Initial Project Document

Li-Fi (Light Fidelity)

An alternative to the wireless transmission with RF spectrums through visible light communication.

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Project Narrative

Currently there are more than 15 billion Wi-Fi enabled devices in the world, and it's not just cell phones and computers. The fact is, most household appliances are equipped with Wi-Fi capabilities, and the spectrum allotted for 802.11 protocol (local wireless networks) is becoming increasingly saturated and scarce. If we look at long haul communication systems, we see that in the past decades the industry has migrated from traditional copper cables to fiber optic systems. Optical systems provide greatly increased bandwidths and bitrates, and here we propose the same concept.

Li-Fi technology is very similar to Wi-Fi technology in the sense that it is a local wireless network, however the signal is visible light instead of in the radio frequencies. Since visible light frequency is much higher on the EM spectrum Li-Fi systems provide bandwidth many times greater than Wi-Fi. In addition Li-Fi is considerably more energy efficient, since the transmitter in the system is an LED instead of a conventional radio transmitter. Li-Fi is also a secure means of data transfer, the modulating light itself represents the data stream, and since light does not penetrate walls there is no way to remotely intercept the data. Our system will also be full duplex unlike VLC systems that are only one-way communications. Li-Fi systems are non-hazardous to other electrical systems in terms of interference, making them more versatile in settings like a airplanes or settings with high sensitivity to electromagnetic radiation.

For this project we propose using two sets of receivers and transmitters, the set of transmitters will use a broadband LED and the other using an IR LED. The receivers will have the ability to not restrict the flow of the data, or have similar response times to the LED itself. In a practical environment, the ceiling lights would serve as our downlink, in this case we will use a regular “off the shelf” LED. Since Li-Fi is a complementary technology, a system would make use of existing data lines, for instance our system will use power over ethernet (POE) to power the LED, reducing energy consumption and excessive electrical wires. The LED would receive the incoming data from the Ethernet port and be directly modulated as a consequence. On the other end a photodetector such as a solar cell will collect the light, and provide a modulated voltage that will be amplified and interfaced with a USB connection, making it a universal system.

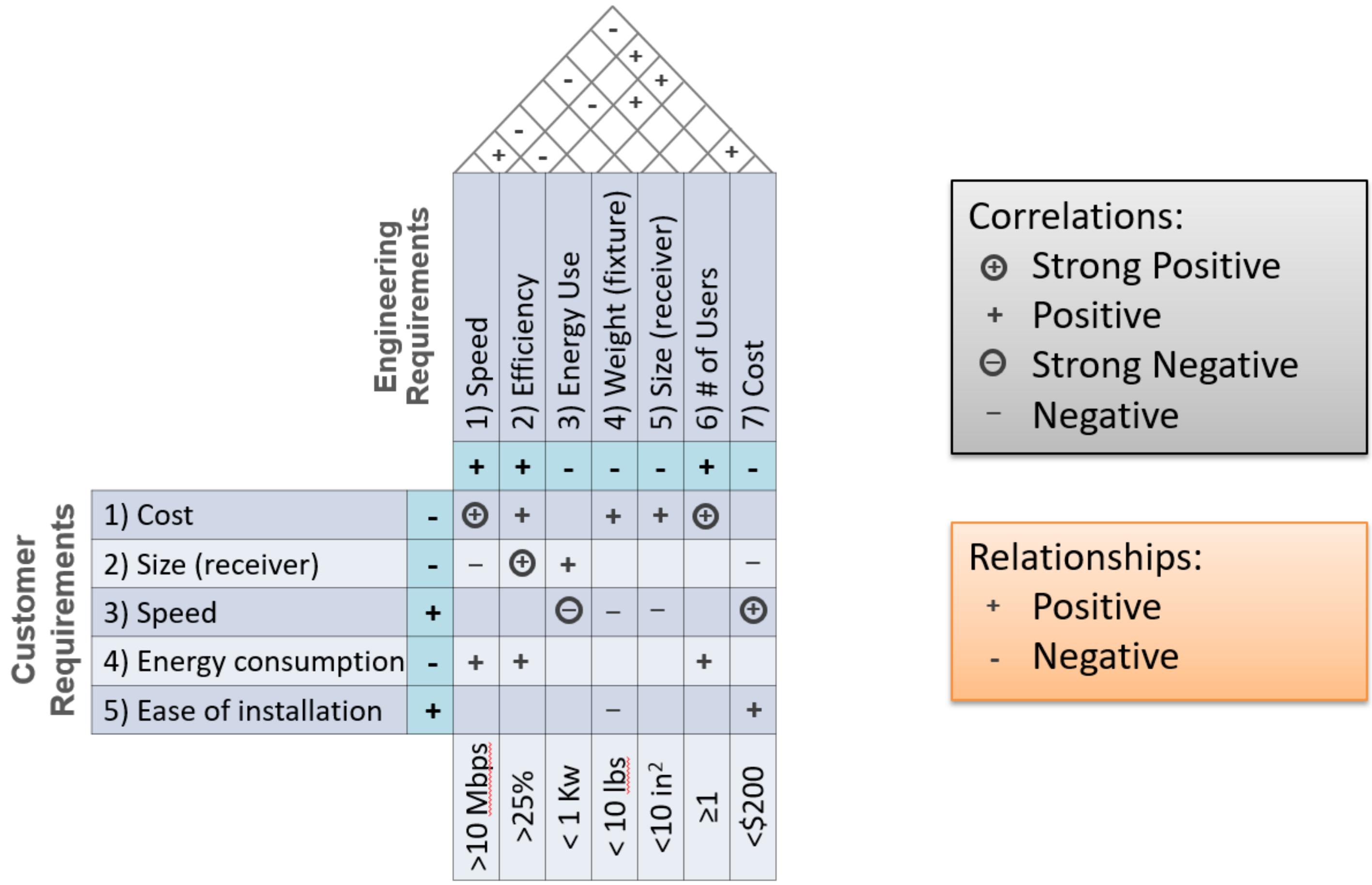
Light emitting diode (LED) light bulbs not only can provide energy efficiency in illuminating houses, and stores, but have the ability to modulate with various schemes such as pulse width modulation (PWM) and or pulse position modulation (PPM). Furthermore techniques such as orthogonal frequency division multiplexing can be implemented to allow for access to multiple users from one transmitting network. This project will focus on implementing a connection from an ethernet port into a intensity modulation format for the LED.

As the internet of things (IoT) continues to evolve, the various devices in the home will require connectivity. This rate of increase is going to impact the ability of our wireless transmitting devices to carry that bandwidth which is where LiFi can be application specific and not be for consumer use. Furthermore the IoT has applications such as theme parks where at each station or ride can have independent data be transmitted to a multimedia device for the consumer such as in augmented reality. The LiFi systems overall is cost effective because of power consumption and it should be comparable to a WiFi module, and can be investigated to implement with PoE and create new applications industry can take advantage of.

Table 1: Requirements Specifications

Requirement ID	Requirement Specification

1.0	The system shall have the ability to transmit information through LED light.
1.1	The system shall have the ability to transmit the information with a comparable or faster bandwidth compared to Wi-Fi.
1.2	The system should be able to convert ethernet 10/100 Base-T input into a modulation scheme for an LED.
1.3	Have the ability to be used in low illumination settings undetectable to the eye.
1.4	LEDs should provide very low power consumptions, and have a very long lifetime.
1.5	The system should not create interference with sensitive electronics.
1.6	Security ability for internet protocols can be maintained.



House of Quality

Figure 1: The house of quality of the system specifications.

The house of quality represents a visual overview of the system requirements. In order to obtain the above relationships our product should be well engineered and tested.

Block Diagram

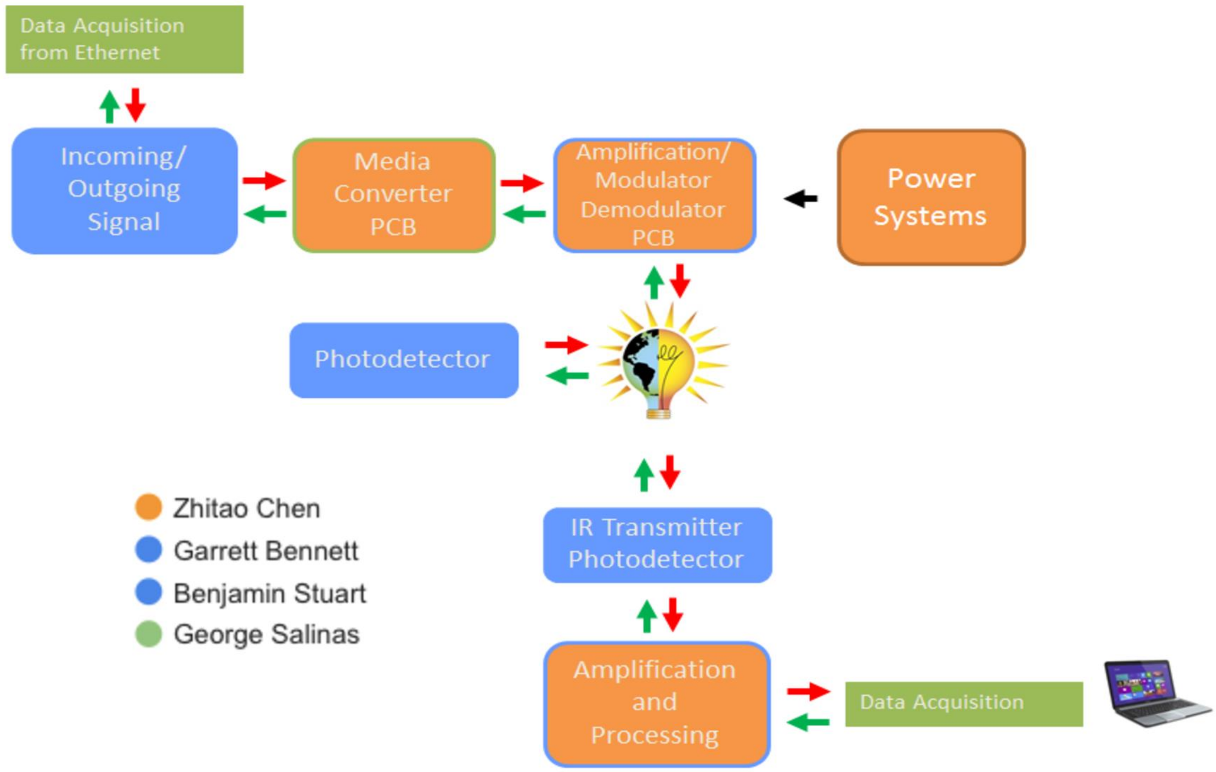


Figure 2: Block diagram for the proposed LiFi system

Project Block Diagram Status:

- The amplification and power systems block may rely on high speed high amperage linear amplifiers and PoE. It will be at least 100 MHz and output 1A.
- The photodetectors and illumination LED has been picked in table _ below.
- Prototyping for the system will be done in stages.

Data Flowchart

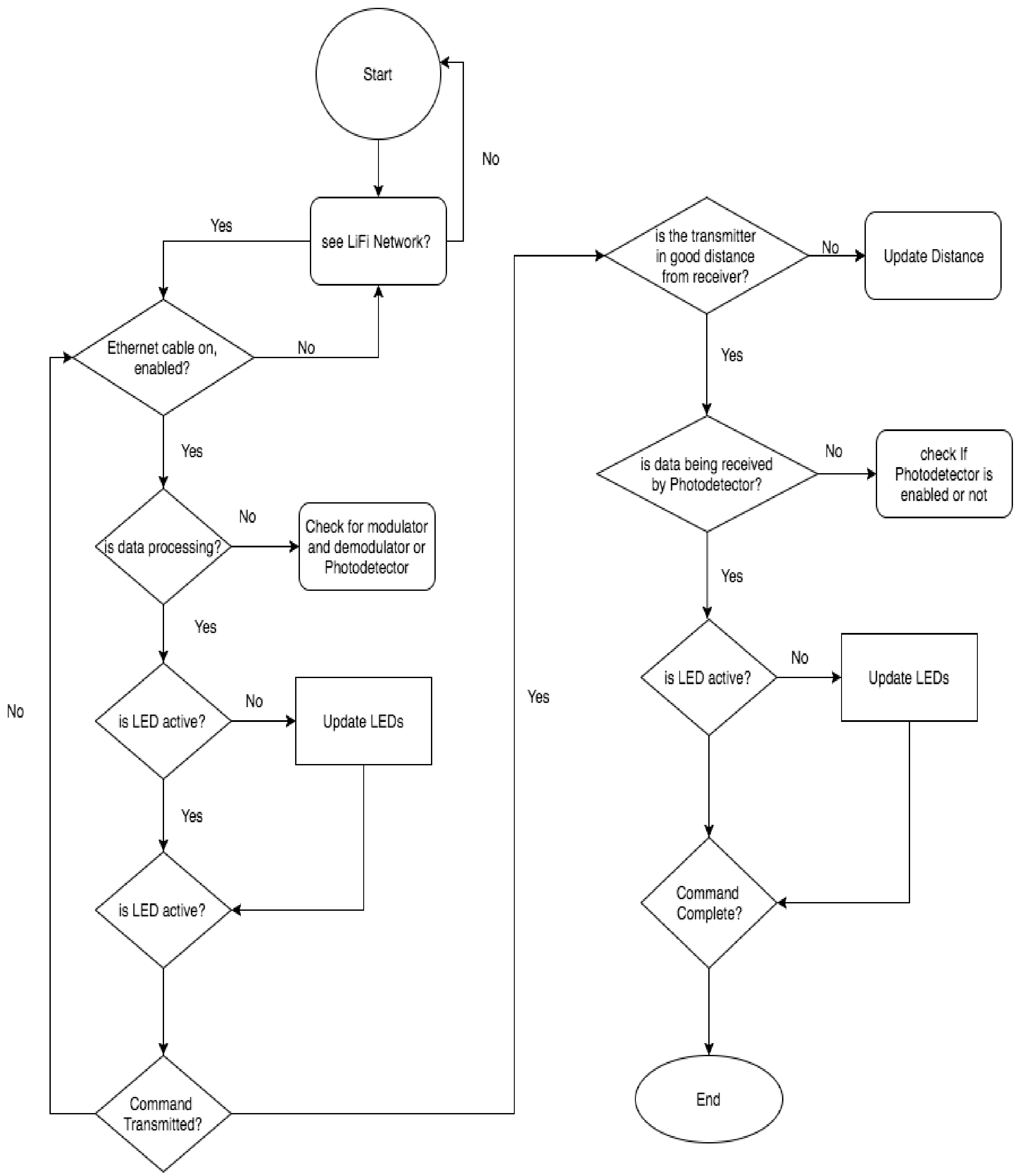


Figure 3: High level overview of data flow.

The estimated project budget and financing is an approximate system demonstration cost. The integrated circuits (IC) will be of vital function and eventually will be the limitations of the design.

Table 2: Estimated Project Budget

Material	Quantity	Unit Cost	Total Cost
Development Kit for MAX 3967A	1	300	300
Various IC	8	$3.12	$24.96
Resistor	20	$.10	$2.00
Capacitor	10	$.50	$5.00
Ethernet cable	1	$2.83	$2.83
PCB	5	$7	$35
LED Light Bulb	2	$14	$28
Photodetector	2	$30	$60
RJ45 jack	20 Pack	$3.33	$3.33
Total Cost Estimate			$461.12

Below is the initial project milestone table for both semesters. Ideally we will try and complete these tasks before the deadline.

Table 3: The Milestone Objectives

Description	Time will take it to complete	Deadline
	Senior design 1	
Form Group	1 hour	5/18/2017
1 page project idea	1 hour	5/19/2017
10 pages report	6-10 hours	6/2/2017
Divide and conquer	30 minutes	6/6/2017
Component Testing Start	N/A	6/6/2017
Meeting with Dr. Hagen	30 minutes	Random
Breadboard Testing	N/A	7/3/2017
60 Page report	10-20 hours	7/7/2017
Design PCB	10-20 hours	7/14/2017
100 pages report	10-20 hours	7/21/2017
Final document	8-12 hours	8/1/2017
Order PCB	3 Weeks	8/1/2017
Testing	N/A	Break
	Senior Design 2	
Finalize Design	1 days	8/25/2017
Send out second PCB	1 week	9/8/2017
Prototype	1 week	9/17/2017
Testing and redesign	2 weeks	10/1/2017
Finalize prototype	2weeks	10/15/2017
Peer presentation	30 minutes	11/1/2017
Final report	2 weeks	11/20/2017
Final Presentation/	30 minutes	12/1/2017

Below is the circuit schematic of a 100Base-T VLC Transceiver found in “Foundations of Visible Light Communication Circuits” by Lih Chieh Png and Kiat Seng Yeo from Singapore University. Png and Yeo have made designs for LED’s which do not have enough luminous flux to light up a room. The team has deduced that the output current from the MAX 3967 will not be enough to drive the illumination

LED and linear amplifiers with >100 MHz and can provide 700 mA to 1200 mA need to be used. Furthermore the OPA 658 is obsolete and the OPA694ID will be able to replace it.

Prototype Design Premise

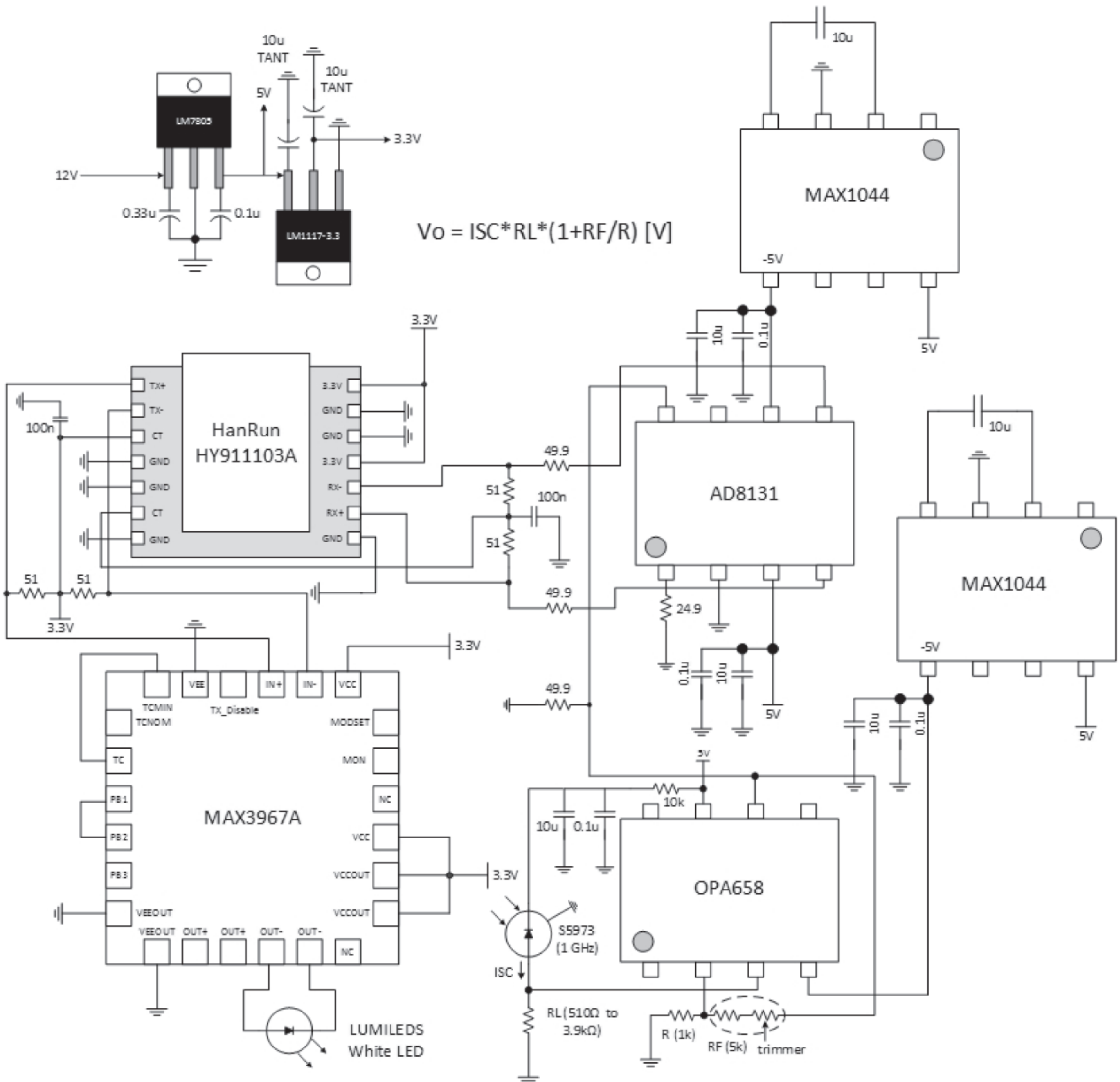


Figure 4: Ethernet Connected 100Base-T VLC Transceiver device

The transceiver model will involve the ability to convert the MLT-3 code from a 100Base-T signal into a suitable regime for an LED. The MLT-3 signal is inherently not applicable for LED illumination because it is a -1 V, 0 V, 1 V signal at around 300 ns. Therefore we need to convert this into a suitable signal for LED modulation. The MLT-3 needs to be converted into a 100base-FX signal which is suitable for LED modulation. The idea is to build a robust system which can convert the Ethernet signals MLT-3 (analog) to digital signals as in binary or NRZI before feeding them into the LED. NRZI signals are also referred to as PECL (positive emitter-coupled logic). At the receiver the conversion will be binary back to MLT-3.

THE BACK UP PLAN. Which we do not want to do.

Portable wireless spectrometer for non destructive testing of produce.
DOI: 10.1038/srep32504

The ability to obtain the optical spectrum of organic tissue can reveal the spectral signature or fingerprint of that organism. The measurement can readily be transformed from the quantitative spectral graph into a qualitative declaration via correlative methods such as cross correlation and auto correlations of the fourier transforms compared to a database. Spectrometers are usually limited for commercial settings because of their required computing device and in ability to be robust. The proposed housing will be robust and have tolerance to high impact to maintain the position of the sensitive optics. The product will be a standalone platform able to communicate with a wireless phone via bluetooth. The bluetooth link in the phone will be able to exchange the information of the calculated quantitative data and display it for the user. In the electrical side It will have charging capabilities and be able to drive an ultraviolet LED at a constant current. The group will focus on making this prototype into a manufacturable product because of the newly designed PCB. The hamamatsu mini-spectrometer chip has the ability to have a spectral response between 340 nm to 850 nm with a 15 nm maximum spectral resolution. The allows for the device to obtain a high quality spectrum. The housing design can also be changed because of the new compactness of the PCB.

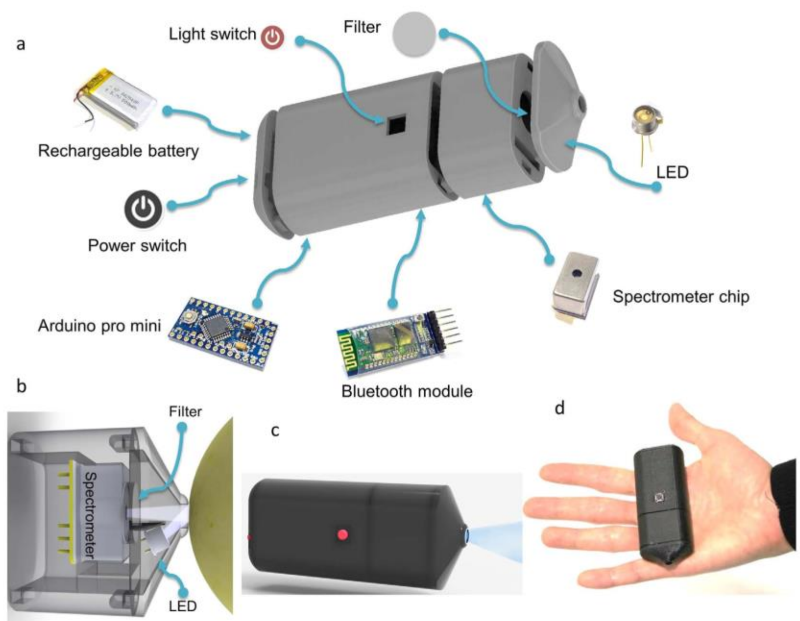


Figure 5. (a) Schematic of the constituent components. (b) Close up of the sensor nozzle depicting the light coupling into the spectrometer and LED illumination. (c) Model of the assembled housing from the previous author. (d) Photograph of a working prototype.

The following is a preliminary price point for development. Manufacturing should be considerably less.

Part List	Price	Description	link	link to spec sheet
Arduino Pro Mini 328 - 5V/16MHz	9.99	ATmega328 running at 16MHz with external resonator (0.5% tolerance), 0.8mm Thin PCB, USB connection off board, Supports auto-reset, 5V regulator, Max 150mA output, Over current protected, Weighs less than 2 grams, DC input 5V up to 12V, On board Power and Status LEDs, Analog Pins: 8, Digital I/Os: 14	https://www.sparkfun.com/products/11113	https://cdn.sparkfun.com/datasheets/Dev/Arduino/Boards/ProMini16MHzv1.pdf
SparkFun FTDI Basic Breakout - 5V	14.95	For burning code to Arduino Pro Mini	https://www.sparkf	https://www.sparkf
Buck board	9.95	3V-5V / 1000ma from 5V-12V onvert just about any battery pack to 5V with VERTER - our fresh new Buck-Boost power converter. VERTER can take battery voltages from 3-12VDC and output a nice 5V DC	https://www.adafruit.com/product/2190	
Battery	7.95	Lithium Ion Polymer Battery - 3.7v 500mAh	https://www.adafruit.com/product/1578	
AC charger	5.95	Adafruit Micro Lipo - USB LiIon/LiPoly charger - v1	ww.adafruit.com/products/130	rn.adafruit.com/adafruit-
Push button	5.99	Sub-Mini Push Button Momentary Switch - Off - (On)	ww.amazon.com/Sub-	
Switch	0.95	Breadboard-friendly SPDT Slide Switch	https://www.adafru	
Break Away Female Headers - Swiss Machine Pin	3.95	Single row of 30-holes, female header with swiss round machined pins. These units have very high quality round pins to accept and retain machine pin headers much better. Can be cut to size with a pair of wire-cutters. Standard .1" spacing. We use them extensively in the Olimex development boards. They mate very well with break away headers.	https://www.sparkfun.com/products/743	
LED	10			
Optical Filter	30			
C12666MA or C12880MA	245			
Total Price	344.68			