CHLORO GAUGE

COST-EFFECTIVE NON-INVASIVE CHLOROPHYLL MEASURMENT DEVICE

GUIDE: Dr Sakthivel G

22BMH1131-ARJUN RAJASEKARAN

22BMH1091-VELAN K

OUTLINE OF THE PRESENTATION

- Introduction
- Literature Review
- Literature Gap
- Statement of the problem
- Objectives
- Methodology
- Work Completed
- Future Work Plan
- Timeline
- References

INTRODUCTION

- The amount of chlorophyll present in leaves directly reflects the photosynthetic capacity of a plant, making it a reliable parameter for assessing growth and overall crop performance.
- Measuring chlorophyll helps farmers and researchers monitor nutrient levels especially nitrogen since chlorophyll content is closely linked to nitrogen availability.
- It also provides early warning of stress conditions such as disease, drought, or nutrient deficiency before visible symptoms appear.
- By accurately measuring chlorophyll, it becomes possible to optimize fertilizer use, improve yield prediction, and support sustainable farming practices while reducing input costs.

We propose a new simple and intuitive sensor-based system which consists of base hand-held module. The leaf nutrients are measured by leaf probe which works by multi-spectral spectroscopy. The data logging is performed by a low power micro-controller and data is sent to a remote server with a dashboard.

LITERATURE REVIEW

TITLE	INFERENCE	LITERATURE GAPS
Smartphone image based digital chlorophyll meter to estimate the value of citrus leaves chlorophyll using Linear Regression, LMBP-ANN and SCGBP-ANN - Journal of King Saud University – Computer and Information Sciences	• Built a low-cost smartphone image method for citrus. • Used controlled imaging, extracted color features, trained LR and ANN models • Achieved reasonable correlation vs reference chlorophyll.	• Focused on one crop (citrus) — may not generalize to others. • Relies on controlled illumination smartphone camera. • Mostly RGB detection no NIR band. • Low accuracy due to environmental factors.
Smartphone-Based SPAD Value Estimation for Jujube Leaves Using Machine Learning -PMCID: PMC12031054	• Used smartphone images + RGB feature extraction and hybrid ML models to predict SPAD. • Shows ML can reliably map RGB:SPAD when trained with local data • Reports good accuracy for jujube plant.	• Strong species/site dependency, model trained on jujube may not work for citrus/others. • SPAD to absolute chlorophyll conversion still required if you need readable values. • ML models need large labelled datasets across illumination and leaf stages.
A 3D-Printable smartphone accessory for plant leaf chlorophyll measurement -Volume 20 e00597 DOI 10.17605/OSF.IO/93WY4	• Describes a 3D-printable clamp that aligns a 663 nm LED and uses the phone ambient light sensor to measure transmitted light. • validated on five tropical species with good repeatability.	• Uses single red band (663 nm) transmission. • Ambient-sensor based measurement is dependent on phone model and sensor spectral response. • No proper calibration.

LITERATURE REVIEW

TITLE	INFERENCE	LITERATURE GAPS
Extraction Characteristic and Degradation of Chlorophyll from Suji Leaves (Pleomele angustifolia). -	• Chlorophyll is typically extracted using organic solvents (ethanol, acetone, DMF, DMSO), then measured with spectrophotometry (600–700 nm). • Considered the most accurate "gold standard" method.	• Time-consuming and destructive (not suitable for repeated monitoring). • Expensive when applied at scale. • Needs lab setup, impractical for field use. • Needs expertise and wide knowledge.
Relationship among Electrical Signals, Chlorophyll Fluorescence, and Root Vitality of Strawberry Seedlings under Drought Stress. -	• Stem electrical signals (time & frequency features) change under drought stress. • These signals correlate with chlorophyll fluorescence parameters (Fv/Fm, PSII yield). • Also linked to root vitality, showing whole-plant stress response.	• No direct chlorophyll quantification (only fluorescence proxies). • Results are species-specific (tested only on strawberry). • Mechanism behind signal–chlorophyll link not fully explained. • Limited info on sensitivity/early detection limits.
HPLC determination of photosynthetic pigments during greening of etiolated barley leaves — Nakamura et al., FEBS Letters (1998).	• Employed reverse-phase HPLC to separate chlorophyll a, its biosynthetic intermediates. • Demonstrated clean separation of multiple chlorophyll-related compounds. • Provided detailed chromatographic profiles.	• Laboratory-based and not scalable for rapid, field-use or large-scale sampling. • Requires destructive sampling, sophisticated instrumentation, and technical expertise.

LITERATURE REVIEW

TITLE	INFERENCE	LITERATURE GAPS
Retrieval of Leaf Chlorophyll Content using Drone Imagery and Fusion with Sentinel-2 Data. - Priyanka et al., Smart Agricultural Technology (2023)	• High-resolution chlorophyll mapping via fused UAV and satellite spectral data • Accurate machine learning predictions. • Large scale area specific monitoring.	• Requires complex data fusion. • Sensitive to environmental conditions. • Limited standalone portability. • Not plant accurate. • Expensive and not user friendly.
Smartphone-Based Leaf Colorimetric Analysis of Grapevine (Vitis vinifera L.) Genotypes. - Plants, MDPI;2021; Volume & Issue: 10(11):1179	• Used RGB data from smartphone images and derived CIE LxAxB parameters. • Established high correlations between both RGB-based vegetation indices. • Beyond chlorophyll estimation, the colorimetric data could be used to distinguish different genotypes.	• Plant specific not transferrable to other species. • Environmental and Lighting Sensitivity. • Needs deep calibration. • Not accurate up to gold standards.
Mapping chlorophyll-A in Upper Lake Bhopal using IRS-1C data— Geospatial World (Geospatial Media & Communications);2009	• Utilized IRS-1C satellite imagery alongside GIS to model chl-a data spatially within the lake. • Produced a spatial map showing chl-a zones, highlighting polluted areas. • Demonstrated that GIS-based modeling with remote sensing offers a more comprehensive data than traditional point-based interpolation	• Limited Spectral Range. • Region-Specific Model. • The study doesn’t elaborate on atmospheric correction or sensor-specific calibration. • Not accessible to common man. • Needs extensive knowledge

SUMMARY OF LITERATURE SURVEY

- Spectrophotometry – Measures chlorophyll concentration by extracting pigments and analyzing absorbance at specific wavelengths.
- Fluorescence (Chlorophyll Fluorometry) – Uses light excitation to measure chlorophyll fluorescence, indicating photosynthetic activity.
- Hyperspectral Imaging – Captures reflectance across many wavelengths to map chlorophyll distribution in leaves or canopies.
- Remote Sensing (Satellite/Drones) – Uses vegetation indices (NDVI) from reflected light to estimate chlorophyll content over large areas.
- High-Performance Liquid Chromatography (HPLC) – Separates and quantifies individual chlorophyll pigments with high precision.

SUMMARY OF LITERATURE GAPS

- Spectrophotometry – not user friendly, expensive, bulky, destructive.
- Fluorescence (Chlorophyll Fluorometry) – not directly corelated to usable chlorophyll levels, not accurate, needs expertise.
- Hyperspectral Imaging – current products are expensive, not accurate up to gold standards.
- Remote Sensing (Satellite/Drones) – area specific, large scale monitoring, not accurate, needs user expertise.
- High-Performance Liquid Chromatography (HPLC) – expensive setup, not portable, expensive, needs extensive operational knowledge.

OBJECTIVES

Make a product that can achieve the following:

- Easy to use – just turn on and measure.
- High accuracy within 1-2% error of gold standards.
- Compatible with all species of plants.
- Non-Destructive testing.
- Low interference from environment (Automated calibration).
- Anti Glare OLED display for use in sunny environment.
- Compact and portable with in built battery power and type-c charging.
- Easy to use even by un-educated people.
- Affordable to everyone (<5,000Rs).
- Web-Dashboard with wireless data transfer from device to server.

METHODOLOGY

- PROBLEM IDENTIFICATION
- EXISTING PRODUCTS
- IDEA FORMULATION
- COMPONENT SELECTION
- SCHEMATIC DESIGNING
- PCB DESIGNING
- CAD MODEL DESIGNIN
- ASSEMBLY OF PRODUCT
- BASE TRUTH MEASURMENT
- PRODUCT VALIDATION

EXISTING PRODUCTS

SPAD METER
>1 LAKH

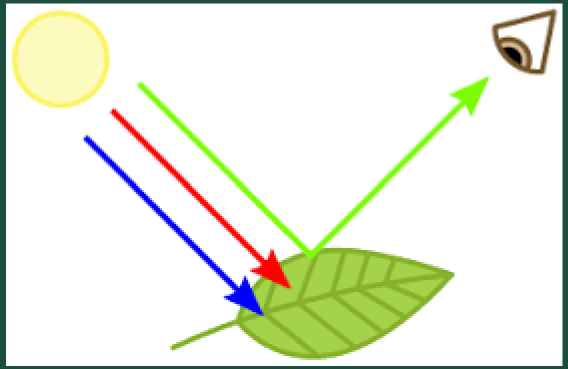
APOGEE MC-100
>1 LAKH

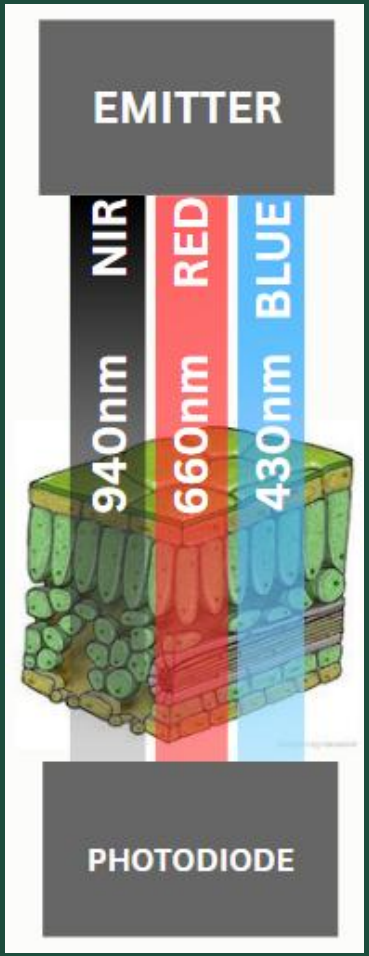
SPECTROMETER
>30 LAKHS
NEEDS EXPERTISE

AT-LEAF
>60,000
LOW-ACCURACY

CONCEPT

NDVI (Normalized Difference Vegetation Index) = $$NDVI = \frac{NIR - Red}{NIR + Red}$$





Chlorophyll Index = $$CI_{Blue} = \frac{R_{NIR}}{R_{Blue}} - 1$$

Modified Chlorophyll = Formula

- $Chl\% \propto \frac{R_{NIR} - R_{Red}}{R_{NIR} + R_{Blue}}$
- $\mathrm{Chl}\% = a \cdot \left(\frac{R_{940} - R_{660}}{R_{940} + R_{468}} \right) + b$
- $a = \frac{\sum_{i=1}^{n} (Index_i - \bar{Index})(Chl\%_i - \bar{Chl\%})}{\sum_{i=1}^{n} (Index_i - \bar{Index})^2}$
- $b = \bar{Chl\%} - a \cdot \bar{Index}$
- $Index_i = \frac{R_{940,i} - R_{660,i}}{R_{940,i} + R_{468,i}}$

CONCEPT

Modified Chlorophyll = Formula

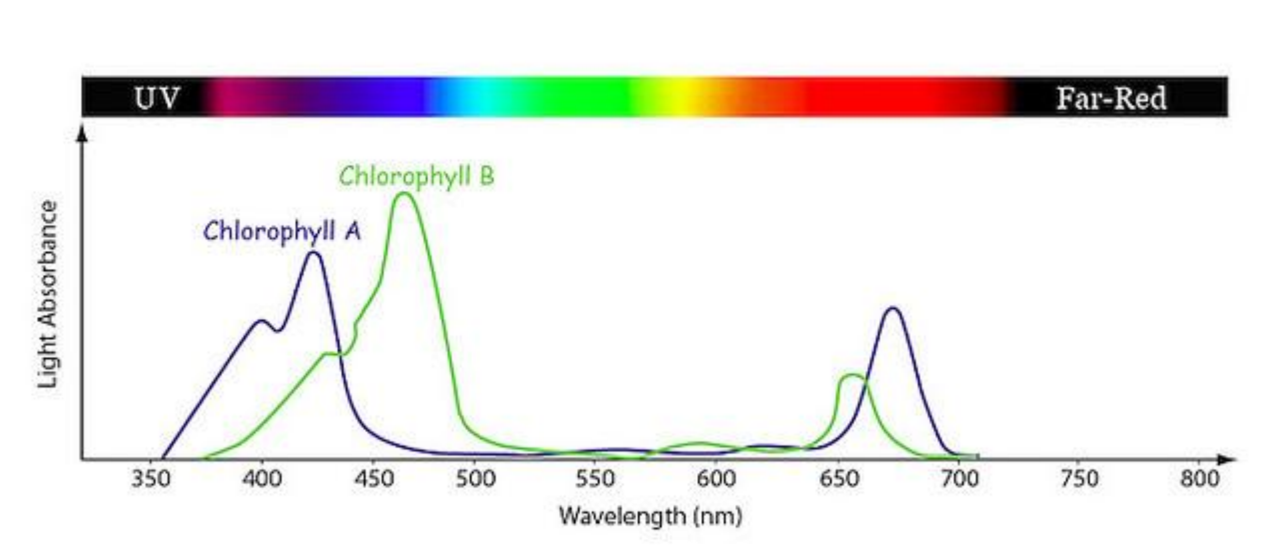
- $Chl\% \propto \frac{R_{NIR} - R_{Red}}{R_{NIR} + R_{Blue}}$
- $\mathrm{Chl\%} = a \cdot \left(\frac{R_{940} - R_{660}}{R_{940} + R_{468}} \right) + b$
- $a = \frac{\sum_{i=1}^{n}(Index_i - \bar{Index})(Chl\%_i - \bar{Chl\%})}{\sum_{i=1}^{n}(Index_i - \bar{Index})^2}$
- $b = \bar{Chl\%} - a \cdot \bar{Index}$
- $Index_i = \frac{R_{940,i} - R_{660,i}}{R_{940,i} + R_{468,i}}$

MAX ABSORPTION AT:
400-450nm (BLUE)
650-700nm (RED)

NIR(940nm) is used as differential baseline

NDWI (Normalized Differential Water Index) = $\mathrm{NDWI}_{940} = \frac{R_{940} - R_{660}}{R_{940} + R_{660}}$

*INTEGRATED TO MEASURE THE WATER CONTENT IN THE LEAF



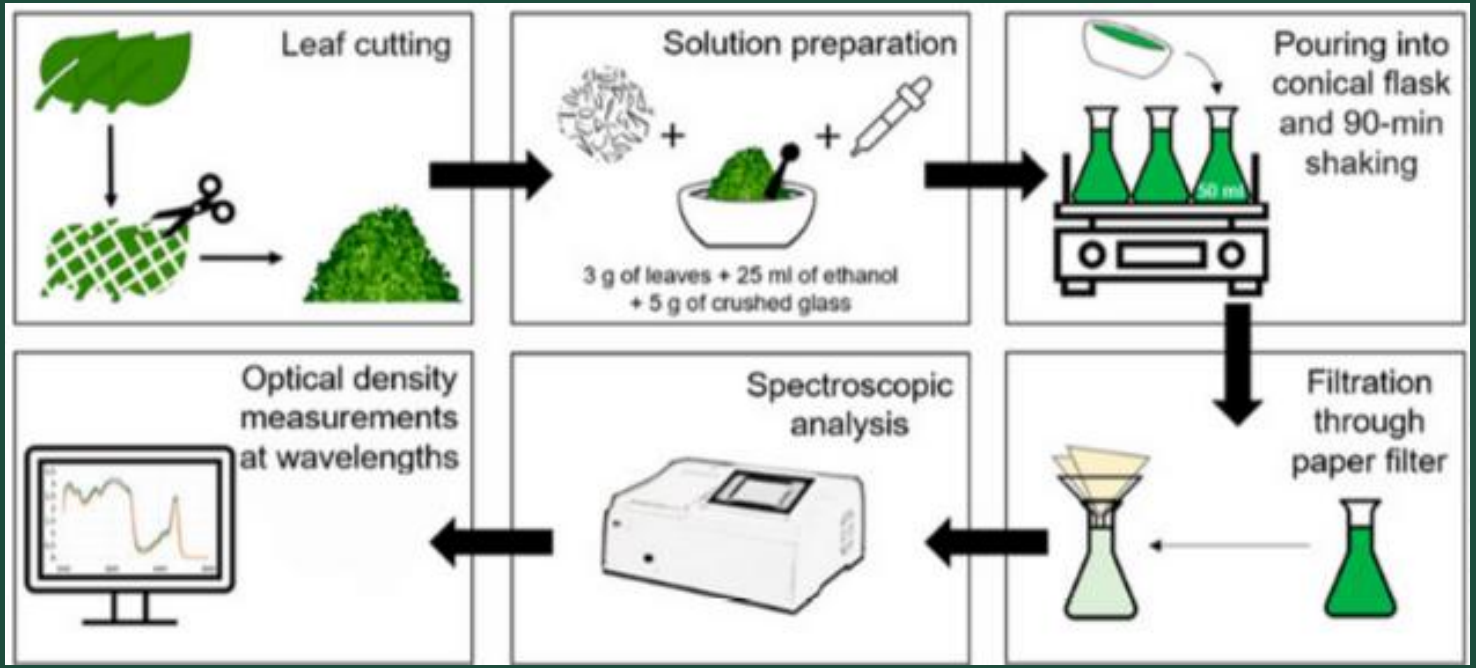
BASE TRUTH MEASURMENT

Chlorophyll :

$$a = \frac{\sum_{i=1}^{n}(Index_i - In\bar{d}ex)(Chl\%_i - C\bar{h}l\%)}{\sum_{i=1}^{n}(Index_i - In\bar{d}ex)^2}$$

$$b = C\bar{h}l\% - a \cdot In\bar{d}ex$$

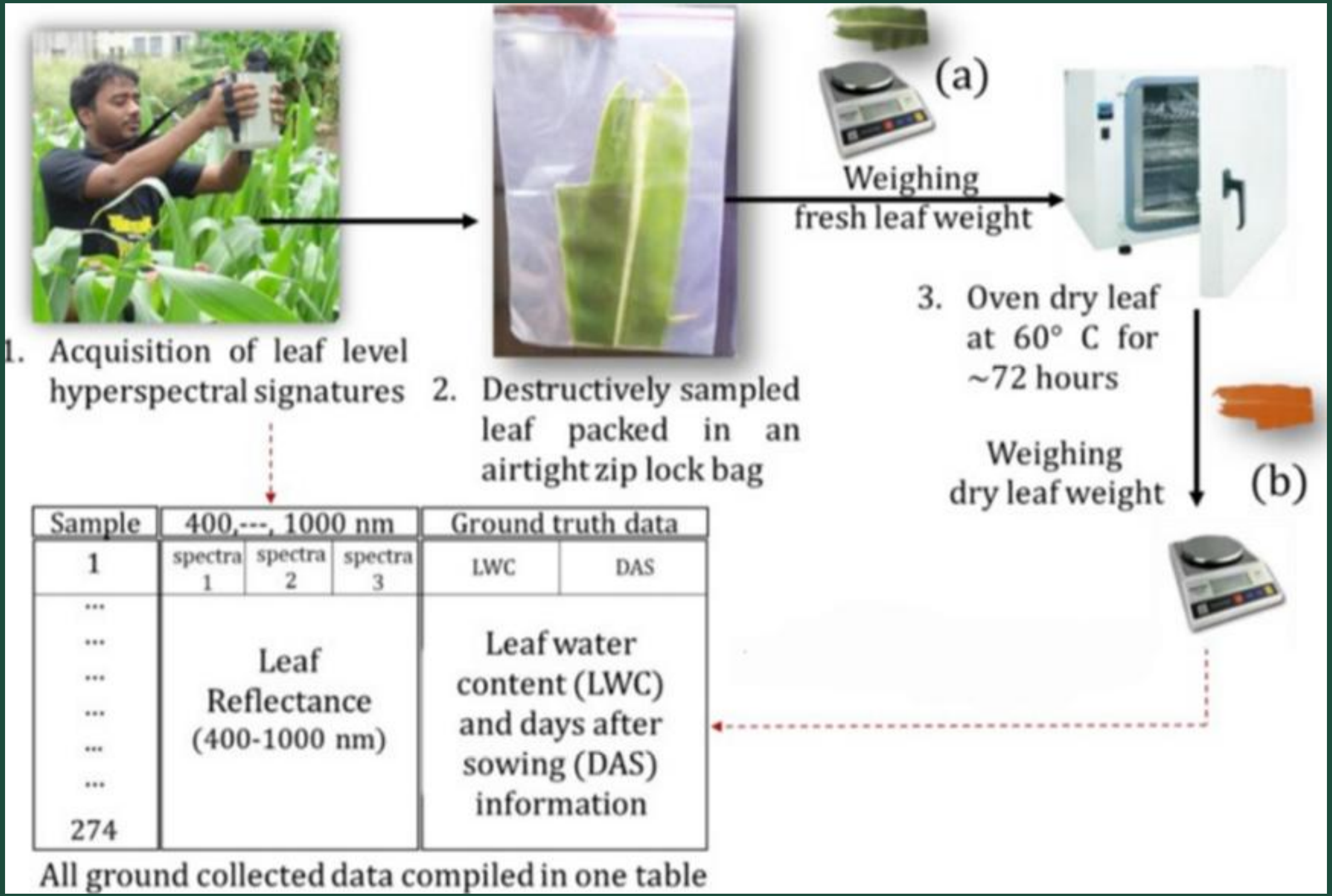
$$Index_i = \frac{R_{940,i} - R_{660,i}}{R_{940,i} + R_{468,i}}$$



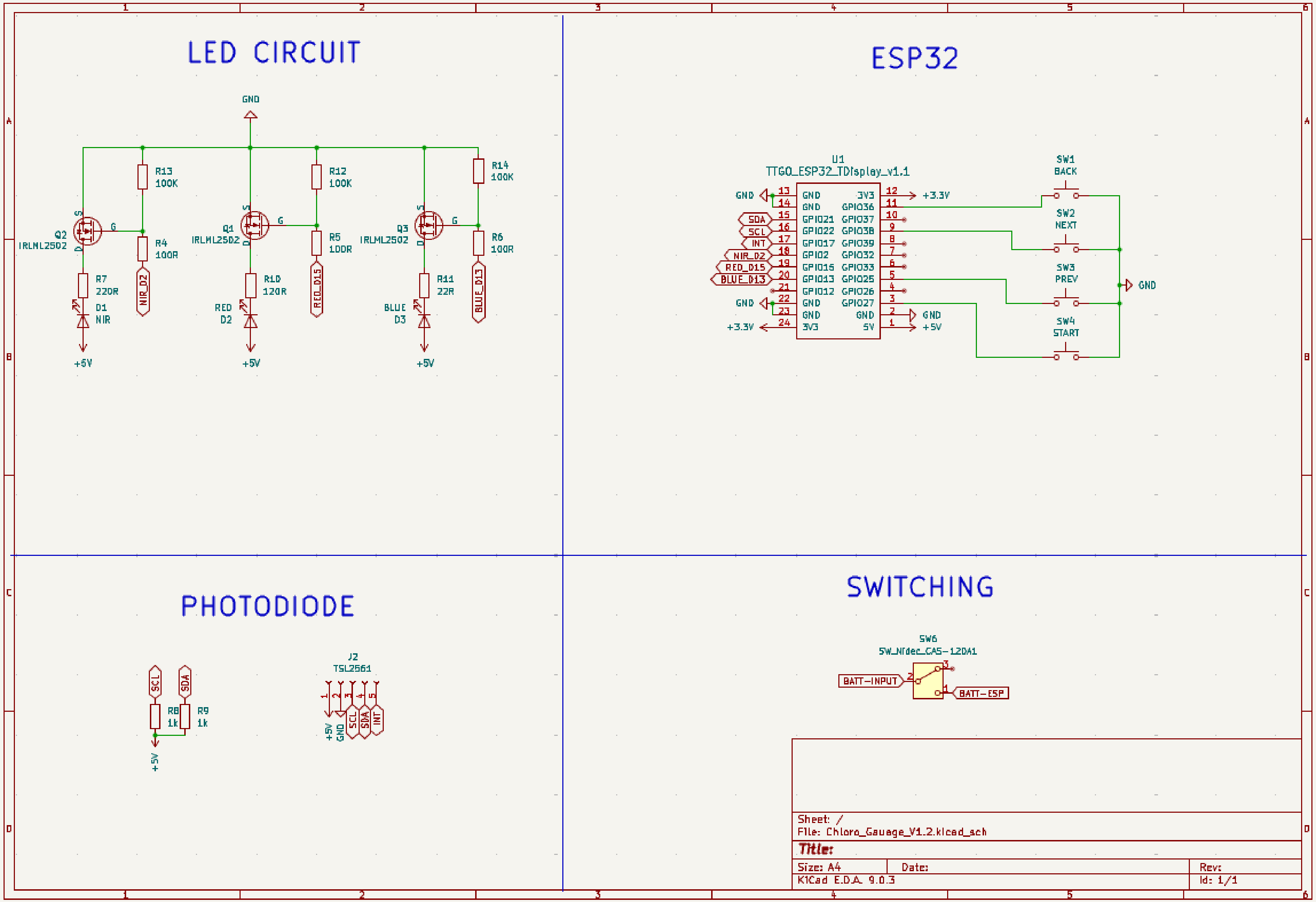
BASE TRUTH MEASURMENT

Water Content :

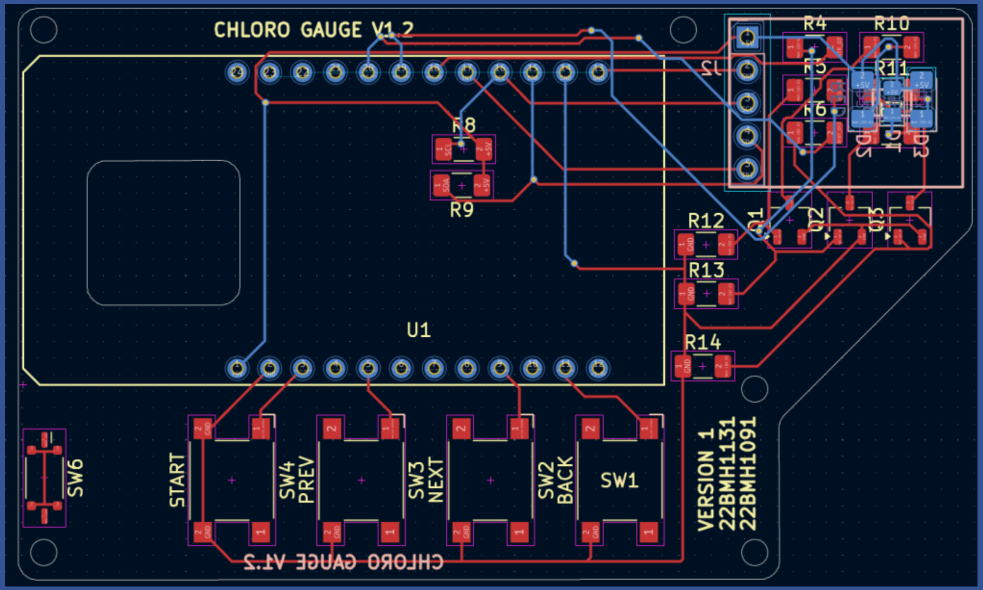
NDWI (Normalized Differential Water Index) = $\text{NDWI}_{940} = \frac{R_{940} - R_{660}}{R_{940} + R_{660}}$



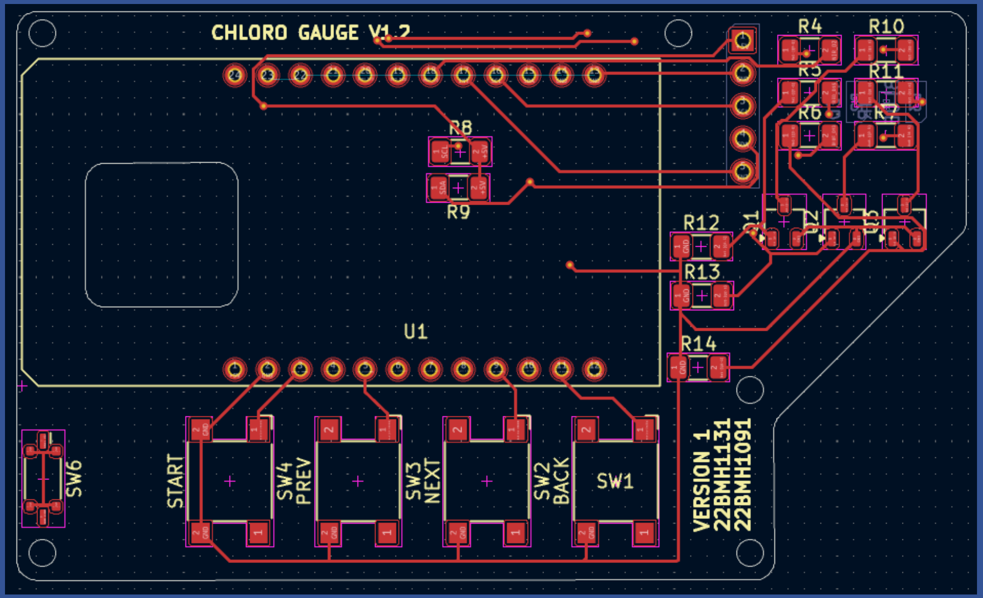
SCHEMATIC


LED CIRCUIT
ESP32
PHOTODIODE
SWITCHING
GND
R13
100K
R12
100K
R14
100K
Q2
IRLML2502
Q1
IRLML2502
Q3
IRLML2502
R4
100R
R5
100R
R6
100R
NIR_D2
RED_D15
BLUE_D13
R7
220R
R10
120R
R11
22R
D1
NIR
RED
D2
BLUE
D3
+5V
U1
TTGO_ESP32_TDisplay_v1.1
SW1
BACK
SW2
NEXT
SW3
PREV
SW4
START
+3.3V
SDA
SCL
INT
J2
TSL2561
R8
1k
R9
1k
SW6
SW_Nidec_CAS-120A1
BATT-INPUT
BATT-ESP
Sheet: /
File: Chloro_Gauage_V1.2.kicad_sch
Title:
Size: A4
Date:
Rev:
KiCad E.D.A. 9.0.3
Id: 1/1

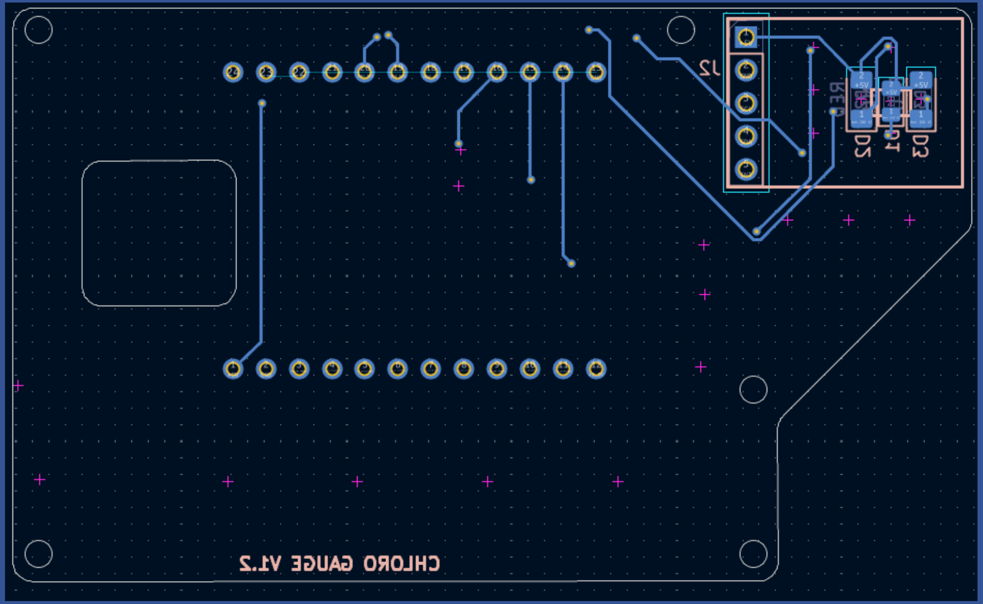
PCB



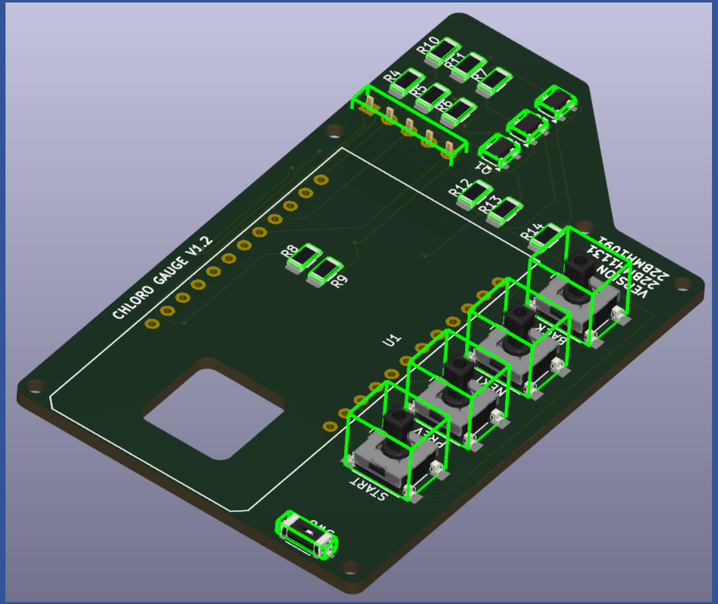
Full View



Cu-Top Layer

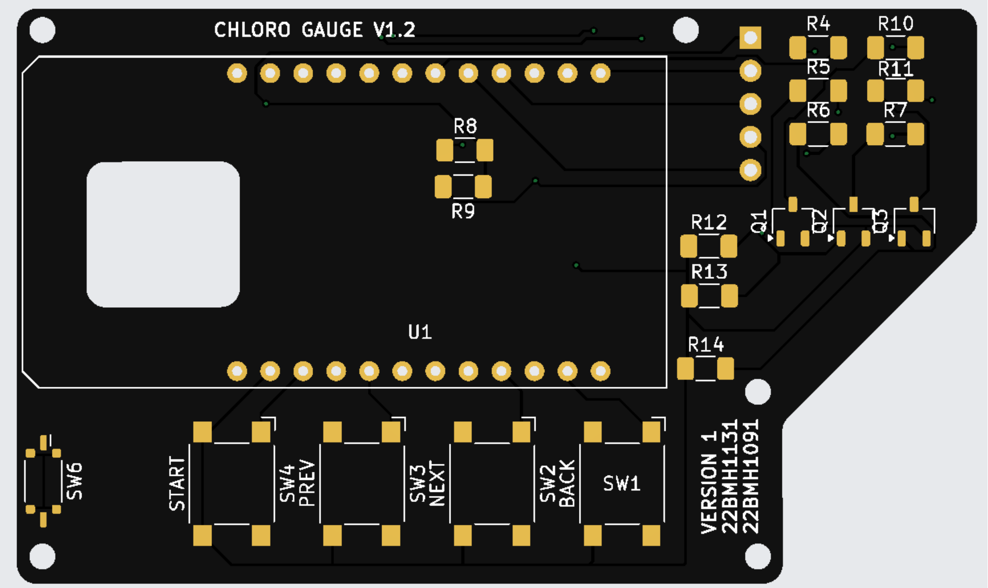


Cu-Bottom Layer

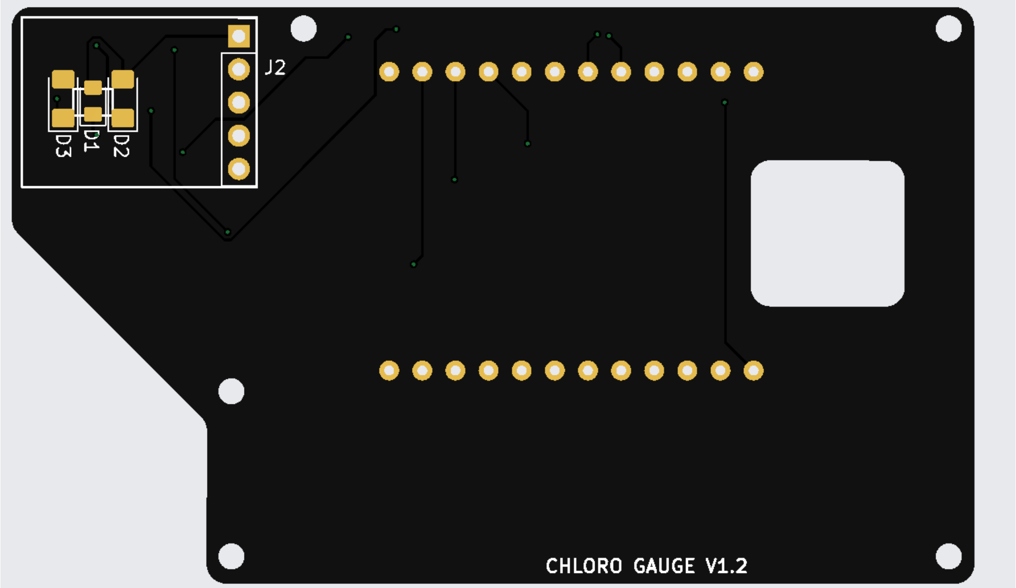


3D-View

PRODUCTION PCB

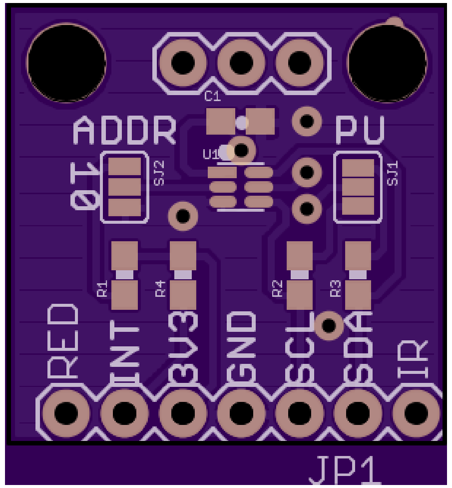


Top Side

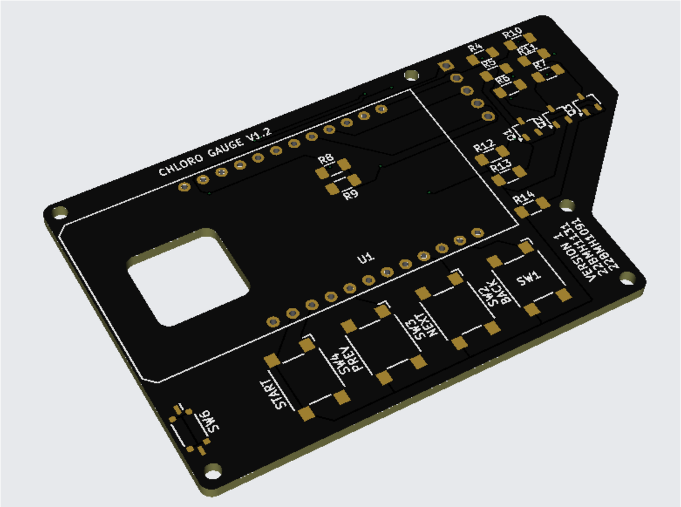


Bottom Side

- FR-4
- 2 Layers
- 1oZ Copper
- JLC PCB

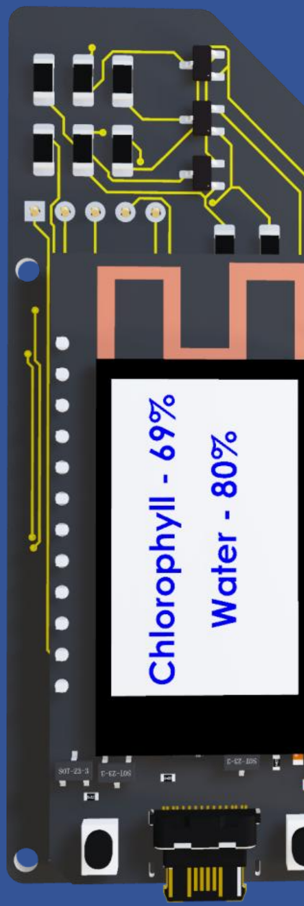


Photodiode Circuit

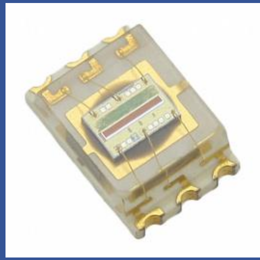


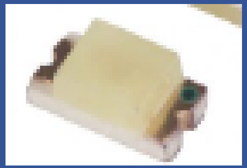
3D- View

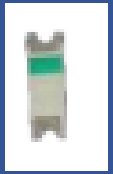
COMPONENTS



COMPONENT	NAME	WAVELENGTH	MAX VOLTAGE
IR17-21C/TR8	NIR SMD LED	940nm	1.5v
23-21B/BHC-AP1Q2/2A	BLUE SMD LED	468 nm	3.3v
SML-LX1206SRC-TR	RED SMD LED	660nm	2.2v
IRLML2502TR	N-MOS	-	20v
TSL2561	LDC	300~1100nm	3.6v
LILYGO-T-ESP32	ESP32	-	-
3.7v-LIPO	Battery 1500mah	-	3.7

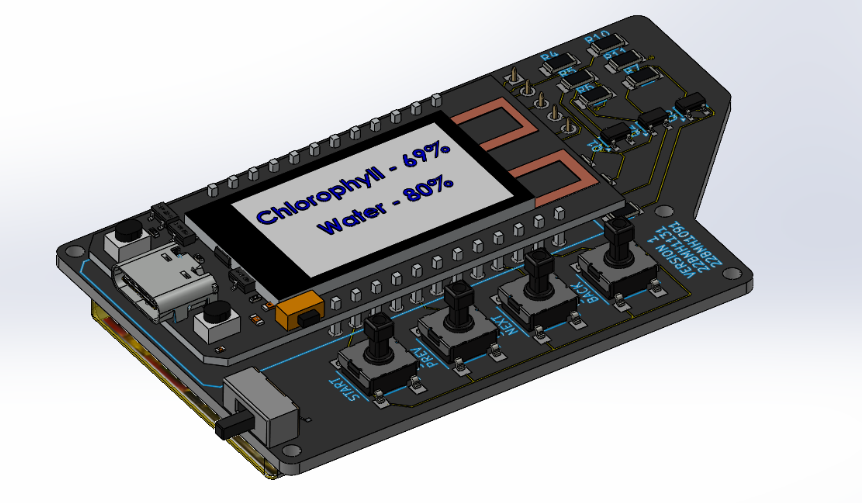


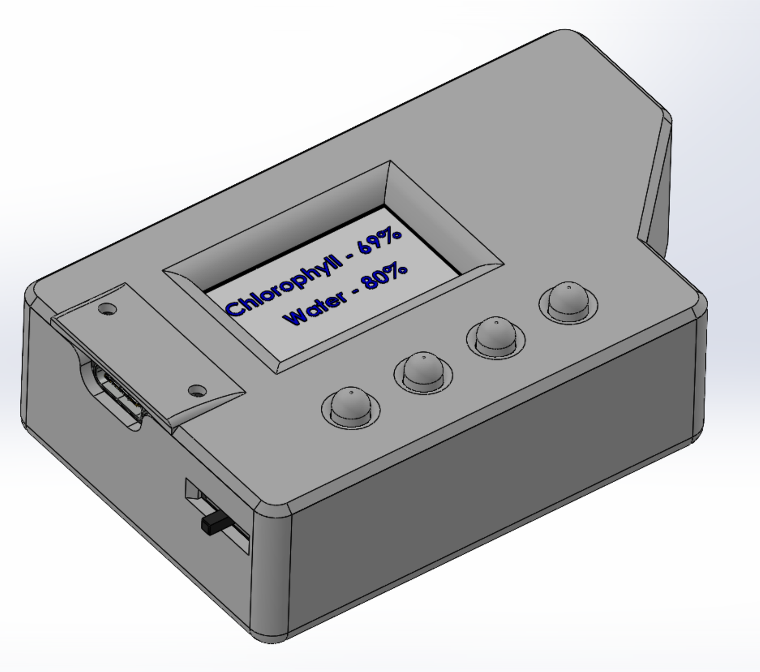


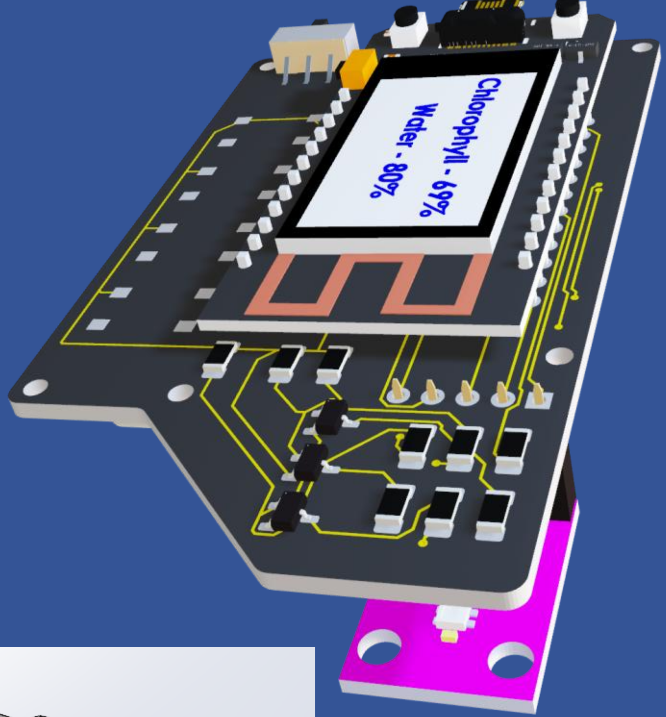


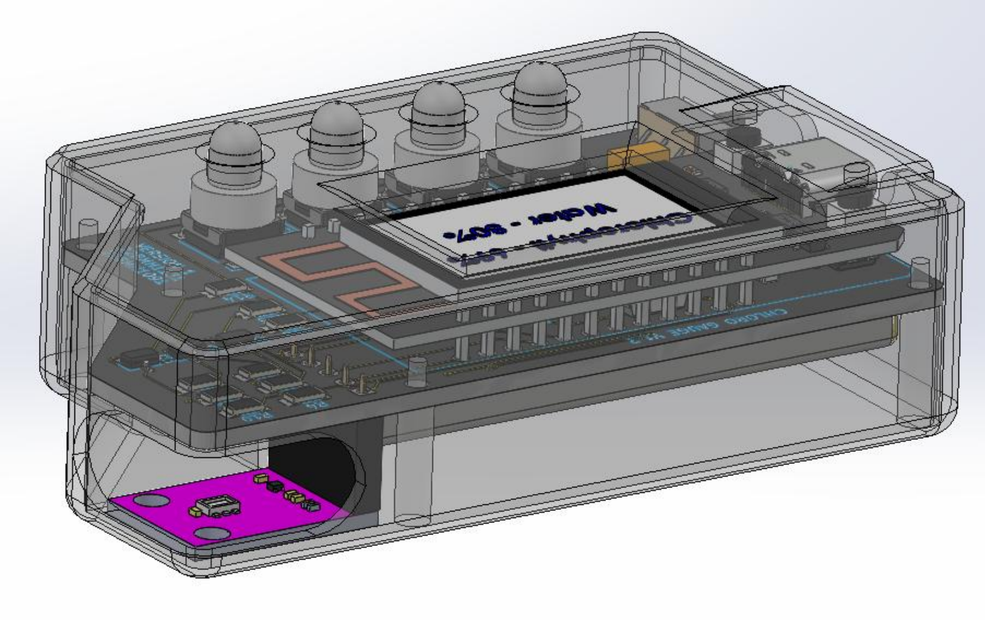
APPROX PROTOTYPING COSTING – 3000/-

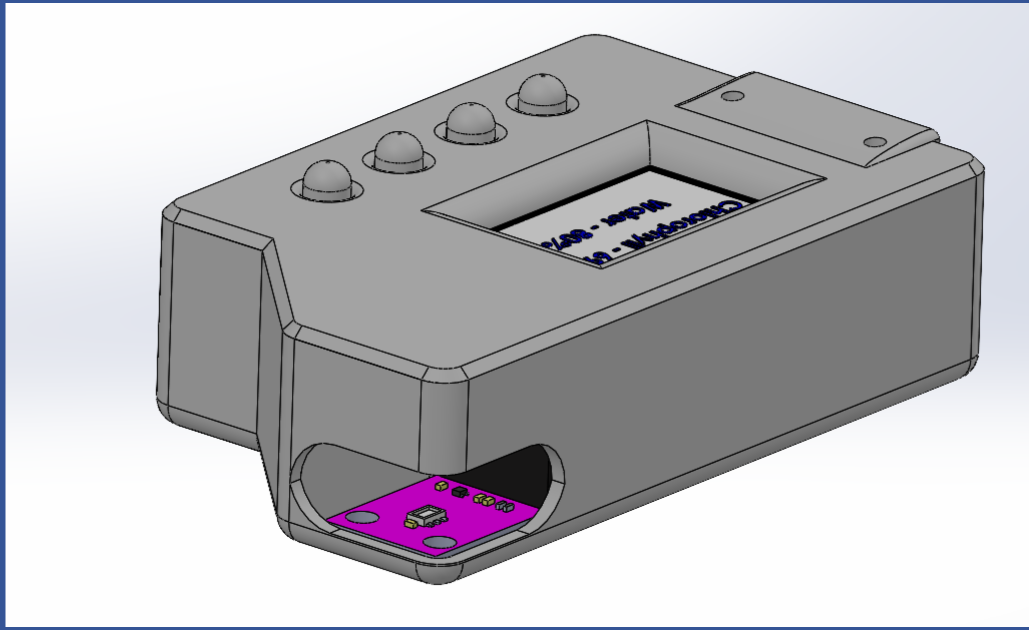
CAD MODEL


Chlorophyll - 69%
Water - 80%
START
PREV
NEXT
BACK


Chlorophyll - 69%
Water - 80%

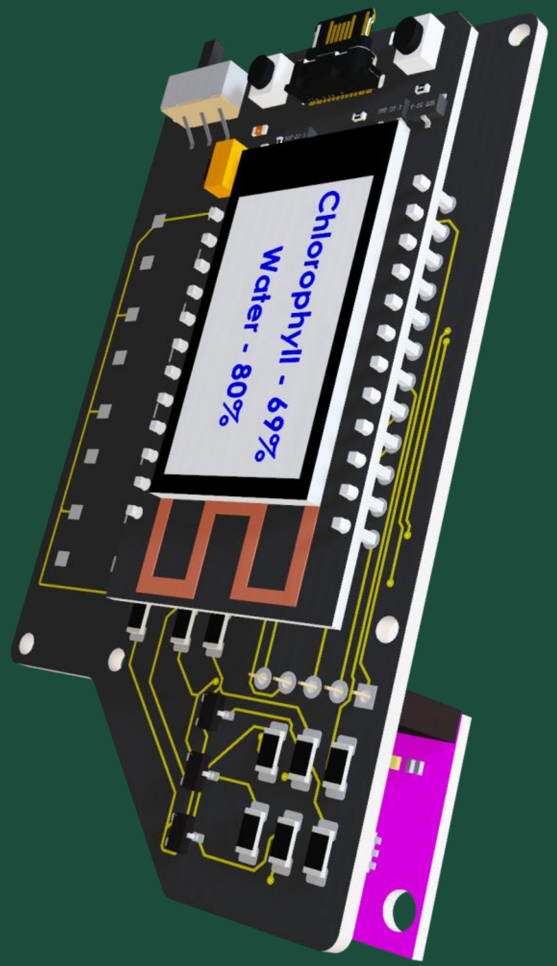

Chlorophyll - 69%
Water - 80%



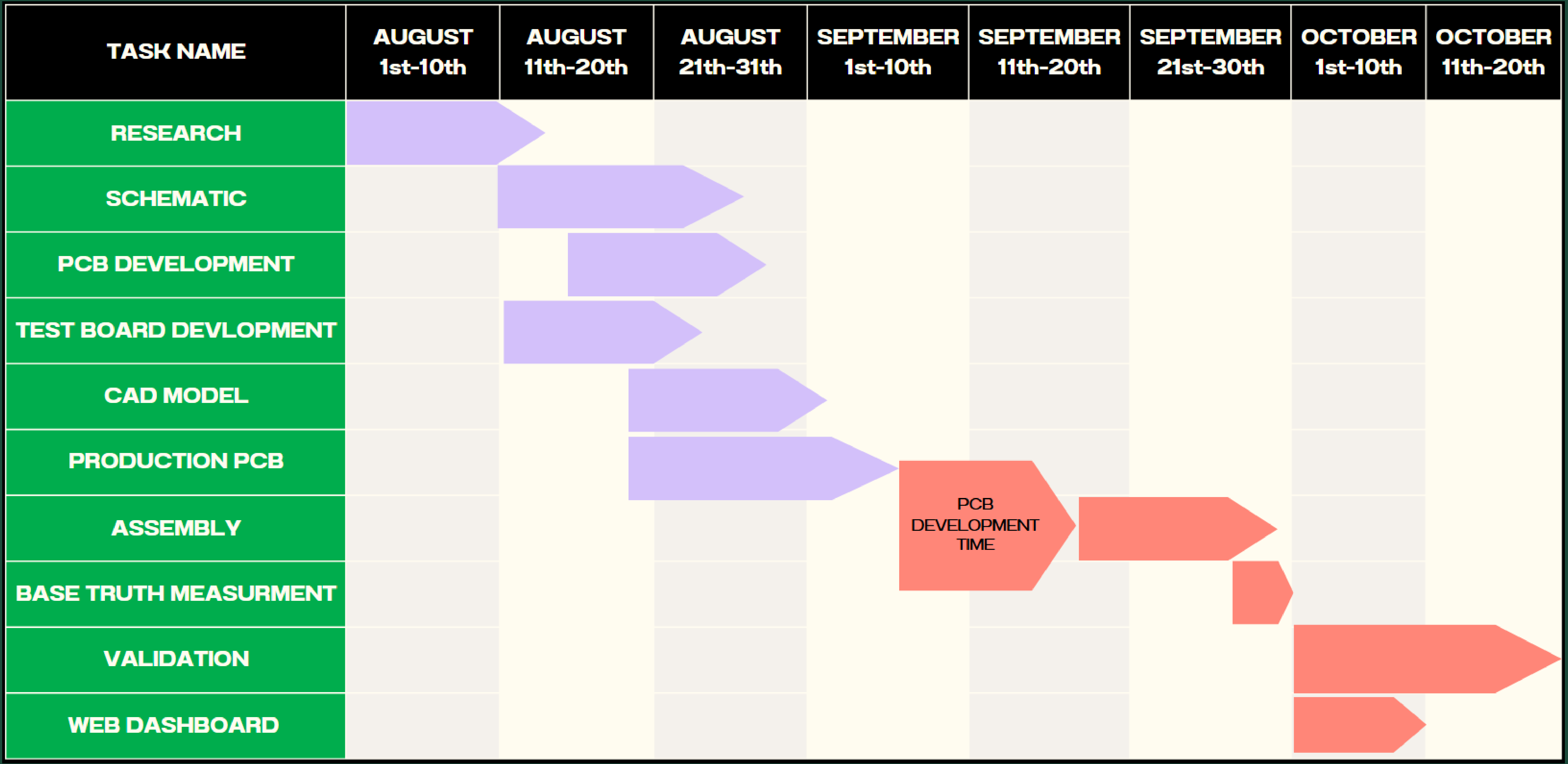


FUTURE PLANS

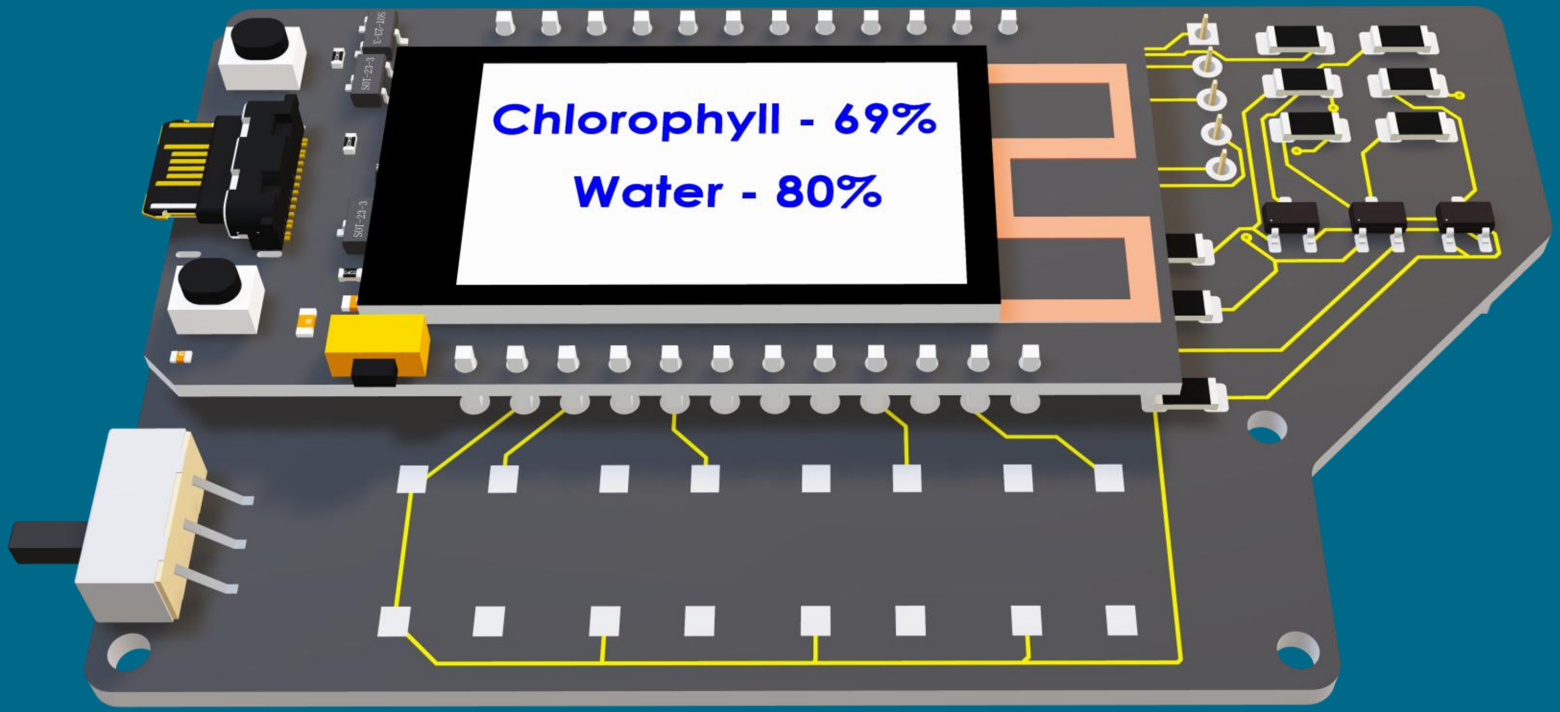
1. Manufacturing main PCB through JLC pcb.
2. Assembly of product with necessary components.
3. Validation of performance of components.
4. Base Truth measurement and calculation.
5. Real world calibration and validation.
6. Web dashboard with BLYNK.



TIMELINE


TASK NAME
AUGUST 1st-10th
AUGUST 11th-20th
AUGUST 21th-31th
SEPTEMBER 1st-10th
SEPTEMBER 11th-20th
SEPTEMBER 21st-30th
OCTOBER 1st-10th
OCTOBER 11th-20th
RESEARCH
SCHEMATIC
PCB DEVELOPMENT
TEST BOARD DEVLOPMENT
CAD MODEL
PRODUCTION PCB
ASSEMBLY
BASE TRUTH MEASURMENT
VALIDATION
WEB DASHBOARD
PCB DEVELOPMENT TIME

THANK YOU



“If agriculture goes wrong, nothing else can go right in a country. Tech must serve the soil, not just the market.” - *M.S. Swaminathan (Father of the Indian Green Revolution)*