

1. Altium schematics needs a double check by pulling the netlabel to make sure it is labelled and connected to the right net.
2. Time spent in review will reduce the debug time in lab significantly
3. Always be ready to check the current consumption when you are turning on the board for the first time
4. Practical power consumption depends on the complexity of the circuit and the quality/tolerance of the parts used in the circuit.

5. The timing of a protocol is very critical for successful communication. Especially SPI and I2C in this case.

Prudhvi:

1. Power budgeting should be kept flexible to allow additional features to be developed along the project timeline
2. Ease of integration should be taken into consideration before selecting sensor which are complex to integrate and always should check for sensors with good documentation before hand
3. PMIC Simulation can be done with extra tolerance to avoid unseen issues
4. Keeping test points on the i2c lines let us run an i2c scanner first to verify if all the sensors are soldered without any shorts using Arduino (this is before developing the MCU code)
5. Part Tolerances are really important especially in the case of components that are on a RF signal chain/antenna tuning circuit, part tolerances should be followed to the tee without any compromises.

Jithendra:

1. Building library for our required PCB components following the datasheet
2. Project ideation, planning, scheduling and execution
3. Silicon micro-controllers low power capabilities such as EM0-EM4 and other peripherals
4. PMIC circuitry design as per our project 3V requirements
5. Types of RF antenna design, working and measures to consider
6. Hardware brings up and boot loading using simplicity studio
7. Debug tool importance such as AD2 while sniffing SPI signal