Signoff Request - September 13th, 2022 - Navigation (Flash Hardware)

Saturday, August 13, 2022 1:17 PM

Navigation Subsystem - Flash Hardware

Abstract: Flash Hardware Signoff Takeaways

This signoff request is for the flash hardware which will be used in the design for the Autonomous Crawl Space Inspection Robot. The flash hardware will reside in the "Navigation Subsystem" on our block diagram and will be responsible for illuminating the crawl space for pictures and live video feed. First, for this signoff request, the expectations or specifications of the flash hardware are explained in verbal terms. Then, analysis is performed so that the specifications of the flash hardware can be stated quantitatively as constraints and so that the quantitatively stated specifications can be justified. Finally, the flash hardware is chosen, examined, and analyzed to whether or not it can meet the specifications and constraints of the atomic subsystem.

Specifications:

1. *The device chosen for the flash hardware must allow for proper illumination (strong enough lux or lumens per area) on pictures and videos taken by the HD Camera while within the crawlspace.*
2. *The device chosen for the flash hardware must be powered by the Raspberry Pi 4B or powered through the line that also powers the Raspberry Pi 4B.*

Constraints:

1. *The device chosen for the flash hardware must allow for proper illumination of surfaces for pictures and live video feed to be taken of those surfaces. Illumination is measured in lux (lumens per unit area) and the flash hardware must provide **at least 50 lux,** where an increase in lux increases the brightness of the image captured and a decrease in lux rapidly decreases the brightness of the image*
2. *The device chosen for the flash hardware must be one meter (3 feet) away from the object of which the picture is being taken **when** the picture is being taken (wall, pillar, etc…)*
3. *The device chosen for the flash hardware must have a brightness of at least 50 lumens, which would allow for an intensity of at least 50 lux (as specified in the first constraint)*
4. *The deivce chosen for the flash hardware must be powered by the Raspberry Pi 4B 5 Volt pin or USB, or be powered by the 5 Volt line that also powers the Raspberry Pi 4B*
5. *The device chosen for the flash hardware must be able to be toggled by the Raspberry Pi 4B so that it will only be in use when taking pictures or live streaming video*

Analysis:

In order to analyze the brightness that the flash hardware needs to provide, "brightness" was broken down into two different components: lux and lumens. Lumens, the flux which is emitted from a light source, can be thought of as the amount of "force" present in emitted light [1]. Lux, the amount of lumens per unit area, can be thought of the amount of "force" that is present across a unit area, somewhat like light intensity [1]. According to the "Inverse Square Law", as a light source moves farther away from the surface which it is illuminating, the illumination intensity (lux = lumens/area) inversely decreases by the square of the distance from the illuminated surface, as shown in figure 1 [1]. Thus, in order to calculate a "unit-vector" style characterization of intensity, a reference area of 1 meter squared is chosen which represents the strongest uniform illumination of a surface [2]. If a light source and camera are positioned exactly 1 meter from a surface, the resulting illumination intensity would be calculated based on an area of 1 m^2, and if the camera was set to capture an image with an area of approximately 1 m^2, then the image would be a representaiton of the surface with a maximum illumination intensity, as shown in figure 1 [1,2].

Figure 1 [1]:

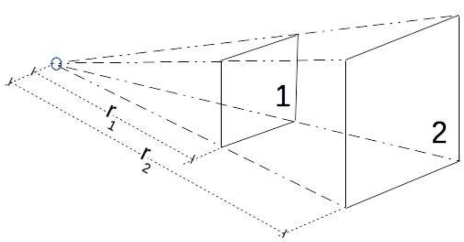
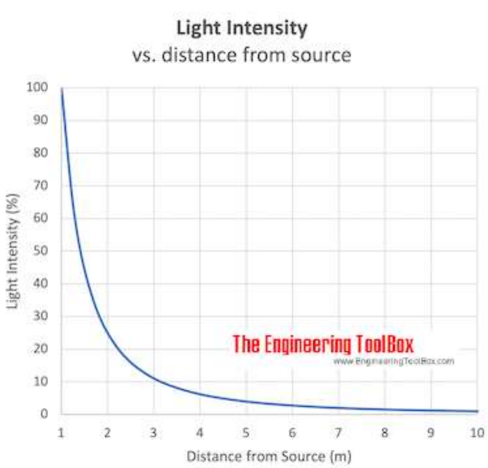


Figure 2 [1]:



*After conducting a thorough literature review, it was discovered that there are very **few** requirements or recommendations of the **lux** levels required for inspection photography of crawlspace* *environments. In order to properly analyze the amount of light per unit area needed to record the required information of the crawlspace through images, the team members transitioned to analyzing two different branches which, when combined, can help determine the minimum illumination intensity needed. First, the team members reviewed literature which examined the amount of lux (illumination intensity) required for accurately analyzing objects through machine learning algorithms. Next, the team members reviewed literature from government agencies in order to determine the amount of recommended* ***unit lux*** *required for various indoor environments such as homes, businesses, and public facilities. While current commercial products (from manufacturers such as COGNEX) and their associated datasheets were examined, team members were not able to adopt industry constraints for flash hardware as there were not any stated illumination intensity specifications or requirements. Therefore, by combining recommended illumination intensity constraints from academic papers which cover topics in lighting effects on machine learning/computer vision algorithms, as well as lighting constraints for visibility within indoor facilities provided by government agencies, the team members are able to form well-informed constraints for the flash hardware of the inspection robot.*

Students and faculty members at the Islamic Azad University in Tehran, Iran conducted an experiment to determine the optimized lighting and camera height conditions needed to properly implement a machine/computer vision algorithm which would identify when an orange (citrus) was ripe and ready to be retrieved [3]. In order for the algorithm implemented on a computer to properly analyze the picking-state of the orange (citrus), the object needed to be properly illuminated and the camera needed to be positioned at an uniform height which would capture the illumination of the area within the image. To test for the minimum illumination intensity needed to provide the required information for the M./C.V. algorithm, the team members created an experiment with varying bulb types (LED, Fluorescent, RGB, etc..), camera height, and illumination intensity (lux). The team members found that when the camera was positioned at a distance equivalent to the length and width of the area which the image captured (think unit area needed for maximum illumination with the inverse square law), a LED light with a lux intensity of 50.33 was enough to properly illuminate the object being captured for the M/C.V. algorithm [3]. If a lux of 50.33 provided enough illumination for the M./C.V. algorithm implemented in this experiment to calculate the picking-state of the orange, shown in figure 3 and figure 4, which was based on color diagnosis, surface deficiency, and shape/texture, then a minimum lux of 50 should provide a sufficient illumination for information within an image to be properly observed by users that are inspecting a crawlspace [3].

Figure 3 [3]:

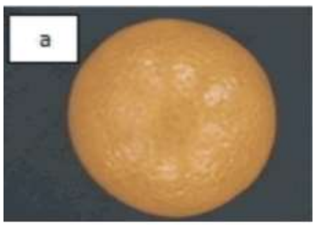
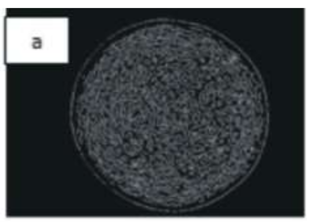


Figure 4 [3]:



Government organizations, such as the United States General Services Administration (GSA) and the European Society of Lighting and Lights (SLL) of the Chartered Institution of Building Services Engineers (CIBSE), have created recommendations and requirements for the amount of illumination intensity (lux) needed for performing physical tasks and for being present within indoor environments including homes, businesses, and public facilities. While these two government organizations reside in different countries, many of the given specifications and constraints for indoor illumination are aligned and in support of one-another, as the illumination intensity (lux) is an international measurement. According to the European standard 12464, the minimum illumination intensity (lux) on an unit-area of 1 m^2 *needed for properly visulaizing a working environment is 30 lux on ceilings and 50 lux on walls and other surfaces [2]. Note, the minimum constraints of 30 lux and 50 lux are based on an area of 1 square meter, meaning that this is the minimum amount of illumination per unit area needed for a person to be able to properly see and complete working tasks [2]. While an illumination intensity of 50 lux on an area of 1 meter squared can be seen as the* ***minimum Illumination*** *intensity required for proper visulization within an indoor environment, both the Society of Lighting and Lights of the Chartered Institution of Builing Services Engineers (CIBSE) and the United States Government Services Administration (GSA) have a recommeneded illumination intensity of 200 lux per unit area of 1 square meter for various indoor envrironments shown in figure 5 [4] and figure 6 [2]. While these recommendations are not specifically for photography, the recommendations from the SLL and GSA organizations are the closest standards found which are applicable for the amount of illumination intensity to complete tasks within various indoor environments. Therefore, by combining a minimum illumination intensity recommendation of 50.33 lux from an academic study on recognizing object characterisitcs for image processing through maching/computer vision with illumination standards for proper lighting levels within various indoor environments, the team members feel confident that 50 lux is a minimum constraint for illumination intensity of an unit area of 1* m^2 *and that this constraint is extremely relevant to the inspection robot [2, 3, 4]. Furthermore, team members believe that a recommended illumination intensity level of rouhgly 200 lux will provide more than enough illumination of an image area of 1 square meter. In order to visualize how well a commercially available, low-voltage-low-current light performs within a crawlspace, the team members tested a "low intensity" 150 lumens flash light within a crawlspace. The results of this test are shown in figure 7 and figure 8 , which shows that the 150 lumen flashlight provided enough illumination for an unit area of 1* m^2 *at a distance of 1 meter away (the resulting lux at this area would be 150 lux). Additionally, the light was plenty strong to provide illumination of the crawlspace at least 10 feet away, which, for live-video navigation, will be sufficient.*

Figure 5 [4]:

Area	Nominal Illumination Level in Lumens/Square Meter (lux)
Office Space	
Normal work station space, open or closed offices[1]	500
ADP Areas	500
Conference Rooms	300
Training Rooms	500
Internal Corridors	200
Auditoria	150-200
Public Areas	
Entrance Lobbies, Atria	200
Elevator Lobbies, Public Corridors	200
Ped. Tunnels and Bridges	200
Stairwells	200
Support Spaces	
Toilets	200
Staff Locker Rooms	200
Storage Rooms, Janitors' Closets	200
Electrical Rooms, Generator Rooms	200
Mechanical Rooms	200
Communications Rooms	200
Maintenance Shops	200
Loading Docks	200

Figure 6 [2]:

Activity	Illuminance (*lx, lumen/m²*)
Public areas with dark surroundings	20 - 50
Simple orientation for short visits	50 - 100
Areas with traffic and corridors - stairways, escalators and travelators - lifts - storage spaces	100
Working areas where visual tasks are only occasionally performed	100 - 150
Warehouses, homes, theaters, archives, loading bays	150
Coffee break room, technical facilities, ball-mill areas, pulp plants, waiting rooms,	200
Easy office work	250
Class rooms	300

Figure 7:

Figure 8:

Chosen Component:

Voltaic - USB LED Light - $13.99/Unit - 1 Unit Needed - $13.99 BOM

Voltaic Systems Emergency USB LED Light

The Emergency USB LED Light, manufactured by Voltaic, is shown in figure 9 [5]. The Voltaic light features white (3000k) LEDs with an adjustable brightness from 20 lumens to 200 lumens, which are ideal for lighting up dark areas, as shown previously in figures 5 [4] and figure 6 [2]. The Voltaic light requires a constant voltage of 5 Volts and has a working current of 600 mAmps and can be connected to and powered from a device via the USB 2.0 connections, shown in figure 9 [1]. Additionally, the light features a metal, weatherproof case that shields the internal electronic components from exposure of up to 1 meter of water for 30 minutes, shown in figure 10, figure 11, figure 12, and figure 13 [9]. The Voltaic light is available via multiple online commerce websites, such as amazon, for an average price of $13.99 [5].

Figure 9 [5]:

Figure 10 [5]:

Figure 11 [5]:

Figure 12 [5]:

Figure 13 [5]:

Adhering to the Given Specifications of the Autonomous Crawl Space Inspection Robot

Flash hardware is needed in the design of the Autonomous Crawl Space Inspection Robot to illuminate the crawl space environment so that images can be recorded for technicians and home owners as well as live video feed for manually operating the robot. In order to be sufficient for the design of the inspection robot, the flash hardware chosen will need to be capable of illuminating the crawl space enough for obstacles to be seen in the recorded images and videos. In order to properly illuminate the environment, a minimum illumination intensity of at least 50 lux is required and an illumination intensity of 200 lux is recommended in order to properly illuminate an unit area of $1\ m^2$. The flash hardware will need to be able to be powered by the power subsystem of the inspection robot for at least two hours, which will is the estimated operation time of the inspection robot. The flash hardware will need to require a voltage of 3.3 Volts or 5.0 Volts, be connected to the Raspberry Pi 4B via an USB connection, and will need to have a max operating current of 600 mAmps or less so that the total current supplied used by the Raspberry Pi 4B and its connected devices does not exceed 3 Amps. The Raspberry Pi 4B uses on average 1.5 Amps under normal operation, the ultrasonic sensors will use an estimated 32 mAmps, the Lidar sensor will uses an estimated 0.6 Amps, the HD Camera will use no more than 0.2 Amps, and the flash hardware will use an estimated 0.6 Amps, totaling roughly 2.9 Amps, which Is within the maximum current draw of the Raspberry Pi 4B [6, 7, 8, 9]. Finally, the flash hardware will need to have a waterproof and environment-proof case which will allow the hardware to not be damaged by possible water and dust exposure while operating within the crawl space. After considering all requirements and specifications of the autonomous crawl space inspection robot, it can be seen that the Voltaic Emergency USB LED Light is an acceptable flash-light for the design of the inspection robot and will allow for proper illumination of the crawl space environment. While the light levels of the light can be adjusted from 200 lumens down to 20 lumens, the light can be set at its maximum brightness of 200 lumens and will not need to be reset when powered off [5]. Additionally, as the brightness of the light is 200 lumens, on an unit area of $1\ m^2$, the illumination intensity would be 200 lux, which is well over the minimum constraint of 50 lux and is aligned with the recommended illumination intenstiy to complete tasks and observe an environment set by the United States General Services Administration (GSA) and the European Society of Lighting and Lights (SLL) of the Chartered Institution of Building Services Engineers (CIBSE). The electrical connections of the Voltaic Light to the Raspberry Pi 4B are shown in figure 14. The proposed physical connections of the light to the inspection robot are shown through a proposed Solid Works model in figure 15 [10] and figure 16 [10].

Figure 14: [6, 7, 8, 9]

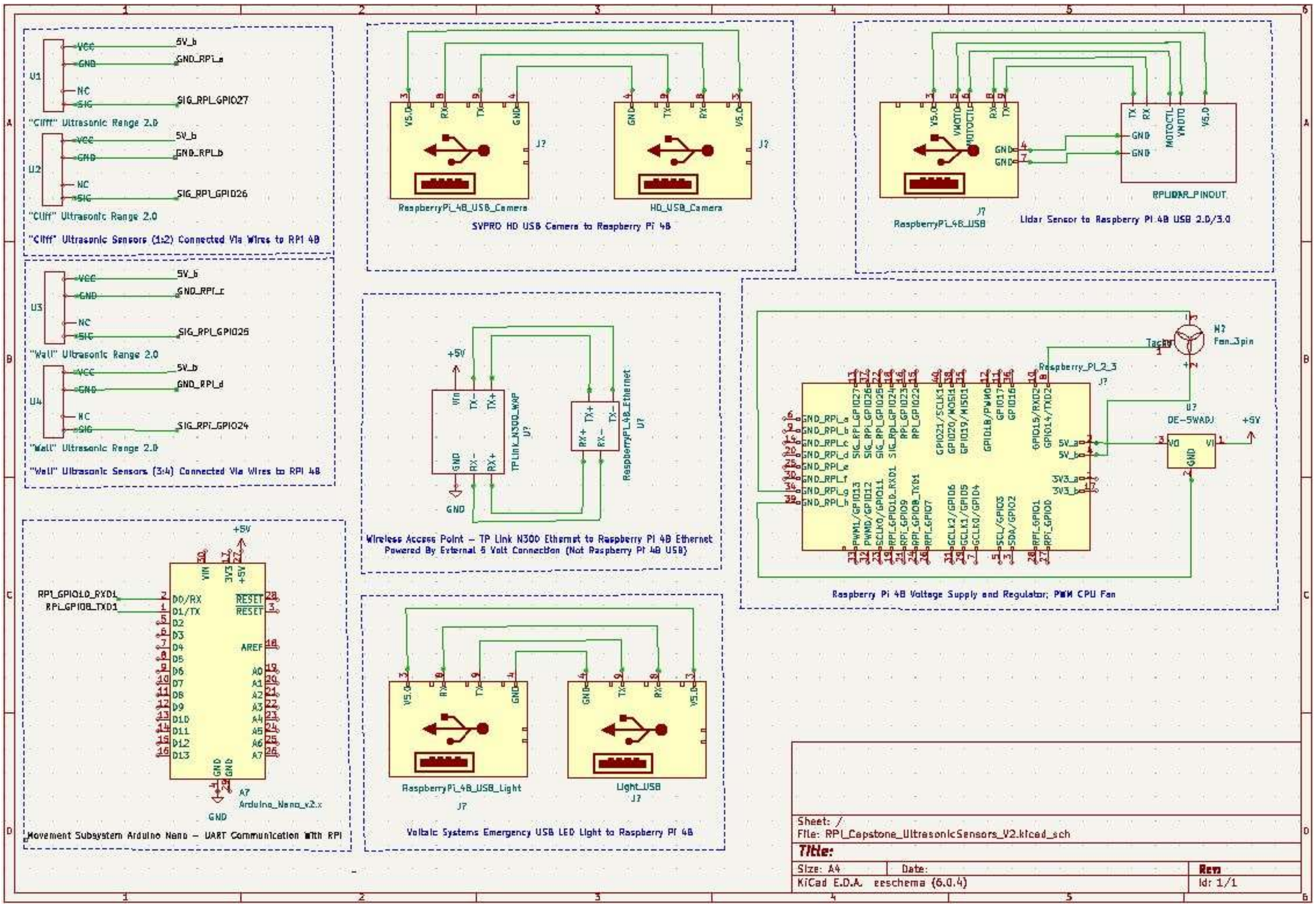


Figure 15 [10]:

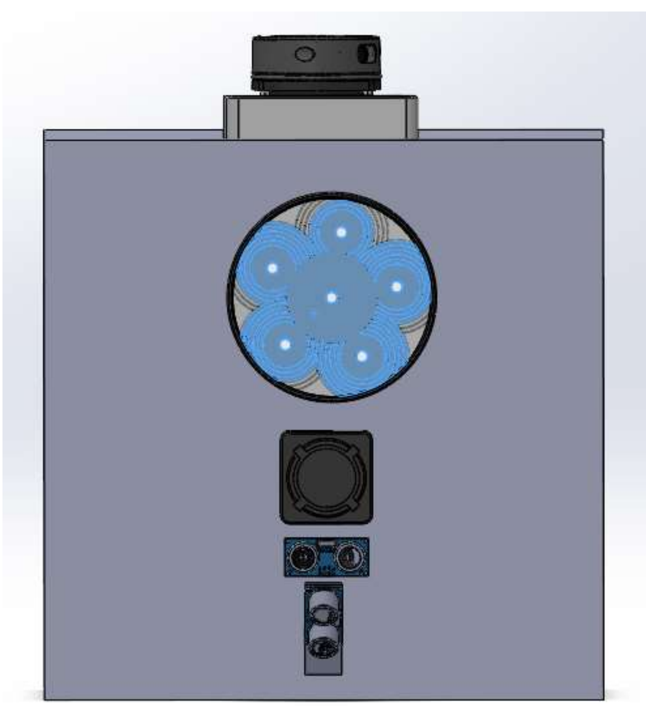
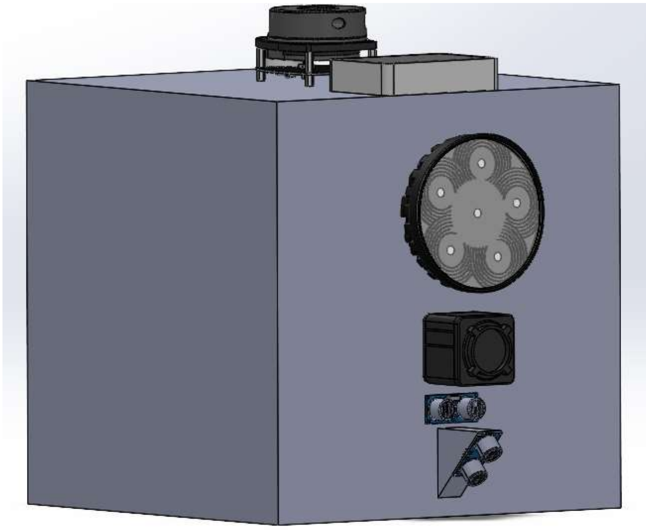


Figure 16 [10]:



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