M WIZ

Team 6 - Embedded Wizards

Pradyumna, Shuran


Project Introduction
Project Description - Use Cases
System Block Diagram
Low Power Timeline
Project Description
System Block Diagram

Project Description

- Health Monitoring System
- The biggest benefit is to allow doctors to keep an eye on their patients at all times so that the number of hospital visits can be reduced significantly
- Two Versions
- Hospital – Values at every 1 hr
- Personal – Values as per user defines in a day


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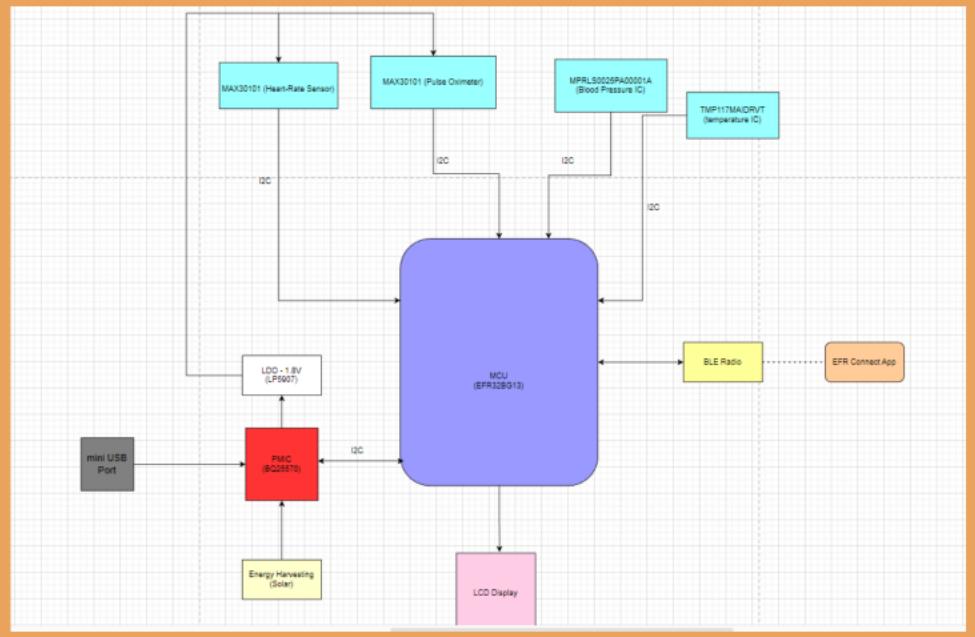
System Block Diagram

System Block Diagram

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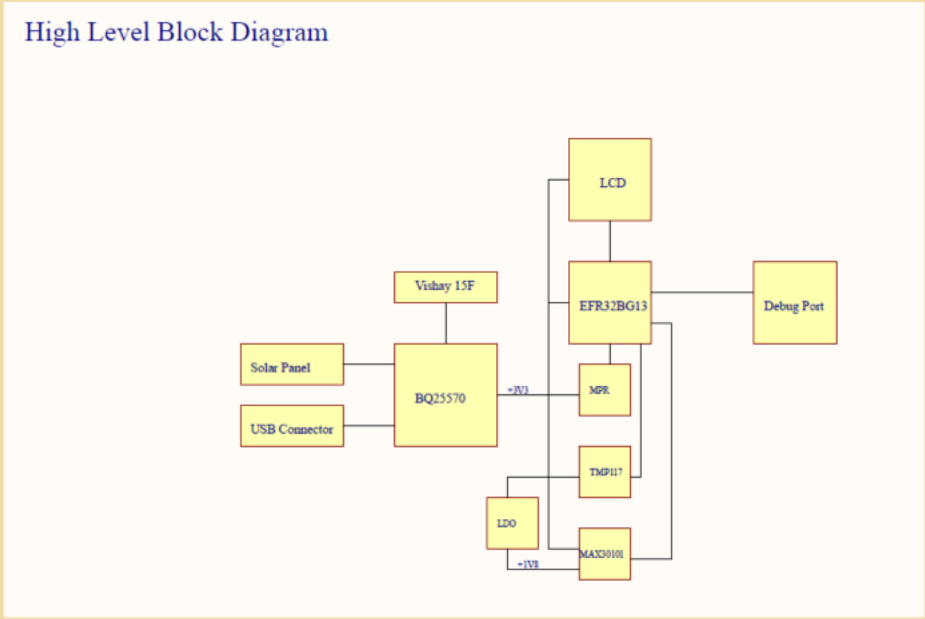
Hardware Design

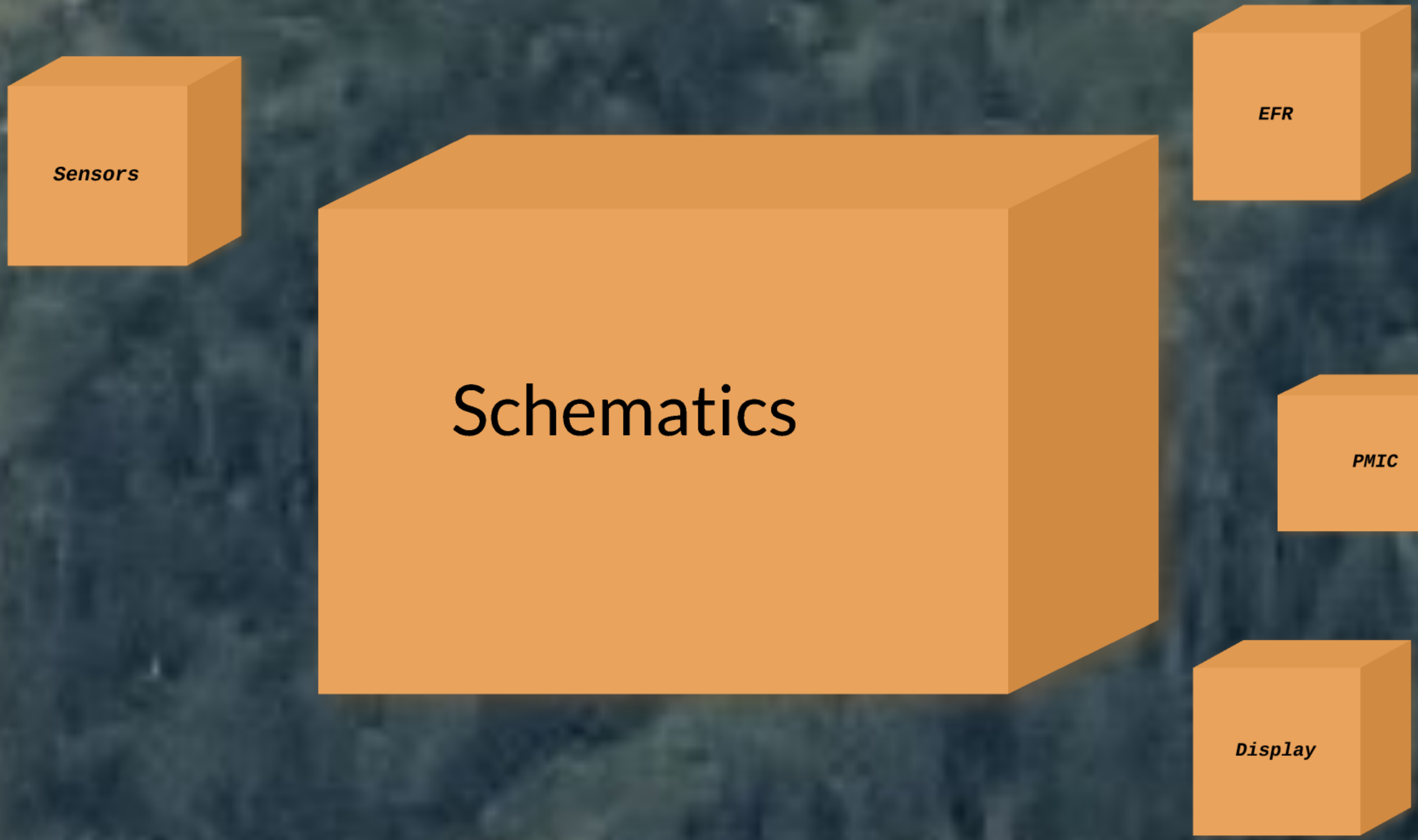
Hardware System Diagram



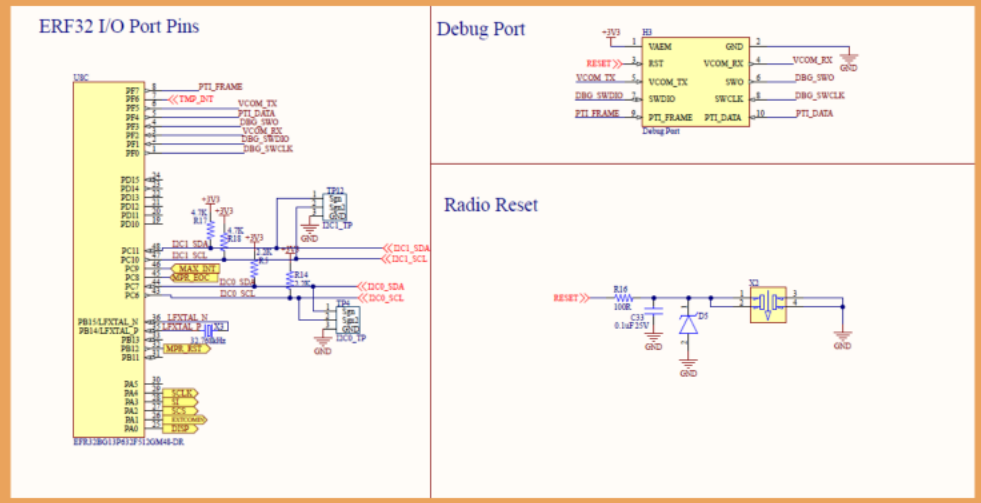
Parts

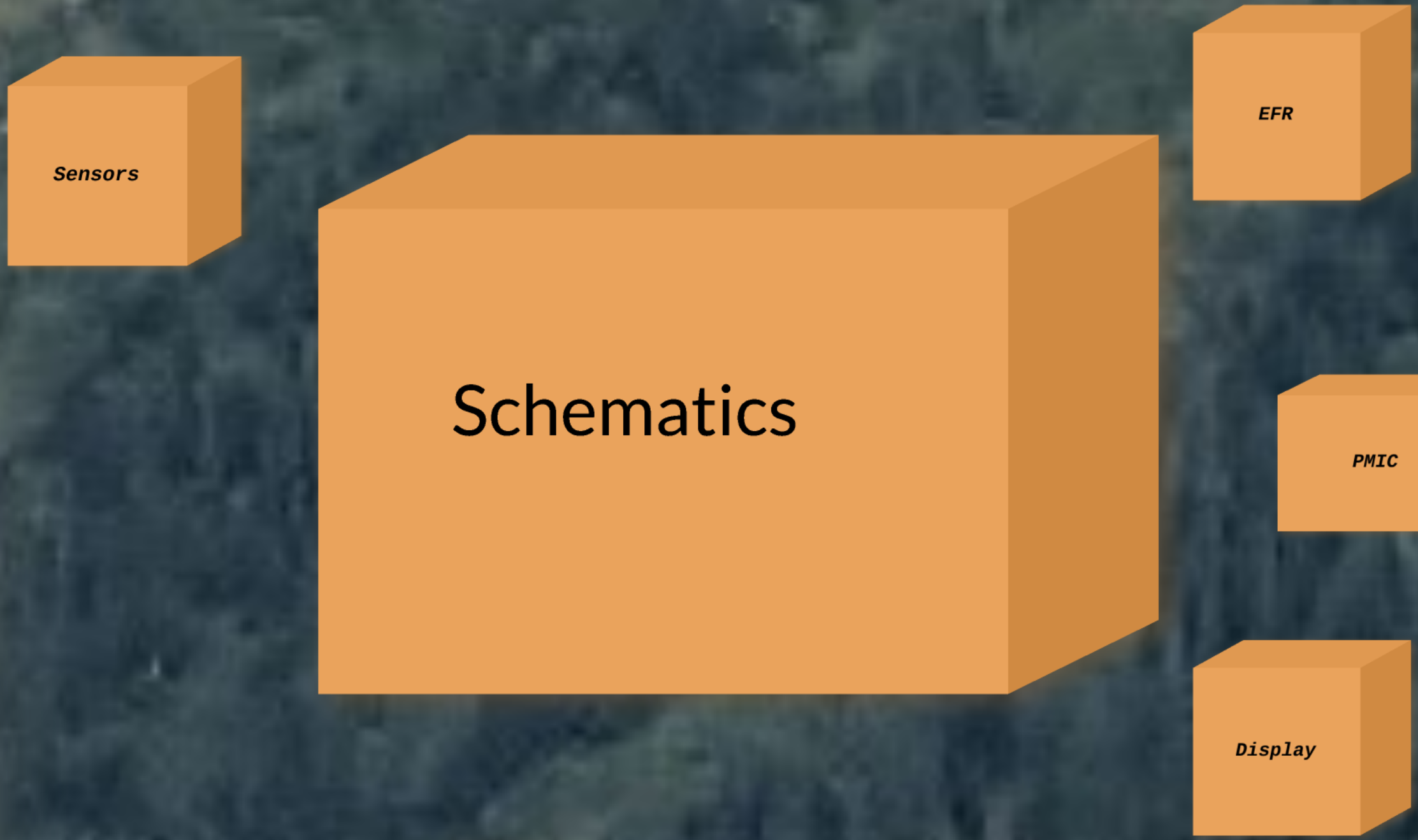
Schematics

Layout

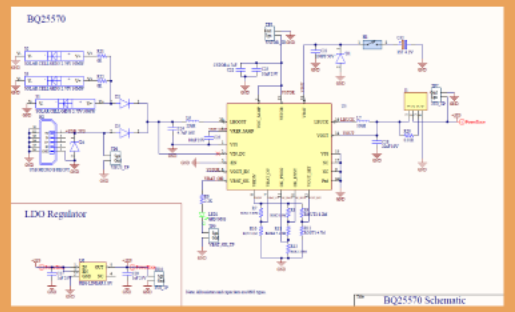

Sensors
Schematics
EFR
PMIC
Display

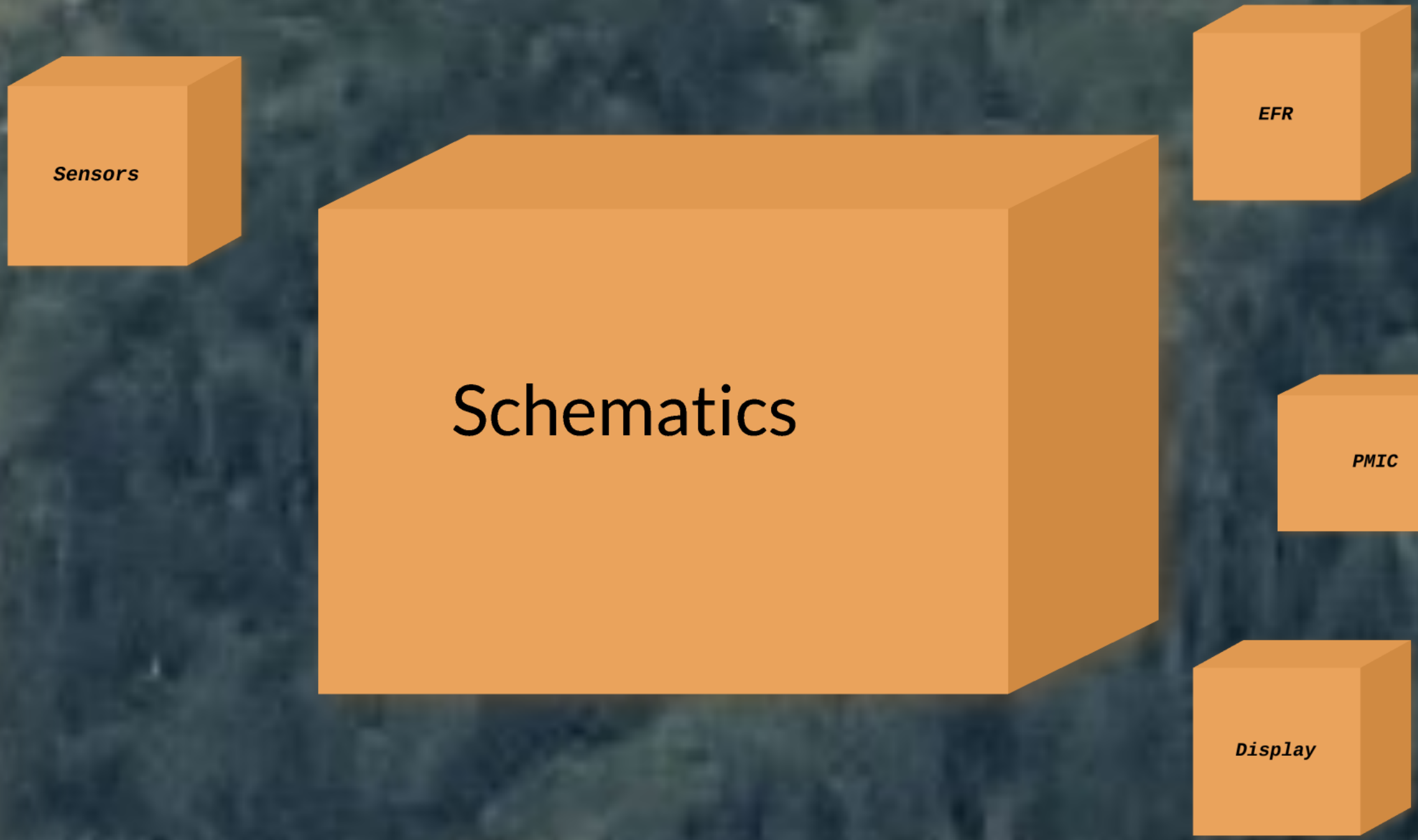
- Reset button circuit to reset the system
- Debug port for SoC programming
- Test points for I2C lines




Sensors
Schematics
EFR
PMIC
Display

- Power Management Circuit
- Solar Cells as alternative sources
- TVS diodes used for ESD protection
- USB port as primary source
- Test point & LED indicator for Power Good Indication
- Header for delivering power to ICs

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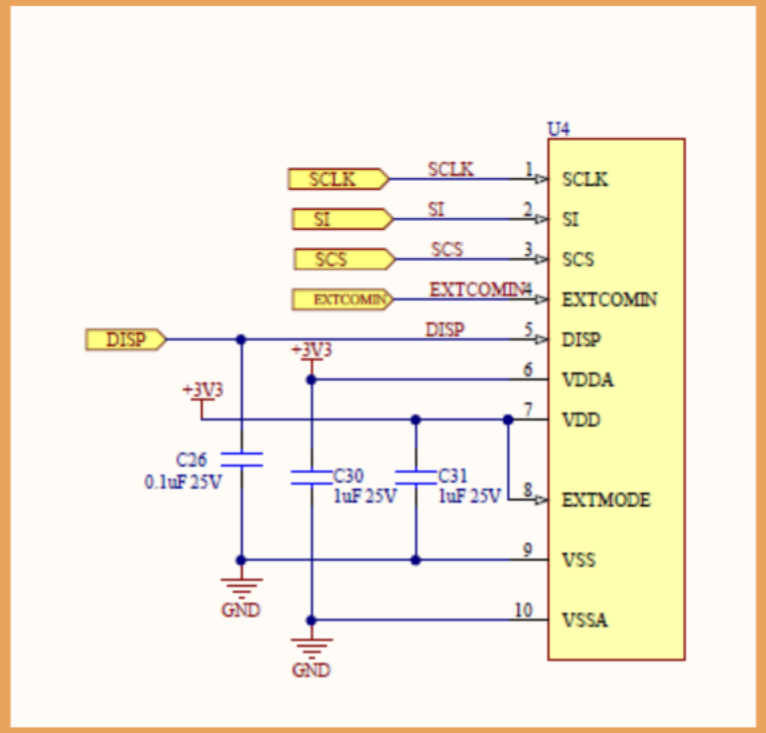
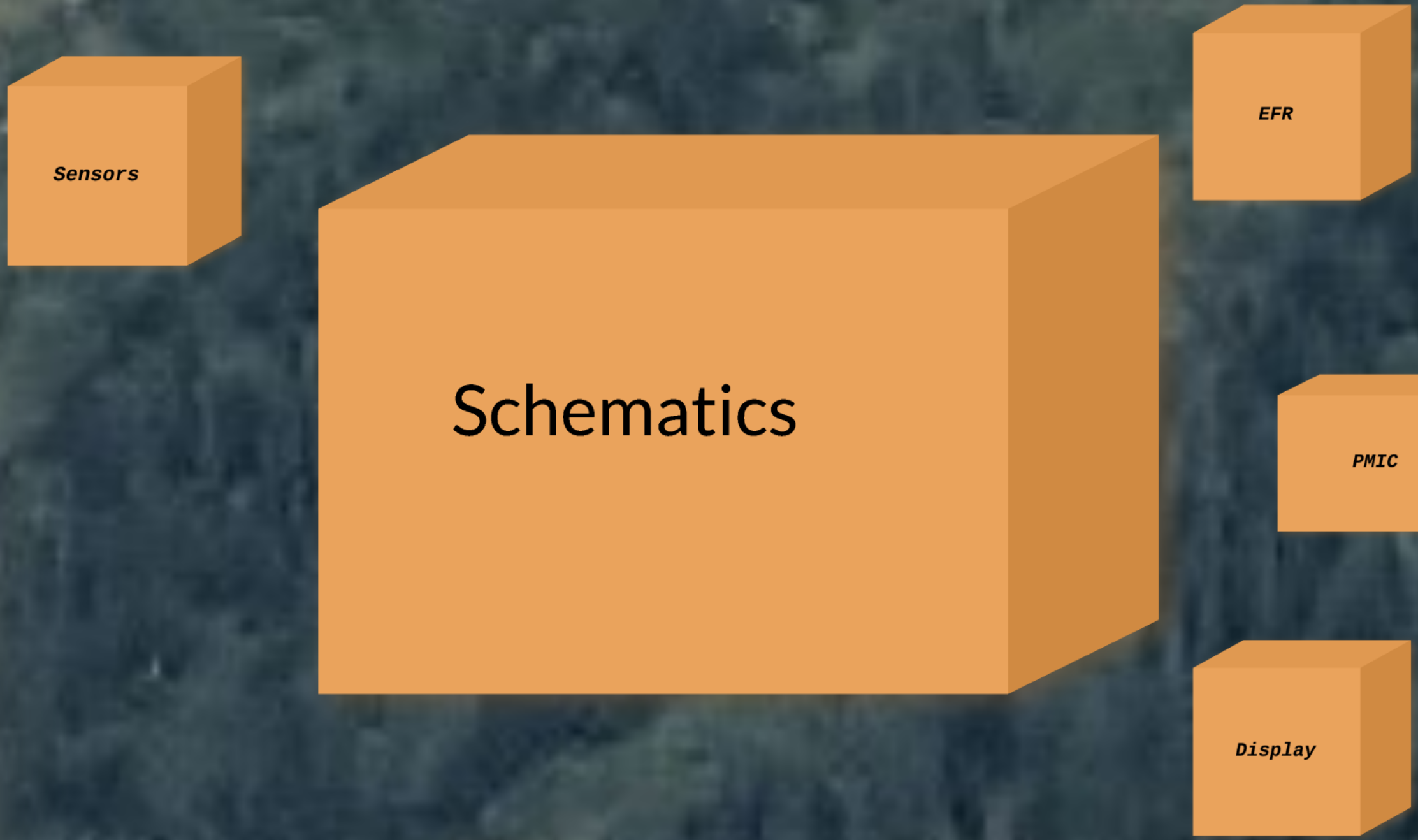

U4
SCLK
SI
SCS
EXTCOMIN
DISP
+3V3
+3V3
C26
0.1uF 25V
C30
1uF 25V
C31
1uF 25V
GND
GND
SCLK
SI
SCS
EXTCOMIN
DISP
VDDA
VDD
EXTMODE
VSS
VSSA
1
2
3
4
5
6
7
8
9
10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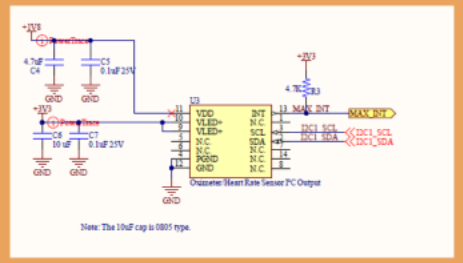
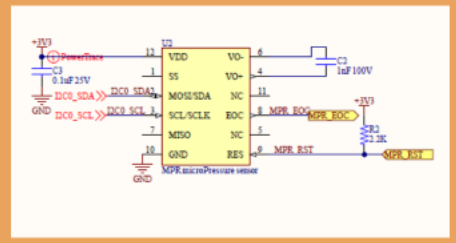
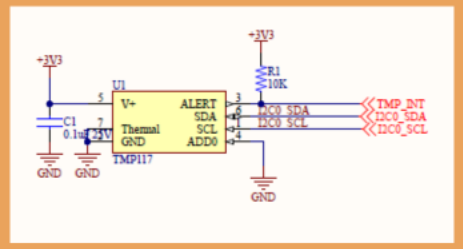
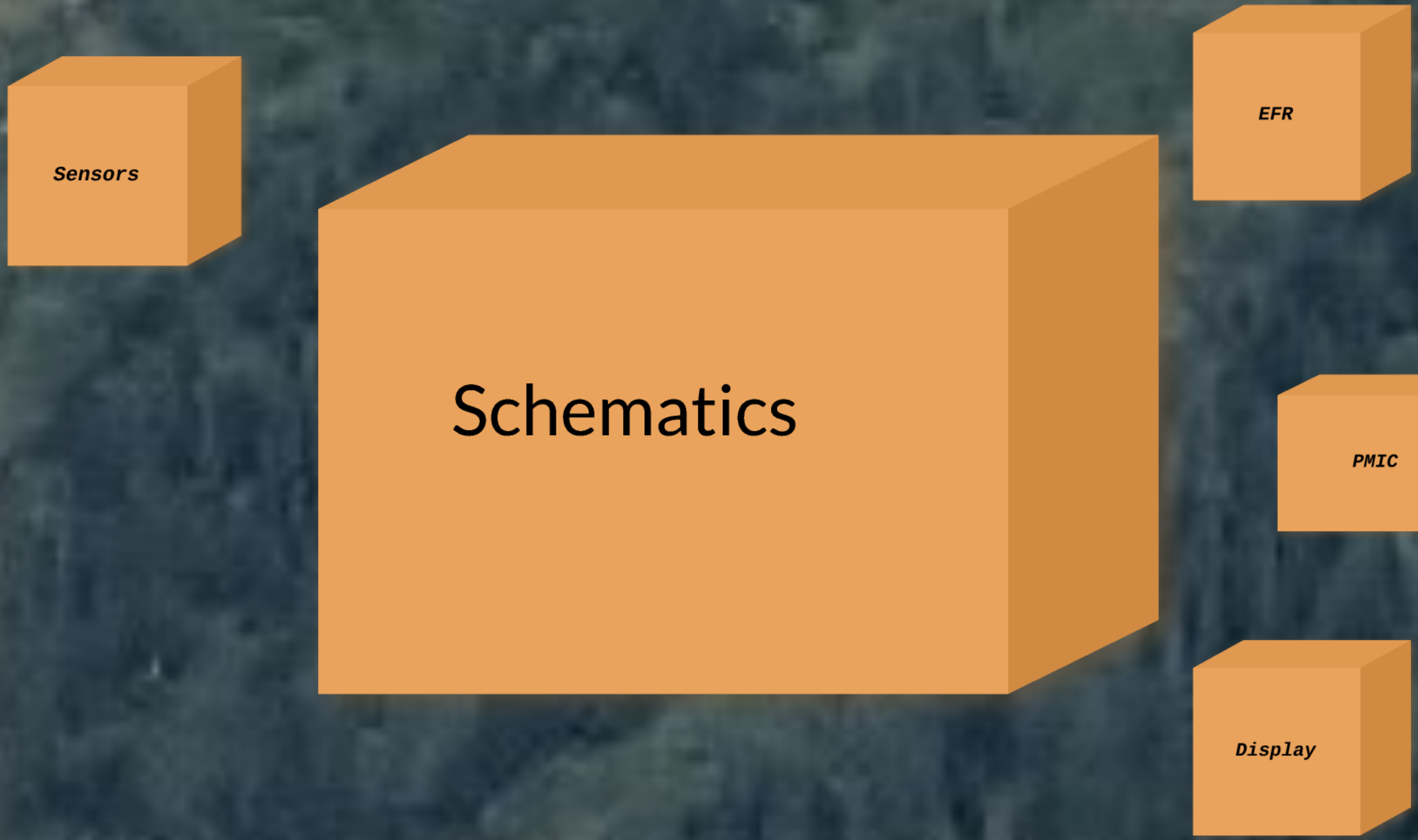
- Bypass capacitors added to Vcc pin for each sensor
- Design based on Sparkfun breakout board schematic





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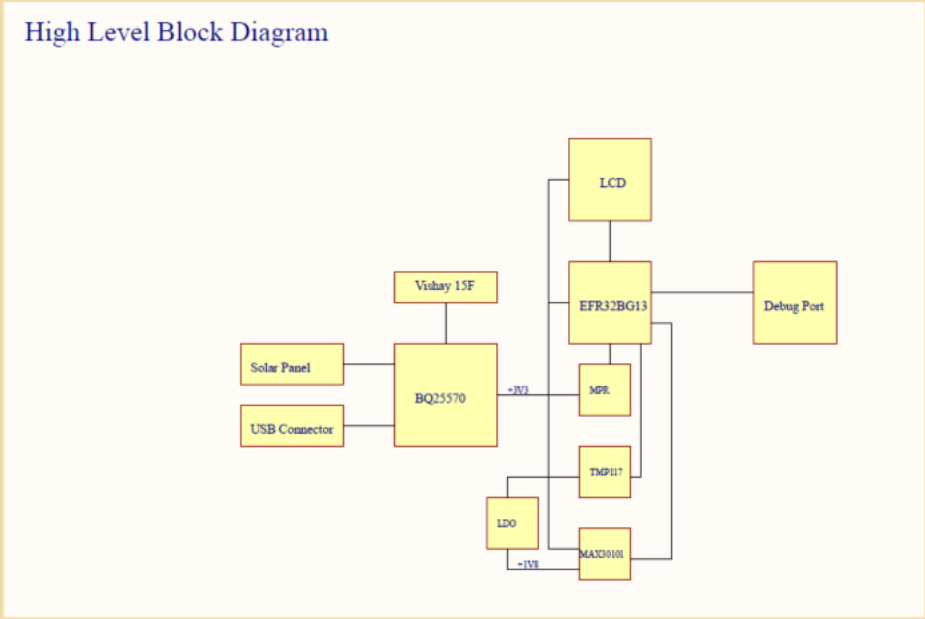
Hardware System Diagram



Parts

Schematics

Layout

BQ25570

Vishay 15F Super Capacitor

LP5907 LDO

Three sensors used :

- TMP117
- MPR
- MAX30101

TMP117

MPR

MAX30101

TMP117 Temperature sensor

High-precision digital
temperature sensor.
Low power consumption:
3.5-uA, 1-Hz conversion cycle
Operate from 1.7V

BQ25570

Vishay 15F Super Capacitor

LP5907 LDO

Three sensors used :

- TMP117
- MPR
- MAX30101

TMP117

MPR

MAX30101

BQ25570 PMIC

Ultra Low Power DC-DC Boost Charger
Designed for Energy Harvesting applications
Allow energy to be stored to super capacitors

BQ25570

Vishay 15F Super Capacitor

LP5907 LDO

Three sensors used :

- TMP117
- MPR
- MAX30101

TMP117

MPR

MAX30101

Vishay 15F Super Capacitor

- Provides high capacity and energy density
- Long useful life: up to 2000 h at 85 °C
- Maintenance-free, no service necessary
- Burst power support for wireless transmitters

BQ25570

Vishay 15F Super Capacitor

LP5907 LDO

Three sensors used :

- TMP117
- MPR
- MAX30101

TMP117

MPR

MAX30101

LP5907 LDO

Supply up to 250 mA output current.
Provides low noise, quiescent current, and load transient response
No noise bypass capacitor required

BQ25570

Vishay 15F Super Capacitor

LP5907 LDO

Three sensors used :

- TMP117
- MPR
- MAX30101

TMP117

MPR

MAX30101

MPR Micro-Pressure sensor

- Designed for medical applications
- Provide pressure reading over the specified full scale pressure span and temperature range
- Typical 10mW power consumption

BQ25570

Vishay 15F Super Capacitor

LP5907 LDO

Three sensors used :

- TMP117
- MPR
- MAX30101

TMP117

MPR

MAX30101

MAX30101 Heart Rate sensor

- Provides high-precision pulse oximetry and heart-rate
- Programmable Sample Rate and LED Current for Power Savings
- Low-Power consumption (< 1mW)

BQ25570

Vishay 15F Super Capacitor

LP5907 LDO

Three sensors used :

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- MAX30101

TMP117

MPR

MAX30101

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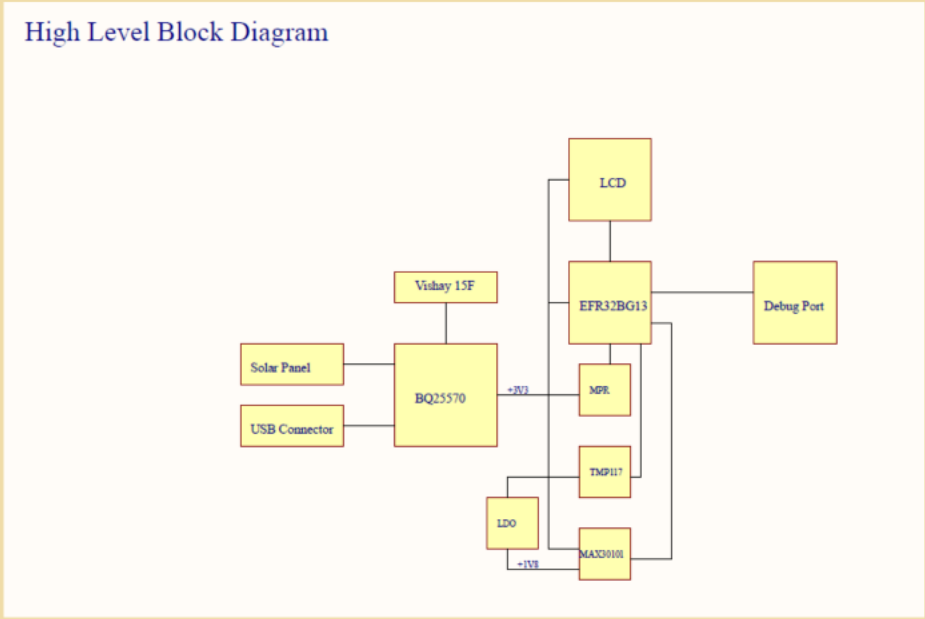

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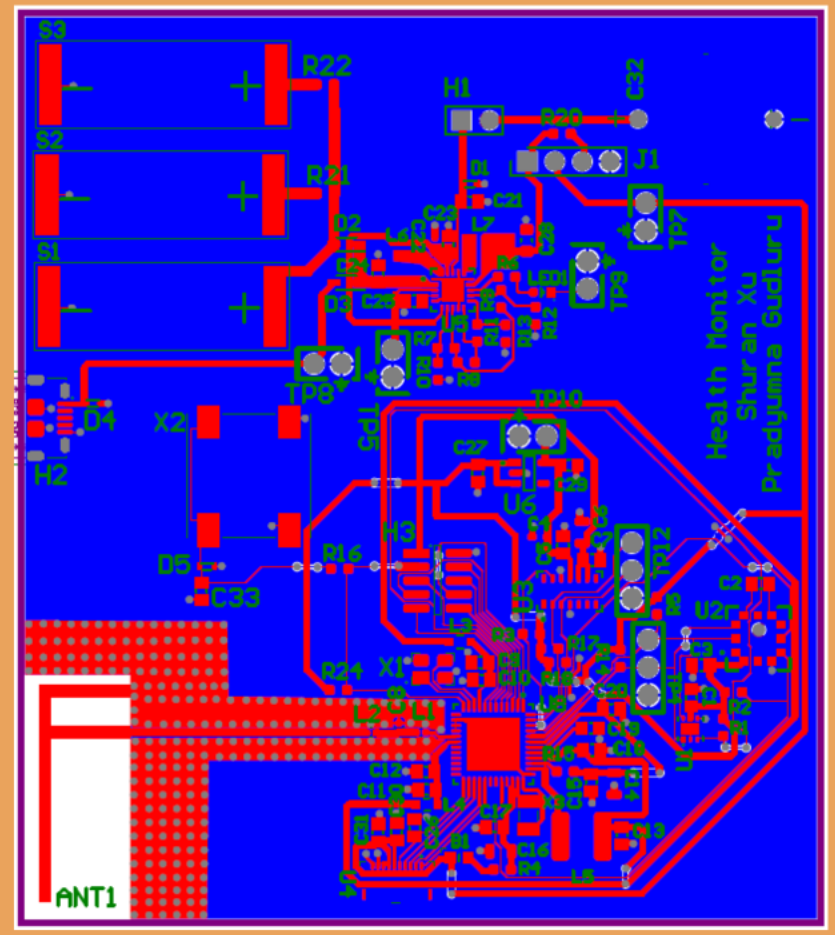
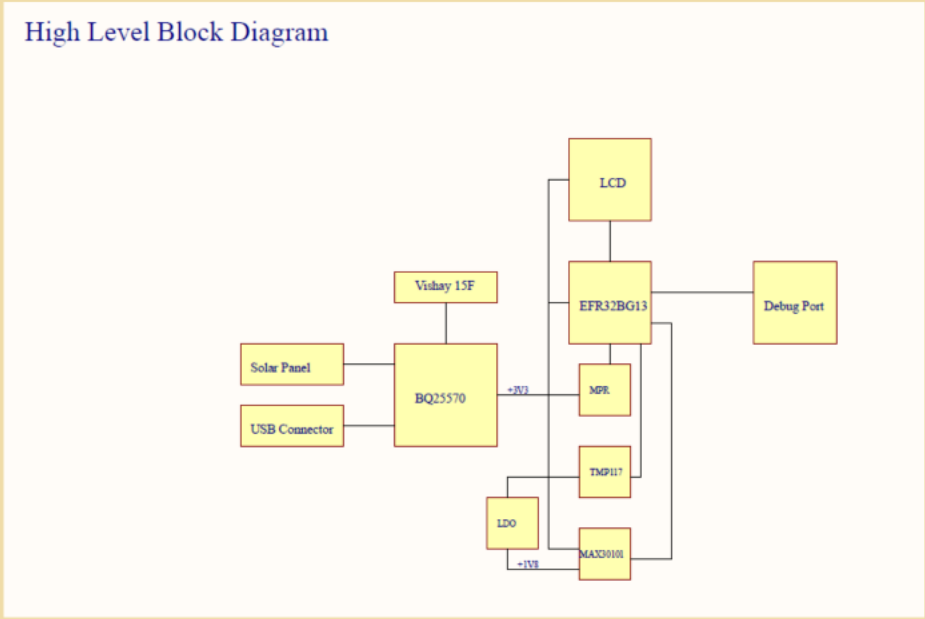

S3
S2
S1
R22
R21
H1
C32
J1
TP7
TP8
TP9
D2
D3
D4
X2
H2
H3
D5
C33
R16
R21
X1
ANT1
Health Monitor
Shuran Xu
Pradyumna Gudluru

Hardware Design

Hardware System Diagram



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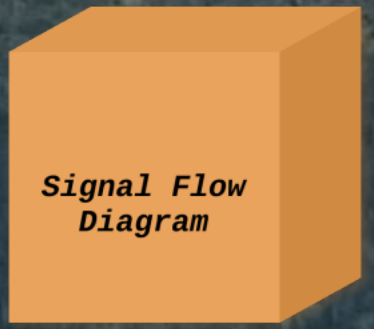
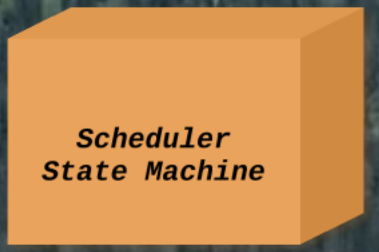
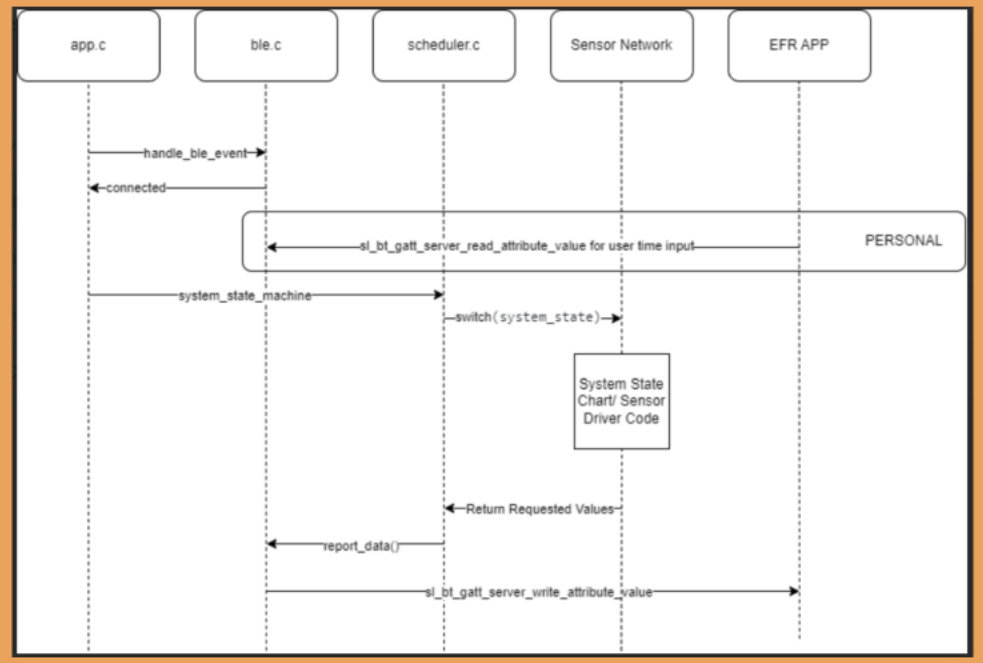
Software Design

- Signal Flow
- Scheduler State Machine

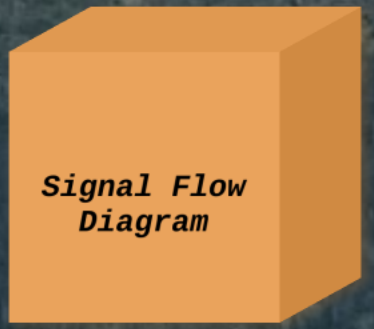


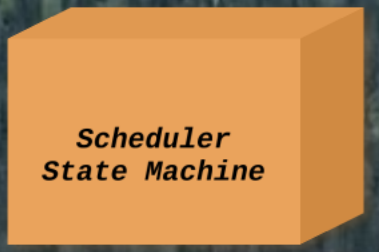


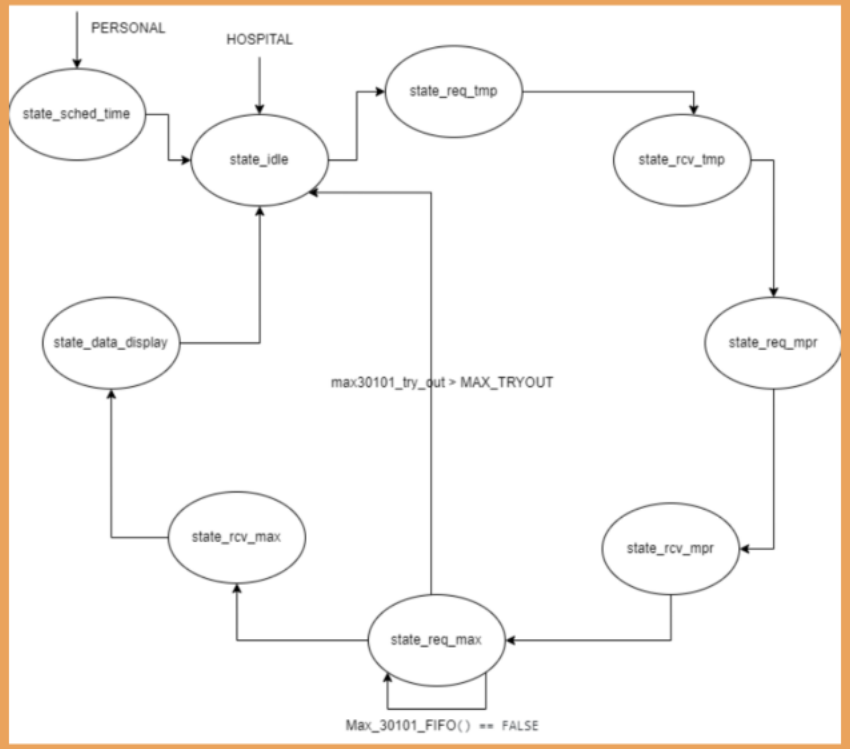

app.c
ble.c
scheduler.c
Sensor Network
EFR APP
handle_ble_event
connected
PERSONAL
sl_bt_gatt_server_read_attribute_value for user time input
system_state_machine
switch(system_state)
System State Chart/ Sensor Driver Code
Return Requested Values
report_data()
sl_bt_gatt_server_write_attribute_value

Software Design

- Signal Flow
- Scheduler State Machine

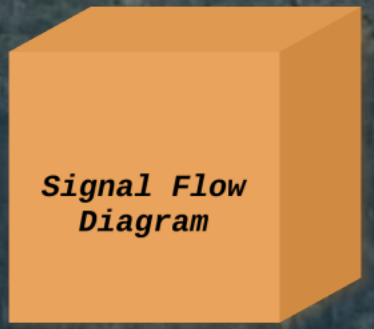


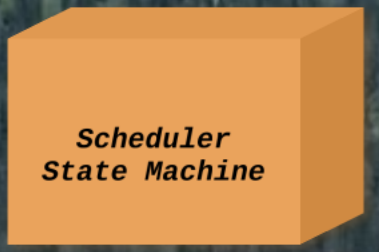



PERSONAL
HOSPITAL
state_sched_time
state_idle
state_req_tmp
state_rcv_tmp
state_req_mpr
state_rcv_mpr
state_req_max
state_rcv_max
state_data_display
max30101_try_out > MAX_TRYOUT
Max_30101_FIFO() == FALSE

Software Design

- Signal Flow
- Scheduler State Machine





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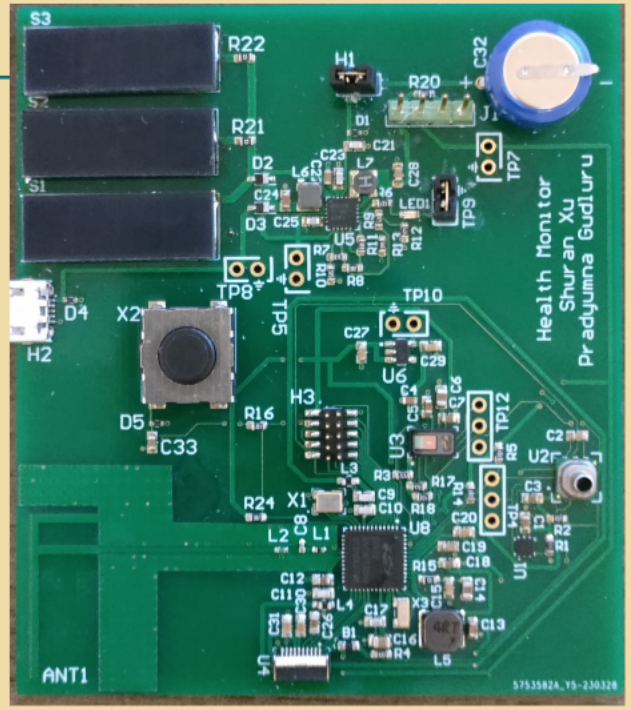
Prototype



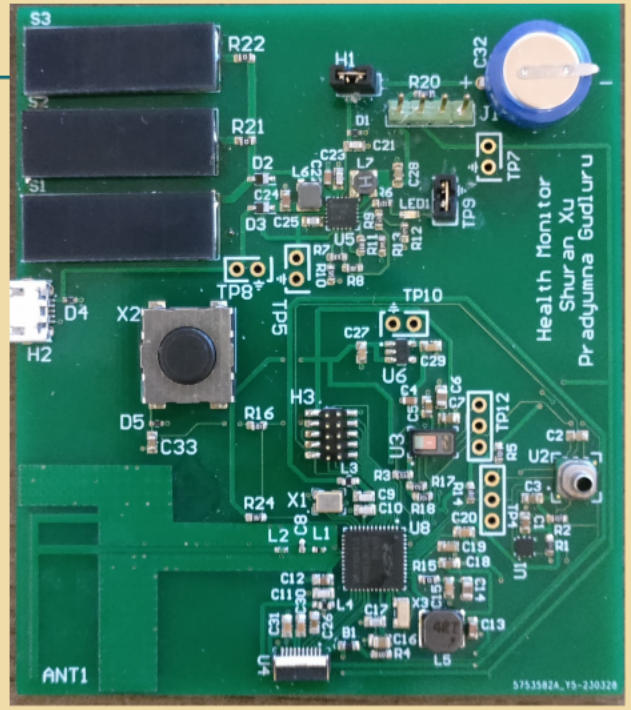
Demo

Demo Video

Demo Video - https://drive.google.com/drive/u/1/folders/1-0CTmdrobbZdlNEUt3MRblIyAVFG-Fmh

FigmaLink: https://www.figma.com/file/gZhAeWZR09H4w28NTdUNeG/M-WIZ?type=design&node-id=0-1&t=NAK0ykwtnA8rLesO-0

Prototype



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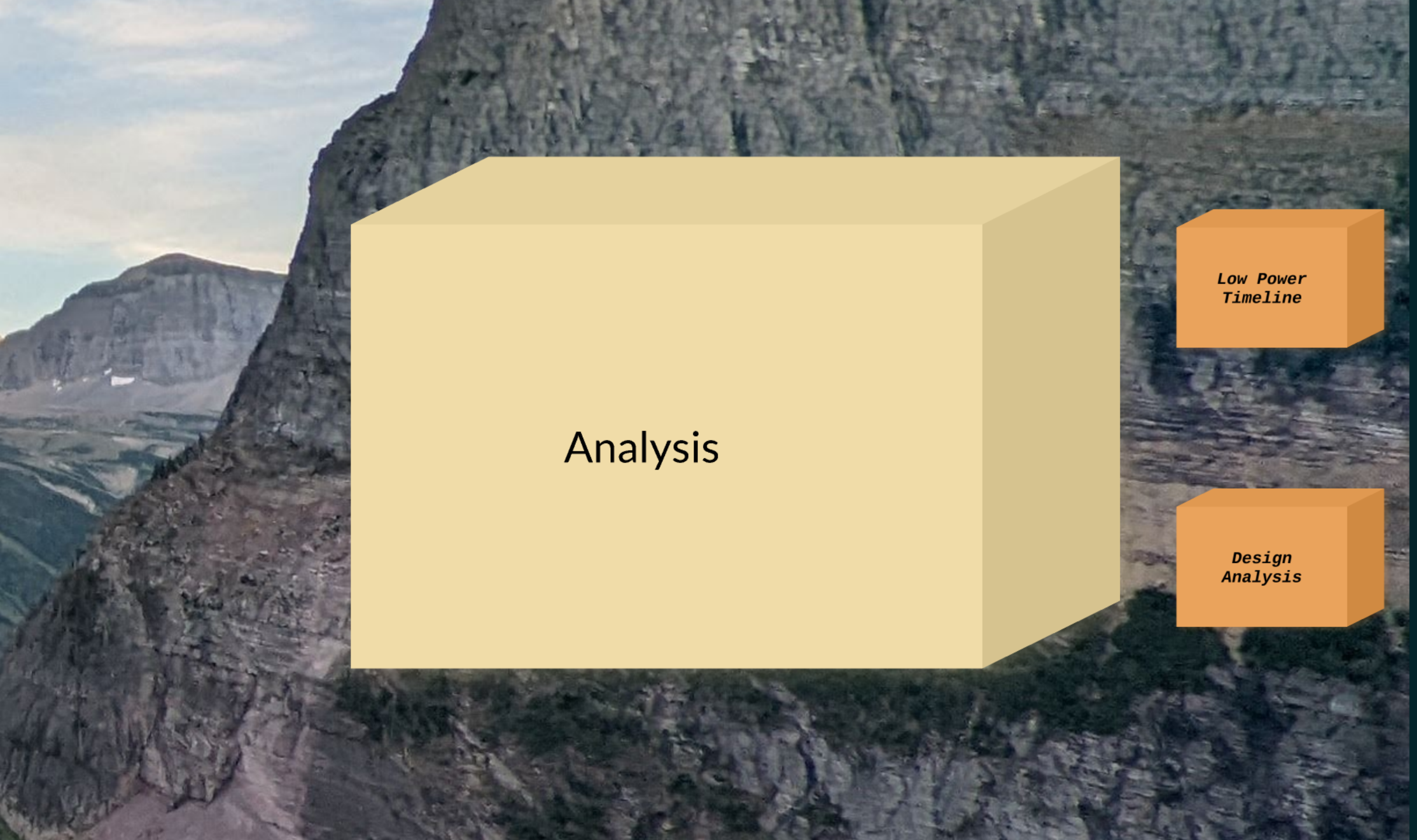
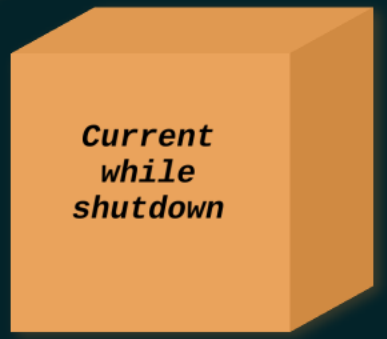
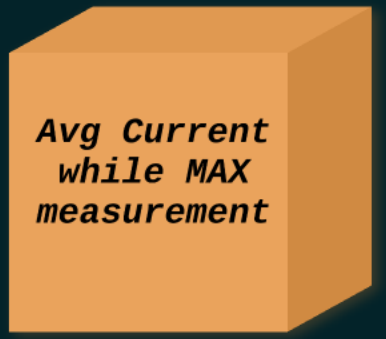
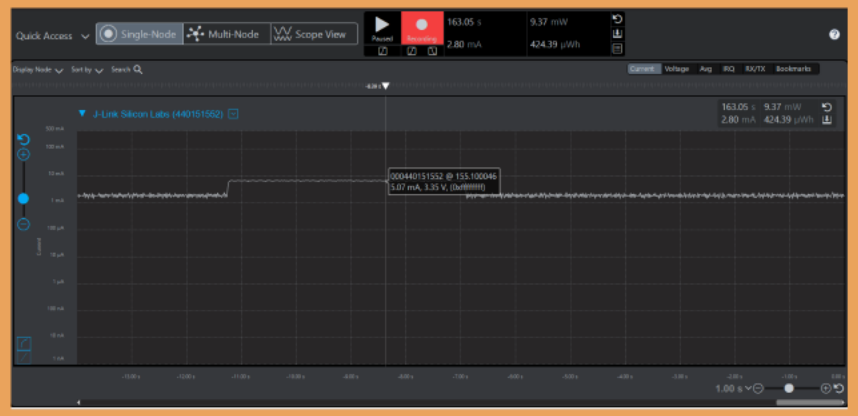

Analysis
Low Power Timeline
Design Analysis

Low Power Timeline

Current consumption while measurement
Current measurement while shutdown
Average current while finger placed (MAX working)
Average current while finger not present

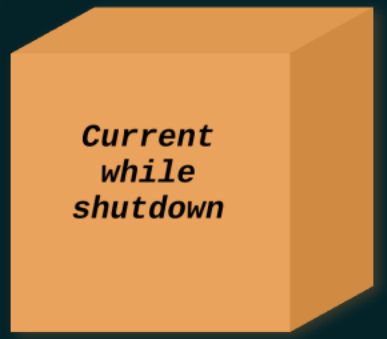


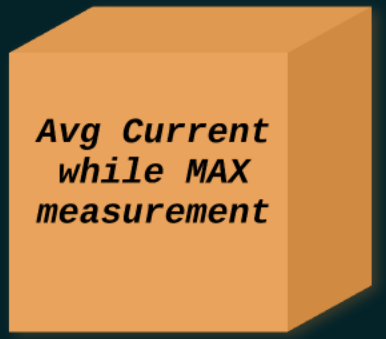


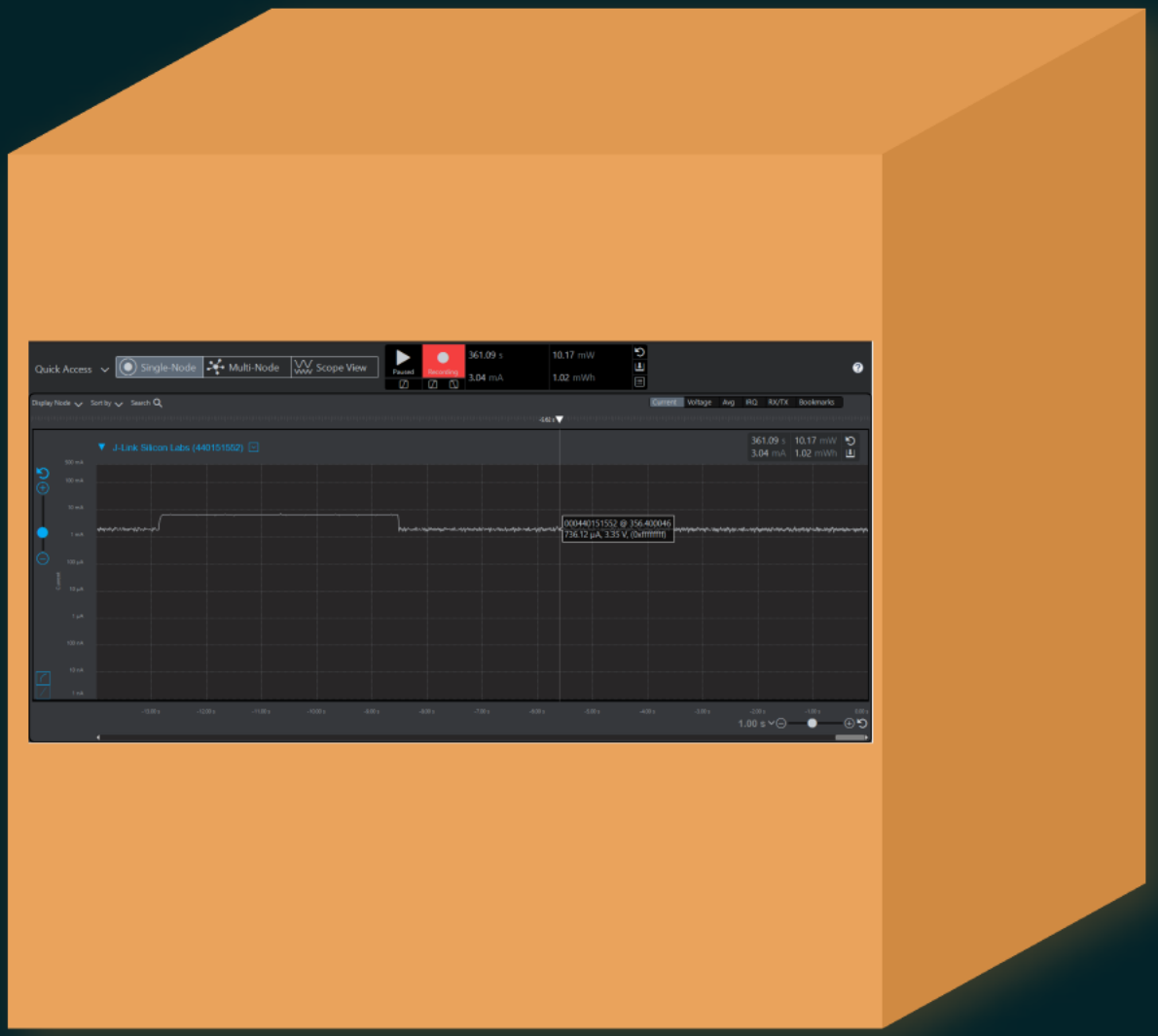

Quick Access
Single-Node
Multi-Node
Scope View
Paused
Recording
163.05 s
9.37 mW
2.80 mA
424.39 µWh
Current
Voltage
Avg
IRQ
RX/TX
Bookmarks
J-Link Silicon Labs (440151552)
163.05 s 9.37 mW
2.80 mA 424.39 µWh
000440151552 @ 155.100046
5.07 mA, 3.35 V, (0xffffffff)
1.00 s

Low Power Timeline

- Current consumption while measurement
- Current measurement while shutdown
- Average current while finger placed (MAX working)
- Average current while finger not present

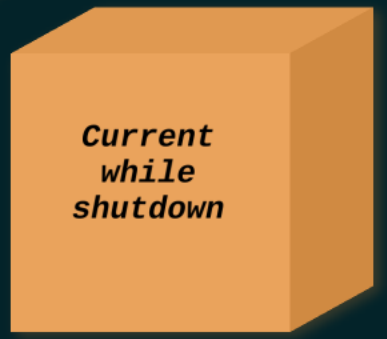


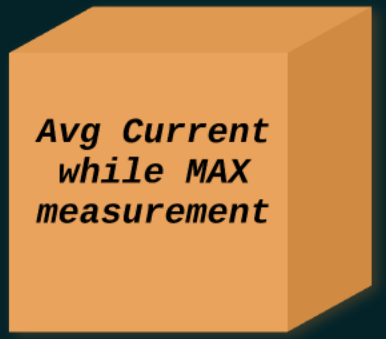



Quick Access
Single-Node
Multi-Node
Scope View
Paused
Recording
361.09 s
3.04 mA
10.17 mW
1.02 mWh
Display Node
Sort by
Search
Current
Voltage
Avg
IRQ
RX/TX
Bookmarks
J-Link Silicon Labs (440151552)
361.09 s
3.04 mA
10.17 mW
1.02 mWh
000440151552 @ 356.400046
736.12 µA, 3.35 V, (0xffffffff)
1.00 s

Low Power Timeline

- Current consumption while measurement
- Current measurement while shutdown
- Average current while finger placed (MAX working)
- Average current while finger not present

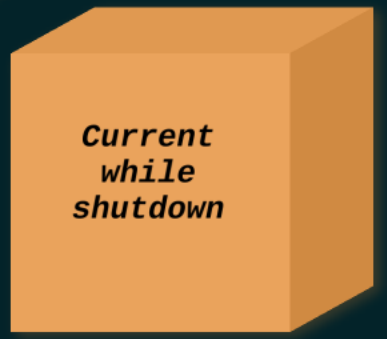


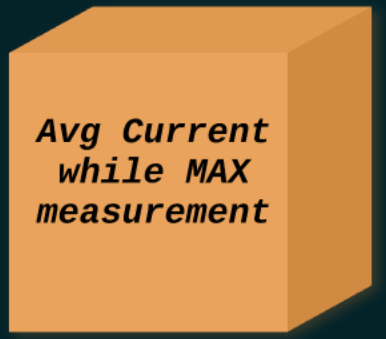



Quick Access
Single-Node
Multi-Node
Scope View
Paused
Recording
495.46 s
3.07 mA
10.28 mW
1.41 mWh
Display Node
Sort by
Search
Current
Voltage
Avg
IRQ
RX/TX
Bookmarks
J-Link Silicon Labs (440151552)
495.46 s
3.07 mA
10.28 mW
1.41 mWh
Average
1.00 s

Low Power Timeline

- Current consumption while measurement
- Current measurement while shutdown
- Average current while finger placed (MAX working)
- Average current while finger not present






Quick Access
Single-Node
Multi-Node
Scope View
Paused
Recording
434.87 s
3.08 mA
10.31 mW
1.25 mWh
J-Link Silicon Labs (440151552)
434.87 s 10.31 mW
3.08 mA 1.25 mWh
10 mA
1 mA
Average
Current
1.00 s

Low Power Timeline

- Current consumption while measurement
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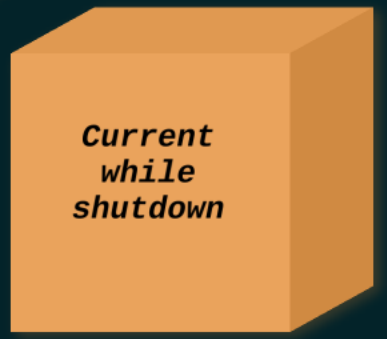
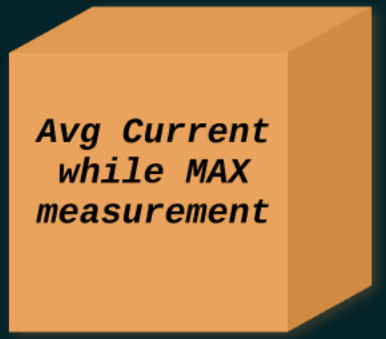
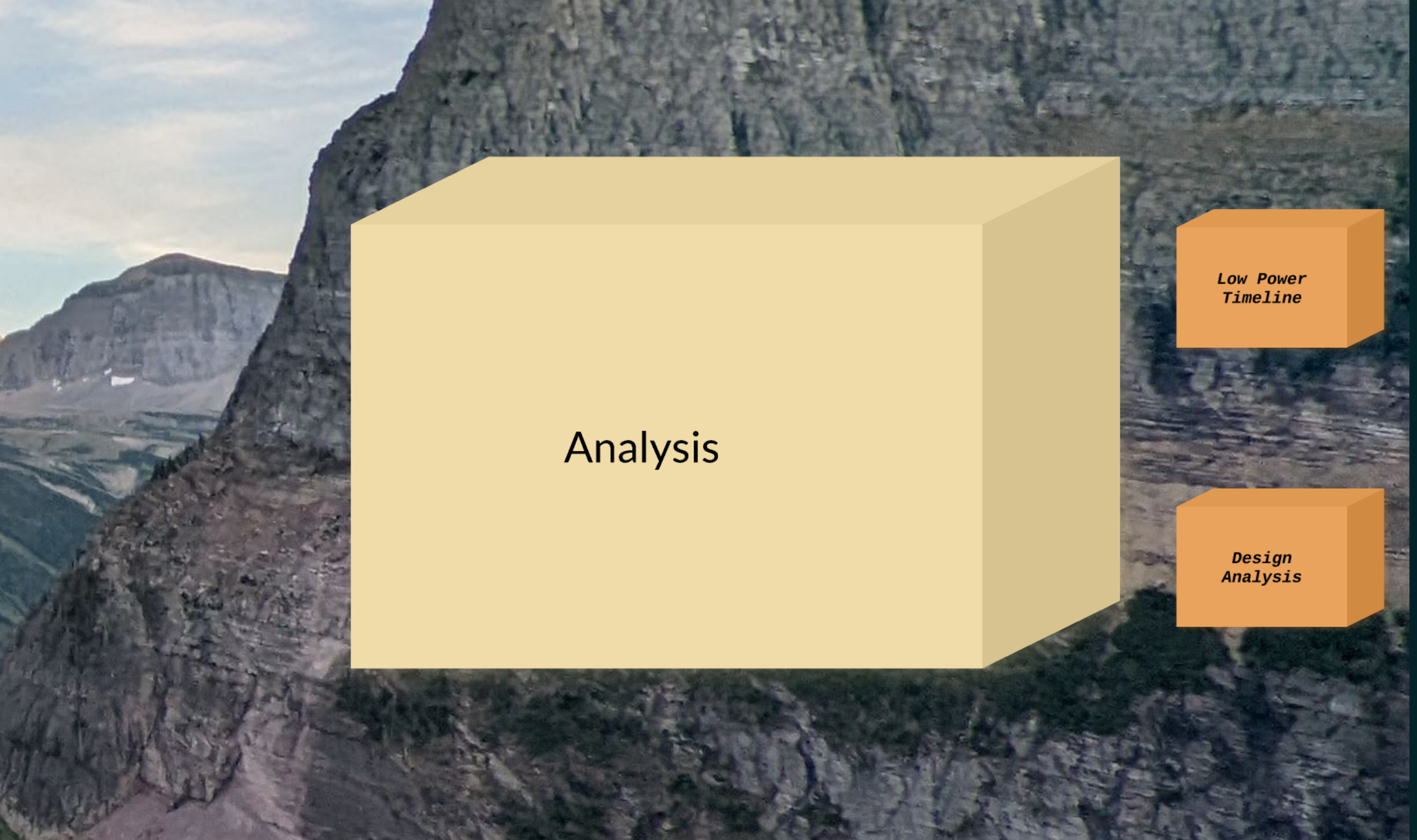
- Average current while finger not present



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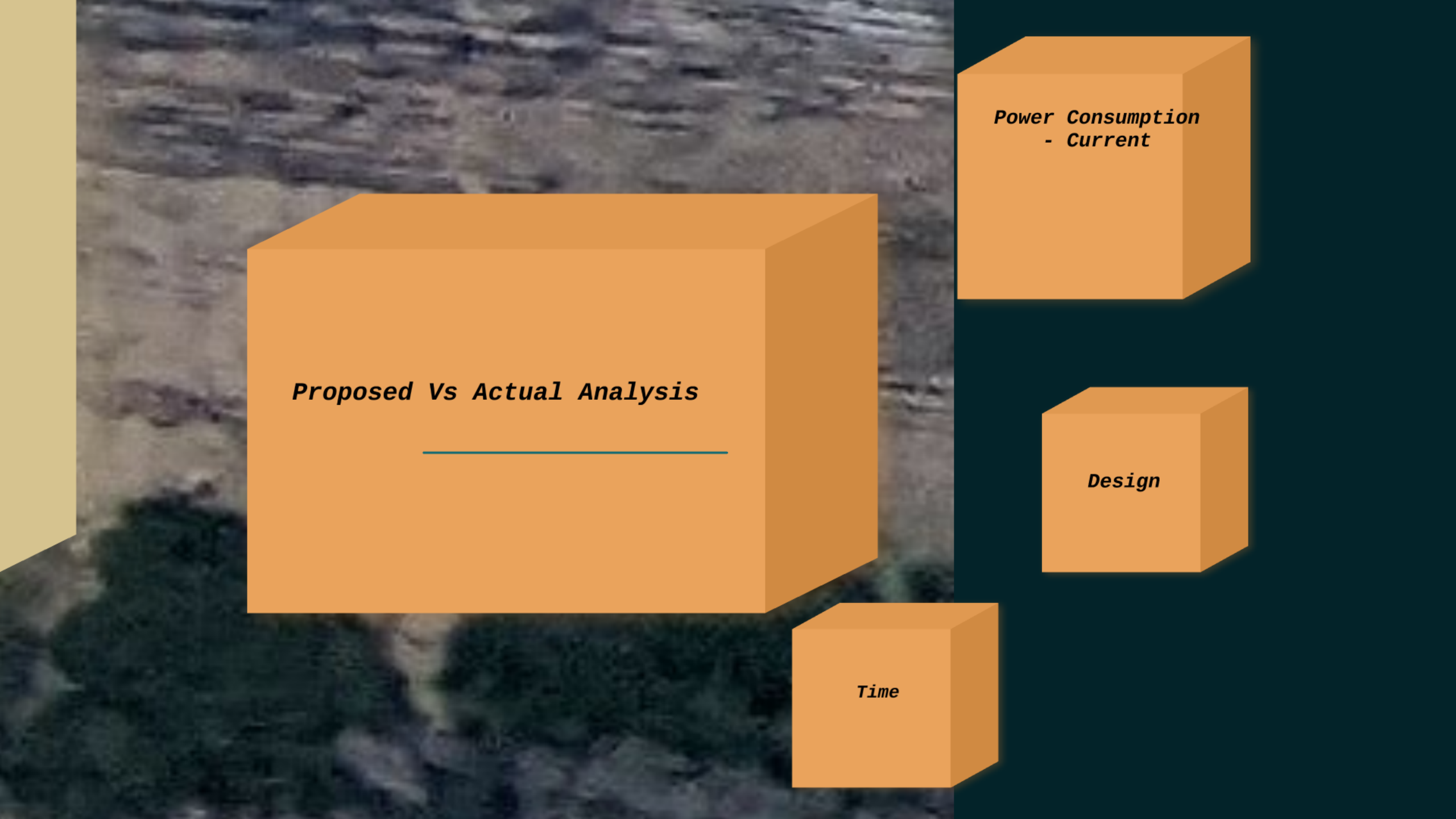
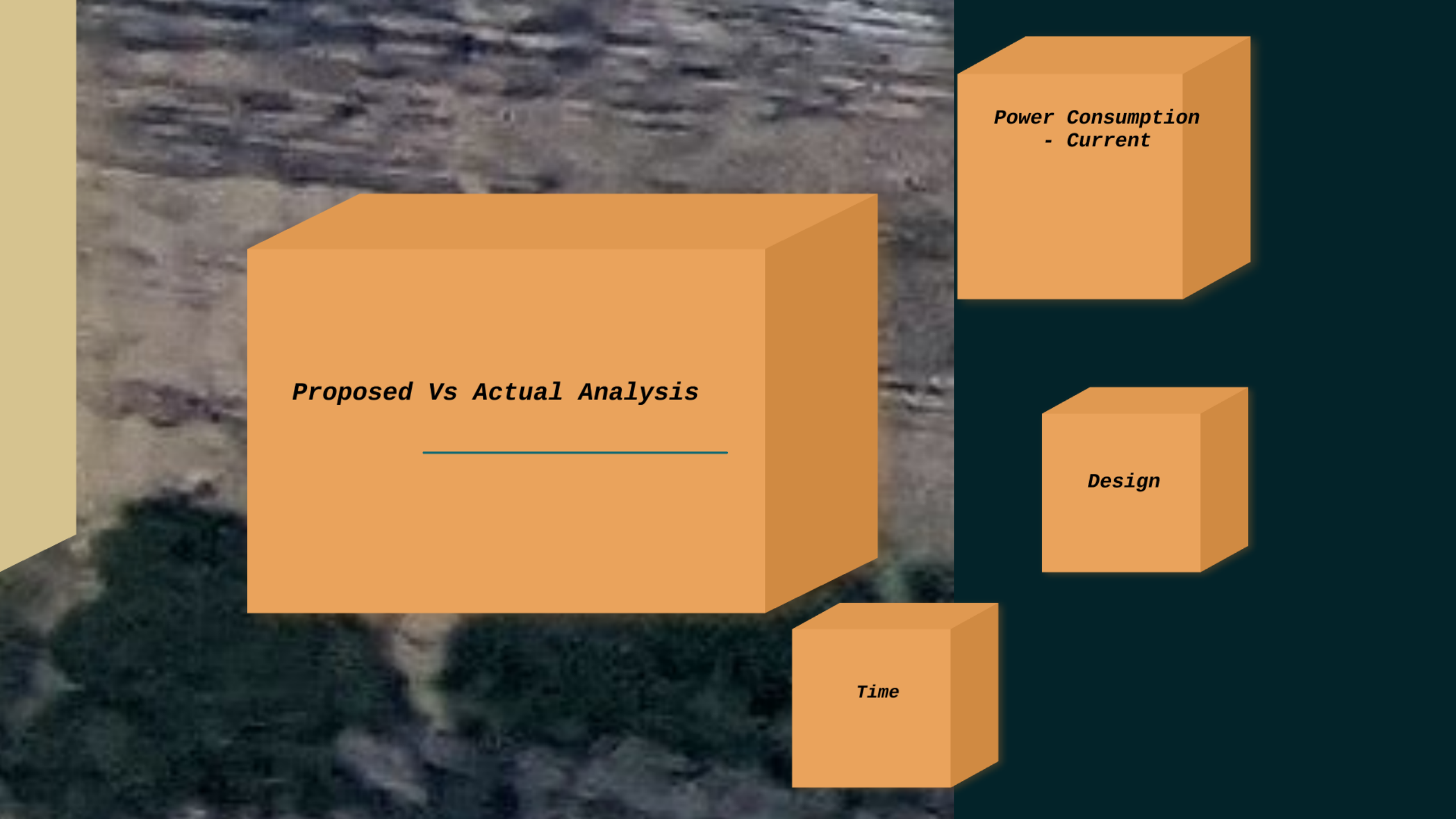
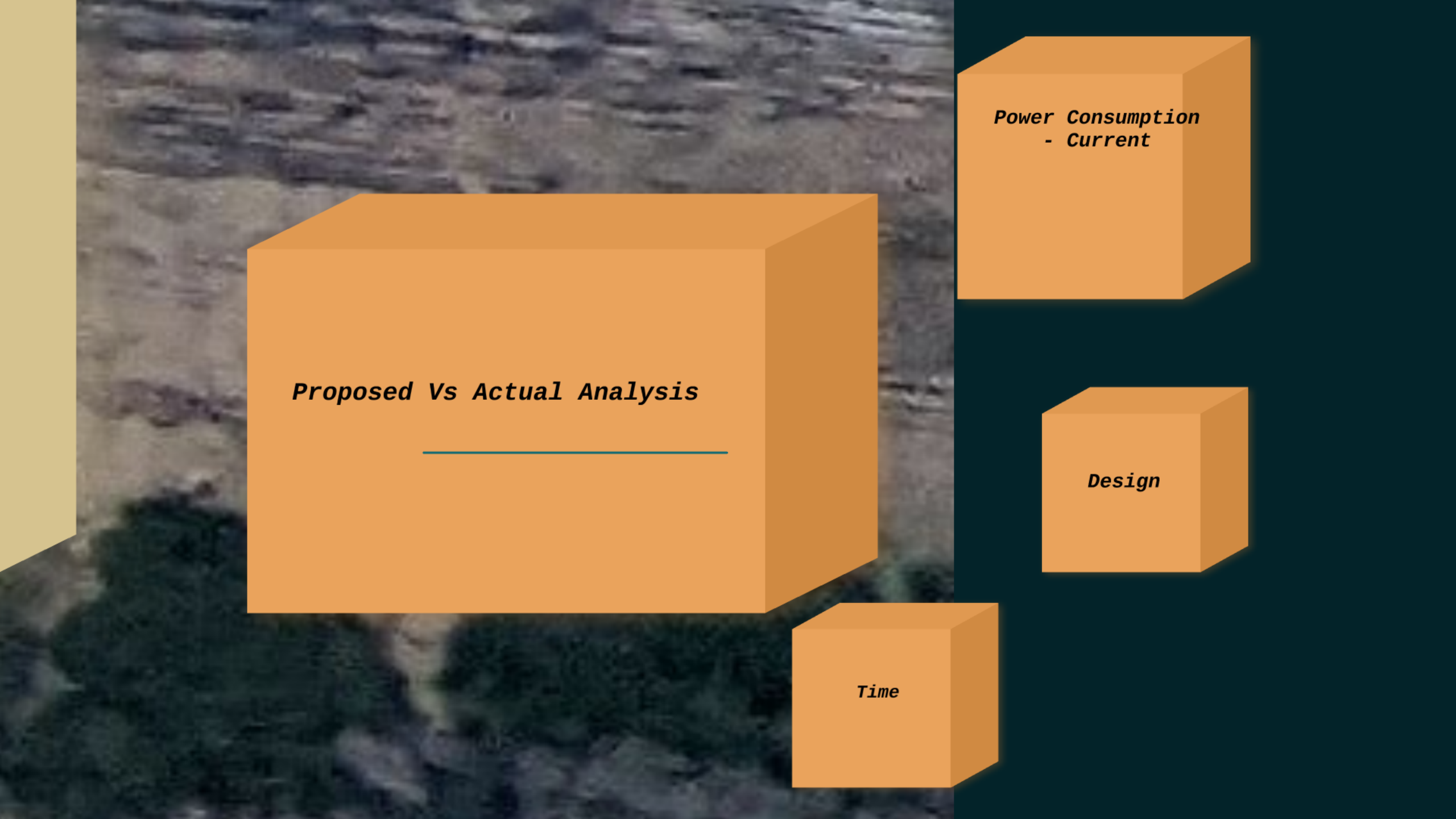
Low Power Timeline
Design Analysis


Proposed Vs Actual Analysis
Power Consumption
- Current
Design
Time

Energy Mode	Current Consumption (mA) - Proposed	Current Consumption (mA) - Actual
EM0	EFR32BG13: 128 uA/MHz * 38.4 MHz / 1000 = 4.915 mA TMP117: 0.022 MPR: 0.000221 LCD: 0.01516 MAX30101: 0.0025 I2C:0 Total current = 4.915 + 0.022 + 0.000221 + 0.01516 + 0.0025 = 4.955	From the energy profiler current consumed = 5.23mA
EM1	EFR32BG13:10 I2C: 0.33 LCD: 0.01516 TMP117: 0.135 MPR: 0.000682 MAX30101: 1.1 Total current = 10 + 0.33 + 0.01516 + 0.135 + 0.000682 + 1.1 = 11.58	From the energy profiler current consumed = 5.07mA
EM3	EFR32BG13: 1.53 uA I2C: 0 TMP117: 0.022 MPR: 0.000221 LCD: 0.01516 MAX30101: 0.0025 Total current = 0.00153 + 0.022 + 0.000221 + 0.01516 + 0.0025 = 0.0415	From the energy profiler current consumed = 0.736 mA


Proposed Vs Actual Analysis
Power Consumption
- Current
Design
Time

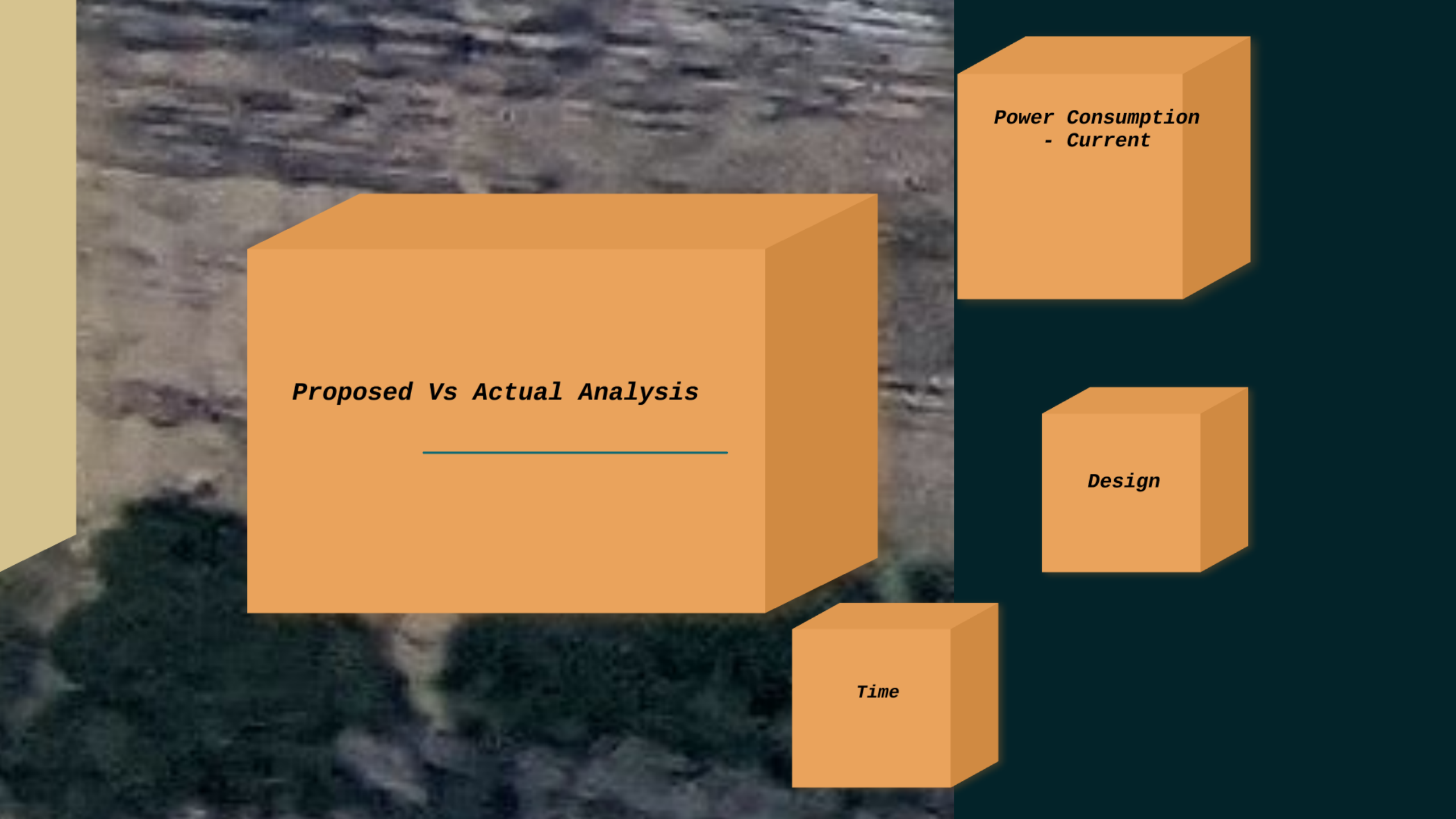
Proposed	Actual
Second Push Button for user interfacing	Did not include Push Button, which made us to tradeoff on some user specific requirements
Initially added the HUB MAX32664GWEA	Removed it for reducing placement and layout complexities
Micropressure Sensor on SPI	Changed to I2C for easy integration
Planned to use MAX Interrupt and MPR EOC	After working on custom board, MAX Interrupt was not much useful and MPR EOC is similar to checking the status bit.

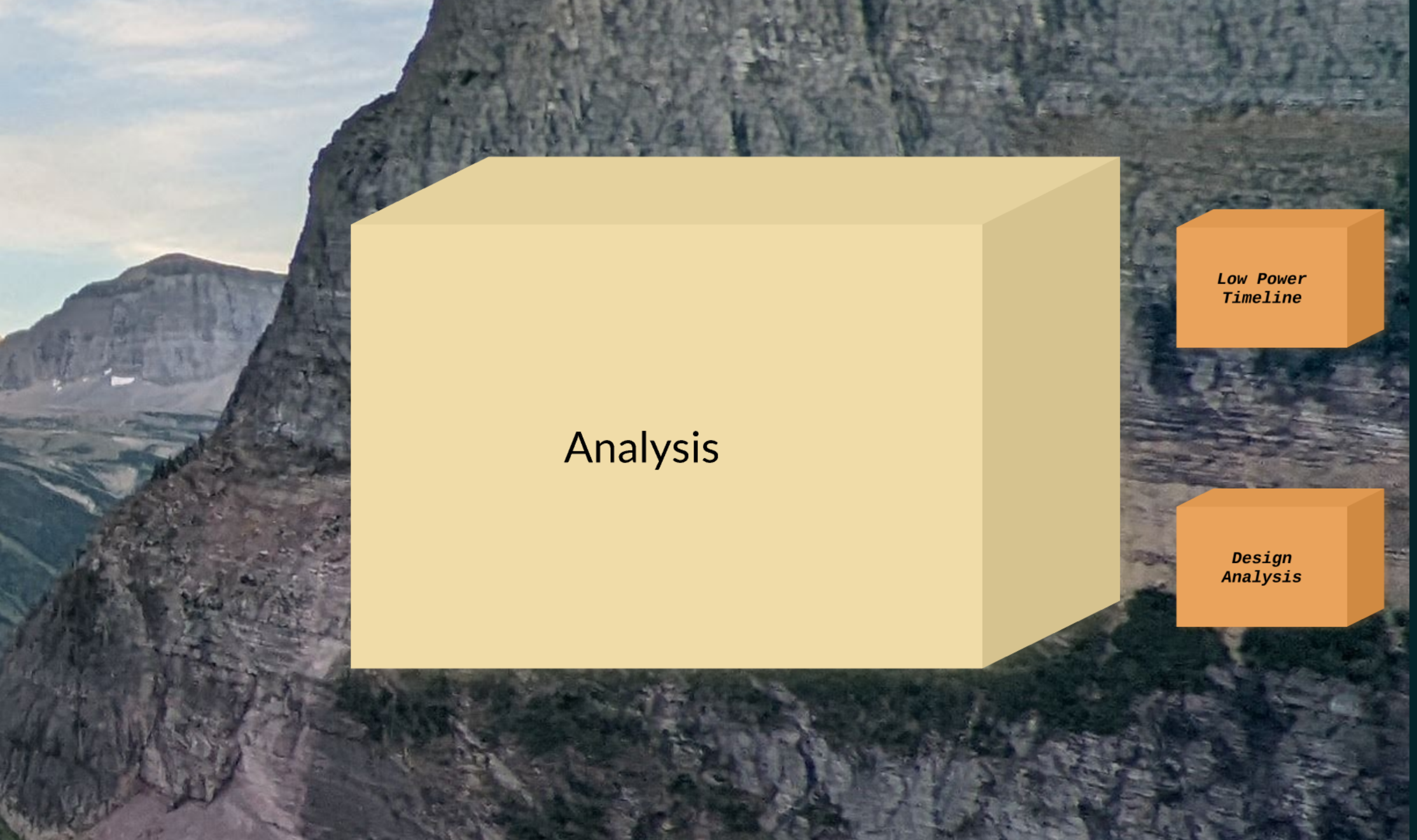

Proposed Vs Actual Analysis
Power Consumption
- Current
Design
Time

Time - HOSPITAL Case

Activity	Duration (sec) - Proposed	Duration Actual
BLE Connectivity	20	5
Sensor Reading	2 x 2 secs + 3 sec = 7 secs (The heart rate and blood oxygen require 3 second)	1(0.5+0.5 approximately) + 2.5(MAX) < 4sec
Mobile App update	5	<1sec
LCD Update	10	<1sec

Energy Mode	Time Elapsed (secs) - Proposed	Time Elapsed (secs) - Actual
EM0	20	init 5sec + <1sec for update
EM1	22	4.5sec
EM3	3558	3595.5 sec


Proposed Vs Actual Analysis
Power Consumption
- Current
Design
Time


Analysis
Low Power Timeline
Design Analysis

M WIZ

Team 6 - Embedded Wizards

Pradyumna, Shuran

Summary

Pain Points

Lessons Learnt

Q&A

Acknowledgement

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Pain Points

Issues	Resolution
The I2C lines MAX30101 are swapped	Programmed the SDA line on the board to SCL and vice versa.
I2C Probing issues	Added headers to the I2C test points.
Missing user-driven push button	Used a GATT characteristic to allow users specify the monitor measure period.
Test point connected in series with LED indicator	Added a header to the test point.

Summary

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Lessons Learnt

- Footprint error: Careful review for footprint before schematic design
- Missing push-button: Synchronize the design and the plan to ensure no missing parts
- MAX30101 Accuracy issue: Design the LETimer period to meet the MAX30101 data sampling resolution

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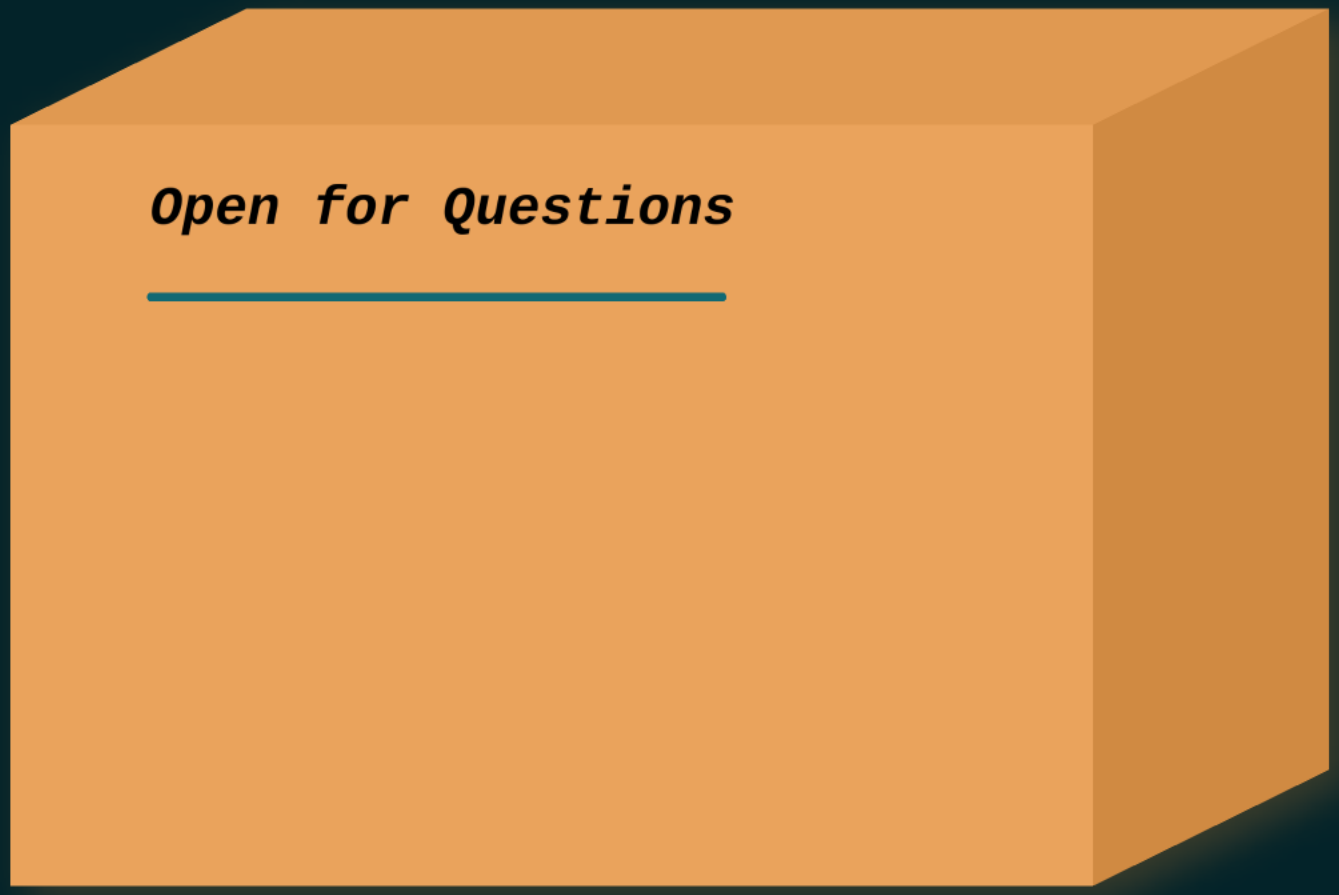
Open for Questions

Summary

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Thank you Note!

We appreciate help from

1. Prof. Spalding
2. Chris
3. Bhargav
4. Akshay
5. Lauren

their continous support to make MWIZ happen.

Summary

Pain Points

Lessons Learnt

Q&A

Acknowledgement

References

References

1. Data Sheets of MAX30101, MPR, TMP117, PMIC, LCD Display, etc
2. EFR32 datasheet, reference manual, schematic, etc
3. Presentation Tools Prezi, Figma, etc
4. MAX Algorithm Analysis https://www.maximintegrated.com/en/design/technical-documents/app-notes/6/6845.html

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