The Development of a Low

Cost Pyranometer

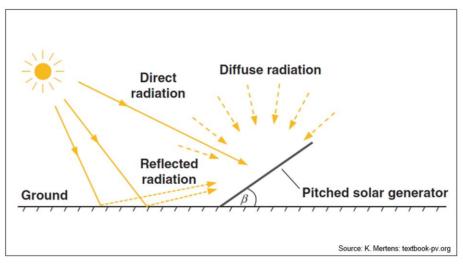
Presented by the Solar Sailors

Adriana Oliveira, Lukas Vermeulen,

Nickolas Borek, and Brady Jerome

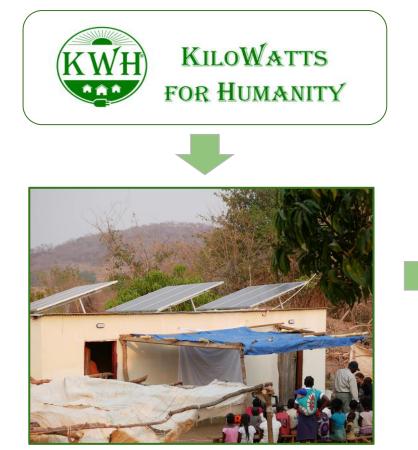
Background

Solar Irradiance: W/m²





Value Proposition

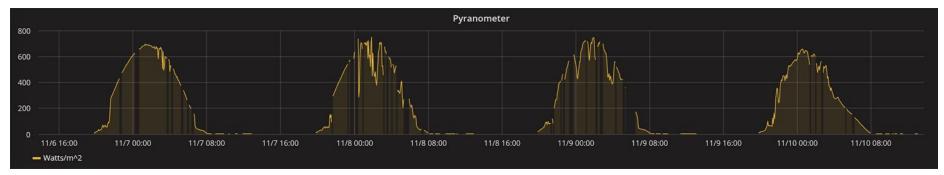




Community Needs

- Communication
- Information
- Refrigeration

Data from the Filibaba Zambia Station





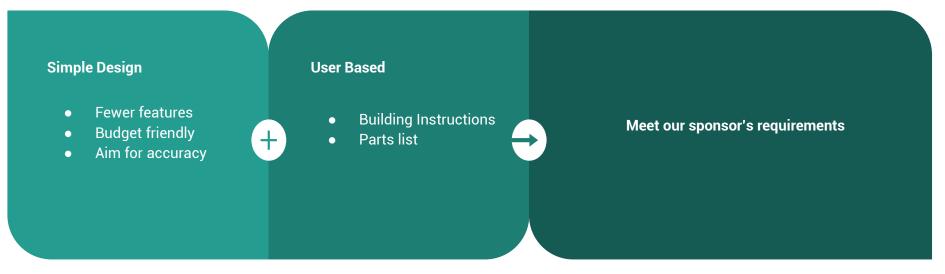
Requirements

Commercial Pyranometer

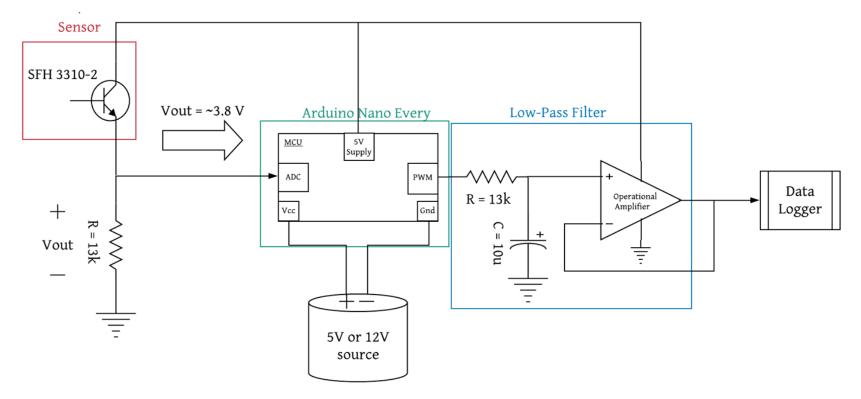


Affordable	\$20-\$80
Accurate	 Provides a 0 - 5 VDC control signal < 15% error
User Friendly	Easy to install and maintainRepeatable





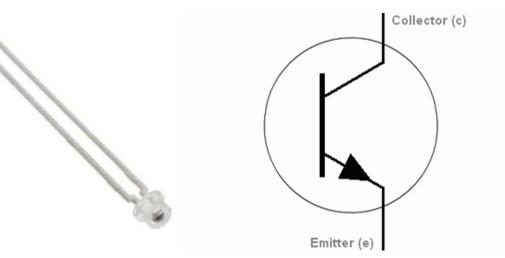
Conceptual Development: The Big Picture



Conceptual Development: The sensor

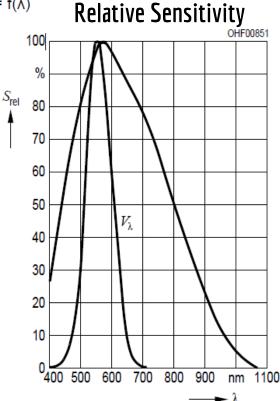
Phototransistor

- Light Sensitive BJT
- Capable of turning light energy into electric energy
- Our sensor
 - SFH 3310
 - 150 degree viewing angle

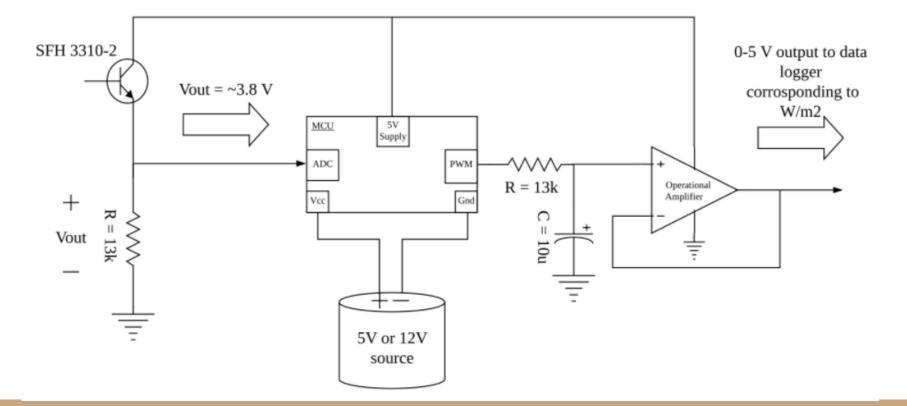


Conceptual Development: The sensor $S_{rel} = f(\lambda)$

- Why this sensor?
 - Affordable: \$0.82 per unit
 - \circ 150 degree field of view
 - Measures necessary light spectrum:
 350 nm 970 nm



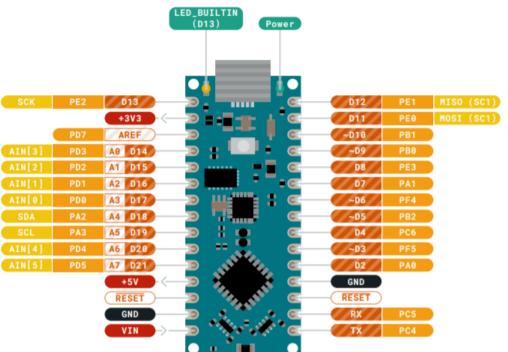
Conceptual Development: The Circuitry



Conceptual Development: The Microcontroller

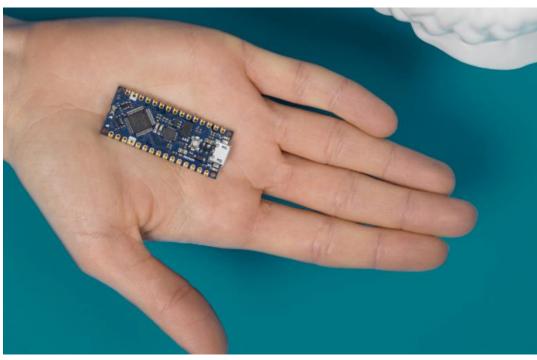
Arduino Nano Every

- Inputs: A0-A7
- Outputs: D3, D5, D6, D9, D10
 - Pulse Width Modulation (PWM)

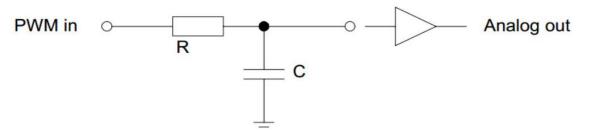


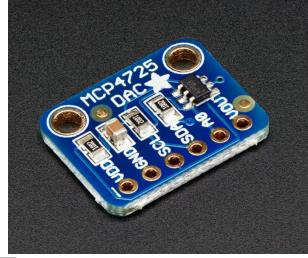
Conceptual Development: Why the Nano Every?

- Affordable: \$9.30
- Easy to implement:
 - Forums
 - Instruction manuals
 - Arduino IDE
- Compact: 15mm x 45 mm
- Excellent customer support



Conceptual Development: PWM vs DAC





	PWM	DAC
Cost (One Unit, without shipping)	\$1.13	\$4.95
Accuracy	99.8% Depends on R and C values.	99.9 %
Response Time	700 ms Depends on R and C values.	1 ms
Footprint	3.05mm x 10mm	33mm x 33mm
Implementation	Direct connection	I2C communication

Material Selection 3D Printing (ABS vs PETG)

ABS

- Higher temperature
- Strength characteristics
- Cheaper
- Toxic

Recommendation: use ABS when cost is a significant concern and you have the proper printing setup.

PETG

- Solar resistance
- More expensive.
- Intermediate print difficulty

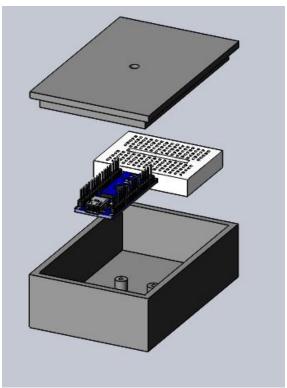
Recommendation: use PETG when economically and structurally possible since its UV resistance makes up for its downsides.

Conceptual Development: The Case

• 3D printed made of PETG

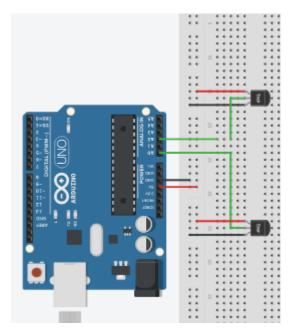
• Currently relies on a snap fitting with plans to update to use fasteners.

• Plans on keeping particles larger than 1mm out and be water resistant.



Thermistor Prototype Reasoning

- Serves as a cross competitor with our phototransistor design
- Widens our view of potential solutions for our project
- Does not affect our teams budget



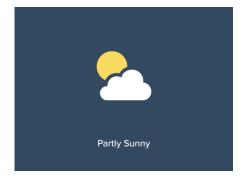
Recommendations: Moving Forward

- Use the phototransistor prototype.
- Use PWM to output to data logger.
- Implement the circuitry and case previously shown.
- Test our product against industry grade products.
 O Three comparable products



Identification: Potential Risks





- Environmental Issues
 - Weather-proof exterior, and protected components
- Product Failure
 - Perform many product tests to ensure a working device and test life-span
- Sensor Drift
 - Properly calibrate the sensor
- Improper Soldering
 - \circ Look into an interlocking PCB
- User Error
 - Create a durable and impact-reducing case

Validation: Testing

- Test circuit for desired output
 - Is it outputting 0-5V?
- Test and calibrate phototransistor
 - Is it working properly?
- Test phototransistor pyranometer prototype
 - Compare with other pyranometers
- Re-evaluate prototype design
 - Did it work properly?
 - Is this the best design?
- Test the thermistor prototype
 - To make an accurate phototransistor choice
- Test case and circuitry in Environment Chamber
 - Does it meet environment requirements?





MP-100: Pyranometer Integral Sensor \$361.00

SP-215-SS: AMPLIFIED 0-5 VOLT PYRANOMETER





CMP10 Pyranometer Provided by the University of Idaho

Project Schedule

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			START	DUE DATE	DURATI	OF	0	0000		_			0		A . C .																		7.00		Dece
WBS NUMBER	TASK TITLE	TASK OWNER	DATE	DUE DATE	ON	TASK COMP		_	_	_	_		_									_		_		_		_	ov. 23, 20	_		_	_	_	
1	Project Conception and Initiation	Lukas				LETE	MIW	RFI	MIIW	R	MIIW	RF	MIW	RFI	w i w	RFN	i i w	к н м	a i w	RFM	(I W	K F I	a i w	RFI	w i jw	RFN	a i w	крм	TWR	FM	I W R	FM	IWR	FMI	WRF
1.01	Designate Team Roles	All Sailors	9/8/20	9/11/20	3	95%																											11		
1.02	Research in Pyranometer Design	All Sailors	9/7/20	12/14/20	97	65%				ŤŤŤ	i i	İ					İİ		İİ						ТТ,		Ť Ť Ť								
1.03	Develop Rough Budget	Lukas V	9/17/20	9/29/20	12	100%				İTT																									
1.04	Select a sensor	All Sailors	9/21/20	9/30/20	9	100%																													
1.05	Team Contact	All Sailors	9/10/20	9/10/20	0	100%				111																									
1.06	Select a microcontroller	Lukas V	9/14/20	10/7/20	23	100%																													
1.07	1st Team Instructer Meeting	All Sailors	9/14/20	9/15/20	1	100%																													
1.08	Preliminary circuit design	Lukas V	9/14/20	9/15/20	1	100%																													
1.09	Product Requirment Documents	All Sailors	9/14/20	9/24/20	10	100%																													
1.1	Project Schedule	All Sailors	9/29/20	10/6/20	7	100%																													
1.11	Rough 3D CAD Design of Case	Nick B.	9/21/20	10/13/20	22	100%																													
1.12	Develop circuit based on research	All Sailors	9/14/20	10/7/20	23	100%																													
1.13	Portfolio	All Sailors	9/29/20	10/8/20	9	100%																													
1.14	Logbook Check	All Sailors	10/5/20	10/9/20	4	100%																													
1.15	Snapshot 1#	All Sailors	10/2/20	10/13/20	11	100%																													
2	Prototyping	Adriana																																	
2.01	Create funding proposal	Lukas and Adriana	10/5/20	10/10/20	5	100%																													
2.01.2	Order Inital Supplies	Lukas will email Dr. Li	10/26/20	10/30/20	4	100%																													
2.02	Update Budget	Lukas V	10/7/20	10/23/20	16	85%																													
2.03	Print Case Prototype	Nick B.	11/30/20	1/22/21	52	0%																													
2.04	Start Code for the Microcontroler	All sailors (will break up later)	11/9/20	1/22/21	73	0%																							~						
2.05	Assemble Circuit	Lukas, Brady, Adriana	1/13/21	3/6/21	53	0%																							ga						
2.06	Assemble Prototype	All Sailors	2/8/21	3/13/21	35	0%																							Break						EXAMS
2.07	Test Pyranometer accuracy	All Sailors	3/15/21	4/3/21	18	0%																													₹
2.08	Test Case Durability	Nick B.	4/5/21	4/17/21	12	0%																							Ĕ						×
2.09	Refine Prototype Design	All Sailors	3/15/21	5/8/21	53	0%																							.≥						۳.
2.1	Create Updated Parts list, if needed	Nick B.	1/25/21	2/13/21	18	0%																							SG						¥
3	Refining Design	Brady																											Thanksgiving						FINAL
3.01	Order Updated Parts List	All Sailors	2/15/21	2/20/21	5	0%																							Ja						u
3.02	Construct Updated Circut	Lukas, Brady, Adriana	2/15/21	2/22/21	7	0%																							F						

Project Budget

Low Cost Pyranometer for			ng a low-cos		ator (One y	nit)					
Last Updated		Developi	ng a low-cos	груганош	eter (Offe u	mi)					
Last Opuateu	11/10/20			V.	ear				Item		
Expense Items (\$)	Sent	Oct	Nov	Dec	Jan	Feb	Mar	Ann	Total		
Expense items (5)	Sept	Ott	INOV	Dec	Jan	reu	Mar	Apr	Total		
Equipment/Tools:											
Travel:									S -		
Gas									S -		
Supplies / Parts / Services:											
3D printing filiment									S -		
Fasteners									S -		
Arduino Nano Every Headers			\$ 4.99						\$ 4.99		
Resistors			\$ 6.99						\$ 6.99		
Capacitors			\$ 9.84						\$ 9.84		
Op Amp NJM5532DD - 10 pack			\$ 10.50						\$ 10.50		
Photo Transistor SFH 3310			\$ 8.16						\$ 8.16		
Electrical wiring									S -		
Arduino Nano Every - 6 pack			\$ 55.80						\$ 55.80		
Weather proofing									S -		
Shipping costs/postage			\$ 19.05						\$ 19.05		
Circuit Board									S -		
Expo Costs									S -		Expense
Taxes			\$ 0.85						\$ 0.85	\$ 116	Subtota
Shop Usage (Hrs):									Hours		
3D Printing									0		
Prototype construction									0		
Solar lamp calibration(?)									0		
Prototype field testing									0		
									0		
									0		
							Shop	Overhead	\$ 10		
								10% Error	\$ 11.62		
								Totals	\$ 138	\$ 400	\$ 262
									Costs	Budget	Excess

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Cost per unit

Current Cost P	er l	Jnit					
Item	Tot	tal Cost	Quantity	С	ost for 1		
10 uF Capacitors (50 count)	\$	4.92	50	\$	0.10		
Resistors (600 count)	\$	4.99	600	\$	0.05		
Arduino Nano Every (6 count)	\$	55.80	6	\$	9.30		
Arduino Nano Every Headers (400 count)	\$	4.99	13	\$	0.38		
3D printing filament (1 count)	\$	22.99	1	\$	3.83		
Op Amp NJM5532DD (10 count)	\$	10.50	10	\$	1.05		
Photo Transistor SFH 3310 (10 count)	\$	8.57	10	\$	0.86		
	Current Cost Per Unit						
	\$				15.57		

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Recommendation: Future Ideas

- Convert 0-5V voltage output to 0-20mA current output.
 - Eliminates voltage drop over a distance.
- Research and test the viability of a two-sensors system.
- PCB vs Breadboard



Any Questions?