ECE 445 - Senior Design Project

Auto-Adjusted Smart Desk Lamp for Healthy Lighting

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ECE 445 – Senior Design Project

Slide 2: Problem Statement, Solution, High-level Requirements

2.1 Problem

- Prolonged desk work under poor lighting → **eye strain, headaches, fatigue**
- Most desk lamps are **static** → manual adjustment needed, no adaptation to daylight/tasks
- Result: lighting often **too dim or too bright**, reducing comfort and productivity
- **Digital eye strain** is rising with screen use; poor desk lighting worsens the problem

Slide 2: Problem Statement, Solution, High-level Requirements

2.2 Solution

- **Smart desk lamp** that adapts to surrounding lighting in real time
- **Sensors**: ambient brightness + color temperature
- **MCU (ESP32)**: processes data, filters noise, applies control logic
- **LEDs**: warm white (2700–3000K) + cool white (6000–6500K)
  - Mixed via **PWM** to achieve wide **Correlated Color Temperature** range (color of light represented in number)
  - Current Driven by **Mosfets** for stability for each LEDs
- **Smooth transitions**: gamma correction + rate limiter (no flicker or jumps)

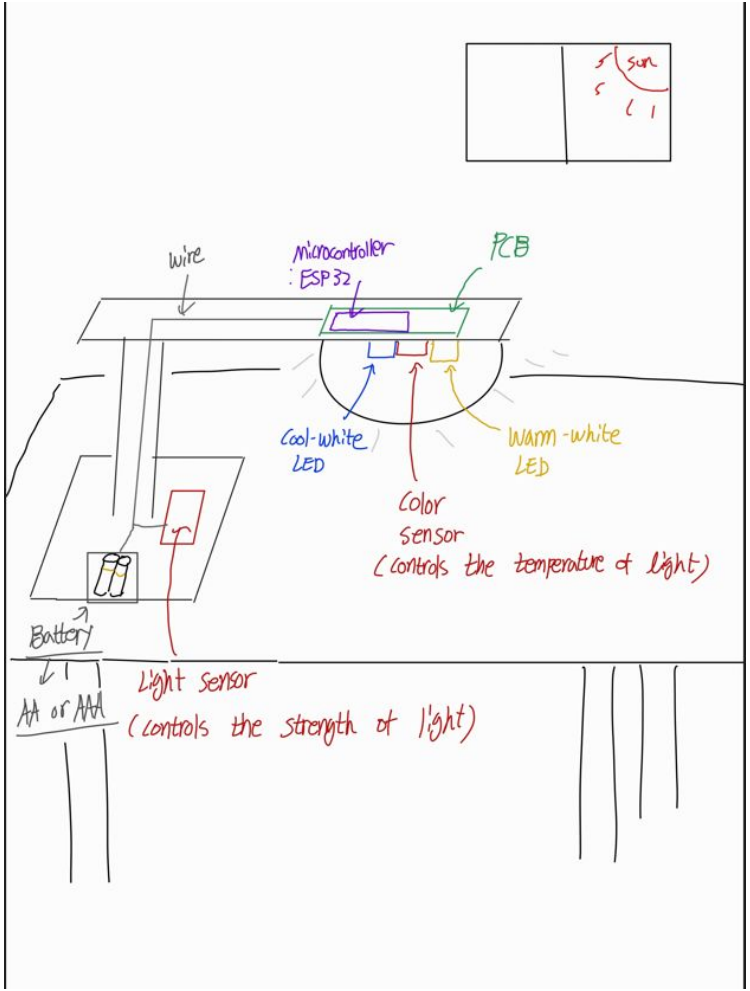
Slide 2: Problem Statement, Solution, High-level Requirements

2.3 High-Level Requirements

1. The lamp must maintain the desk surface illumination within **±10% of the target brightness**:
    - **Study Mode:** ~500 lux
    - **Relax Mode:** ~300 lux
    - Must adapt even as surrounding light conditions change.
2. The lamp must adjust **brightness and color temperature smoothly**, with transitions limited to **≤2% change per second**, ensuring no visible flicker or sudden jumps.
3. The lamp must achieve at least **30% power savings** compared to full brightness when sufficient ambient daylight is present.

Slide 3: Conceptual Design

- **2 Sensors:** 1 measure room light + 1 color temperature.
- **MCU (ESP32):** processes data, decides lamp output.
- **Mosfets:** Controlling the Current to the LED from Power source
- **LED Sources:** warm-white + cool-white LEDs for adjustable CCT.



Slide 4: Light Sensors

Light Sensor: OPT101P

Description from Datasheet : It is a photodiode integrated with an on-chip transimpedance amplifier and a factory trimmed 1M ohms feedback resistor

Reason for Choosing this sensor:

- Output of the sensor is in analog voltage that we can directly use it with a ADC on our microcontroller chip.
- Sensor has a internal amplifier. So we do not have to amplify the signal again on external circuit
- It can work with a ESP32 chips, which can provide up to 3.3v to the sensor.

Product Index > Sensors, Transducers > Optical Sensors > Ambient Light, IR, UV Sensors > Texas Instruments OPT101P

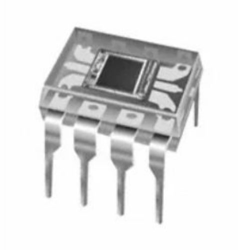


Image shown is a representation only. Exact specifications should be obtained from the product data sheet.

OPT101P

DigiKey Part Number	296-23090-5-ND
Manufacturer	Texas Instruments
Manufacturer Product Number	OPT101P
Description	SENSOR OPT 650NMAMB 8 DIP
Manufacturer Standard Lead Time	12 Weeks
Customer Reference	
Detailed Description	Optical Sensor Ambient 650nm Voltage 8-DIP (0.300", 7.62mm)
Datasheet	Datasheet
EDA/CAD Models	OPT101P Models

1 Features

- Single Supply: 2.7 to 36 V

Slide 5: Color Sensors (2 options available)

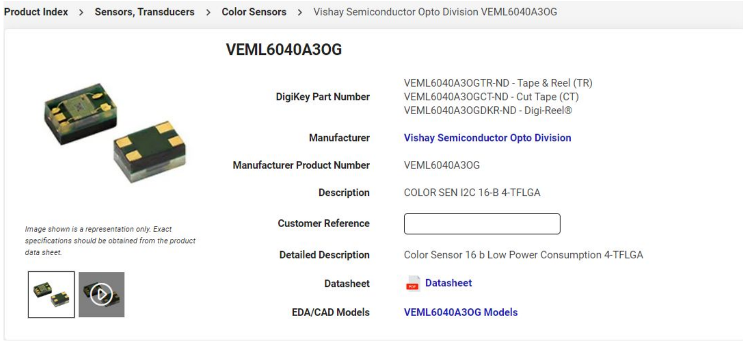
Color Sensor :VEML6040

-Tiny, Standalone color sensor for the pcb

-Supports I2R protocol for communication with microcontroller.

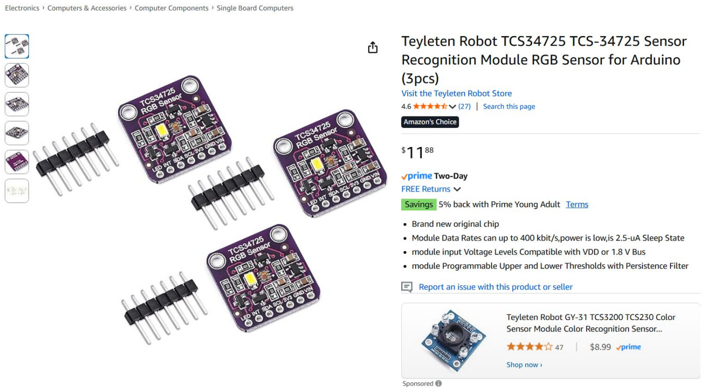
However, **Big challenges** are existing using this standalone sensor

VEML6040 is a **tiny 2×1.25x1.00 mm surface-mount package** → very hard to solder by hand



Color Sensor [Backup]: TCS-34725

- **Most popular color sensor** in the commercial and for project
- Easy soldering & convenient I2R protocol for communication with microcontroller.
- **We will try our best to use VEML6040.** But if we failed to solder it on PCB due to the small size of it, **TCS-34725** will be used as a backup sensor for easy soldering on pcb as a color sensor



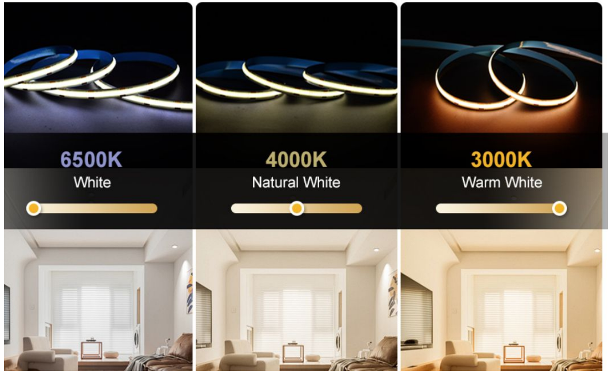
Slide 5: LED White Lighting Sources

- **Warm White (2700–3000K)** – natural indoor / evening light.
- **Cool White (6000–6500K)** – daylight / productivity light.

Using two 12V LED channels (warm + cool) for tunable white.

LED strips mount easily to the PCB and provide sufficient, directed illumination.

The MCU reads light and color sensors, computes target lux/CCT, then drives each LED driver’s DIM pin (PWM) to set channel current and control each strip’s brightness.



Slide 6: Mosfets that control the amount of current into LED source

We selected the **IRLML0030TRPbF** MOSFET from the ECE Shop.

- It can block up to **30 V** across drain–source, while our input is only **12 V**, so it is safe to use.
- Its **gate threshold voltage (Vgs(th)) is ~1.7 V** (1.3–2.3 V range), which means the **ESP32's 3.3 V PWM** signal can fully switch it on.
- This allows us to reliably control LED strip current and brightness by applying PWM to the gate.

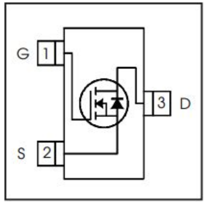
International
IOR Rectifier

PD - 96278B

IRLML0030TRPbF

HEXFET® Power MOSFET

V_{DS}	30	V
$V_{GS\ Max}$	± 20	V
$R_{DS(on)\ max}$ (@V_{GS} = 10V)	27	mΩ
$R_{DS(on)\ max}$ (@V_{GS} = 4.5V)	40	mΩ



Micro3[TM] (SOT-23)
IRLML0030TRPbF

Electric Characteristics @ T_J = 25°C (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)DSS}$	Drain-to-Source Breakdown Voltage	30	—	—	V	V_{GS} = 0V, I_D = 250μA
$\Delta V_{(BR)DSS}/\Delta T_J$	Breakdown Voltage Temp. Coefficient	—	0.02	—	V/°C	Reference to 25°C, I_D = 1mA
$R_{DS(on)}$	Static Drain-to-Source On-Resistance	—	33	40	mΩ	V_{GS} = 4.5V, I_D = 4.2A ②
		—	22	27		V_{GS} = 10V, I_D = 5.2A ②
$V_{GS(th)}$	Gate Threshold Voltage	1.3	1.7	2.3	V	V_{DS} = V_{GS}, I_D = 25μA

Slide 7: Microcontroller Choice

Slide 6: Microcontroller Choice

- **ESP32** (primary candidate):
  - Multiple ADC/I²C channels for sensors.
  - PWM outputs for LED dimming.

***compare to other MCs available

*know how i2c works

*adc for sensor -> MC

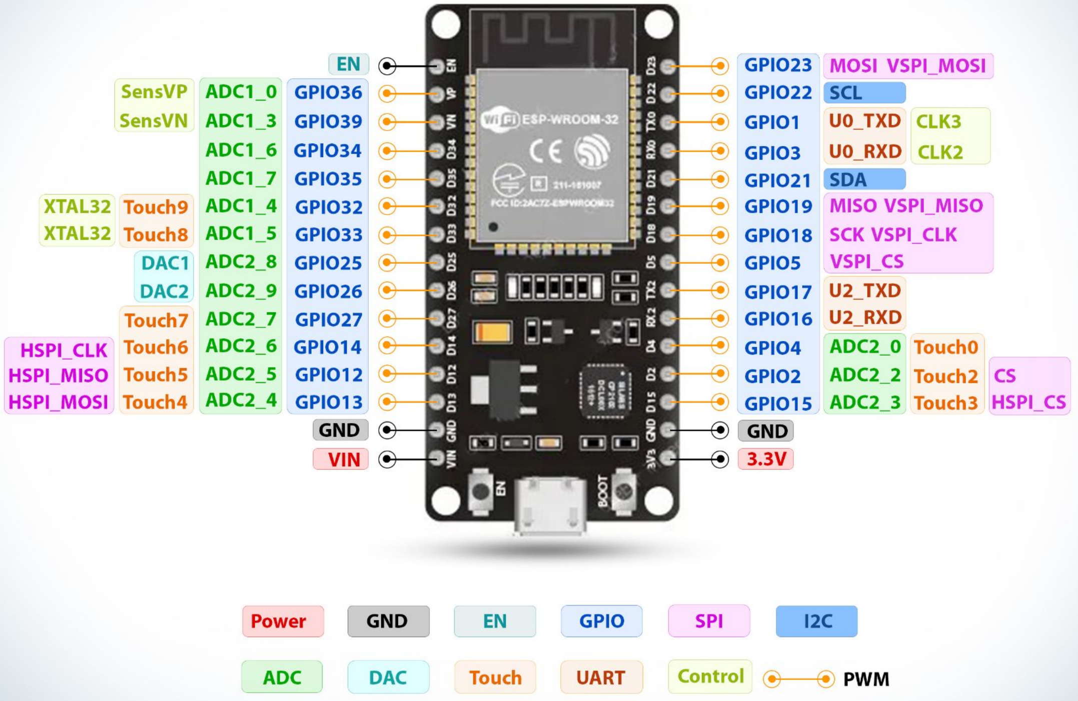
*pwm for output

Reference link for alternative RGB Led project from youtube

esp 32 datasheet en.pdf

https://www.youtube.com/watch?v=lMaDJlYp29s

ESP32 DEV. BOARD PINOUT



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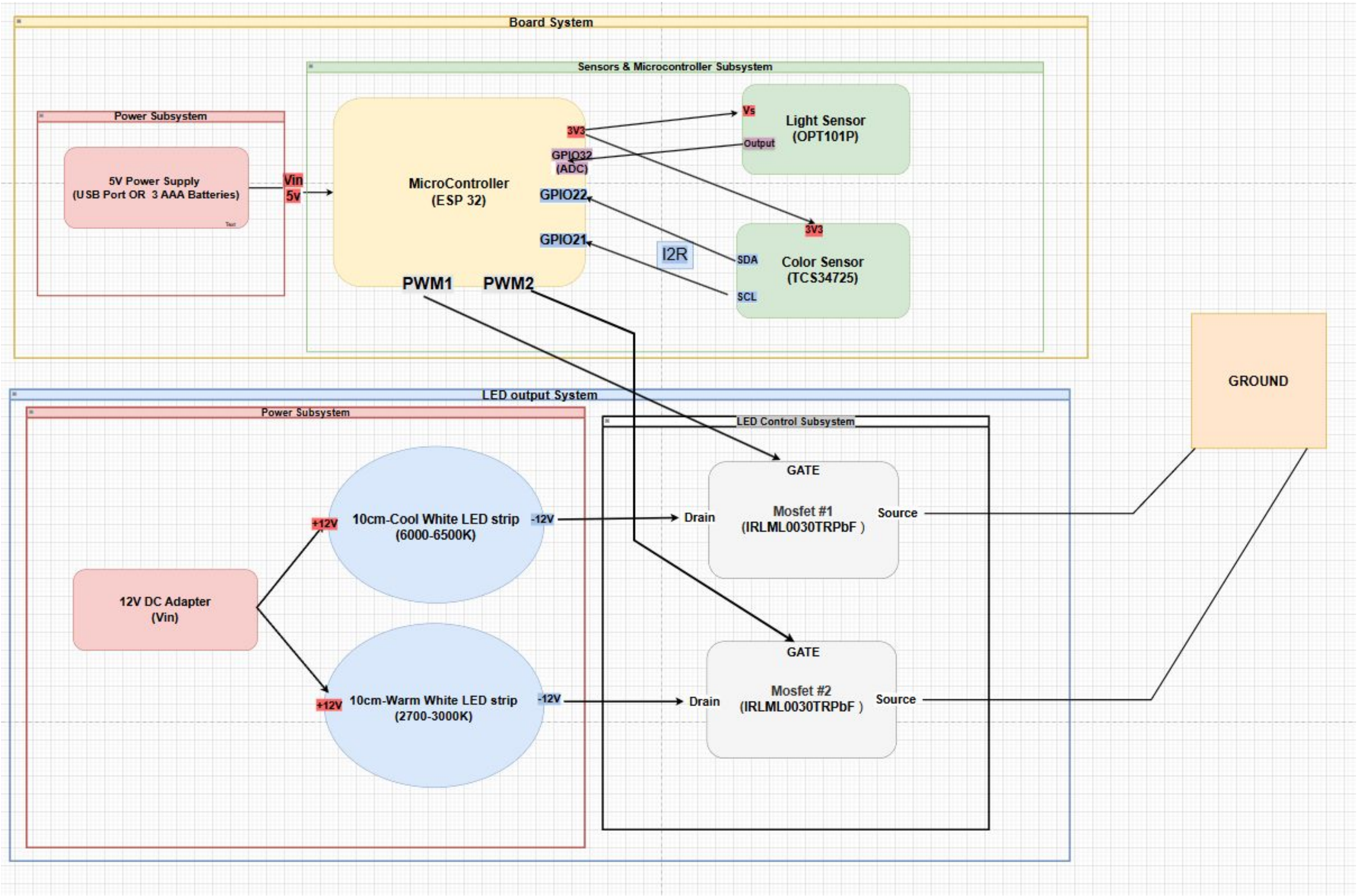
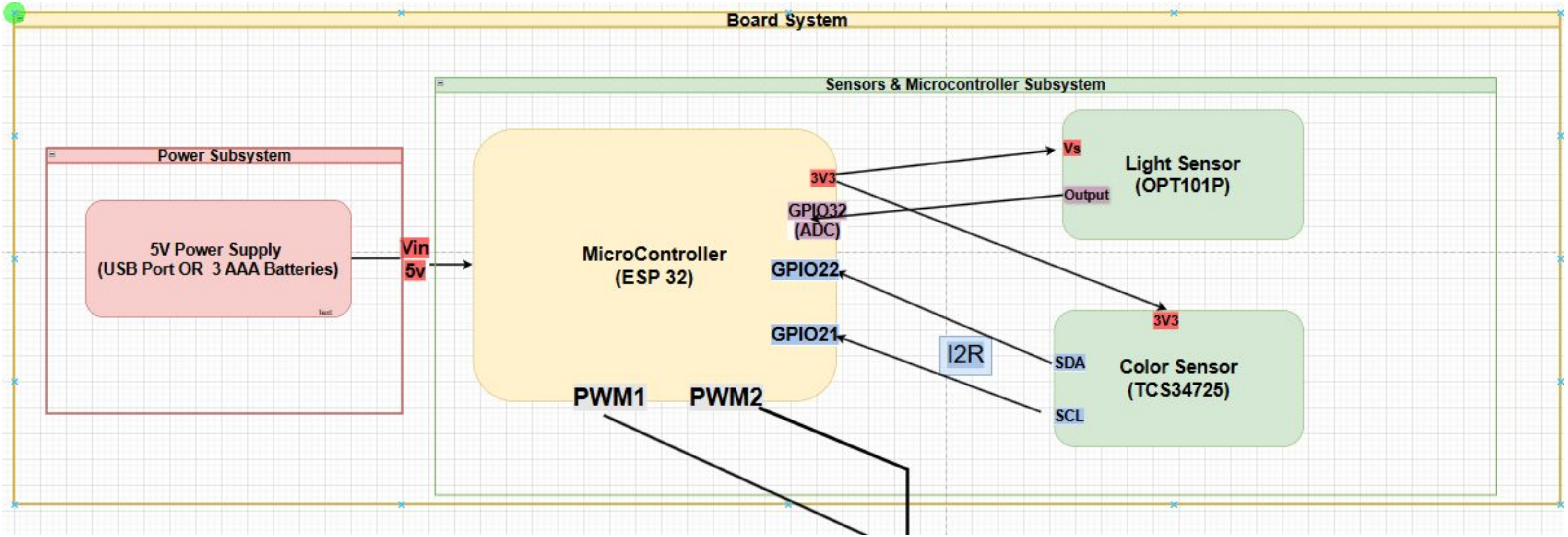
Block Diagram



Sensors & Microcontroller Subsystem Close-up

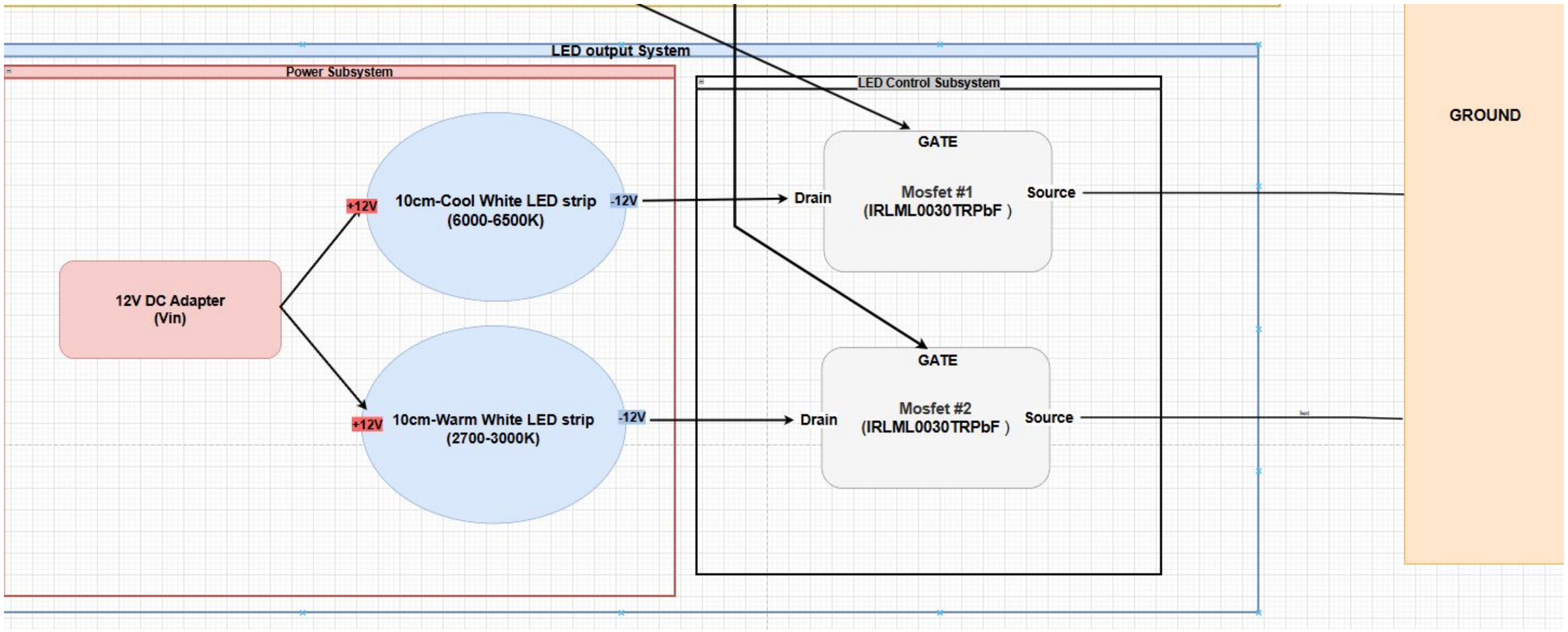


The main goals of this subsystem are 1) **Powering** sensors & MCU

2) **Collecting** Datas from sensors into MCU

3) **Sending** PWM signal into MOSFET's Gate based on the datas from sensors.

LED Output Subsystems Close-up



The main goals of this subsystem are 1) **Powering** LEDs from 12V DC Adapter

2) **Controlling** amount of currents flowing through LEDs with MOSFETs