

MODULAR HOME MONITORING SYSTEM

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MOTIVATION

- We want to make smart home technology convenient and accessible for the consumer.
- Commercial products are limited in features, and not easily extensible.
 - Many also require a monthly subscription to a monitoring service.
- There is a demand for a simple, modular, and low-cost home monitoring solution.

GOALS AND OBJECTIVES

- Modular interface that can easily accommodate new sensors
- Web-based remote monitoring interface
 - Live and recorded video
 - Real-time graphs of sensor data
- Sensor data stored in the cloud (IBM Bluemix)
 - Remote access
 - Data analysis
- Wireless communication between sensors and base station
- Basic sensor suite
 - Carbon monoxide, smoke, humidity, cameras
 - More to be added if time permits

SPECIFICATIONS

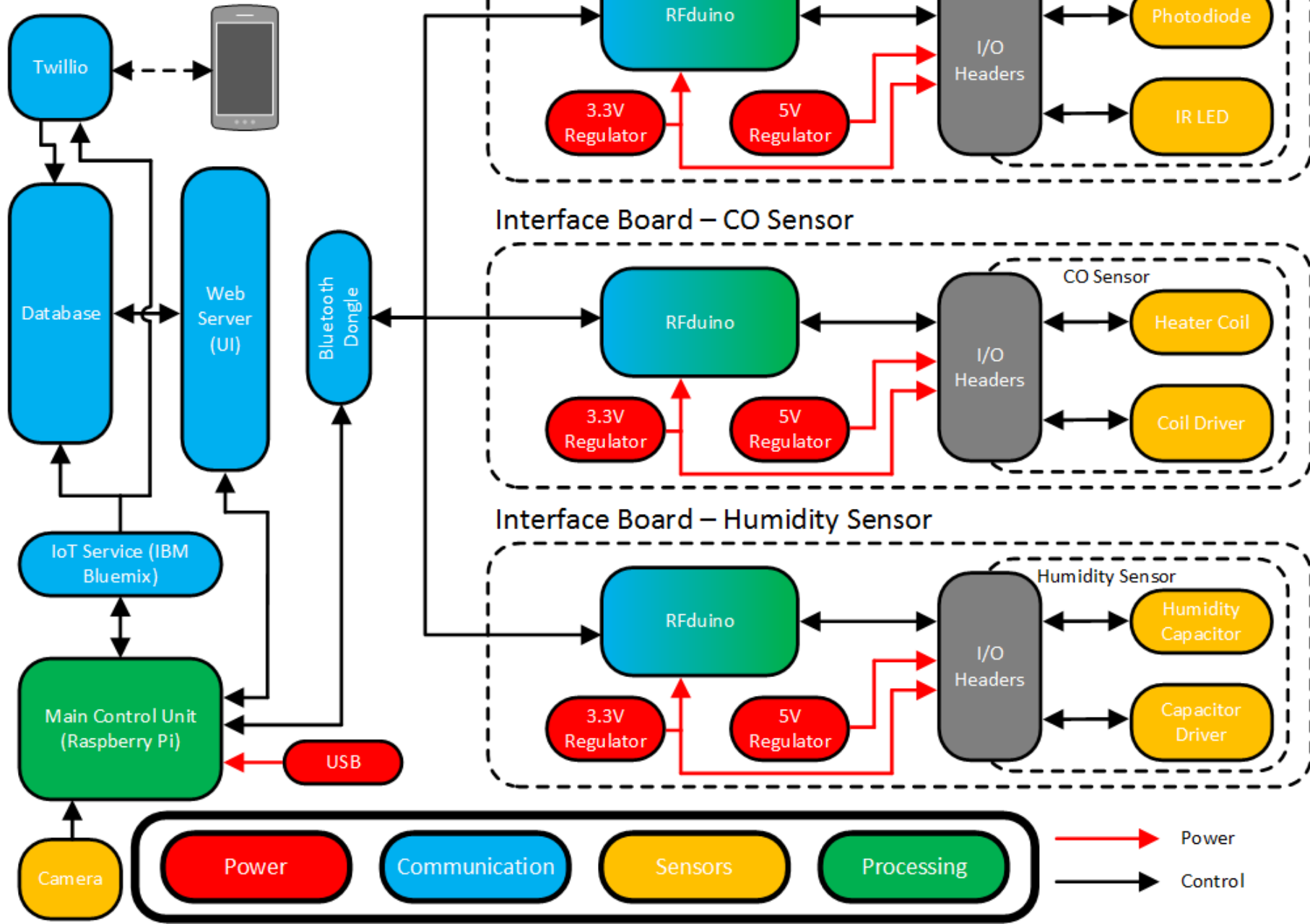
Component	Parameter	Requirement
Main Control Unit	Size	< 7" x 7" x 4"
	Weight	< 5 lbs
Sensor Unit	Size	< 4" x 3" x 2"
	Weight	< 2 lbs
Carbon Monoxide	Accuracy	50 ppm
Humidity Sensor	Accuracy	±5% Relative Humidity
Smoke Sensor	Accuracy	13obs/m

RELATED STANDARDS

- Electrical Code of Federal Regulations Title 47 – Telecommunications
- Bluetooth 4.0
- IEEE 802.11 WiFi
- ISO 7240-15:2014 Fire Detection and Alarm Systems
- CSI-3 Camera Serial Interface Standard
- BSR/IEEE 2413-201x Standard for an Architectural Framework for the IoT

HARDWARE DESIGN

OVERALL BLOCK DIAGRAM



MAIN CONTROL UNIT

- Raspberry Pi 2 Model B running Raspbian
- Competitors: Beaglebone Black
- Reasons chosen:
 - Supported by Bluemix Internet of Things Foundation
 - Cheap and powerful off-the-shelf
 - Familiarity with Debian Linux distributions
 - Universal linux libraries for low level hardware interaction
- Hub of Bluetooth and WiFi communication

Specs:

900MHz Quad Core CPU
1GB RAM
4 USB ports
CSI Camera Interface

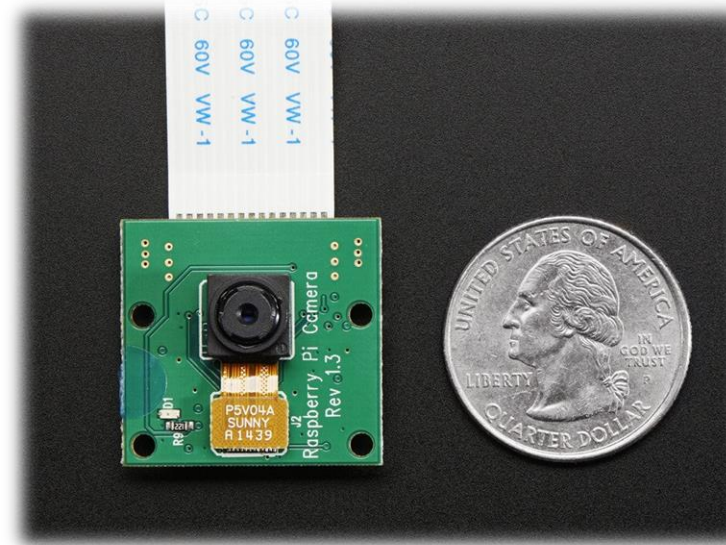
Cost:

\$35 most retailers
\$10 WiFi Dongle
\$13 Bluetooth Dongle



CAMERA

- 5MP (2592x1944) sensor
- Video formats:
 - 1080p30
 - 720p60
 - 640x480p60/90



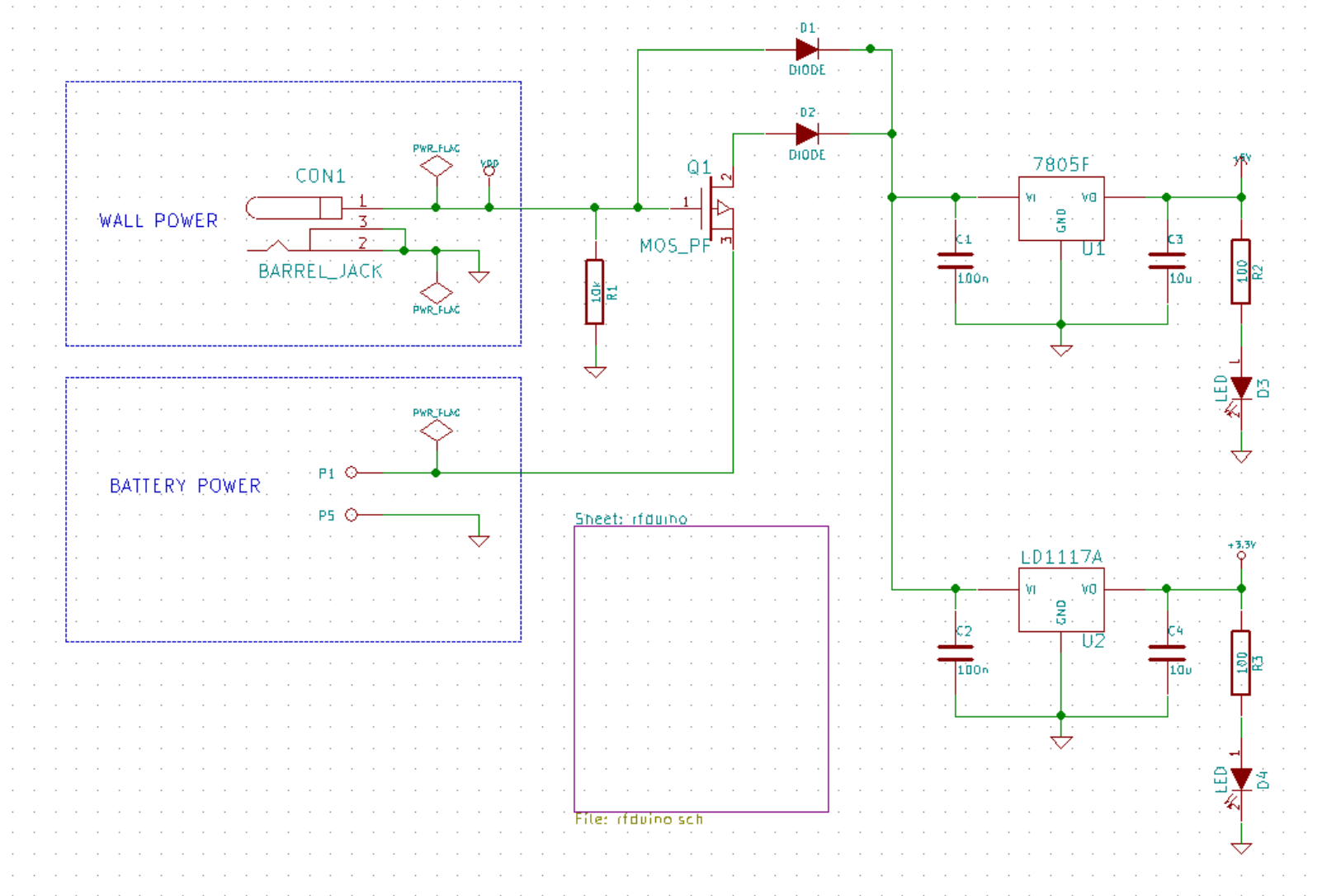
- Dedicated Camera Serial Interface (CSI) interface directly to Raspberry Pi
- Use MJPEG-Streamer software to stream video to web interface



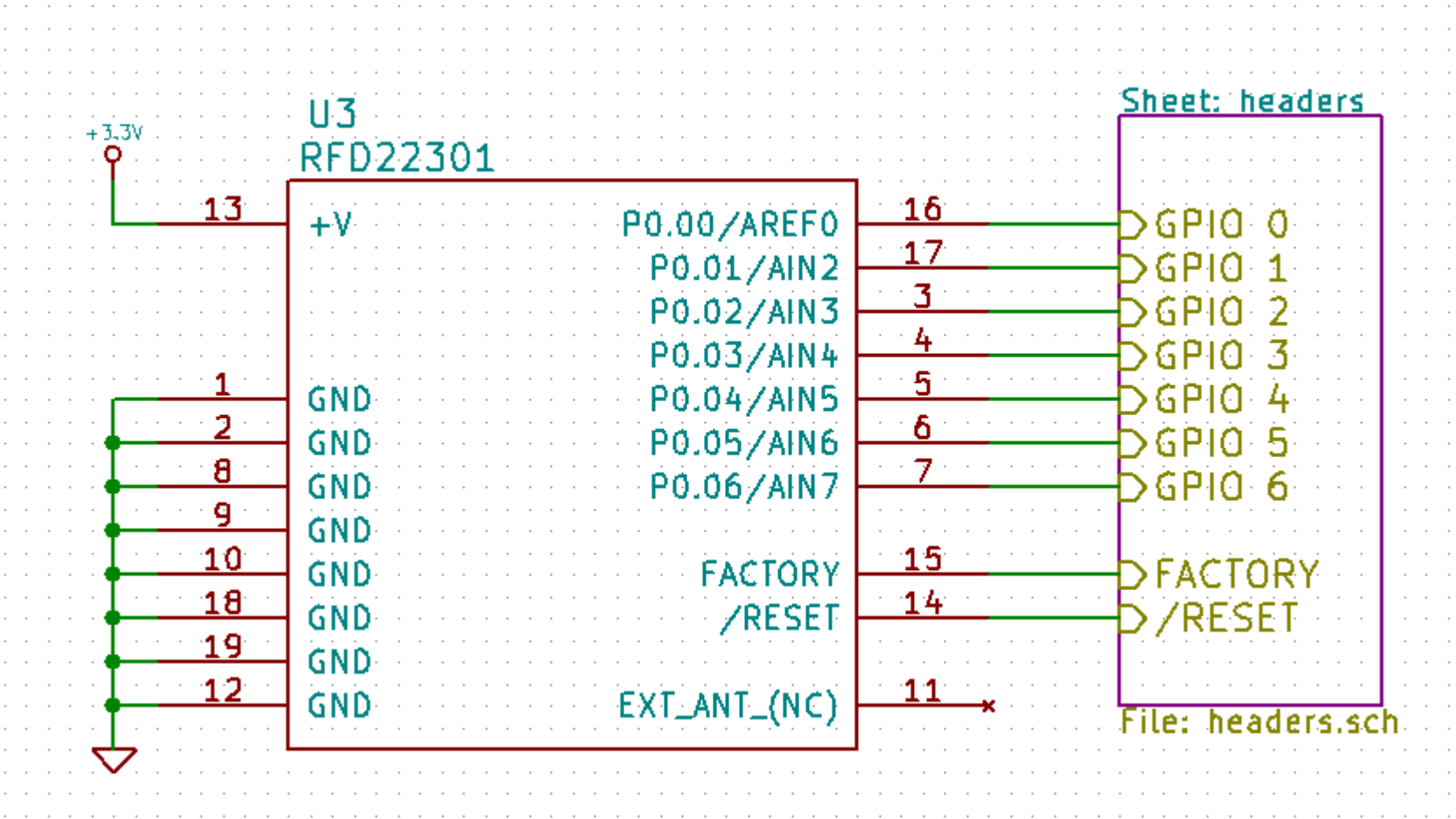
INTERFACE BOARD

- The interface board connects to and supports the sensor modules.
- Bluetooth is used to send data to and receive commands from the base station.
- Wall power is used when available, with a primary (non-rechargeable) backup in case of a power outage.

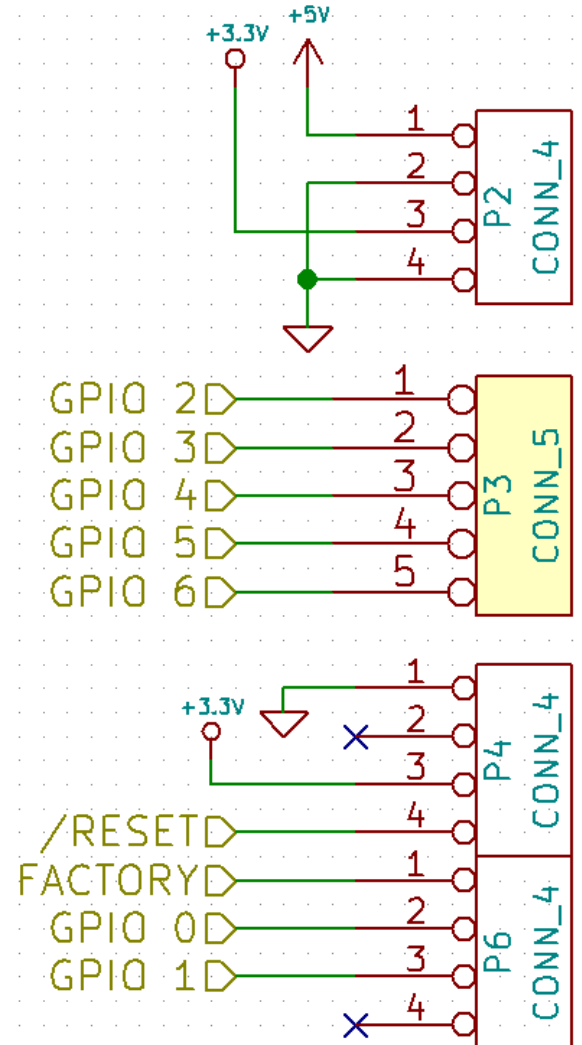
INTERFACE BOARD SCHEMATIC



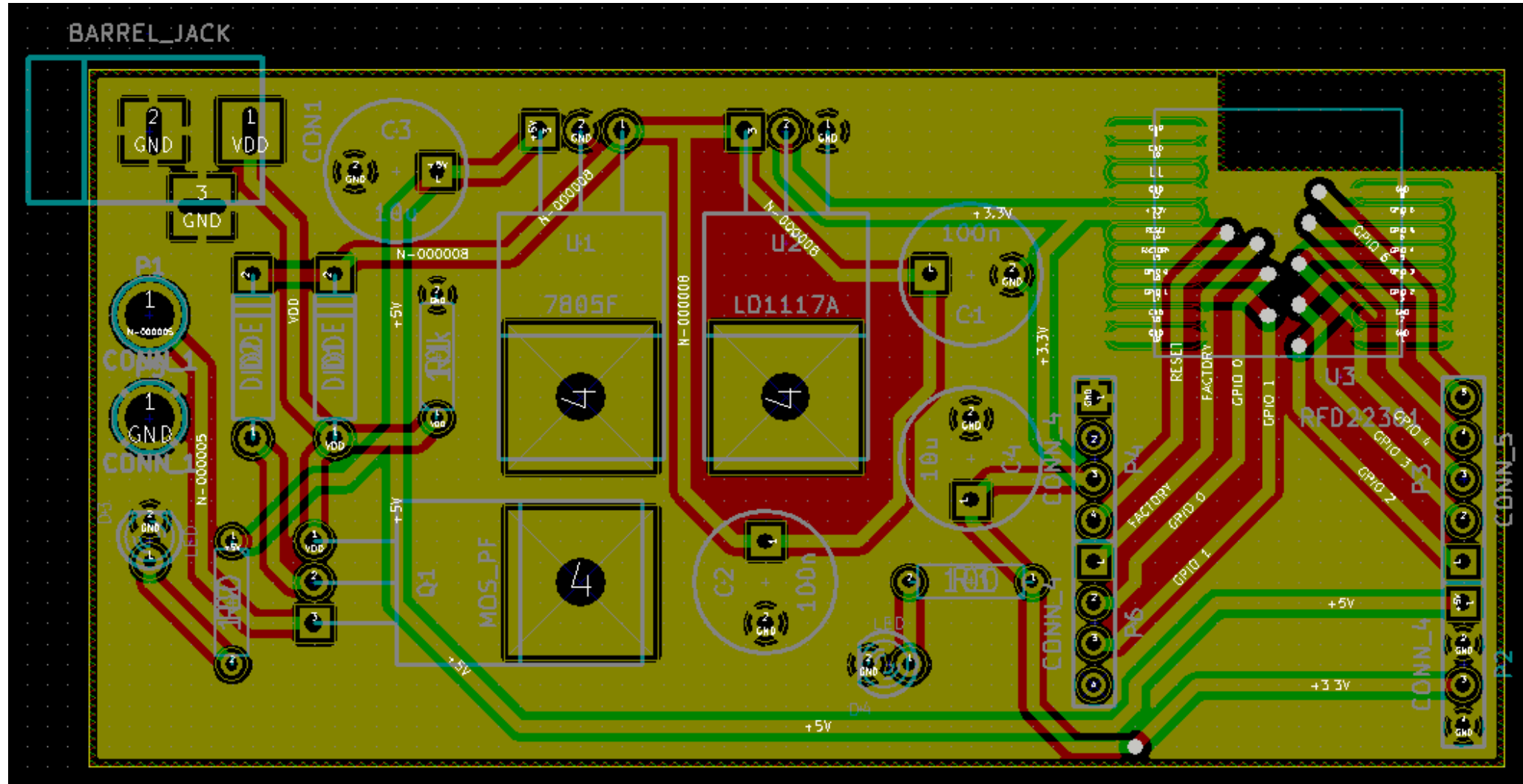
INTERFACE BOARD SCHEMATIC



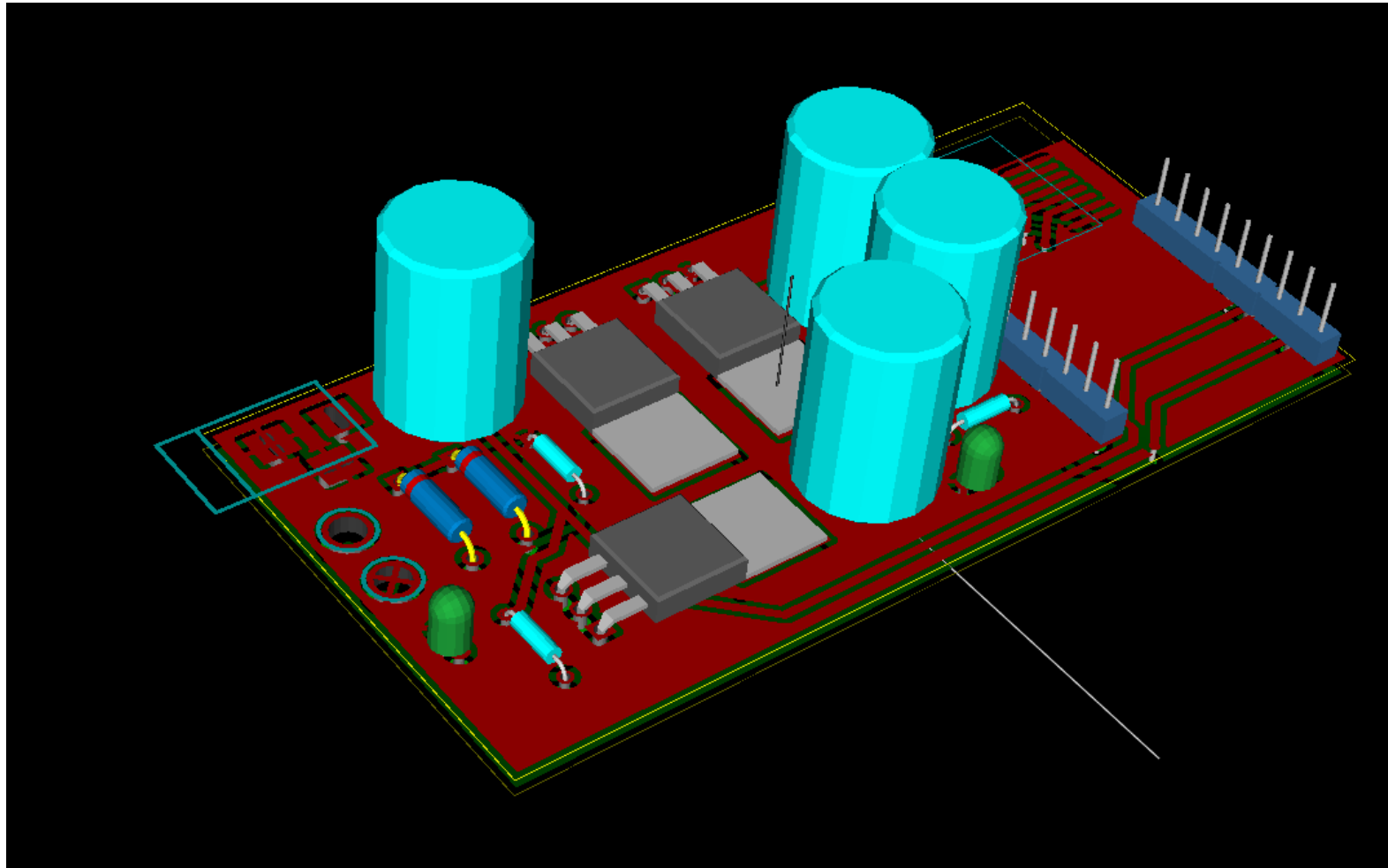
INTERFACE BOARD SCHEMATIC



INTERFACE BOARD PCB LAYOUT



INTERFACE BOARD PCB LAYOUT



RFDUINO

- Bluetooth 4.0 enabled Arduino microcontroller
- Based on the Nordic Semiconductor nRF51822 SoC
- Chosen Because:
 - Arduino ease of use
 - Bluetooth libraries provided by the company
 - Prototyping made easy

Specs

CPU: 16MHz ARM Cortex-M0

Flash: 128KB

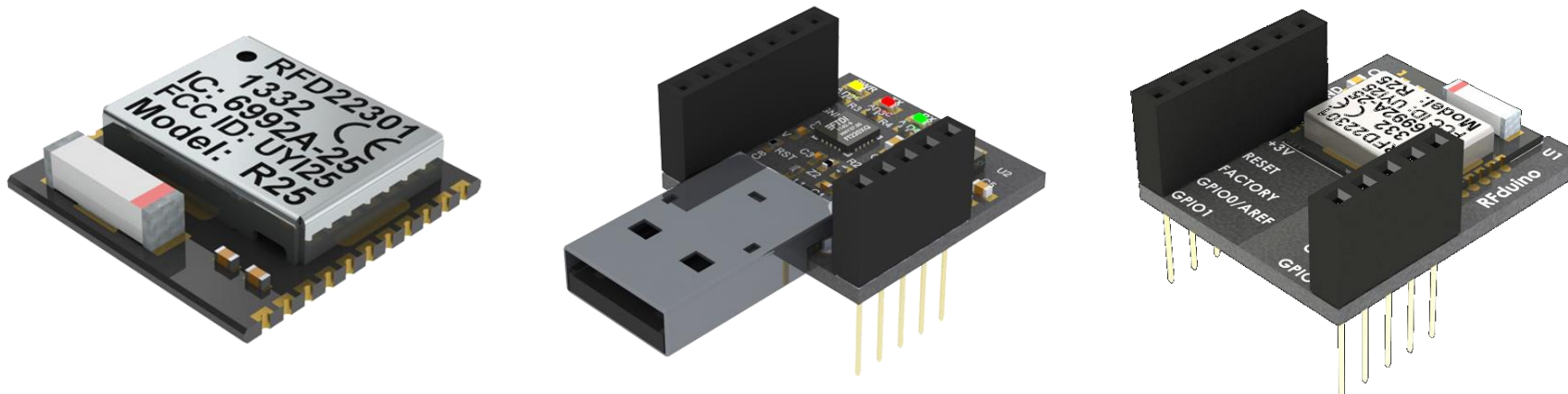
RAM: 8KB

Band: 2.4 GHz

Transmit Power: 4dbm

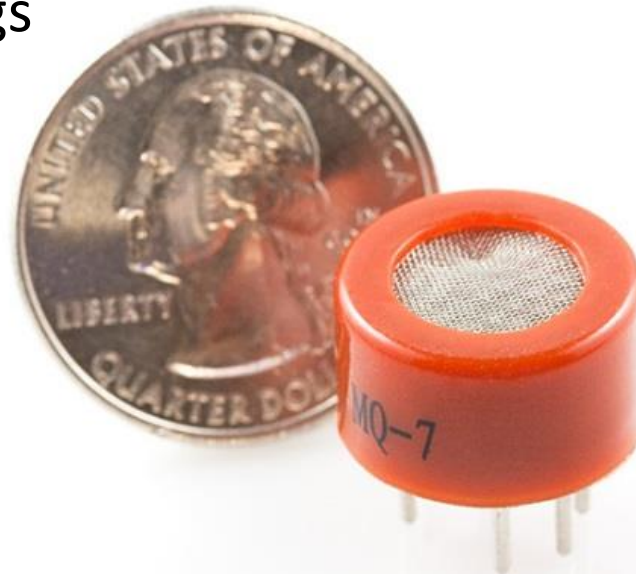
Cost:

\$15 per SMT module



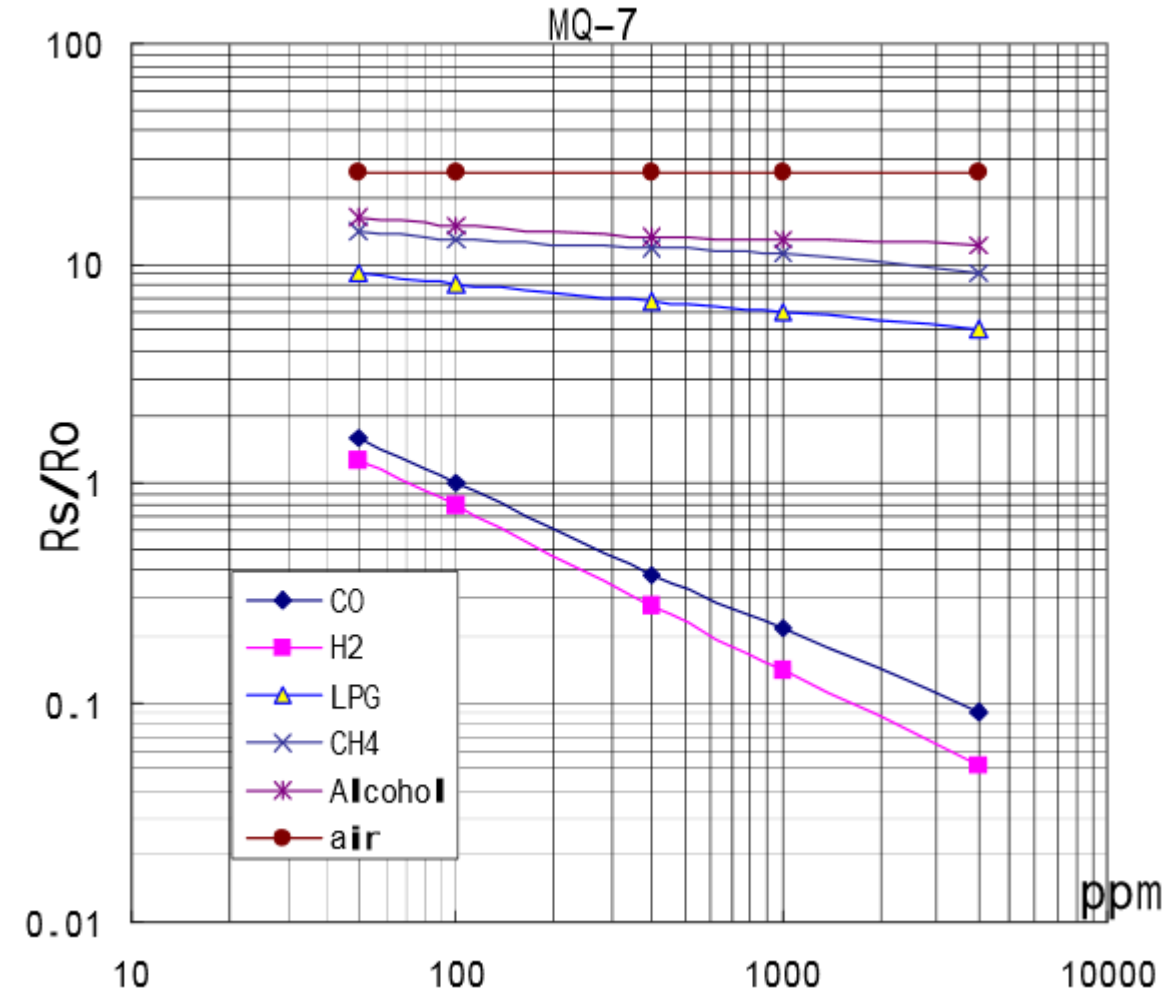
CO SENSOR

- The MQ-7 carbon monoxide sensor is the best fit for our project
 - Low cost (less than \$10)
 - Simple output (resistance changes with CO concentration)
 - Moderate power consumption (1 W)
 - Sensitive to other gases (Hydrogen, LPG, Methane, etc.)
 - Must be pre-heated for stable readings



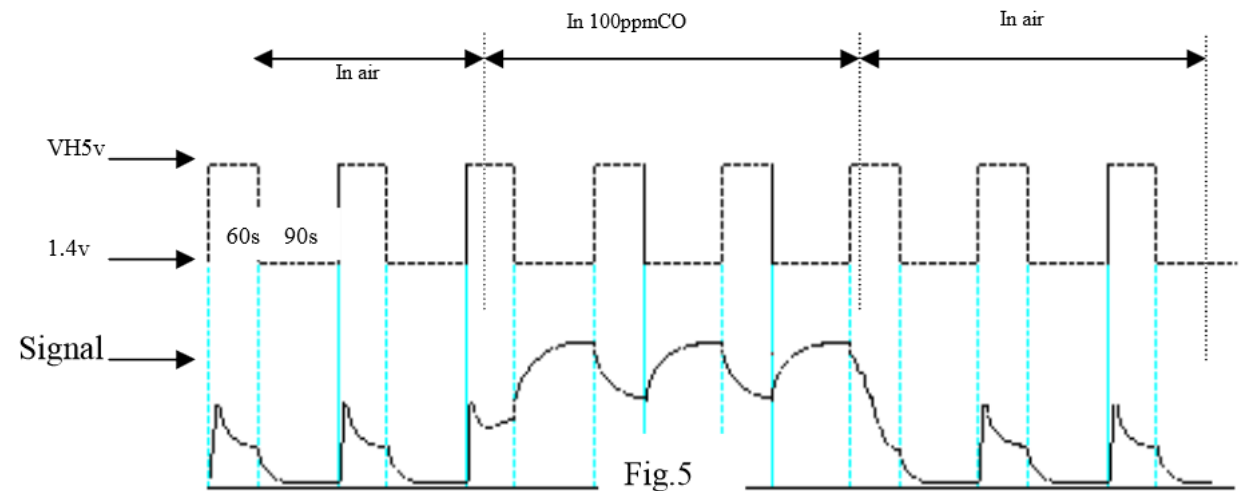
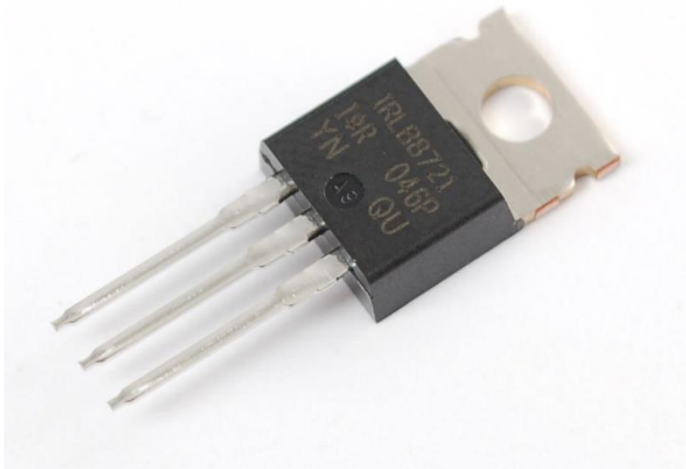
CO SENSOR

- The sensor decreases in resistance as CO concentration increases.
- Output resistance is referenced to a fixed 10 kOhm resistor.



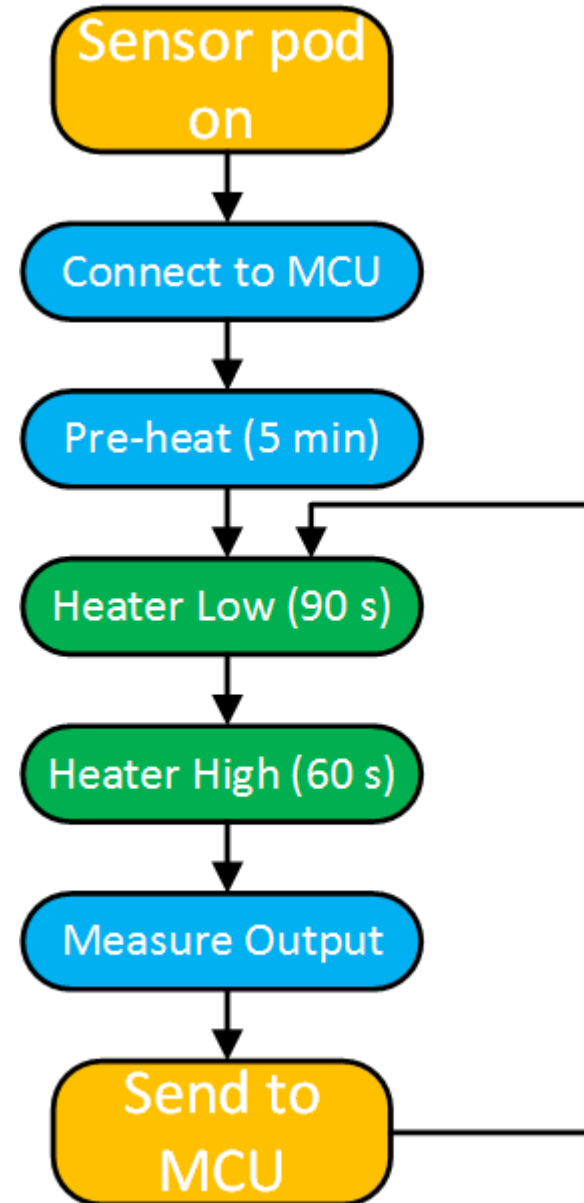
CO Sensor

- The sensor operates by detecting CO adsorbed onto the semiconductor surface.
- A significant peak heater current (200 mA) is needed for this process
- However, a lower current is necessary to periodically refresh the sensor.

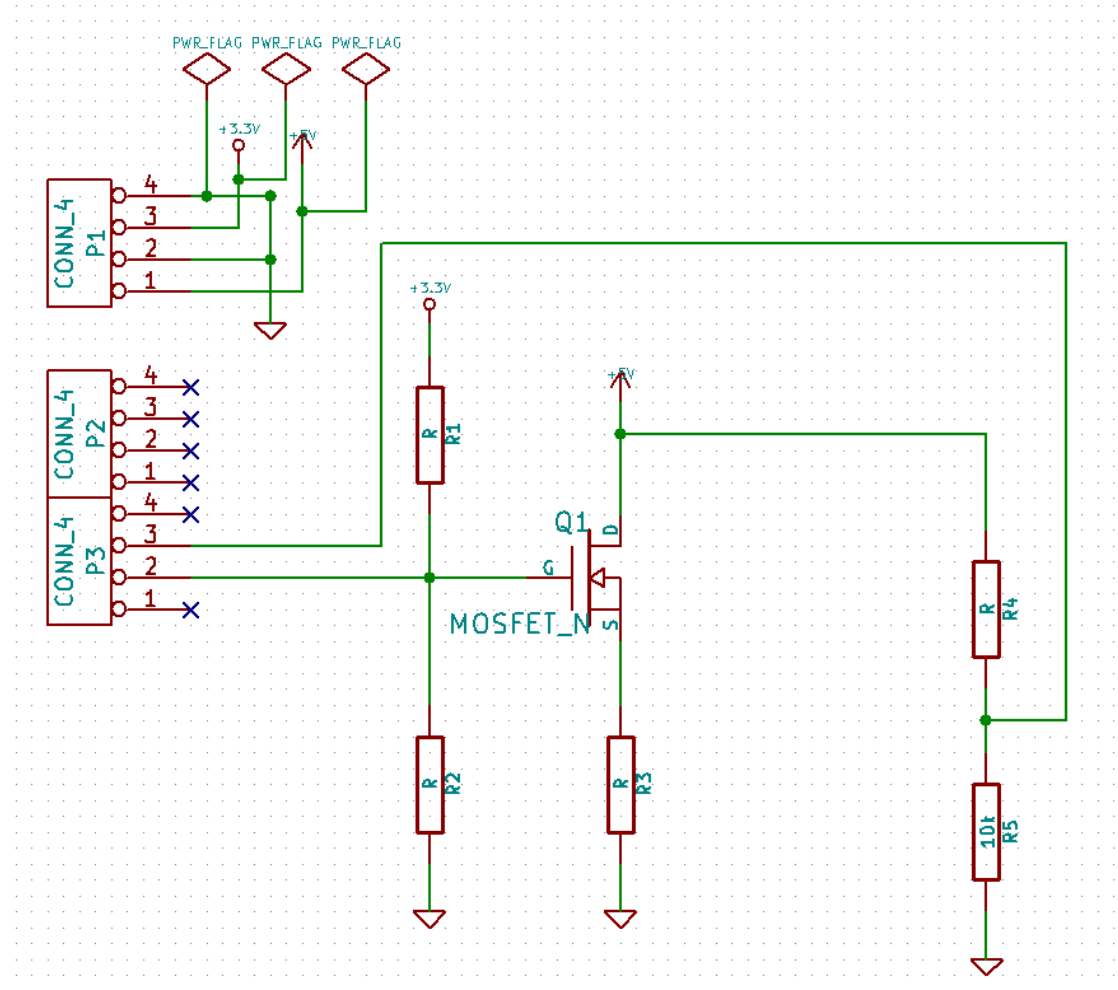


CO Sensor

- The sensor will report at intervals of 1.5 minutes.
- For more stable readings, a rolling average may be desirable, but this will be implemented on the MCU for simplicity.
- A power saving mode is not practical, due to the large warm-up time required.

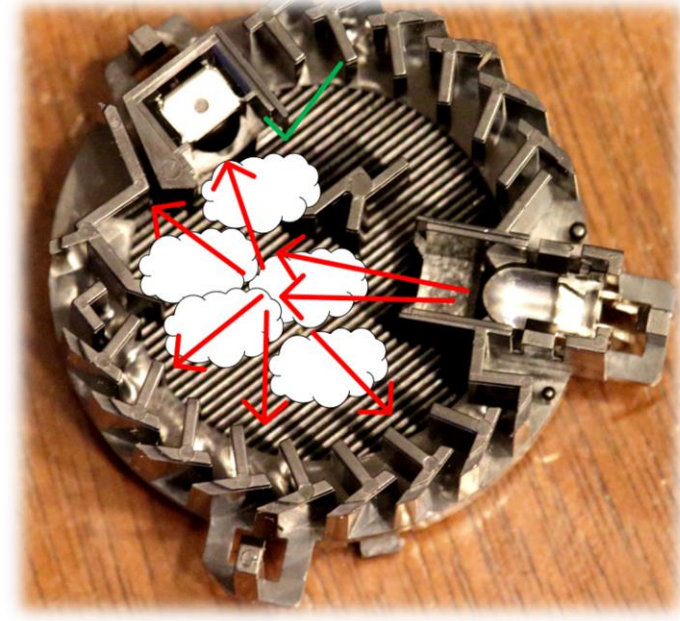
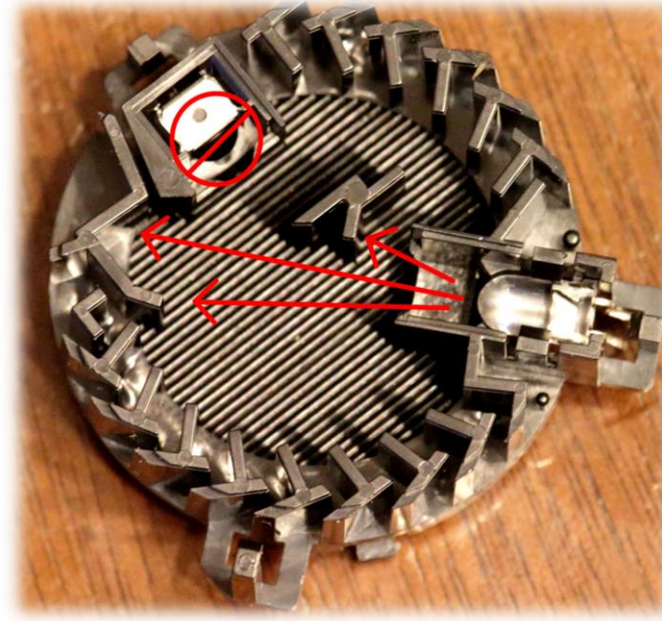
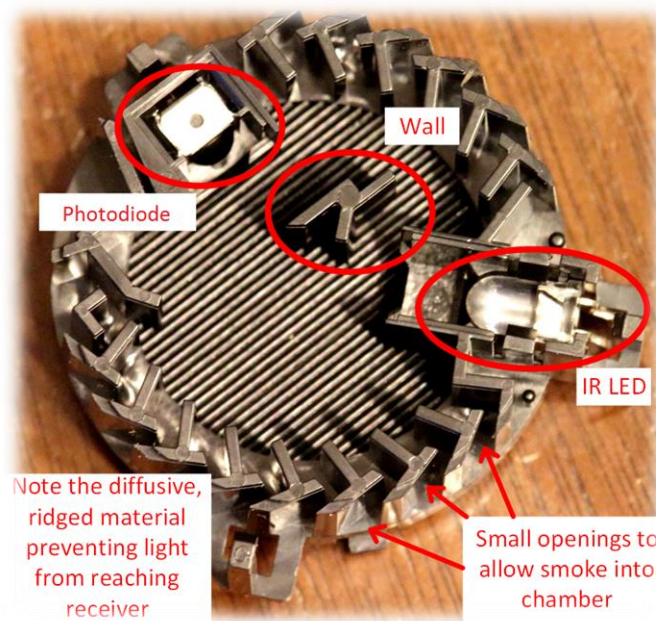


CO Sensor Schematic



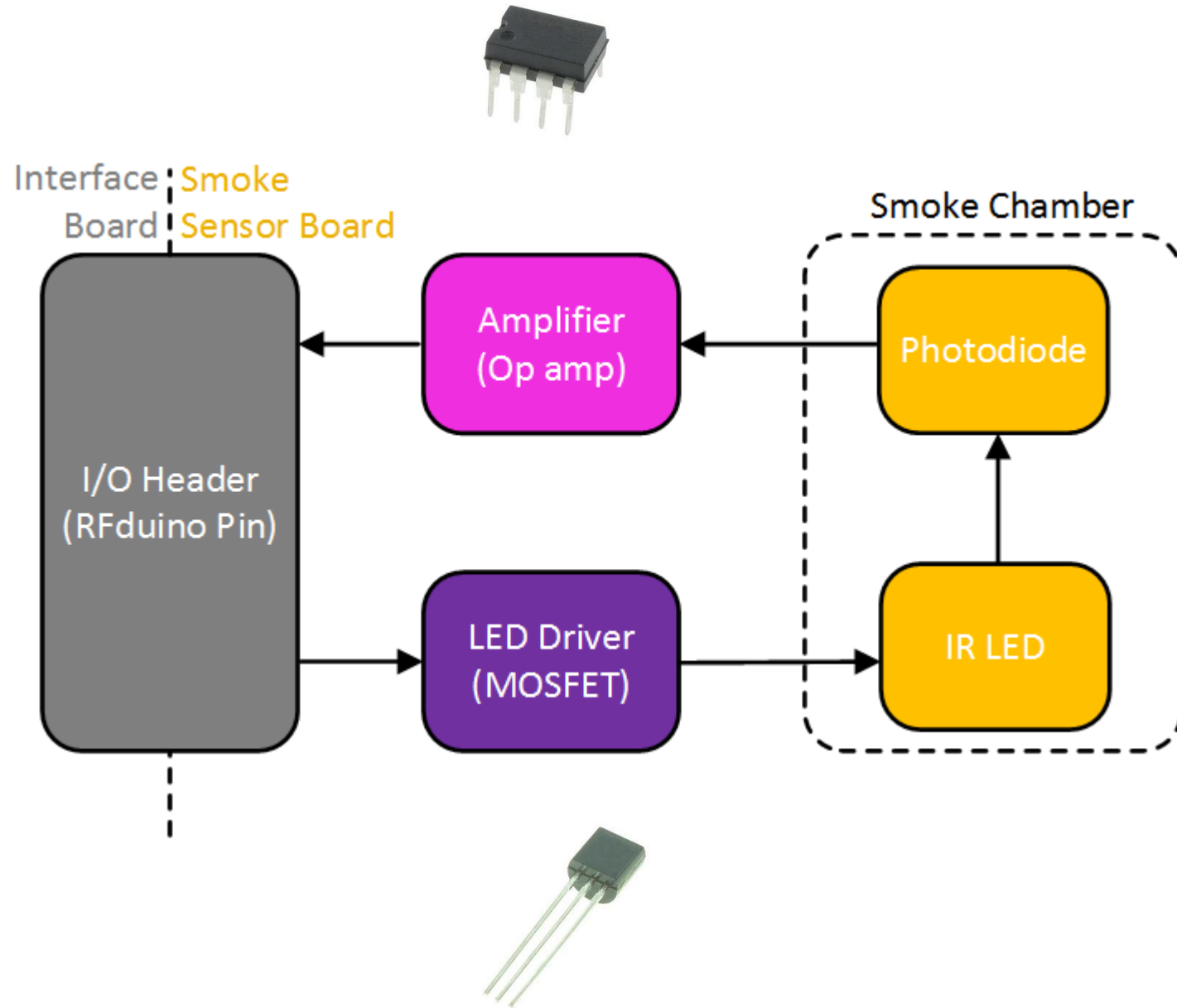
SMOKE SENSOR

- Photoelectric smoke sensor
 - Cannot detect fires that do not produce smoke
- Consists of an IR LED and a photodiode in a special chamber



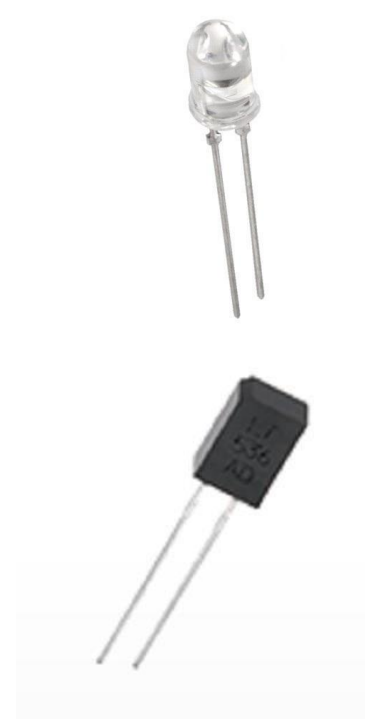
SMOKE SENSOR

- Small photocurrent results in small voltage, need amplification
- RFduino pins cannot drive LED directly, need driver
- Op amp: ON Semiconductor 863-LM358NG | \$0.45 | Mouser
 - Output current: 40 mA
 - Min supply voltage: 3 V
 - Slew rate: 0.6 V/ μ s
- N-channel MOSFET: ON Semiconductor 5LN01SP | \$0.41 | Mouser
 - On resistance: 10 Ω
 - Threshold voltage: 1.3 V
 - Continuous drain current: 100 mA



SMOKE SENSOR

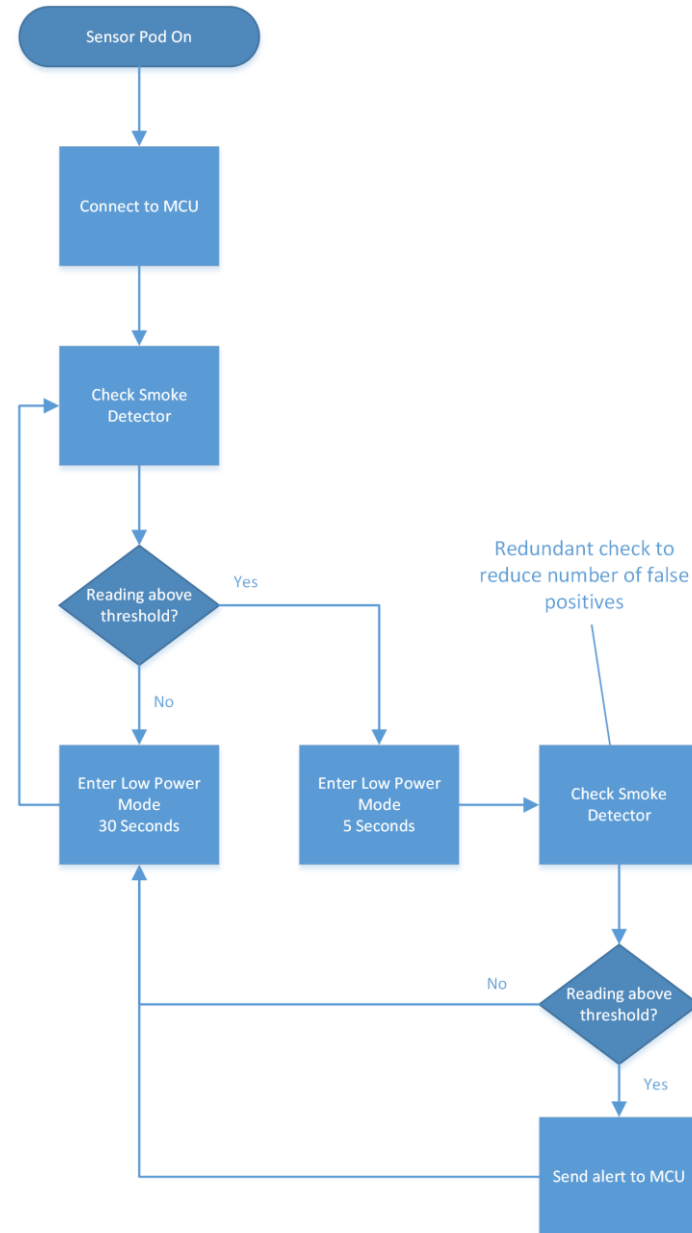
- Smoke Chamber: Kidde FireX Smoke Alarm | \$21.37 | Home Depot
 - Had to purchase entire system to salvage chamber (high cost)
- IR LED: Vishay 78-TSHF6210 | \$0.67 | Mouser
 - Wavelength: 890 nm
 - Max current: 100 mA
 - Voltage drop: 1.4 V to 1.6 V
- Photodiode: Lite-On 859-LTR-546AD | \$0.64 | Mouser
 - Photocurrent: 100 μ A
 - Peak Wavelength: 900 nm
 - Rise/fall time: 50 ns



SMOKE SENSOR

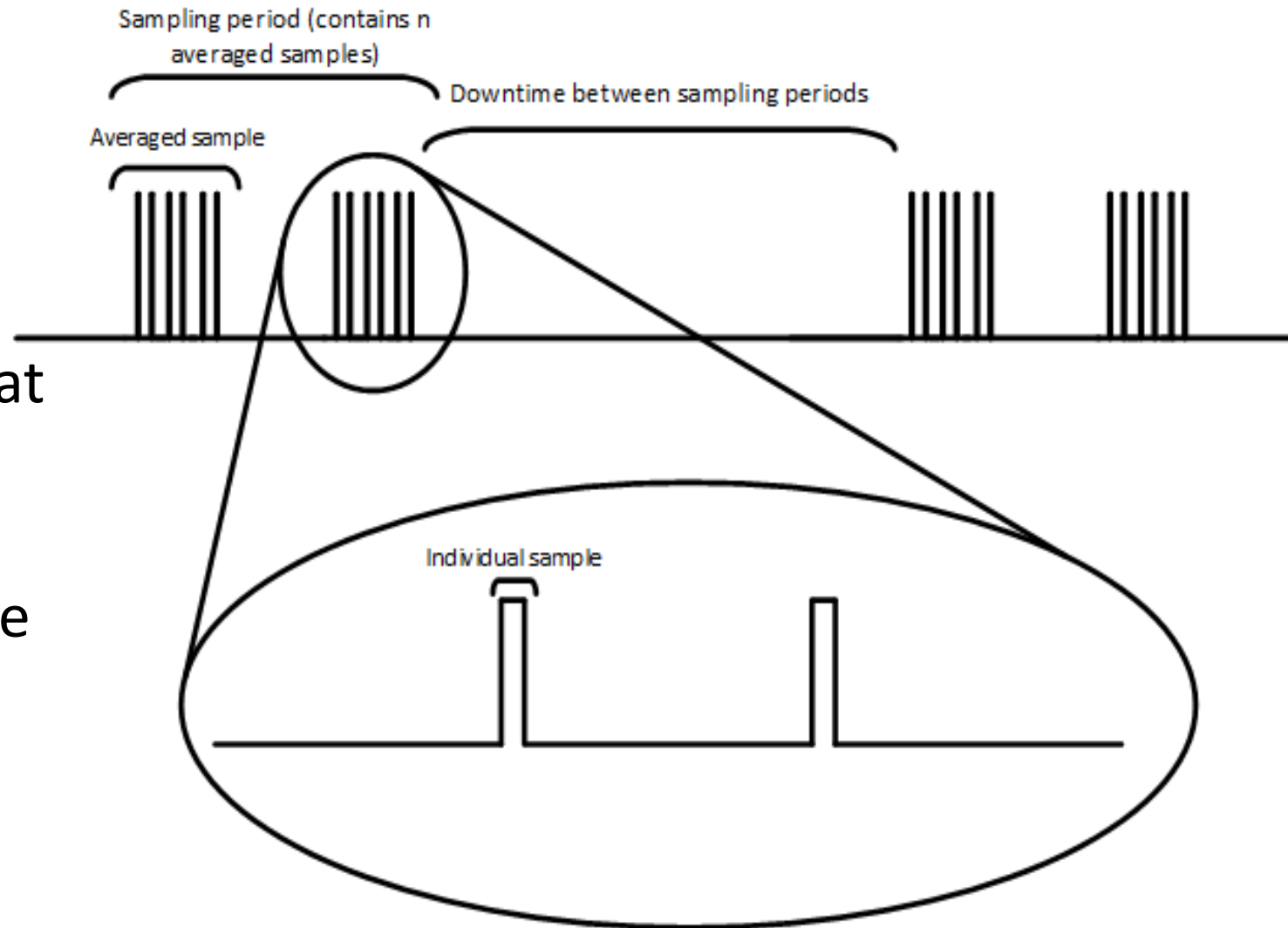
- Note that the redundant check can be extended and performed any number of times as needed
- The “check smoke detector” block has its own considerations, discussed next slide

Smoke Sensor Pod Software Flowchart



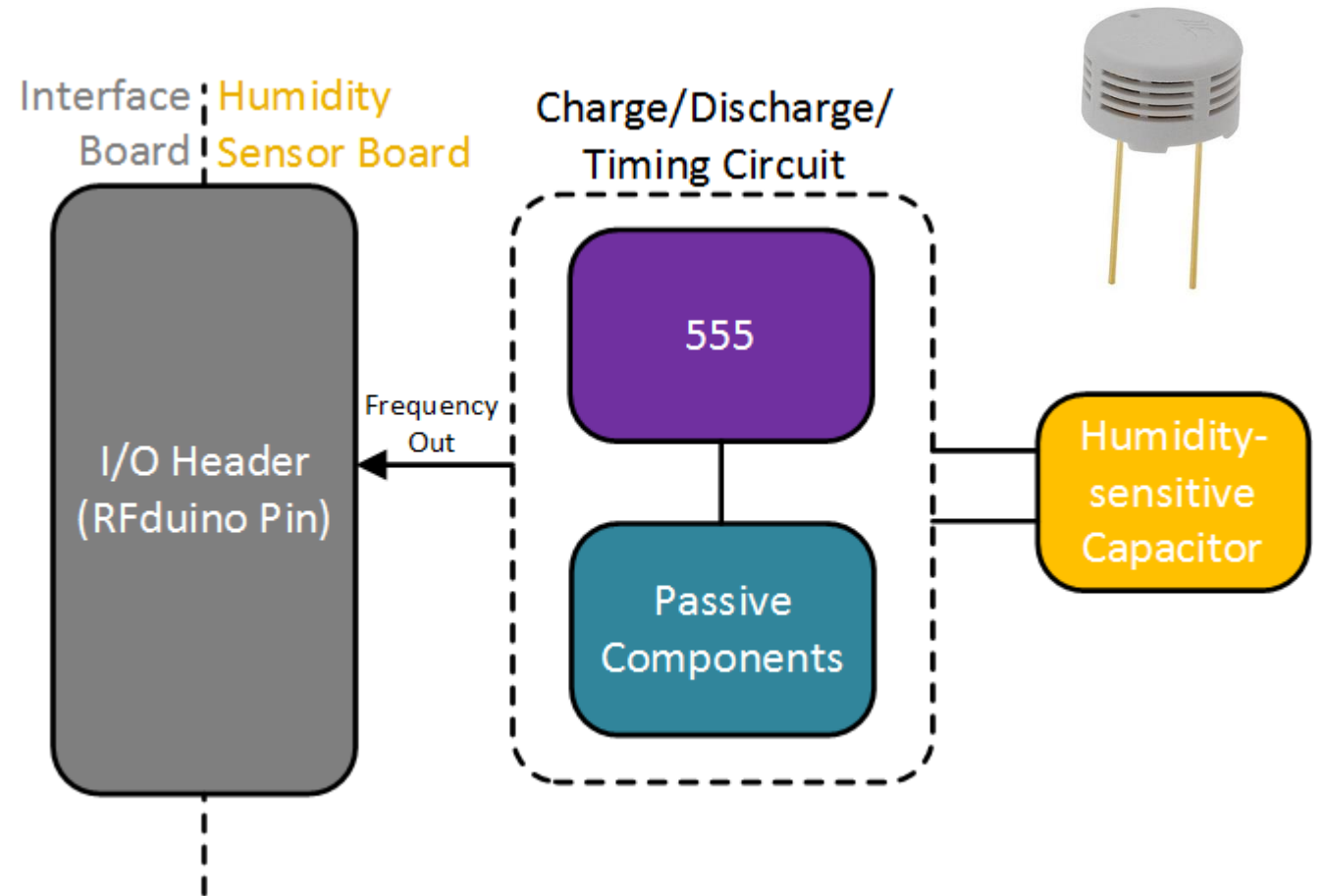
SMOKE SENSOR

- Continuous driving of the LED and conversion of photodiode output is an inefficient solution
- Instead, the LED will be pulsed at high frequency and low duty cycle while checking for smoke
- Frequency and duty cycle will be adjusted per testing to perform reliably



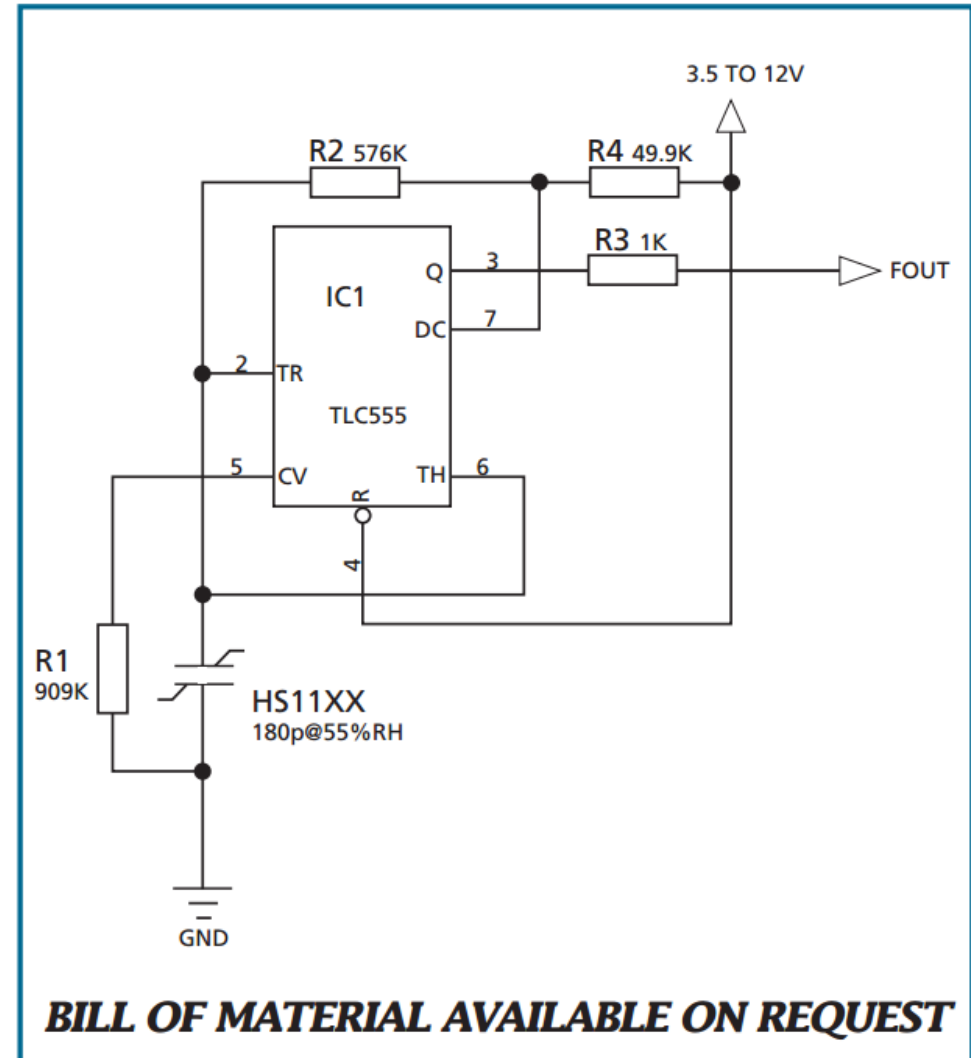
HUMIDITY SENSOR

- Humidity-sensitive capacitor continuously charged/discharged to determine relative humidity (RH) level
- Capacitor: Parallax 27920 (HS1101) | \$8.99 | Mouser
 - Transfer function: approx. linear
 - Response time: 5 s
 - Low cost in terms of humidity sensors

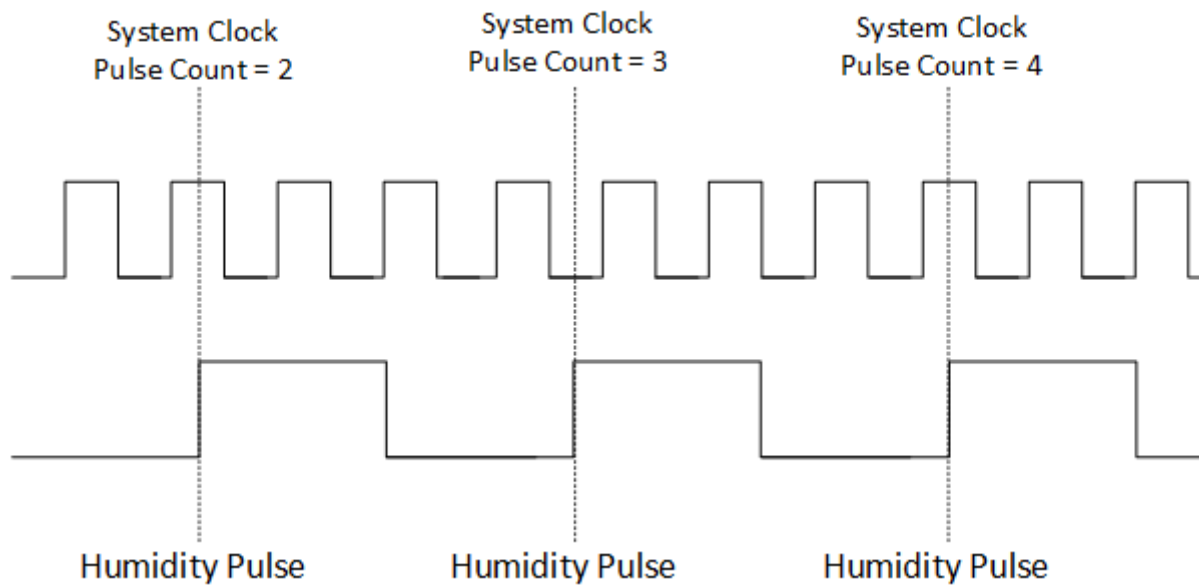


HUMIDITY SENSOR – CHARGE/DISCHARGE CIRCUIT

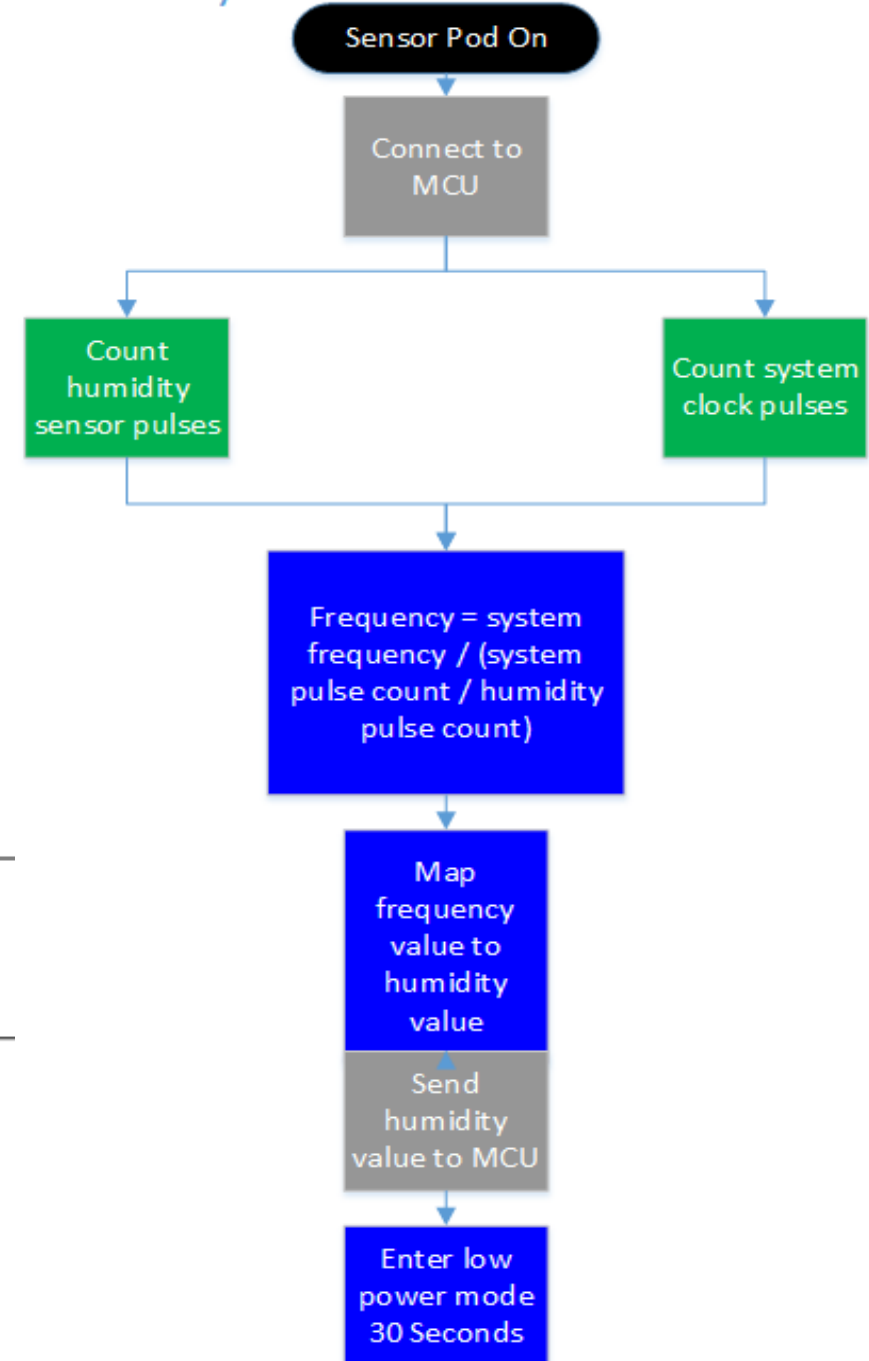
- 555 Timer: TI TLC551CP | \$1.84 | Mouser
 - Supply voltage: 1 V to 15 V
 - Requires 4 resistors to configure
- Output frequency of circuit varies in the range of approximately 6 kHz to 7.5 kHz
 - Higher frequency means lower % RH
 - Nearly linear transfer function
 - Low output frequency allows simple oversampling for frequency detection



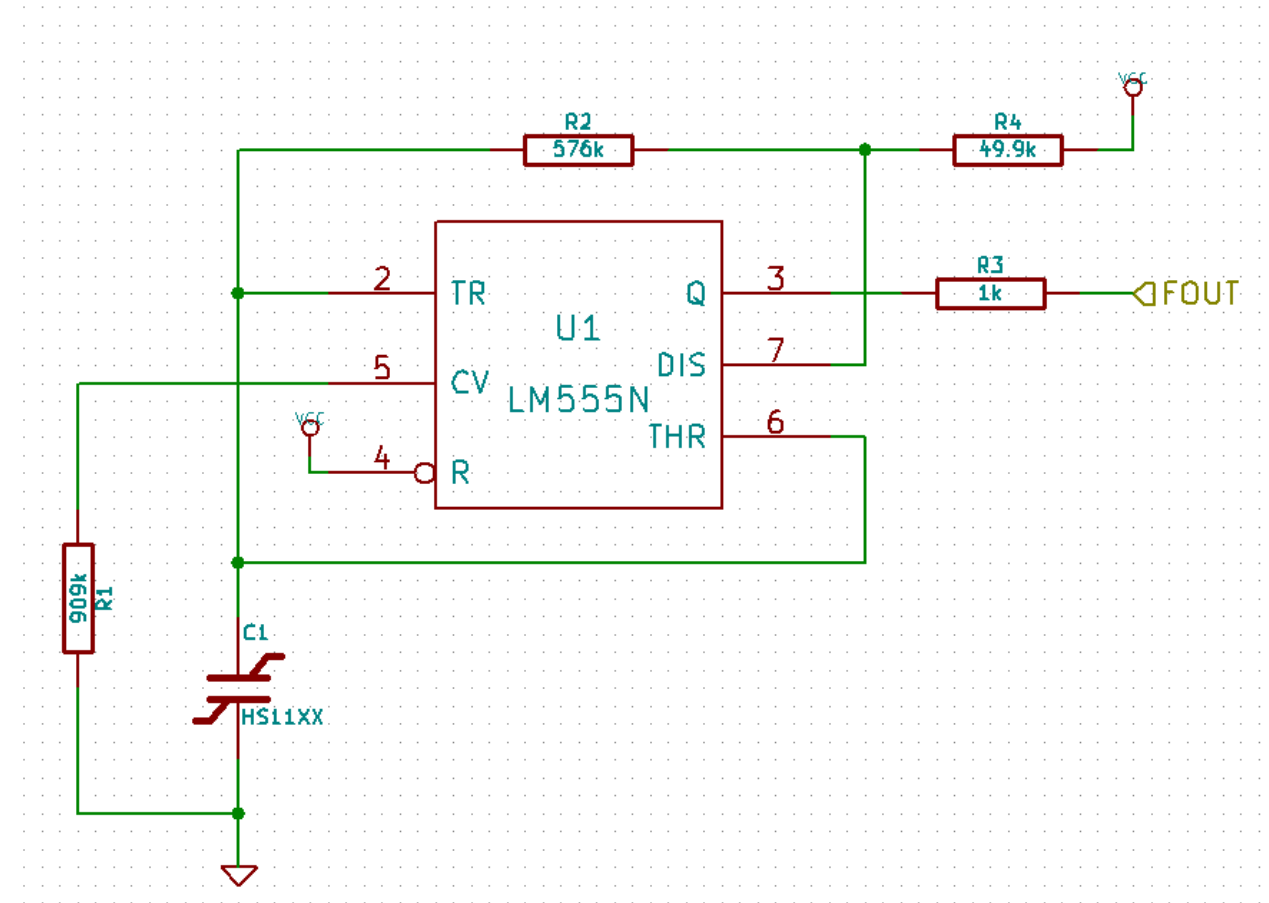
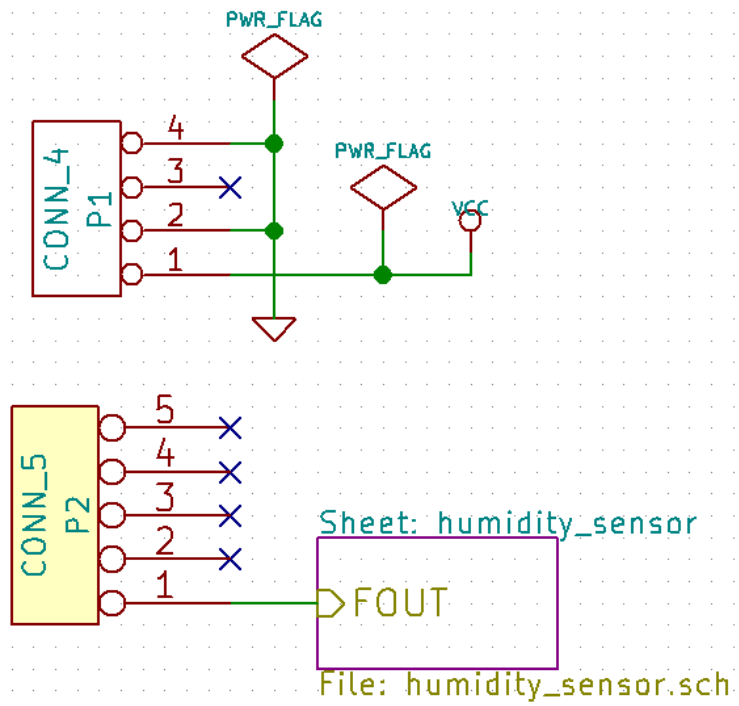
HUMIDITY SENSOR FREQUENCY DETERMINATION



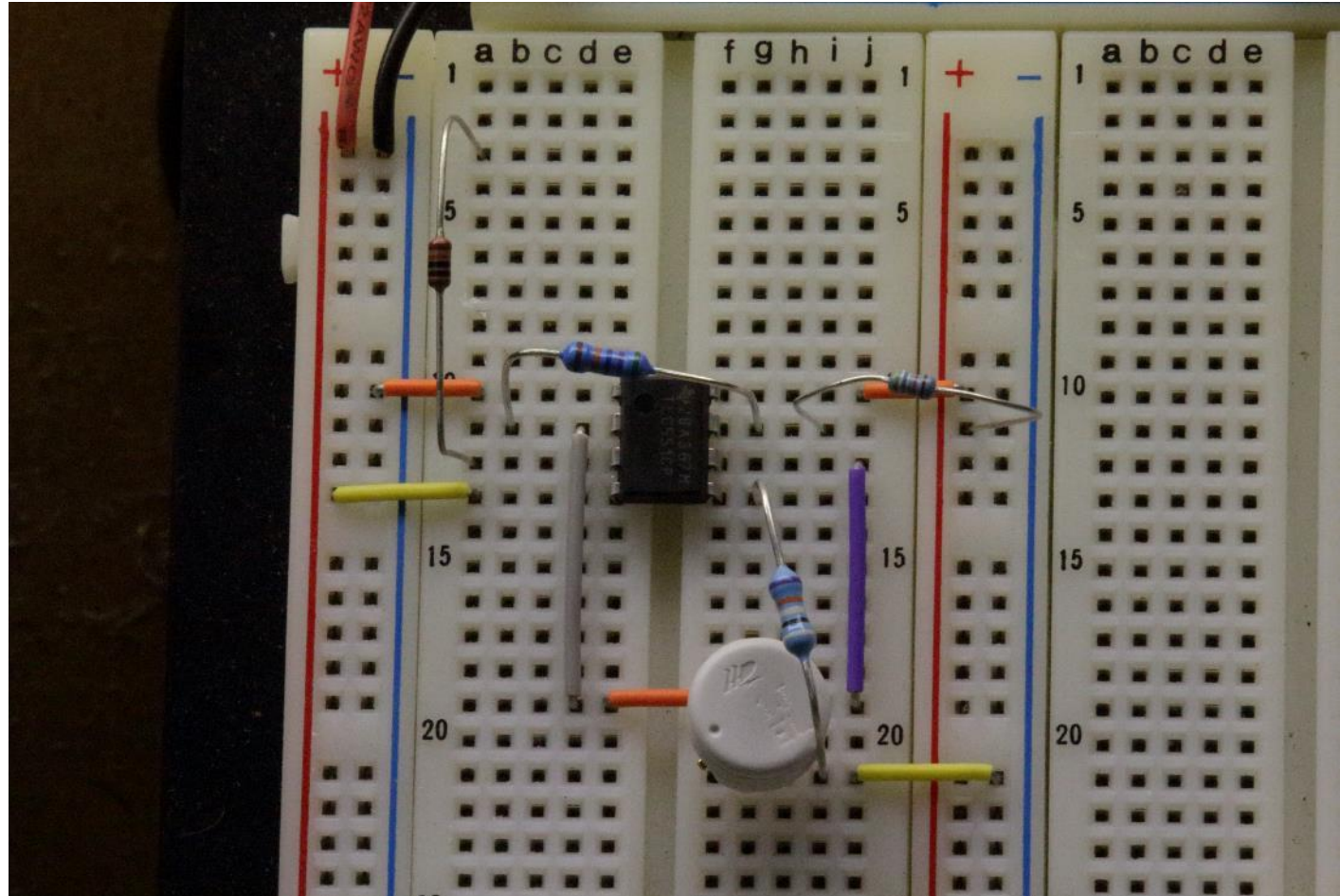
Humidity Sensor Pod Software Flowchart



HUMIDITY SENSOR SCHEMATIC



Humidity Sensor Prototype



POWER

Smoke and Humidity Sensor Configurations

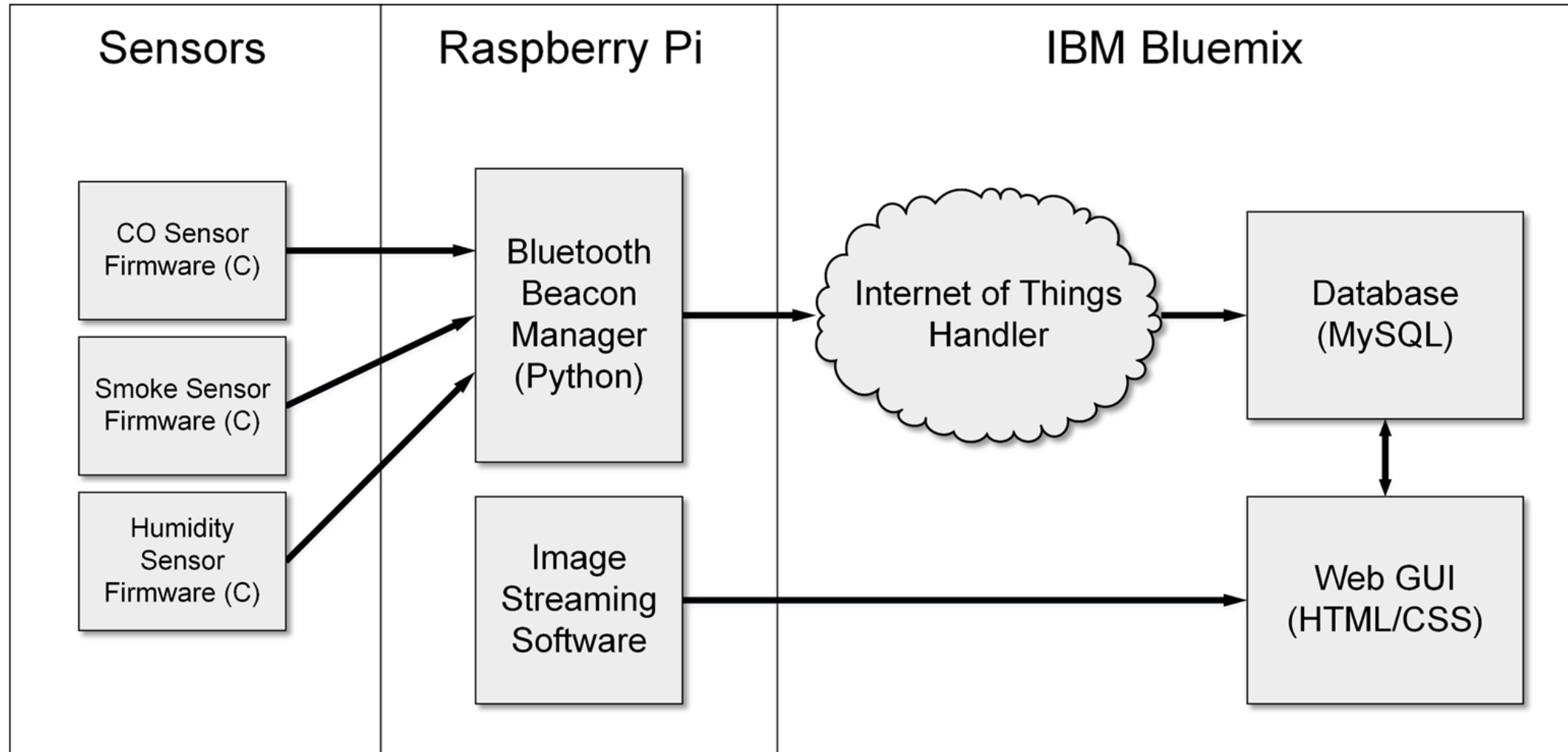
Component	Max Current Draw (mA) - 5.0 V	Max Current Draw (mA) - 3.3 V	Max Component Power Usage (mW)
Rduino		16	52.8
Sensor board		20	66
		Max Total Power Usage (mW)	118.8

CO Sensor Configuration

Component	Max Current Draw (mA) - 5.0 V	Max Current Draw (mA) - 3.3 V	Max Component Power Usage (mW)
Rduino		16	52.8
Sensor board	200		1000
		Max Total Power Usage (mW)	1052.8

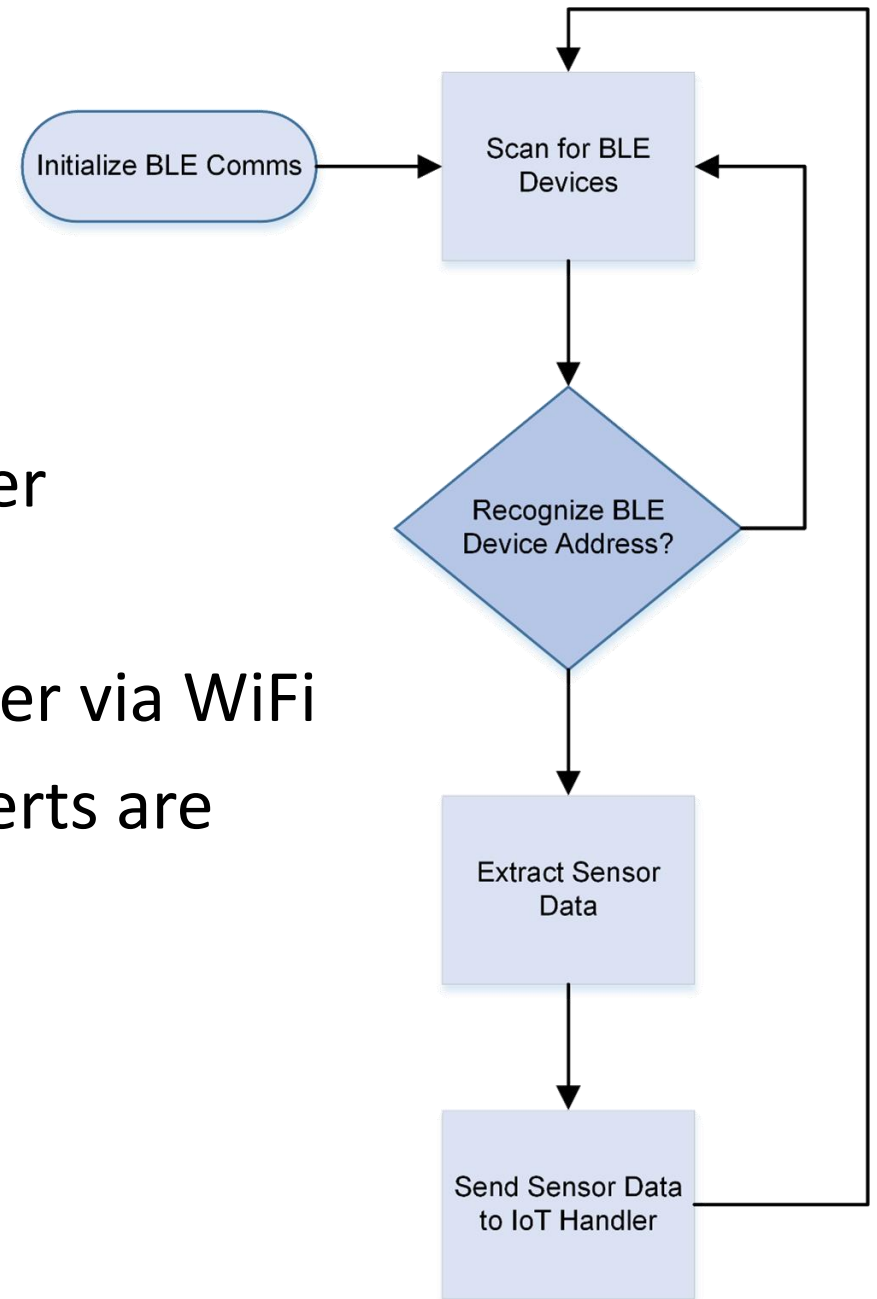
SOFTWARE DESIGN

SOFTWARE BLOCK DIAGRAM



BLUETOOTH BEACON MANAGER

- Python Script
- Bluez C Library, Pybluez BLE python wrapper
- Takes in Sensor information via Bluetooth
- Sends out specific sensor data to IoT handler via WiFi
- Filters data, only status information and alerts are transmitted



CAMERA STREAMING SERVICE

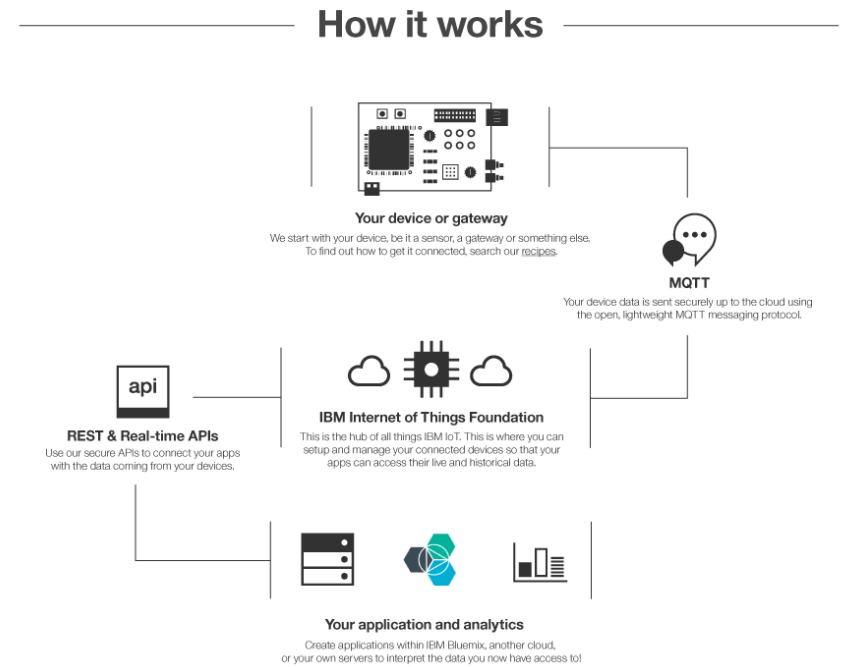
- MJPG-Streamer
- Popular choice for Raspberry Pi surveillance systems
- Sends a stream of JPG files at a specified FPS.
- Chosen because:
 - Not resource intensive
 - Simple to setup
 - Can be password protected
- Explored options:
 - Raspvid
 - Build own application



A screenshot of the MJPG-Streamer Demo Pages website. The page has a grey sidebar on the left with navigation links: Home, Static, Stream, Java, Javascript, VideoLAN, and Control. Below these is a 'Version info' section showing 'v0.1 (Okt 22, 2007)'. The main content area has a red 'Stream' header and the text 'Display the stream'. Below this is a 'Hints' section with a paragraph of text and a 'Source snippet' section showing the code '

INTERNET OF THINGS HANDLER

- IBM Bluemix's Internet of Things Foundation
- Twilio for text message API
- Allows for simple message transfer over MQTT
- Chosen because:
 - Familiarity with the IBM Bluemix Platform
 - Easy to integrate into a larger application
 - Can be used with Node-RED



WEB GUI


- Hosted on Bluemix as part of the cloud application
- Will be developed with a combination of HTML and CSS for styling
- PHP and AJAX will be used to query server dynamically
- Everything on one page
 - Status, Alerts and Feed


Modular Home Monitoring System Control Panel

The mockup shows a control panel with the following components:

- Main Control Unit: Online** (indicated by a green dot)
- Active Sensor Status** (left sidebar):
 - CO Sensor 1 Status : Active
 - CO Sensor 2 Status : Active
 - Smoke Sensor 1 Status : Active
 - Humidity Sensor 1 Status : Active
 - Humidity Sensor 2 Status : Active
- Live Video Feed** (large central area)
- Recent Alerts** (bottom section):
 - 20150721 11:12 Humidity Sensor 2 reading high levels of humidity

DATABASE

Sensor Status	
 PK	ID_Number
	Timestamp
	Device Type
	Device Number
	Status

Sensor Alerts	
 PK	ID_Number
	Timestamp
	Device Type
	Device Number
	Alerted User

- IBM SQL Database
- Stores sensor status and alerts received
- Integrated with the rest of the Cloud App
- Chosen Because:
 - Relational database
 - Free (100MB)
 - Easy to interface with Web GUI



SQL Database

IBM

SOFTWARE CHALLENGES

- Unfamiliarity with languages
- Inexperience with web design
- Getting camera stream to non-local web page
- Working with UCF's WiFi settings Vs. Home WiFi.



ADMINISTRATIVE CONTENT

WORK DISTRIBUTION

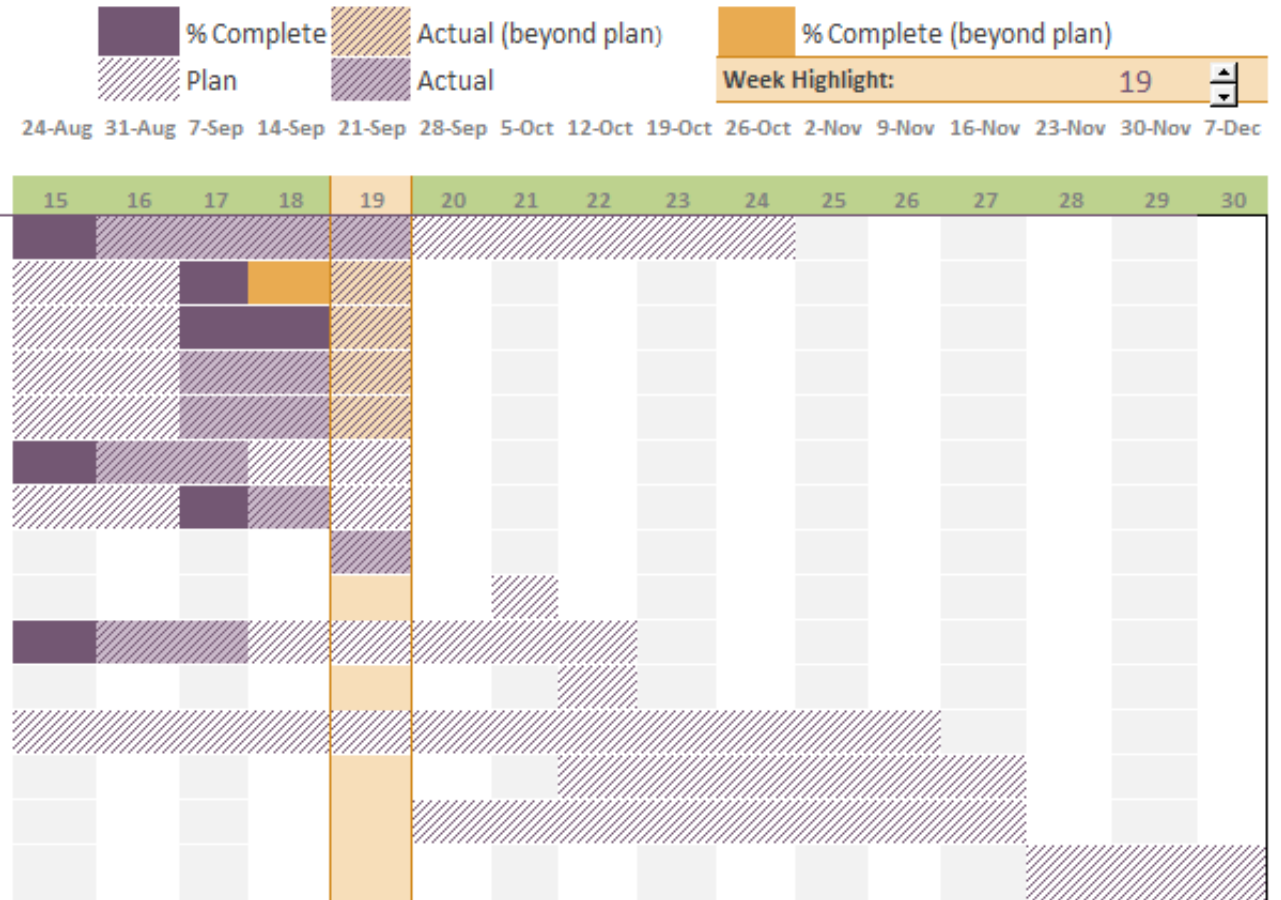
Task	Primary	Secondary
Interface Board HW Design	Robert Short	Gary
CO Sensor Board Design	Robert Short	Gary
Smoke Sensor Board Design	Gary	Robert Simon
Humidity Sensor Board Design	Gary	Robert Short
RFDuino Firmware	Gary	Robert Short
Bluetooth Communication	Robert Simon	Robert Short
Camera Integration	Robert Simon	Gary
Cloud Application Development	Robert Simon	Gary
Procurement	Gary	Robert Short

SCHEDULE

Senior Design

Senior Design II

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Construction	15	10	15	5	30%
Order parts/finalize schematic	15	3	17	3	80%
Start PCB Layout	15	4	17	3	80%
Prototype HW	15	4	17	3	0%
Setup DB	15	4	17	3	0%
SW Communication Demo	15	5	15	3	25%
CDR (Creation)	15	5	17	2	75%
CDR Presentation	19	1	19	1	0%
Order PCB	21	1			0%
Finish SW	15	8	15	3	5%
Mount components	22	1			0%
Subsystem Completion	15	12			0%
Integration	22	6			0%
Testing	20	8			0%
Final Documentation	28	3			0%



FINANCING

- No sponsorships or financial assistance
- Cost of project split into thirds between group members
 - Incentive to keep component costs low





Mouser #	Mfr. #	Manufacturer	Desc.	BOM Qty.	System Qty.	Module Price	Total Cost
MHMS - Humidity Board						\$11.84	
538-22-28-4160	22-28-4160	Molex	Headers & Wire Housings BKWY HDR STR 16P tin	1	1	\$0.52	\$0.52
660-MFS1/4DCT52R4992	MFS1/4DCT52R4992	KOA Speer	Metal Film Resistors - Through Hole 49.9K ohm OHM 1%	1	1	\$0.10	\$0.10
71-CCF501K00FKE36	CCF501K00FKE36	Vishay	Metal Film Resistors - Through Hole 1/3watts 1Kohms 1%	1	1	\$0.10	\$0.10
603-MFR-25FBF52-576K	MFR-25FBF52-576K	Yageo	Metal Film Resistors - Through Hole 576K OHM 1/4W 1%	1	1	\$0.10	\$0.10
279-YR1B909KCC	YR1B909KCC	TE Connectivity	Metal Film Resistors - Through Hole YR1 0.1% 909K	1	1	\$0.19	\$0.19
595-TLC551CP	TLC551CP	Texas Instrument	Timers & Support Products CMOS	1	1	\$1.84	\$1.84
619-27920	27920	Parallax	Board Mount Humidity Sensors Humidity Sensor HS1101	1	1	\$8.99	\$8.99
MHMS - Interface Board						\$22.78	
71-CCF07100RGKE36	CCF07100RGKE36	Vishay	Metal Film Resistors - Through Hole 1/4watt 100ohms 2% Rated to 1/2watt	2	6	\$0.10	\$0.60
71-CCF0710K0GKE36	CCF0710K0GKE36	Vishay	Metal Film Resistors - Through Hole 1/4watt 10Kohms 2% Rated to 1/2watt	1	3	\$0.10	\$0.30
517-929974-01-36-RK	929974-01-36-RK	3M	Headers & Wire Housings BOARDMOUNT SOCKET	1	3	\$2.67	\$8.01
140-REA100M1HBK0511	REA100M1HBK-0511	Lelon	Aluminum Electrolytic Capacitors - Leaded 50V 10uF 20% 5x11mm	2	6	\$0.08	\$0.48
871-B41041A6104M	B41041A6104M	EPCOS / TDK	Aluminum Electrolytic Capacitors - Leaded 0.1 uF 50 Volt	2	6	\$0.10	\$0.60
975-RFD22301	RFD22301	RF Digital	Bluetooth / 802.15.1 Modules RFDuino BLE 4.0 SMT Module	1	3	\$14.99	\$44.97
621-1N4007	1N4007-T	Diodes Incorporated	Rectifiers Vr/1000V Io/1A T/R	2	6	\$0.11	\$0.66
942-IRF5305PBF	IRF5305PBF	International Rectifier	MOSFET MOSFT PCh -55V -31A 60mOhm 42nC	1	3	\$1.87	\$5.61
502-RAPC712X	RAPC712X	Switchcraft	DC Power Connectors R/A POWER JACK	1	3	\$0.95	\$2.85
667-LN28RPX	LN28RPX	Panasonic	Standard LEDs - Through Hole LED RED DIFFUSED 3MM RND	2	6	\$0.47	\$2.82
511-LD1117AV33	LD1117AV33	STMicroelectronics	LDO Voltage Regulators 3.3V 1.0A Positive	1	3	\$0.87	\$2.61
863-NCP7805TG	NCP7805TG	ON Semiconductor	LDO Voltage Regulators 1A LDO	1	3	\$0.47	\$1.41
MHMS - Smoke Board						\$2.79	
863-LM358NG	LM358NG	ON Semiconductor	Operational Amplifiers - Op Amps 3-32V Dual Lo PWR Commercial Temp	1	1	\$0.45	\$0.45
859-LTR-546AD	LTR-546AD	Lite-On	Photodiodes Phototrans Filtered	1	1	\$0.64	\$0.64
538-22-28-4160	22-28-4160	Molex	Headers & Wire Housings BKWY HDR STR 16P tin	1	1	\$0.52	\$0.52
660-MOS1CT52R360J	MOS1CT52R360J	KOA Speer	Metal Oxide Resistors 1W 36 5%	1	1	\$0.10	\$0.10
78-TSHF6210	TSHF6210	Vishay	Infrared Emitters IR Emtr 890nm 10 deg DH Tech 180mW/sr	1	1	\$0.67	\$0.67
863-5LN01SP	5LN01SP	ON Semiconductor	MOSFET NCH 1.5V DRIVE SERIES	1	1	\$0.41	\$0.41

Total \$85.55



Backup

Testing

- Smoke: Light a match and put it out below the smoke sensor.
- CO: Collect car exhaust in jars, place sensor in jar.
- Humidity: Place humidifier, analog humidity reader and sensor in a box