Fire Exit Emergency Hose Coupler

by

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Team 238

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Table of Contents

Abstract

Fire safety is a field in which the technology has been stagnant for quite some time. The rate at which fires occur has never been constant. Because of this it is important that the men and women that will combat these fires have the proper equipment at all times. Communication has always been king amongst human priorities; however, this is an area in which we can improve upon. There is a place for a new communication device in the firefighter's arsenal. This report will first present the background specifications for the design of this device. It is necessary that the process for integrating new technology into the firefighting field is calculated and methodical. If someone's life is reliant upon this new device, it is imperative that the device will hold strong and not fail. The design and testing will also be featured in this report. These sections will detail all of the relevant material to ensure that the device performs its required task every time it is called upon.

1. Problem Statement

1.1 Needs Statement

There is a need for a new reliable tool for use on the attack line that helps firefighters as well as civilians navigate in a smoke-filled building. They should understand where the correct path is simply by looking at the attack line.

1.2 Objective Statement

The objective of this project is to design and prototype a device that will allow fire fighters and civilians to navigate through a fire environment safely. The attack line coupler will communicate with the truck, turn off automatically, light up uniquely for each truck with an arrow pointing towards the truck, and will draw power from the environment. In addition, users have access to a panic button that reports to the truck the location of the coupler if help is required. This device will allow firefighters to easily navigate lines as well as help civilians escape the burning building safely.

1.3 Background and Related Work

The attack line, the fire fighter's main hose, is the most important tool in the field. Several attack lines held by different teams of firefighters will surround the building. Not only is this line used to actually extinguish the fire, but it is also used as a guide to lead people out of a burning, smoke-filled building. One end of the fire hose is connected to the truck which is typically a safe location. Conversely, the other end is in the hands of the heavily geared firefighters who extinguish the fire. Unfortunately, victims have a difficult time finding which direction will lead them to safety. In addition to extinguishing the fire, the attack line is used as a guide to send a replacement team of firefighters to swap with the team manning the front of the attack line. A problem arises in either situation when someone reaches a tangle of attack lines typically causing firefighters to end up following the incorrect path and reaching the wrong team. To rectify this situation they must travel back through the fire-filled building and attempt to follow the correct attack line. This is a huge waste of time especially in a situation where time is critical. A firefighter's tank of air will typically contain approximately 20 to 30 minutes worth of breathable air. With only 20 minutes (being conservative on air management) of breathable air, every second counts in fire fighting situations.

The theory behind this design is to give the attack lines a new function to combat these issues; navigation assistance in a smoke-filled building for firefighters and civilians. Currently, firefighters attempt to follow their own attack line, starting from their truck, to find the other team of firefighters at the front of the hose. This becomes a difficult situation due to the entanglement of multiple attack lines from other trucks. In addition, there is no clear direction as to where the truck or the front of the attack line is located. This updated attack line is similar in comparison to the older model as the hose itself will function exactly the same way it does now. The core difference between the two hoses is that the updated hose will be able to remove most if

not all of the chaos involved with using the current attack line methodology for navigation. This is a new concept and currently there is no technology today that is similar to the proposed design idea.

This advanced attack line coupler will achieve these objectives using a combination of effective systems. The unit harvests power solely from the environment using an industry strength (175°C tolerant) thermoelectric generator. Wirelessly, it communicates to other units as well as a separate unit on the truck through an 868 MHz RF signal. The communication data is constructed and delivered through a specialized networking protocol created specifically for this design. The coupler may display lighting patterns, arrows, or signals through the use of powerful CREE LEDs. All of these processes will be handled by a CC1110 microcontroller. The CC1110 is a TI microcontroller that operates using little-power and will still possess the computational strength required for the objective.

2. The Requirements Specification

2.1 The Requirements

Marketing Requirements	Engineering Requirements	Justification
The device must be robust and survive in the heat and water produced by the environment	The coupler must function and survive in 1000 degrees fahrenheit for 45 seconds	This is the length of time a standard fire hose can survive in identical conditions
	The coupler must survive under 6 inches of water for 60 minutes	Once a room is cleared of fire the coupler sits in the remaining water for on average 60 minutes.
	Coupler must survive a six foot drop onto concrete	This is the probable maximum height at which the coupler will fall from. This height is relative to the height of a fire truck's hose bays
The device's light should be visible from a distance of 30 feet	The coupler must provide a brightness of at least 1000 lumens when lit	This is the common brightness used for search and rescue missions and with the smoke it will need to be visible
The device must be compatible with the Fire Code Standard 3 inch attack line	The device's inner diameter must be at most 3 inches	If the coupler's inner diameter is more than 3 inches, it is no longer compatible with a standard 3 inch hose.
The device must not alter the attack line itself to avoid the need for recertification (i.e. the hose must still be able to fold and the water pressure should not be changed)		
If possible, the device should harness energy from the hose or local environment	The device must be able to supply 10W of power to the system in a 50% duty cycle when required	This is the amount of power needed for the light and communication devices within coupler.
Device should have a panic button	Communication signals must travel 50 feet	The length of a standard attack line section is 50 feet and each coupler needs to relay information to each other.

	The communication signals must go through obstacles	Firefighters may be entering a building, the couplers may be separated by walls and floors.
	The communication signal must be digital	If an analog signal was used then anything outside of the coupler would have a great chance of breaking making it useless
The device should automatically turn on/off	N/A	This feature was necessary in order to ensure user-device interaction simplicity

Table 1

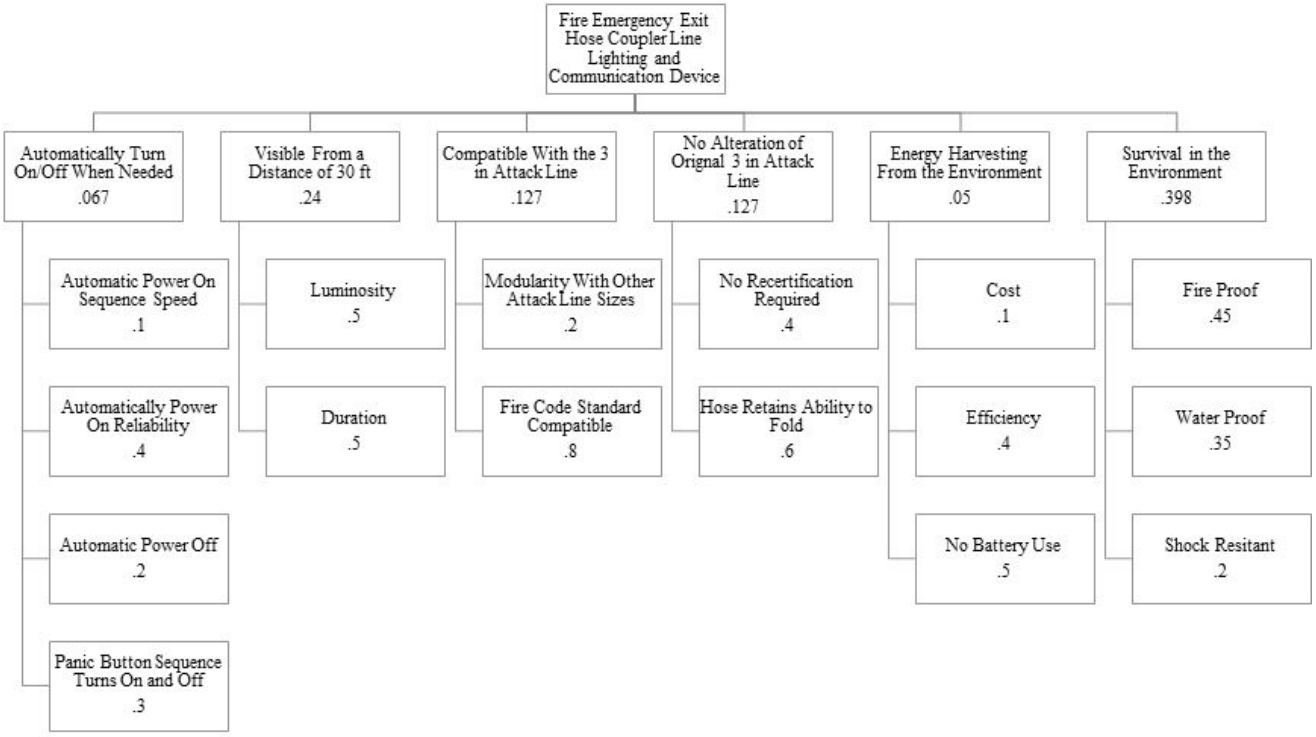

Figure 1

2.2 Constraints

Health & Safety
-The device's light must not be too bright that it harms someone's vision or cause an epileptic seizure.
-The device must not be affected by another coupler that is not on the same line.

Manufacturability
- The device must be compatible with the Fire code Standard 3 inch attack line
- The device must not alter the attack line itself to avoid the need for recertification

Economic
- The device must cost less than or equal to 50 dollars.

Sustainability
- The device must be robust and survive in the heat and water produced by the environment

Environmental
- The device should harness energy from the hose or the local environment instead of using batteries

2.3 Standards

- NFPA 1961: Standard on firehose
- FM Class Number 2111 / 2131, Factory Mutual Approval Standard for Fire Hose
- International Protection Rating: IP67, IP47

3. Design

3.1 Level -1

Figure 2 displays our systems architecture at a glance. The system consists of one master truck device and multiple communication devices located on the couplers on the fire hose.

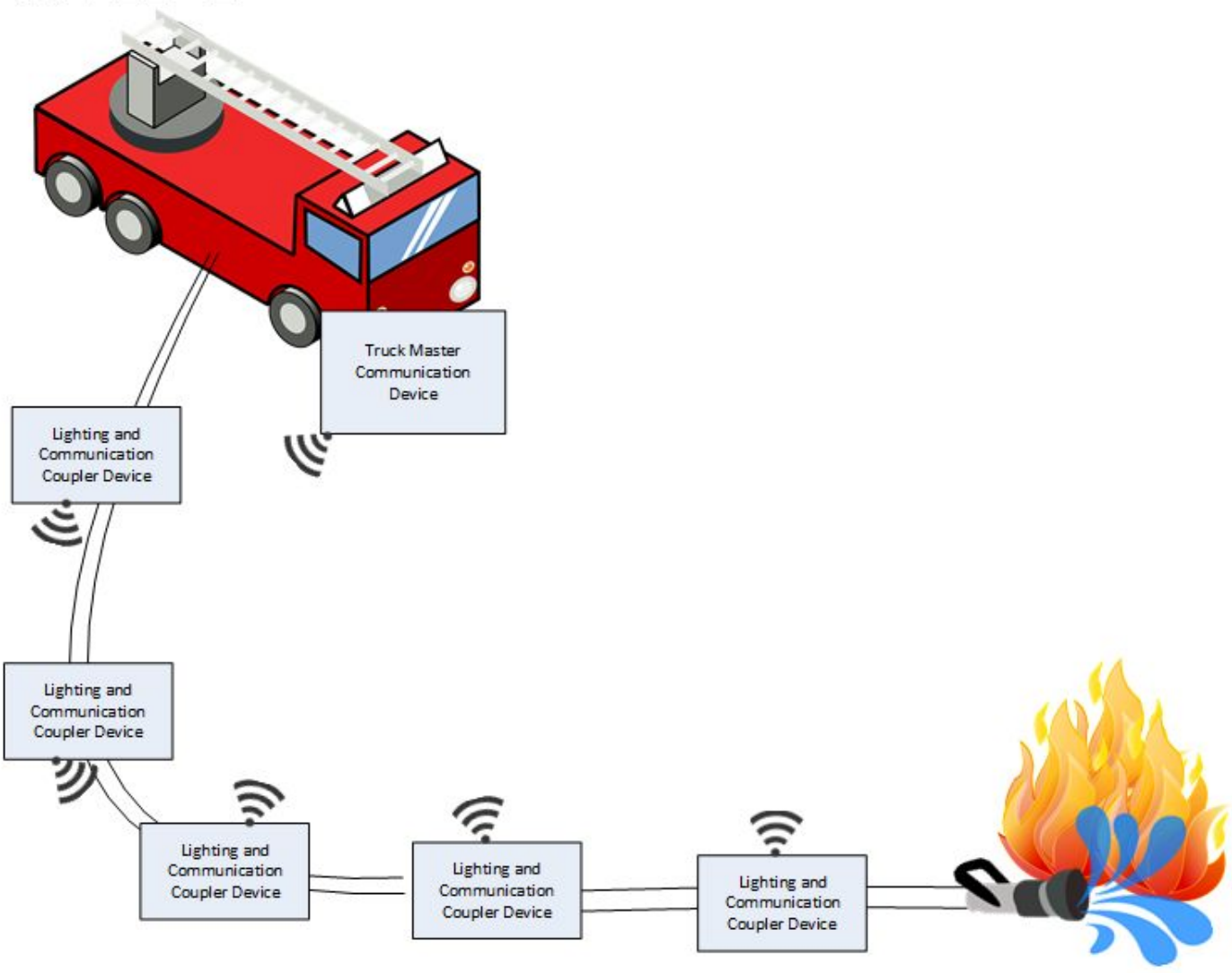

Figure 2

3.2 Level 0

Figure 3 details the generic I/O of the device. The device is actually a two unit pair that will communicate wirelessly using an RF signal. It will feature a main communication signal, which can vary its signal strength and content when necessary.

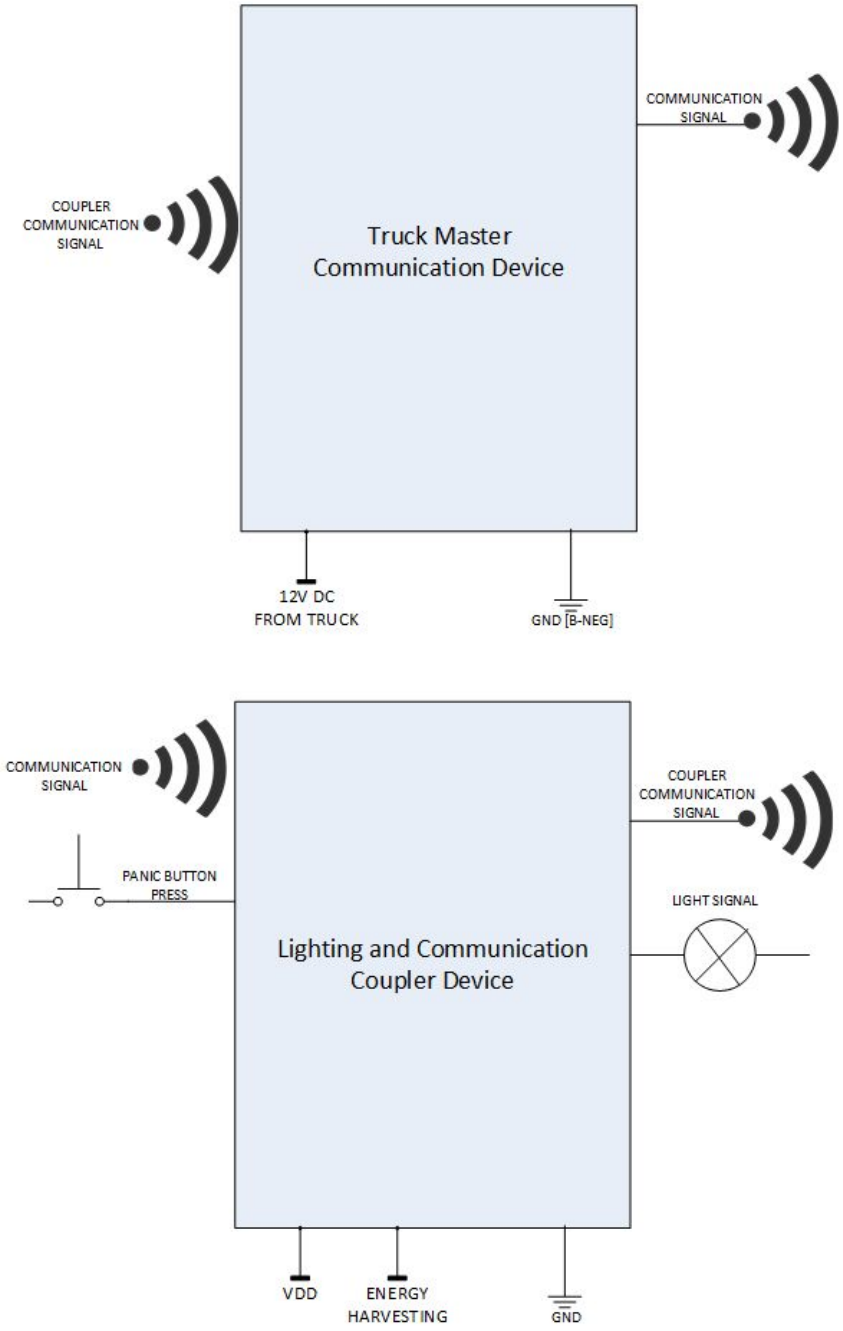

Figure 3

3.3 Level 1

3.3.1 Truck Master Communication Device

The figure 4 diagram details the components that will be used to create the coupler and the truck master devices. The diagrams illustrates what input and output pins are required and which signals will affect the communication between components and ultimately the output of the unit. The truck master handles all of the organization and panic management for the system.

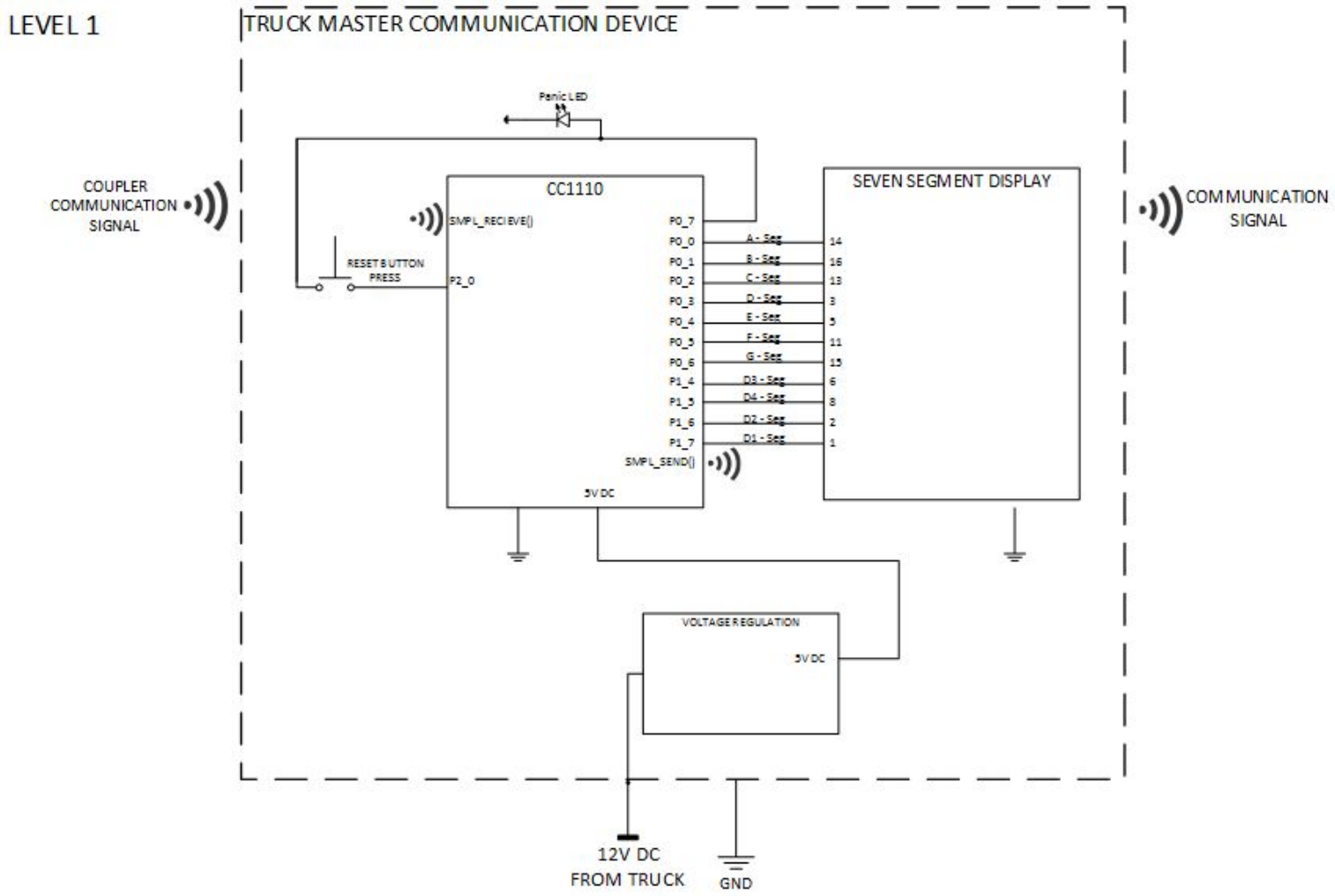

Figure 4

3.3.2 Lighting and Communication Coupler Device

The Lighting and Communication Coupler Device operates differently and figure 5 should display that clearly. The main input to this device is the panic button press. It will handle which light and communication signals will used as outputs.

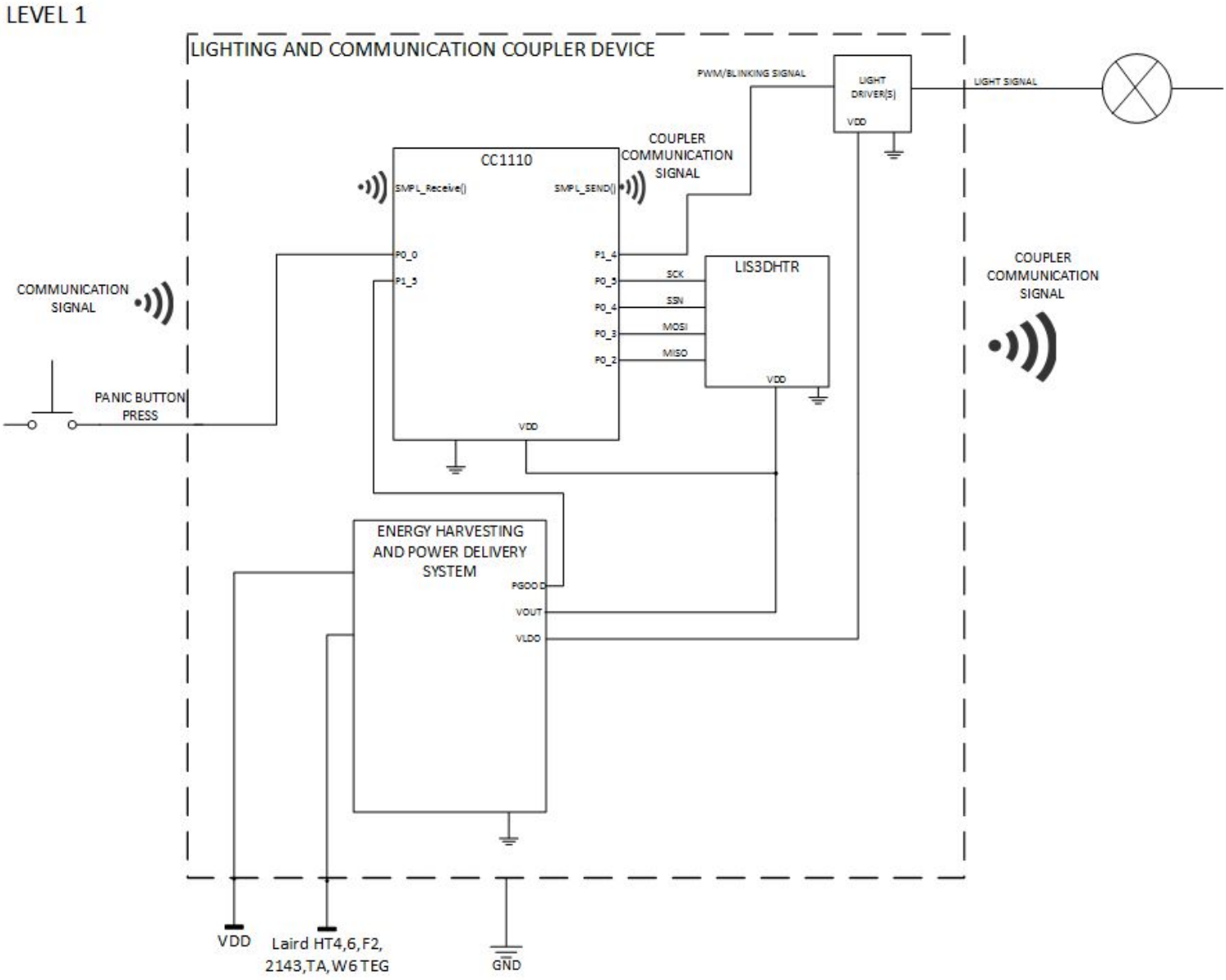

Figure 5

3.4 Level 2

3.4.1 Truck Master Communication Device

Start: The truck master communication device will be off until the unit receives power.

While on: The device waits until it receives a panic button press signal from the first coupler. It then turns on an led and prints a number to a 7-segment display which corresponds to the correct coupler and stays on until the reset button press is pressed. This button press will also send a signal to the first coupler to reset the panic mode in all of the couplers.

End: Once the device is no longer needed, it can simply be turned off - there is no overhead for this device.

3.4.2 Lightning and Communication Coupler Device

Start: The lighting and communication coupler device will use reserve power to initialize itself and then enter a super-low power mode. The device will stay in this mode until it receives a PGOOD signal from the energy harvesting unit telling the device that the coupler is in use. The device will then begin its main routine.

While on: The device will first send a “Who am I” message to the broadcast ID. This will allow the coupler to gain information from existing awake couplers. If there are no couplers awake already, the device will initialize itself. Afterwards, the coupler will begin to flash the CREE LED and periodically wake up from a sleep state to check for any couplers that may have woken up. In addition there will be a one-shotted button on top, that if pressed, will interrupt the device’s sleep and increase the blink rate on the CREE led - the device is now in panic mode. It will alert the other nearby coupler devices to convert to this mode. In addition to this, the device will remain in this mode until the truck master clears the system of the panic input. Once cleared, all devices will return to their normal lighting patterns in order to conserve power.

End: The coupler device will enter its super-low power mode state until they are required again.

4. Design Verification

4.1 Test Results

4.1.1 Integration Tests

Test Writer:		Team 238				
Test Case Name:		Computation block integration test			Test ID#	I-0001
Description:		Verify that the computation block is correctly processing the panic button input			Type:	White Box
Tester Information						
Name of Tester:					Date:	
Hardware revision:		1.0			Time:	
Setup:		Isolate the computation block and panic button				
Step	Action	Result	Pass/Fail	N/A	Comment	
0	Initialize computation block	Initialized	Pass		System is waiting for input	
1	Push button	Pushed	Pass			
2	Verify successful input	Panic state enacted	Pass		Button debounce worked perfectly	
3	Drop button	Destructive		N/A	Would require dropping entire device, attempting to avoid destructive tests	
4	Verify unsuccessful input			N/A		
5	Throw button	Destructive		N/A	Would require throwing entire device, attempting to avoid destructive tests	

Test Writer:	Team 238		
Test Case Name:	Master Slave Unit Testing	Test ID#	I-0002
Description:	Verify that the two independent systems will work together.	Type:	White Box
Tester Information			
Name of Tester:	Cody Dutko	Date:	

Hardware revision:		1.0			Time:	
Setup:		Use the power supply to provide power to both the coupler and truck master unit.				
Step	Action	Result	Pass/Fail	N/A	Comment	
0	Power on the truck master device	Successful	Pass			
1	Send initialization signal to coupler from the truck master from a distance of 1 foot	Successful	Pass			
2	Verify successful initialization sequence	Successful	Pass			
3	Press panic button on coupler 1 foot away from truck master	Successful	Pass			
4	Verify successful input	Successful	Pass		Input LED toggled	
5	Verify successful panic state sequence	Successful	Pass			
6	Send clear panic mode signal from truck 1 foot away	Successful	Pass		Panic LEDs turned off	
7	Verify successful input	Successful	Pass			
8	Repeat steps 1 through 7 from 10 feet away	Successful	Pass		Distance appears to not impair device	
9	Repeat steps 1 through 7 from 30 feet away	Successful	Pass		Distance nor 2 floors of a house residential house appear to impair device	

Test Writer:		Team 238				
Test Case Name:		Accelerometer Output Tester			Test ID#	I-0003
Description:		Test if the accelerometer is accurately returning the orientation of the Z axis to the MCU.			Type:	Black Box
Tester Information						
Name of Tester:		Nick and Cody			Date:	3/31/2016
Hardware revision:		1			Time:	1:00 pm
Setup:		Connect accelerometer to the Microcontroller unit.				
Step	Action	Result	Pass/Fail	N/A	Comment	
1	Connect Accelerometer to i/o pins	Connected	Pass		Wires labeled for easier management	
2	Turn on LED 1 between certain Z values	LED 1 turns on	Fail		We were getting a lot of noise and the LED was flashing.	
3	Raise the MCU until we reached a certain Z value	Turn off LED 1 turn on LED2	Fail			
4	Lower the MCU until we reached a certain Z value	Turn off LED 2 turn on LED1	Fail			
5	Lower the MCU until LED 1 turned off	LED 1 turns off	Fail			
Overall Test Result			Fail		Could not get accurate results, reevaluate code.	

Test Writer:		Team 238			
Test Case Name:		TEG Energy Harvester Unit Output Test		Test ID#	I-0004
Description:		Test energy harvester unit and TEG combination		Type:	Integration
Tester Information					
Name of Tester:		Cody, Nick, and Matt		Date:	4/19/2016
Hardware revision:		1		Time:	2:30 pm
Setup:		Use power supply, heatsink and TEG to create a heat source. Attach main TEG to the heat source along with its own heat sink and connect output to the energy harvester. Lastly read output from a digital multimeter.			
Step	Action	Result	Pass/Fail	N/A	Comment
1	Set power supply to 1 volt	Produce positive voltage output	Pass		Produced 0.15 volts on V_out pin Delta T: 4°F
2	Set input power supply to 1.5 volts	Produce positive voltage output	Fail		Received a lot of noise that did not seem to look right.
3	Set power supply to 2 volt	Produce positive voltage output	Fail		
4	Set input power supply to 2.5 volts	Produce positive voltage output	Fail		
5	Set power supply to 3.5 volt	Produce positive voltage output	Fail		
Overall Test Result			Fail		Reevaluating the energy harvester

4.1.2 Unit Tests

Test Writer:		Team 238			
Test Case Name:		Communication block hello world test		Test ID#	U-0001
Description:		Verify that the wireless communication unit is working correctly		Type:	White Box
Tester Information					
Name of Tester:		Cody Dutko		Date:	
Hardware revision:		1.0		Time:	
Setup:		Isolate two communication units from the rest of the system. Power them with a power supply instead of the energy harvesting unit.			
Step	Action	Result	Pass/Fail	N/A	Comment
0	Initialize both communication units		Pass		Quick and simple
1	Send signal from one unit to the other a distance of 1 foot		Pass		Automatic
2	Check successful signal and data rate	Success	Pass		LEDs signal AKs
3	Send Hello world message from a distance of 1 foot in an open room		Pass		
4	Check successful message and data rate	Success	Pass		
5	Send Hello world message from a distance of 10 feet in an open room		Pass		No stutter still quick send
6	Check successful message and data rate	Success	Pass		ACK received
7	Send Hello world message from a distance of 30 feet in an open room		Pass		
8	Check successful message and data rate	Success	Pass		Quick ACK and response
9	Send Hello world message from a distance of 30 feet between 2 rooms		Pass		
10	Check successful message and data rate	Success	Pass		Not affected by concrete walls
11	Send Hello world message from a distance of 50 feet in an open room		Pass		
12	Check successful message and data rate	Success	Pass		Not affected by increased distance

Test Writer:		Team 238			
Test Case Name:		TEG Output Test		Test ID#	U-0002
Description:		Test TEG output		Type:	White Box
Tester Information					
Name of Tester(s):		Cody, Nick, and Matt		Date:	4/19/2016
Hardware revision:		1		Time:	2:30 pm
Setup:		Use power supply, heatsink and TEG to create a heat source. Attach main TEG to the heat source along with its own heatsink. Lastly read output from a digital multimeter.			
Step	Action	Result	Pass/Fail	N/A	Comment
1	Set input power supply to 1 volt	Produce positive voltage output	Pass		Produced 71 millivolts Delta T: 2°F
2	Set input power supply to 1.5 volts	Produce positive voltage output	Pass		Produced: 0 .134 volts Delta T: 9°F
3	Set input power supply to 2 volts	Produce positive voltage output	Pass		Produced:0.17 volts Delta T: 13°F
4	Set input power supply to 2.5 volts	Produce positive voltage output	Pass		Produced:0.218 volts Delta T: 21°F
5	Set input power supply to 3.5 volts	Produce positive voltage output	Pass		Switched to different power supply, other one capped at 1 amp Produced: 0.425 volts Delta T: 38°F
Overall Test Result			Pass		Seems to output higher voltage as delta T increases.

Test Writer:		Team 238			
Test Case Name:		Basic Truck Master Tester		Test ID#	U-0003
Description:		Test if the Truck Master Microcontroller Unit can output values on a seven segment display, turn on a light, and reset the seven segment display and LED with a button press.		Type:	White Box
Tester Information					
Name of Tester:		Nick Cecchetti		Date:	4/20/2016
Hardware revision:		1		Time:	1:00 pm
Setup:		Connect microcontroller to a seven segment display, LED and push button.			
Step	Action	Result	Pass/Fail	N/A	Comment
1	Turn on Truck Master	Successful boot up	Pass		
2	Initialize LED to 1 and initialize seven segment to display 8	LED turns on and display the number 8 on seven segment display	Pass		Seven Segment is very dim
3	Press reset button	LED turns off, seven segment displays 0	Pass		
Overall Test Result			Pass		The basic version of truck master works

Test Writer:		Team 238			
Test Case Name:		Light Driver(s)		Test ID#	I-0005
Description:		Verify that that the light driver is producing enough light.		Type:	
Tester Information					
Name of Tester:		Cody, Nick, and Matt		Date:	
Hardware revision:		1.0		Time:	
Setup:		Isolate the Light Driver. Connect the driver to a function generator. Use a light meter to assist with testing.			
Step	Action	Result	Pass/Fail	N/A	Comment
1	Turn on the light to the correct duty cycle	Light is on	Pass		
2	Record level of visibility while standing 30 feet away from light source	Light is visible	Pass		Acceptable visibility, could be better may need to modify duty cycle
3	Record lux value from light meter	Strange value from light meter	Fail		Phone light meter seems to be inaccurate, need to reevaluate testing procedure
4	Record level of visibility while standing 60 feet away from light source	Light is decently visible	Pass		Overall visibility went down as distance increased but the evidence of a light was visible.
5	Record lux value from light meter	Strange value from light meter	Fail		Phone light meter seems to be inaccurate, need to reevaluate testing procedure

4.2 Requirements Verification

Engineering Requirements	How Requirement Was Met	If Not, How Can It Be Met	References
The coupler must function and survive in 1000 degrees fahrenheit for 45 seconds	N/A	Although not all of the components can survive at this temperature, they can be protected from the heat from a specialized enclosure. This would be an IP-67 compliant enclosure, which is insulated by another heat resistant-material such as Aerogel.	
The coupler must survive under 6 inches of water for 60 minutes	N/A	Although the device would not survive in water as it is now, an enclosure for the device could make this possible.	
Coupler must survive a six foot drop onto concrete	N/A	Although the device would not survive a six foot drop as it is now, an enclosure for the device could make this possible	
The coupler must provide a brightness of at least 1000 lumens when lit	N/A	N/A	
The device's inner diameter must be at most 3 inches	The device's components are all smaller than 3 inches and can be placed separately around the coupler to minimize the change to the coupler's overall size.	N/A	

The device must be able to supply 10W of power to the system in a 50% duty cycle when required	The device only activates when the energy harvesting device provides enough power. The device also has two AAA batteries as backup.	N/A	Test U-0002
Communication signals must travel 50 feet	The CC1110 microcontroller is capable of transmitting data well over 50 feet.	N/A	Test I-0002 Test U-0001
The communication signals must go through obstacles	The CC1110 microcontroller is capable of transmitting data through multiple walls and floors at a time without any loss of data.	N/A	Test I-0002 Test U-0001
The communication signal must be digital	Communication signal is a digital signal and will not be affected by noise.	N/A	Test I-0002 Test U-0001

4.3 Standards

- NFPA 1961: Standard on firehose
- FM Class Number 2111 / 2131, Factory Mutual Approval Standard for Fire Hose
- International Protection Rating: IP67, IP47

We have not affected the hose in anyway. All IP ratings will be met if an enclosure was created.

5. Summary and Conclusions

Even though we did not create an industry ready device, the functionality of our prototype is capable of being a finalized and fully functional device. All of the components we created will work together and produce the desired effects if and when implemented correctly.

For further work on the project, we have a few recommendations. The heat and water of the environment can be negated by a heat resistant waterproof enclosure and can be aided by materials such as aerogel. The thermoelectric generator is only tolerant up to 175°C so a more durable one could be beneficial, or a hybridization of energy harvesting devices may be more applicable.

Upon completion of this project, we learned many valuable lessons. We now know how to prevent a network storm which is an extreme amount of broadcast traffic in a network caused by infinite resending of packets. This can be avoided by identifying each packet with a unique number based on mixing random numbers with amount of packets sent. This results in an especially low probability that two packets will have the same ID. As engineers, we all gained a sharpening of our time management skills and were able to layout a timeline of how we intended to complete the project. Properly specifying parts was an important part of our project as well. Originally, we intended to use a set of RGB LEDs, however; we discovered later in the project that it was unfeasible to use with our power generation. Ensuring that your design options will actually be within your project's scope is important.

6. References

Angus Fire.http://www.lacountyfirefighters.org/items/Angus_Hose_Brochure.pdf.Angus Fire,2004 Web.23 October 2015.

“National Interagency Fire Center,” National Interagency Fire Center, 19-Feb-2016. [Online]. Available at: https://www.nifc.gov/fireinfo/nfn.htm. [Accessed: Feb-2016].

Appendix A: Project Management Plan

A.1 Work Breakdown Structure & Gantt Chart

Featured on pages following appendix B.

A.2 Development Costs

Part Description	Quantity	Individual Cost	Total Cost
CC1110DK-MINI-868 (Microcontroller Dev Kit)	1	80.08	80.08
LIS3DHTR (Ultra low-power High Performance 3-Axes "Nano" Accelerometer)	1	1.63	1.63
LTC-4627JR (7-Segment Display had from previous class)	1	0.00	0.00
XMLAWT 6000k CREE LED	3	4.90	14.70
LTC3108 (Ultralow Voltage Step-Up Converter and Power Manager)	1	6.28	6.28
LPR6235-752SML (1:100 Turn Transformer)	1	1.35	1.35
HT4,6,F2,2143 (TEG)	1	31.20	31.20
CP85438 (TEG, which was destroyed during testing)	1	19.13	19.13
Total	-	-	$154.37

Appendix B: Software

The software that will be attached are broken into 3 sections.

1. The IDE which was used during the entirety of the project was IAR Embedded Workbench by IAR Systems. The compiler and the debugger of IAR Embedded Workbench are by many considered the best in the industry. The version we are using is based on the 8051 CPU Core and will be included in a .zip file if any future work is needed. In order to compile the project, because of its size, a full-version of the software is required.

2. The file FEEHCLCD is the workspace which contains all of the necessary code needed for the coupler. The project is divided into a few necessary C files, which will build upon the BSP packages TI provides for the CC1110 line of microcontrollers. The most important file amongst these is FEEHCLCD.C, which contains the main operation routines for the device. Along with this, there are C files which enable both PWM and SPI support for the device. All of these will be contained in a .zip file if any future work is required.

3. The final file set is the TruckMaster workspace, which contains the materials necessary for the Truck's device functionality. This set of files contains the same BSP packages that TI provides and builds upon that. The TruckMaster file set does not require any additional files to enable its operation. All of the required files will be contained in a .zip file if modification is necessary.