UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Solar-Powered Traffic Light

ECE 445 - Team 20

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Roles

Bowen Xiao (EE)

- Circuit/PCB design

Richard Przybek (CompE)

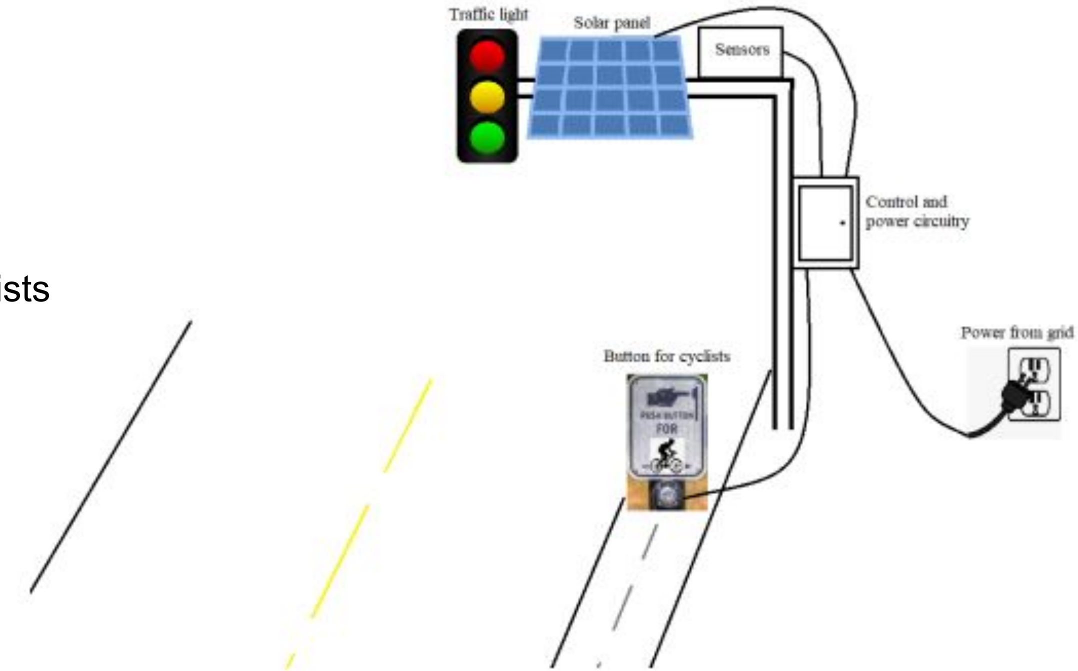
- Firmware design and development

Colin Tarkowski (EE)

- Circuit/PCB design and simulation

Problems

- High energy consumption and costs
- Light pollution due to bright LEDs
- Dangerous encounters between bicyclists and drivers



Visual aid

Objectives

- Automatically switch between solar and grid power based on available sunlight
    - Cannot operate solely on solar power, but will drastically reduce the utilization of grid power

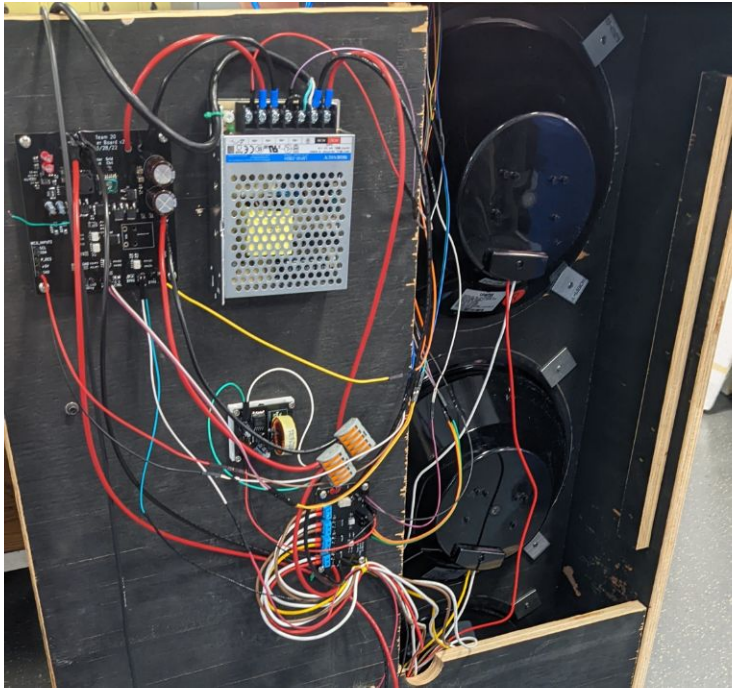
- When the ambient light is sufficiently low, the LEDs will be dimmed via pulse-width modulation (PWM)
    - Will reduce light pollution at night, in addition to the grid power consumption
    - In adverse weather conditions, lights will not be dimmed to ensure proper visibility

- Cyclists will cross the road at the same time as pedestrians, so we have two walk/bike buttons

Project Images

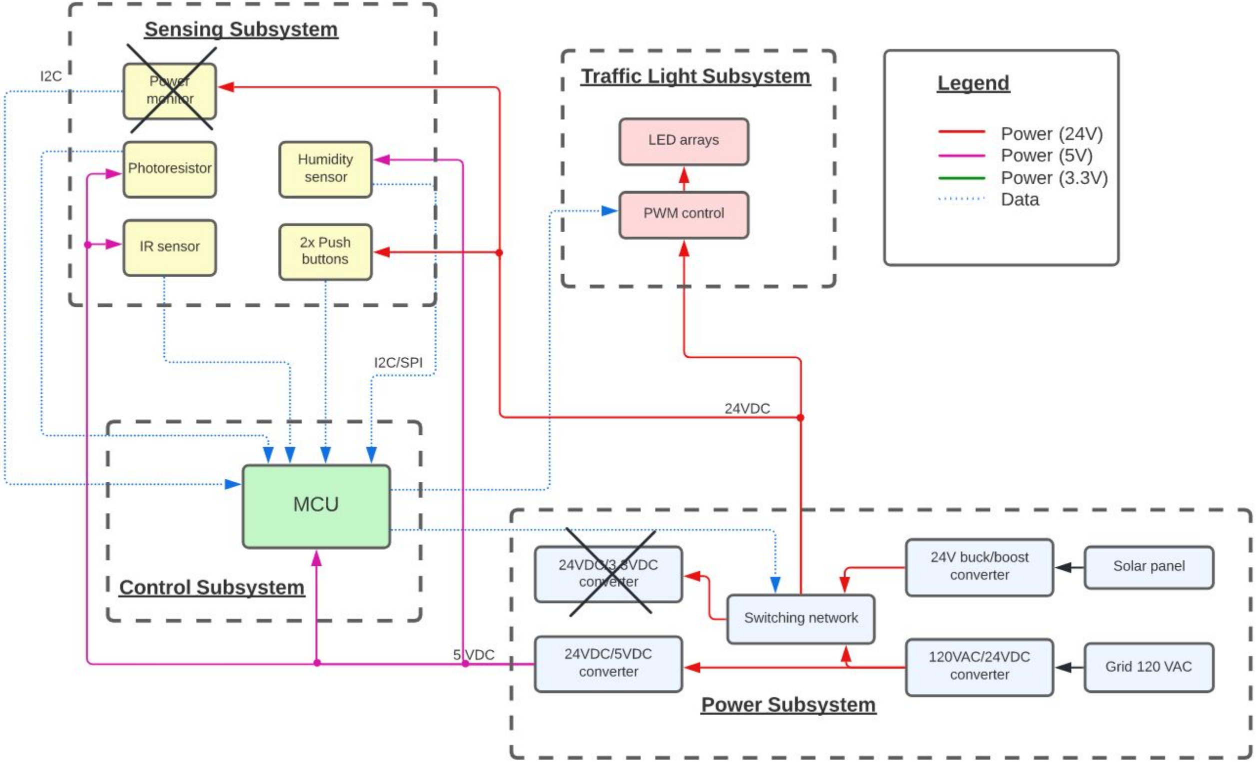
Traffic light enclosure

Sensors/MCU box



Power and light control systems

Block Diagram

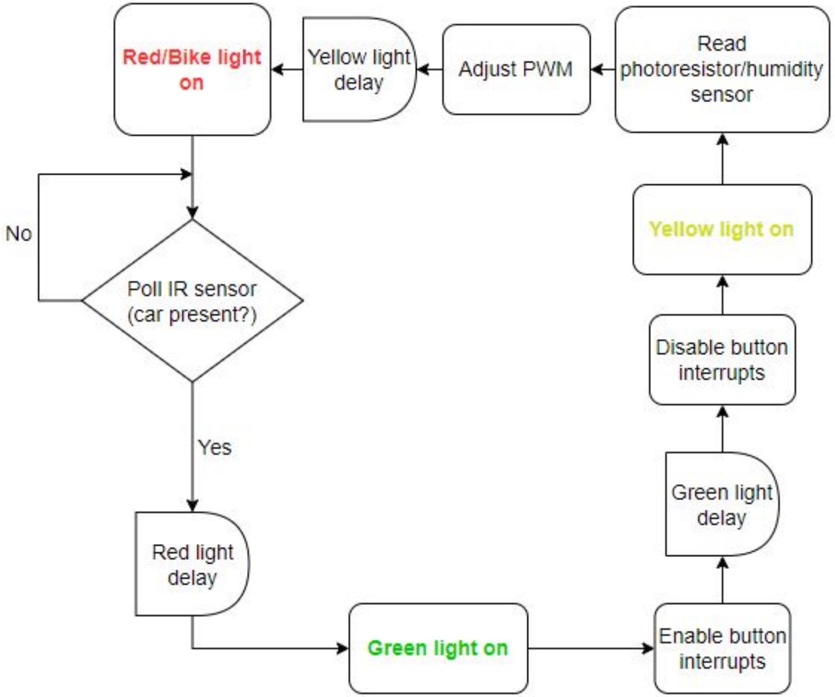


Block diagram

Control Subsystem

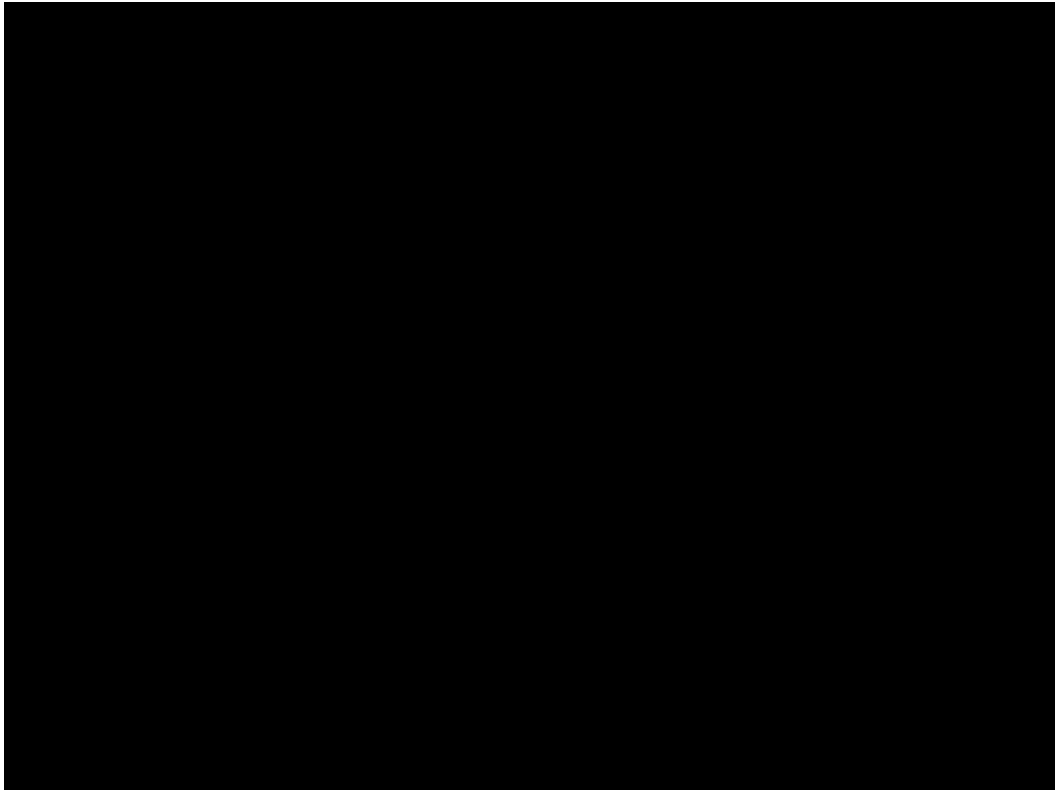
Control Flow

- Photoresistor polling in delay states for switching solar/grid
- Button interrupts escape green light delay



Control flow

Design - Microcontroller (ATmega328p)

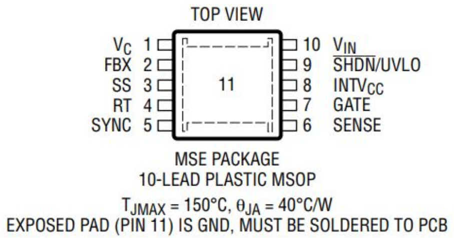


Programmed traffic light

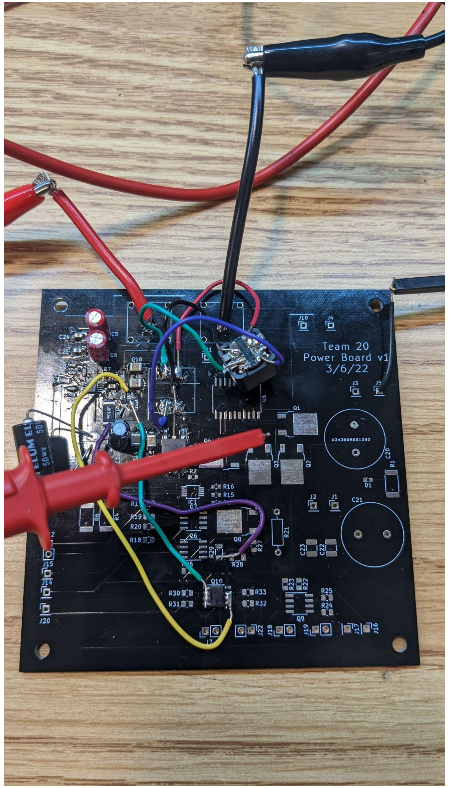
Power Subsystem

Challenges

- Wrong PCB footprints
  - Coupled inductor
  - MOSFET
- Unconnected ground pad



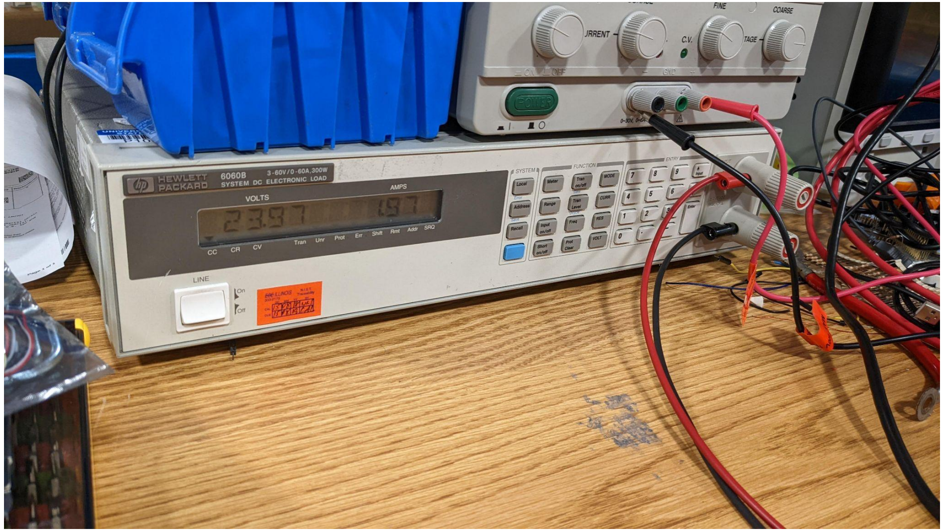
SEPIC controller package [1]



Debugging SEPIC

Results

- Use electronic load to adjust current draw and power supply to adjust input voltage

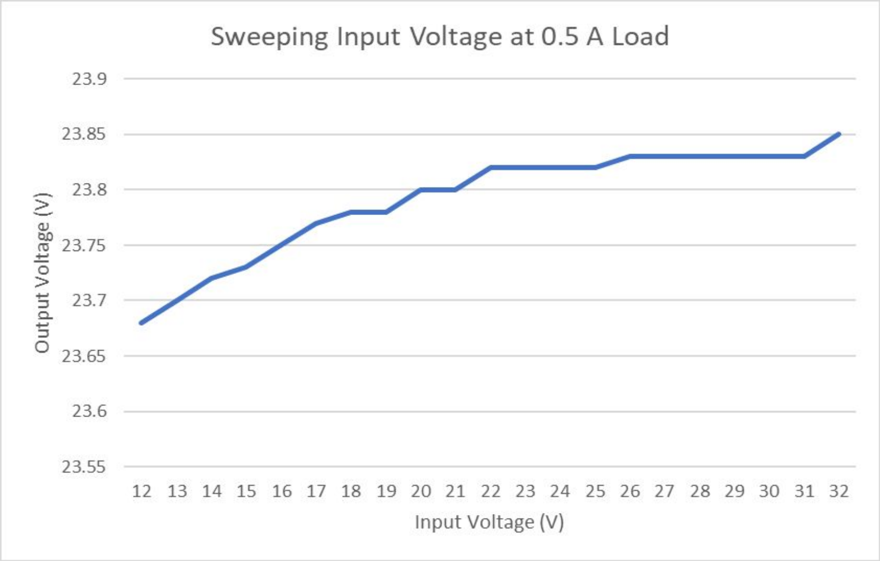


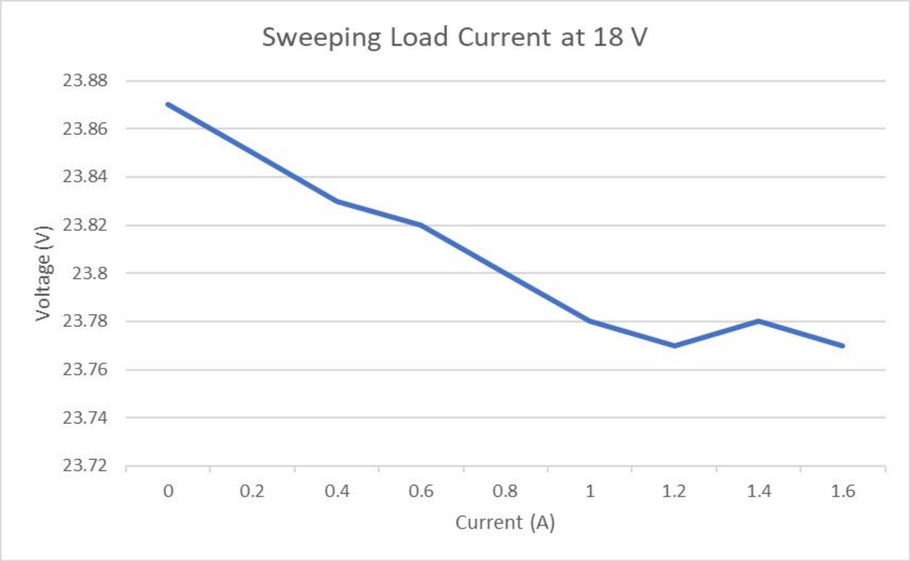
Testing SEPIC converter with 2 A output current

Design - SEPIC Converter

Results

- SEPIC converter output voltage is between the specified range of 22.8 V and 25.2 V

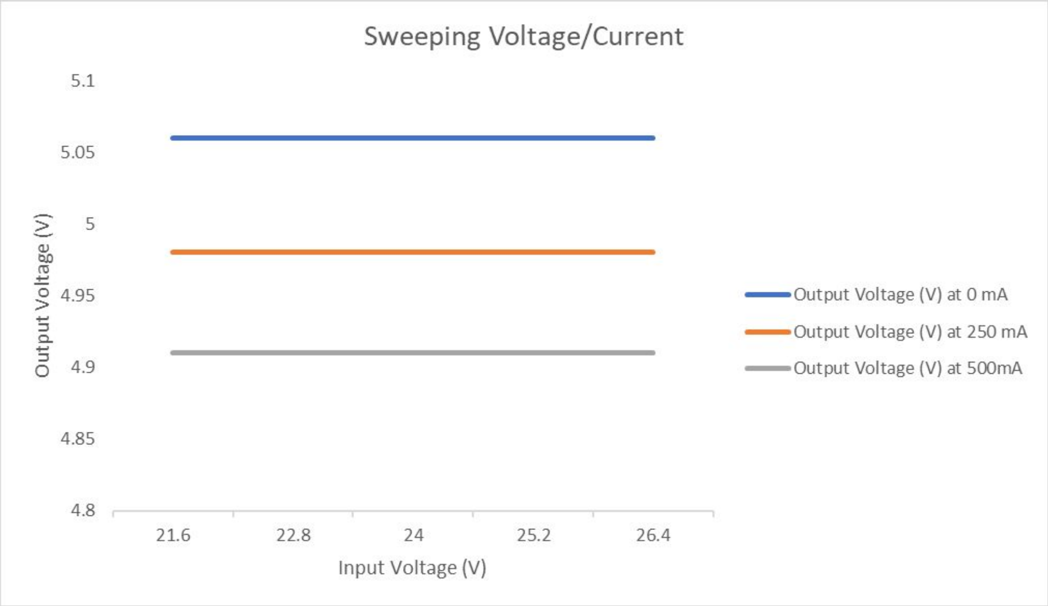




Design - 24 V to 5 V Buck Converter

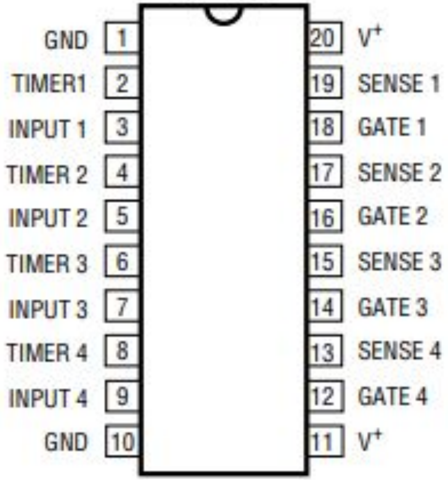
Results

- 5 V buck converter output voltage is between the specified range of 4.75 V and 5.25 V



Challenges

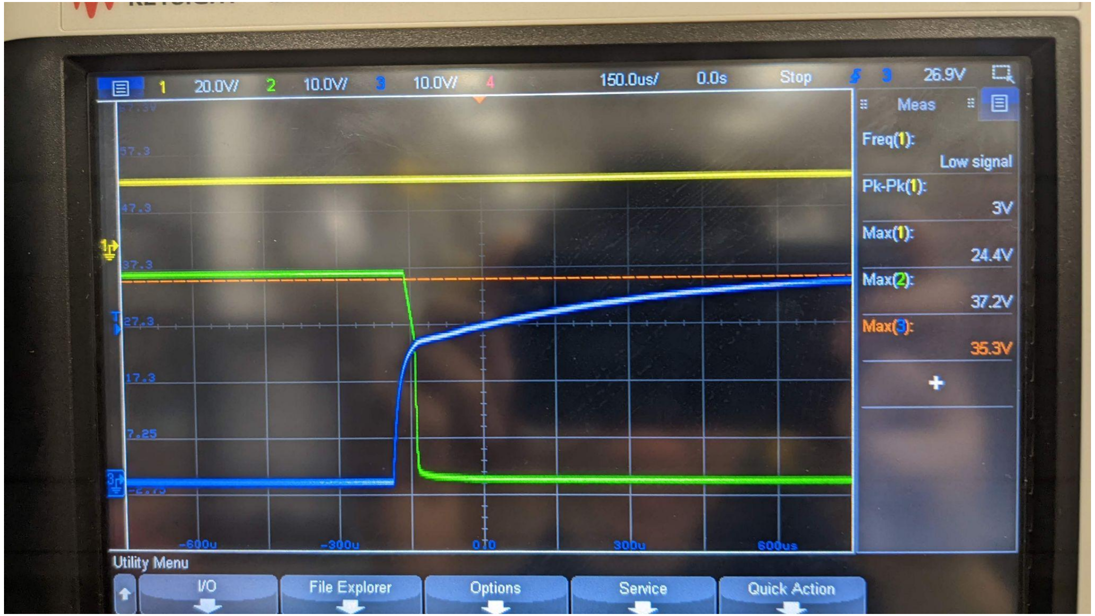
- LT1161 quad protected high-side MOSFET driver
    - Four timer pins should have been left disconnected based on the desired operation
        - During the design process, we connected a 1 uF capacitor to each of these pins
    - Four sense pins are included and are supposed to be connected to the supply voltage (grid) based on the desired operation
        - Two were connected to the grid and two were connected to solar power, which resulted in faulty switching behavior



LT1161 pin layout [2]

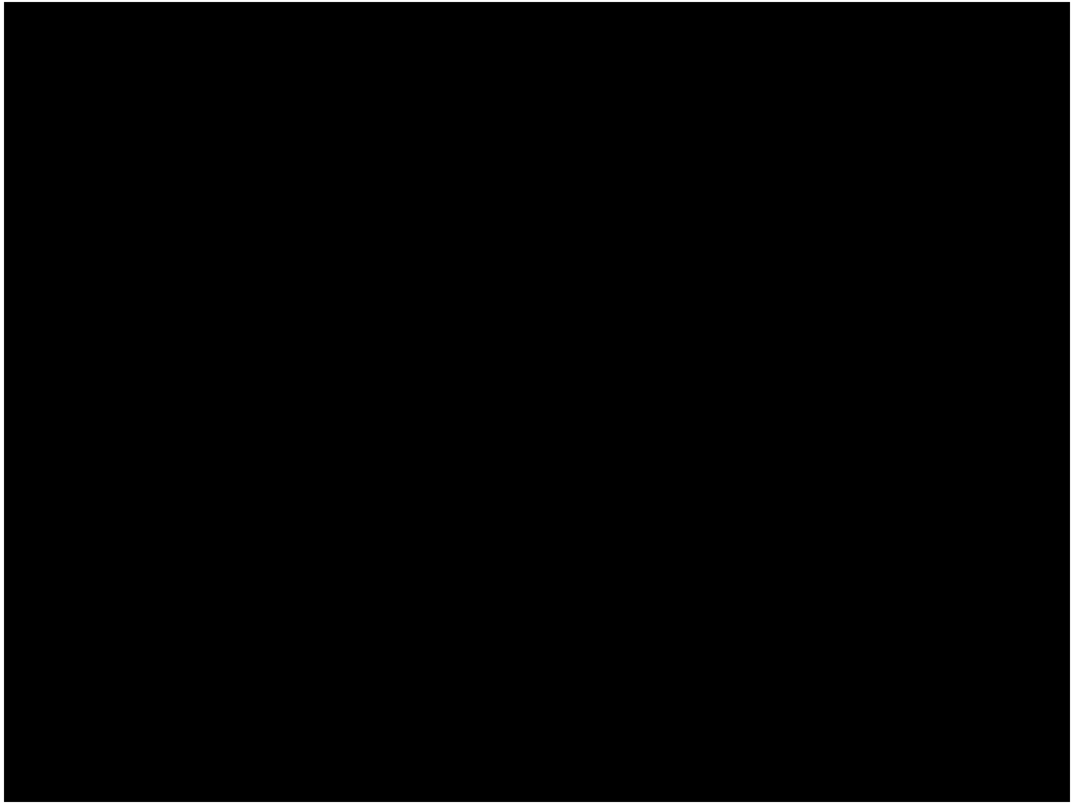
Results

- Output voltage (yellow) does not dip when input voltage sources are switched from grid (green) to solar (blue)



Switching network test - 24 V output (yellow), gate of grid control (green), and gate of solar control (blue)

Design - Switching Network

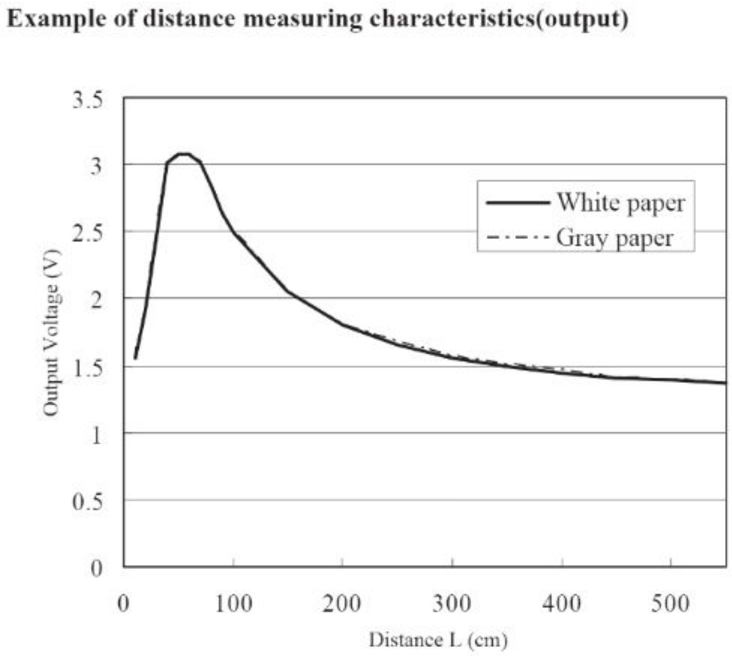


Switching network demonstration

Sensing Subsystem

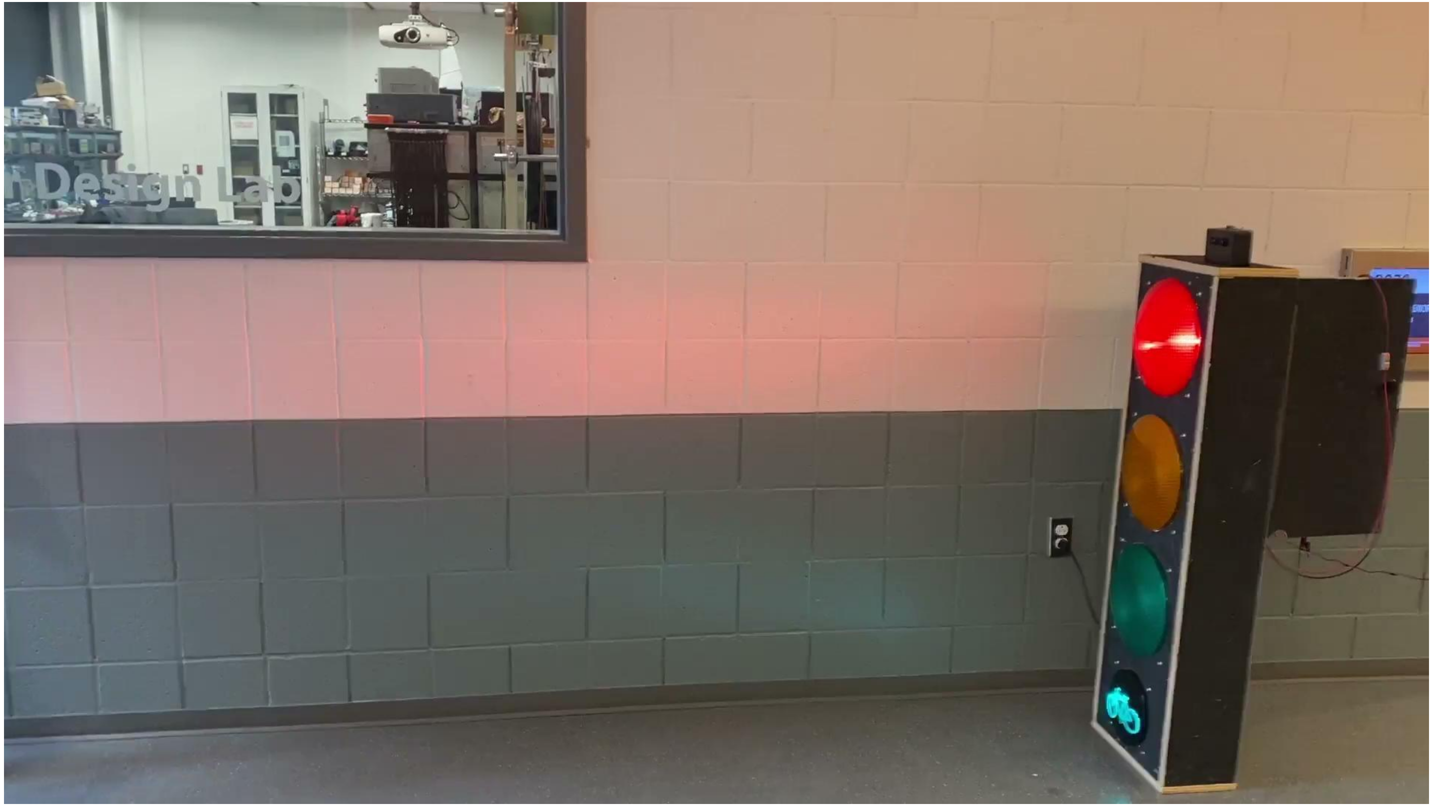
Challenges - Infrared Sensor

- Difficult to sense distances over 250 cm (8.2 ft) accurately
- Works best from 10-250 cm



IR sensor output voltage vs distance [3]

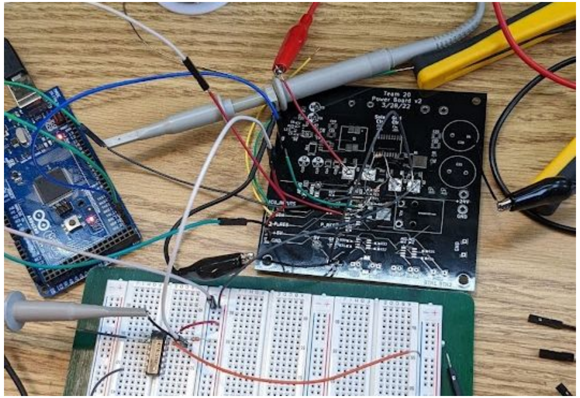
Design - Sensing



IR sensor demonstration

Challenges - Power Monitor

- Power monitor was not found on I2C bus
  - Debug: I2C scanner, oscilloscope, remove optoisolators, hex inverter
  - Possible causes: Overheat, slow optoisolator slew rate, inverted SDAO line
- Workaround: use photoresistor to switch power sources



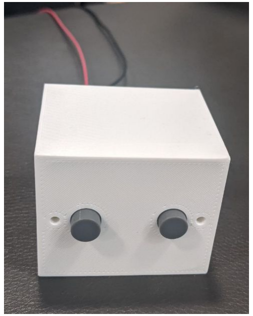
Testing power monitor

Power monitor oscilloscope waveforms

Results

- Photoresistor is able to differentiate between different light intensities
- Power monitor does not work
    - Use photoresistor instead
- Humidity sensor is able to detect differences in humidity from 0% to 100%
- Button interrupts change state after a delay

Button oscilloscope waveforms

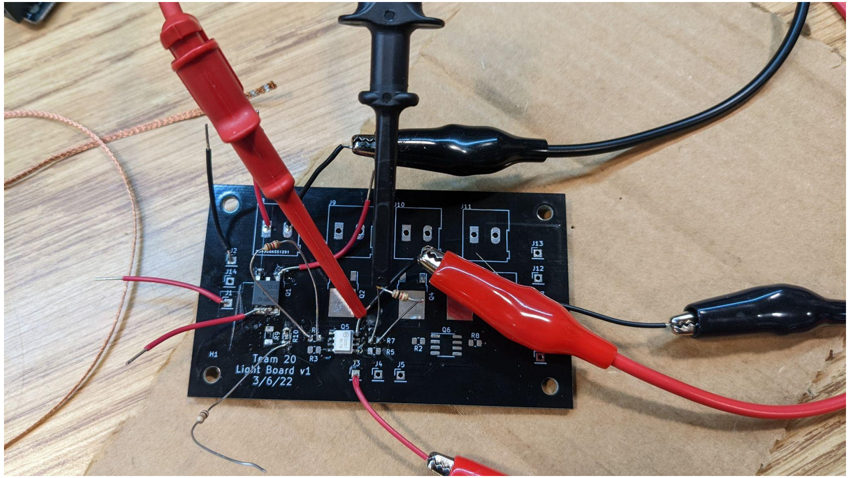


3D printed button enclosure

Traffic Light Subsystem

Challenges

- Lights were not turning on
  - Floating high side N-channel MOSFETs
  - Lower resistor values for isolation
    - 10 kΩ → 150 Ω

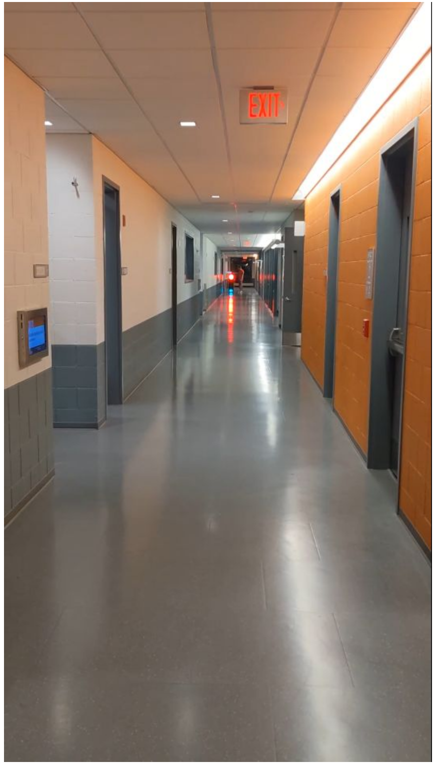


Debugging MOSFETs and isolation

Design - Traffic Light Board

Results

- Light board works as expected
  - Lights visible from 150 ft
  - Able to dim lights
  - No flickering



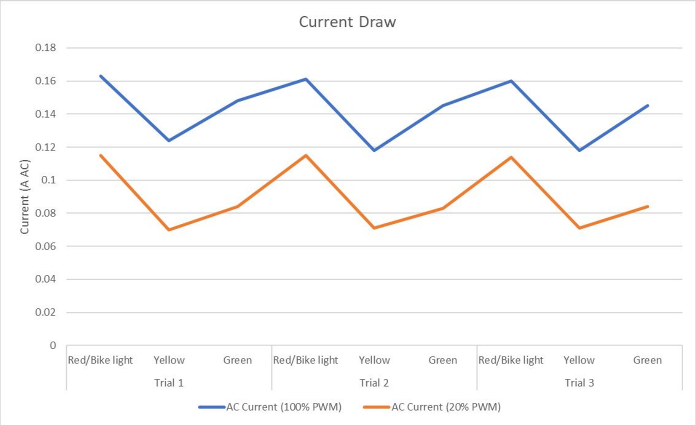
Traffic lights from 150+ ft

Conclusion

Successes

- All objectives were met
- Grid power utilization
  - 16.9 W at 100% PWM
  - 10.7 W at 20% PWM
- Solar power utilization
  - 8.09 W at 100% PWM
- Assuming 12 hours sunlight, 12 hours darkness, and ideal conditions
  - Our traffic light uses 0.385 kWh grid power per day
  - Average traffic light uses 1.08 kWh grid power per day [4]

	A	B	C	D	E	F	G	H	I	J
1		Trial 1			Trial 2			Trial 3		
2	Grid power utilization	Red/Bike light	Yellow	Green	Red/Bike light	Yellow	Green	Red/Bike light	Yellow	Green
3	AC Voltage (100% PWM)	118.7	118.7	118.7	118.7	118.7	118.7	118.7	118.7	118.7
4	AC Current (100% PWM)	0.163	0.124	0.148	0.161	0.118	0.145	0.16	0.118	0.145
5	AC Voltage (20% PWM)	118.9	118.9	118.9	118.9	118.9	118.9	118.9	118.9	118.9
6	AC Current (20% PWM)	0.115	0.07	0.084	0.115	0.071	0.083	0.114	0.071	0.084
7										
8	Average power (100% PWM)	16.90815556								
9	Average power (20% PWM)	10.66136667								
10										
11										
12										
13										
14	Solar power utilization									
15	DC Voltage (100% PWM)	24	24	24	24	24	24	24	24	24
16	DC Current (100% PWM) (A)	0.319	0.294	0.399	0.319	0.294	0.398	0.319	0.294	0.398
17										
18	Average DC Current (A)	0.337								
19	Average power (100% PWM)	8.090666667								



Conclusion

Lessons Learned

- Be more careful picking ICs and sensors
- Test ICs/sensors before creating PCBs for them

What we would have done differently

- Different power monitor, one without inverted SDAO
- Find more accurate IR sensor

Recommendations for further work

- Waterproof enclosure/electronics
- Make full scale system with 4 traffic lights

Citations

[1] Analog Devices, “Boost, Flyback, SEPIC and Inverting Controller.” [Online]. Available: https://www.analog.com/media/en/technical-documentation/data-sheets/lt3757-3757a.pdf

[2] Analog Devices, “Quad Protected High-Side MOSFET Driver.” [Online]. Available: https://www.analog.com/media/en/technical-documentation/data-sheets/1161fa.pdf

[3] Sharp Corporation, “Gp2y0a710k0f.” [Online]. Available: https://cdn-shop.adafruit.com/datasheets/gp2y0a710k.pdf

[4] City of Yakima, “Led Traffic Signals.” [Online]. Available: https://www.yakimawa.gov/services/streets/led-traffic-signals

Thank You

Any questions?

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