Portable Environmental Monitor

https://hackaday.io/project/4977-portable-environmental-monitor

Design Document

Revisions:
V1.0 Radu Motisan / 2015.08.16

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Summary

The portable environmental monitor addresses pollution, the kind that we are unable to see but directly affects our health and can cause life threatening diseases. Airborne toxic chemicals, radioactive dust and radioactive radon are correlated with cases of pulmonary cancer, cardiovascular disease, asthma or pulmonary disease [1].
Since our biological senses can do little to warn us of such possible dangers, we plan to design the Portable environmental monitor as a first line detection and warning system.
This is not the regular detector: packed with powerful sensors capable of detecting both the chemical and the physical harmful factors, these devices are designed with Internet connectivity and will share all readings to the Global uRADMonitor network, www.uradmonitor.com [2]
Online data allows us to build graph, stats and send automated notifications when certain thresholds are reached. The infrastructure has been developed for the uRADMonitor project, semifinalist of HaD 2014 [3]
Knowing what's around us, we have a better chance to take action!

Project Goal

Build a portable environmental monitor that can assert air quality over a wide interval of pollutants, dangerous to human health. Structure data in a way that is easy to interpret by the user (using charts), and centralize data globally for a better image to pollution correlated to various geographical locations.

Image credit: http://www.ctvnews.ca/health/10-million-canadians-at-risk-from-exposure-to-traffic-pollution-researchers-1.1506719

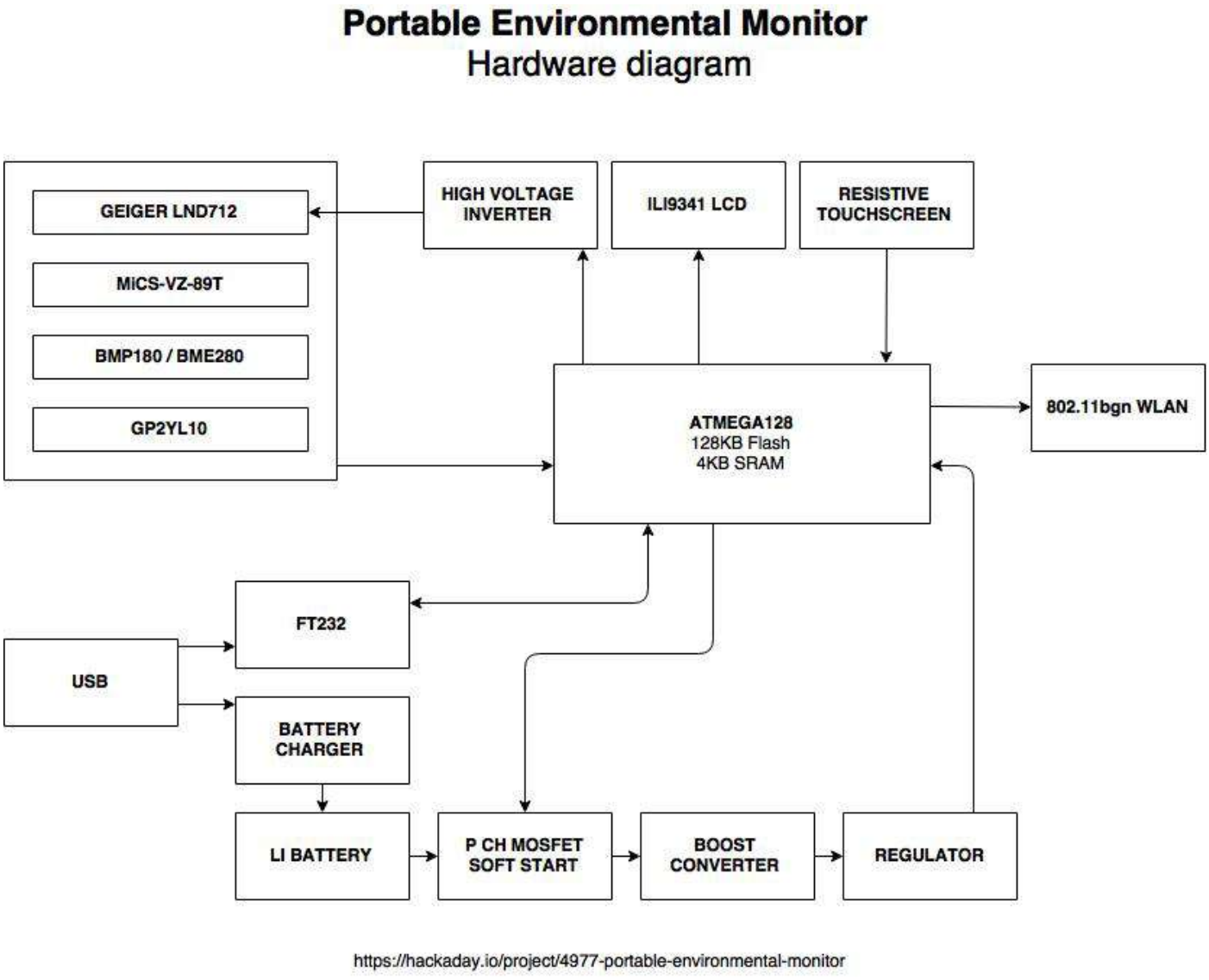
Hardware design

Requirements:

Microcontroller, with sufficient I/O pins and enough Flash memory to sustain the large number of peripherals. Large LCD with touchscreen for interfacing with the user. Low power sensors (where applicable). USB and WLAN 802.11b/g/n connectivity. Battery sufficiently large for a practical mobile use.

Implementation:

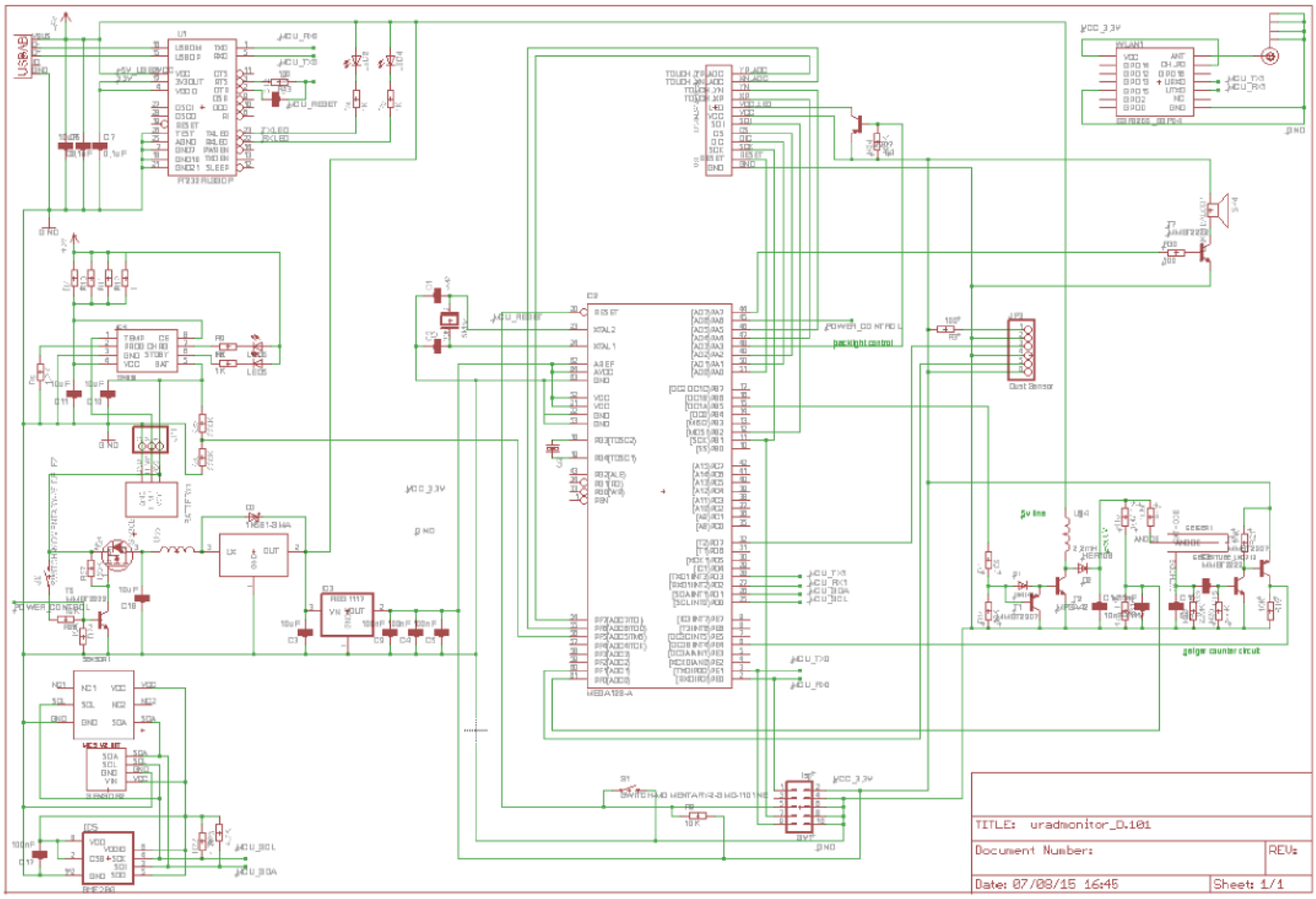
Atmega128 microcontroller, 2.4" ILI9341 color LCD with touchscreen (used directly via ADC), rechargeable 1500mAh battery with charge and temperature control, FT232 USB interface, ESP8266 WLAN interface, LND712 Geiger tube, GP2Y10 dust sensor, MiCS-VZ-89 air quality sensor, BMP180/BME280 air sensors, speaker.

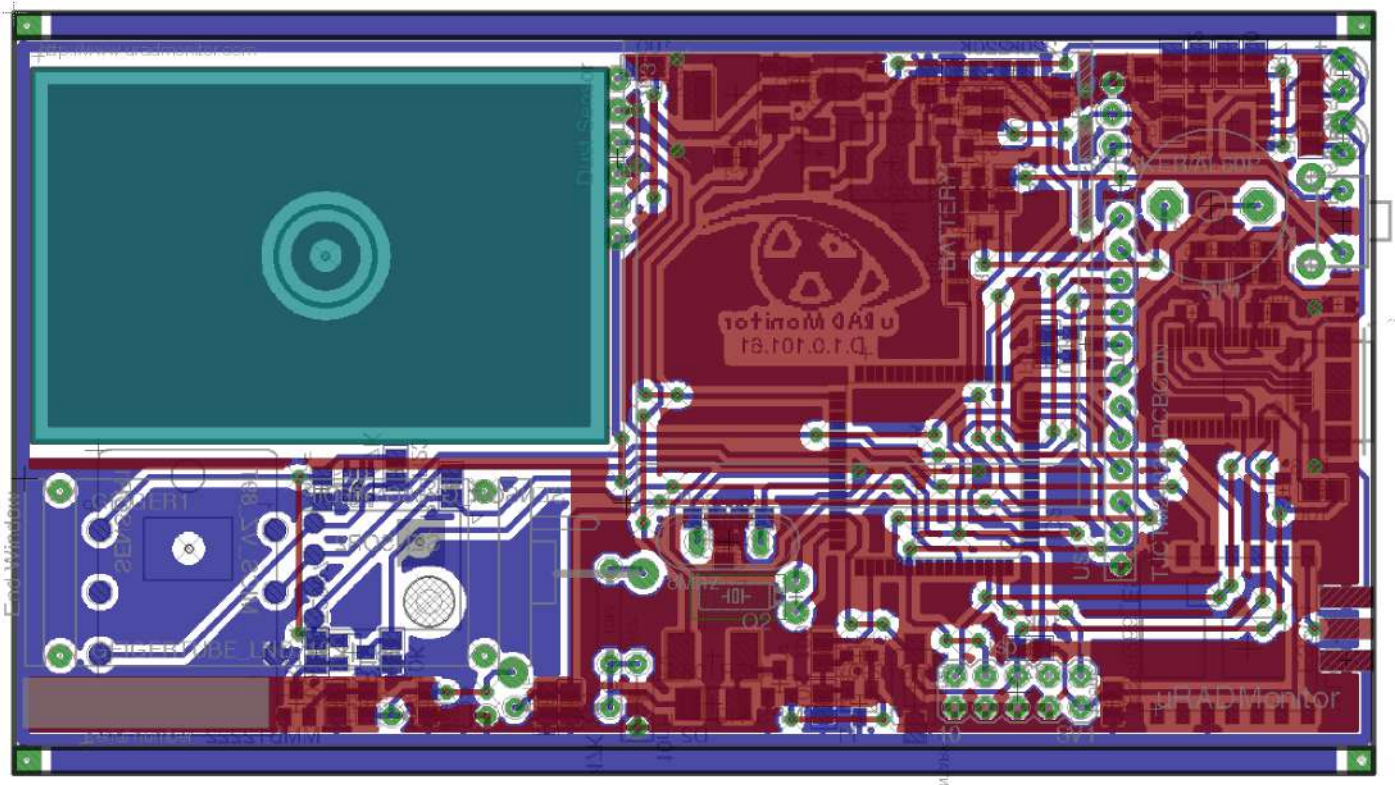


Hardware design notes

- **Li Battery** is a rechargeable 1500mAh Lithium battery with temperature sensor for safe charging
- The **Battery Charger** circuit is based on TP4056 IC . It also controls the two panel LEDs, RED for charging and GREEN for idle.
- The circuit is started using a soft button, that opens a P-CH mosfet, further controlled by the microcontroller until shutdown
- The **Boost converter** offers 5V required for the high voltage inverter to boost from 5V to 450-500V directly (frequency and regulated output controlled in software).
- A LDO **regulator** is responsible for generating 3.3V . The dissipated heat is transferred via copper foil at the base of the dust sensor air vent, to circulate air.
- The **FT232** is responsible for the USB data communication
- The **802.11bgn WLAN** is an ESP8266-v04, that communicates via UART / 9600bps with the microcontroller in order to provide Internet access
- The **Resistive touchscreen** translates user input into screen coordinates used for recognizing pressed buttons and other interactions
- **ILI9341 LCD** is the main display used for the unit
- **High Voltage inverter** is compact inverter initially developed for the uRADMonitor-A units, capable of jumping from 5V directly to 500V while keeping ripple low. It uses a voltage divider on output to send feedback to a microcontroller ADC port and have the duty cycle adjusted so that we match the desired output voltage. It is therefore a regulated high voltage source.
- **Sensor LND712** a high quality Geiger counter with end window, suitable for Alpha, beta and gamma ionising radiation detection
- **Sensor MiCS-VZ-89** an advanced air quality sensor, capable of detecting both environmental CO2 and VOCs at the cost of very little power
- **BMP180/BME280** sensors manufactured by Bosch for basic air parameters such as temperature and pressure.
- **Sensor GP2YL10** for dust concentration in air
- **ATMEGA128** is the central processing unit of the device, responsible for real time sensor readings, power management and user interaction

Circuit diagram and PCB





The PCB is two layer 1.6mm board requiring CNC milling. Better resolution images on Github: https://github.com/radhoo/uradmonitor_d

Bill of Materials

Qty	Value	Device	Parts
1	32.768KHz	CRYSTALTC26H	Q2
1	4R7	INDUCTOR-B82462G	U$5
2		LED3MM	LED5, LED6
2		LEDCHIP-LED0805	LED3, LED4
1		PINHD-1X3	JP1
3	0.1uF	CAP0805	C6, C7, C12
4	1	R-EU_R0805	R7, R10, R11, R12
1	1.2K	R-EU_R0805	R6
4	1K	R-EU_R0805	R4, R5, R8, R9
1	1N581-SMA	1N581-SMA	D3
1	1N4148	DIODESOD-323F	D1
1	2.2mH	INDUCTOR1206H*	U$4
2	4.7K	R-EU_R0805	R22, R23
1	8Mhz	XTAL/S	Q1
6	10K	R-EU_R0805	R2, R14, R19, R21, R28, R29
1	10M	R-EU_0204/7	R17
1	10M 1%	R-EU_0204/7	R15
1	10nF / 1KV	C-EU050-025X075	C14
5	10uF	C-EUC0805K	C3, C8, C10, C11, C18
1	15nF	C-EUC0805K	C13
3	33p	C-EUC0805K	C1, C2, C15
1	47K 1%	R-EU_R0805	R16
1	68pF	C-EUC0805K	C16
4	100	R-EU_R0805	R1, R3, R13, R30
3	100K	R-EU_R0805	R20, R24, R27
4	100nF	C-EUC0805K	C4, C5, C9, C17
1	220K	R-EU_0204/7	R18
2	220K	R-EU_R0805	R25, R26
1	2907	MMBT2907ALT1PNPSOT23BEC	T4
1	BAT-CASIO-NP40BATTERY	BAT-CASIO-NP40BATTERY	BATTERY1
1	BL8530-SOT89-3	BL8530-SOT89-3	U$3
1	BME280	BME280	IC5
1	Dust Sensor Connector	PINHD-1X6CB	JP3
1	ESP8266_ESP04	ESP8266_ESP04	WLAN1
1	FT232RLSSOP	FT232RLSSOP	U1
1	GEIGERTUBE_LND712	GEIGERTUBE_LND712	GEIGER1
1	HER108	DIODE-DO-214AC	D2
1	MEGA128-A	MEGA128-A	IC2
1	MICS_VZ_89T	MICS_VZ_89T	SENSOR1
3	MMBT2222	MMBT2222ALT1NPNSOT23BEC	T3, T6, T7
2	MMBT2907	MMBT2907ALT1PNPSOT23BEC	T1, T5
1	MPSA42	MMBTA42LT1NPN-SOT23BEC	T2
1	REG1117	REG1117	IC3
1	SENSOR_GY68GY-86DIP	SENSOR_GY68GY-86DIP	SENSOR2
1	SI2305	SI2305	Q4
1	SMA_EDGE	SMA_EDGE	J$1
1	SPEAKER/AL60P	SPEAKER/AL60P	SP4
1	SWITCH-MOMENTARY-2-SMD-1101NE	SWITCH-MOMENTARY-2	S1
1	SWITCH-MOMENTARY-2SIDE_EZ	SWITCH-MOMENTARY-	S2
1	TJCTM24024-PCBCON	TJCTM24024-PCBCON	U$1
1	TP4056	TP4056	IC4
1	USB_AB	USB_AB	U$2
1	ISP Programmer connector	MA05-2	SV1

The firmware software

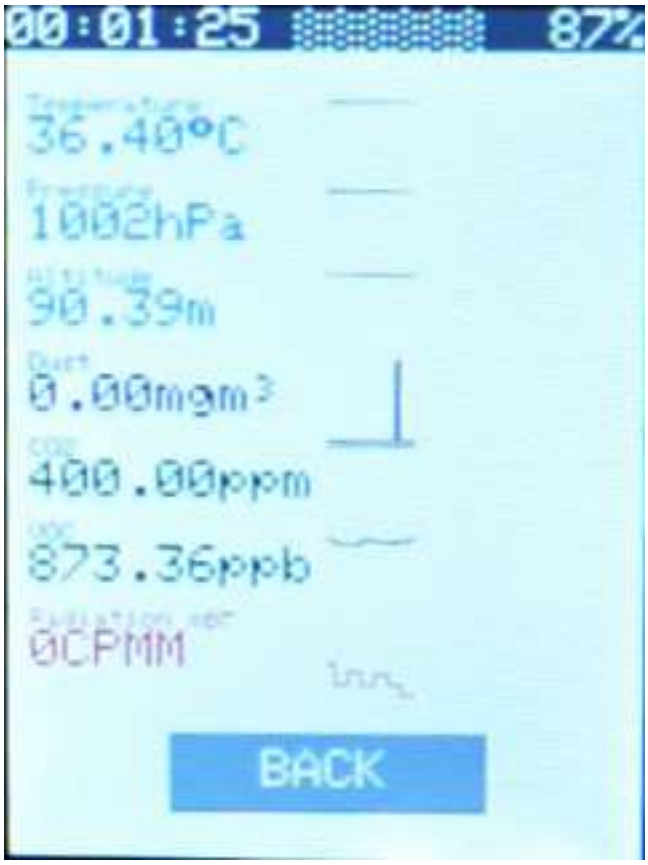
Requirements:
Implement soft start, battery monitor via ADC, timer0 with 32.768KHz crystal for accurate time counting, PWM on OC1A to drive the high voltage inverter, high voltage monitor via ADC, implement drivers for BMP180, GP2Y10, MICS-VZ89, pulse counter on INT4, disable JTAG to use all ADC pins, driver for ILI9341, driver for resistive touchscreen using 2 ADC ports , backlight driver, implement timeout for backlight, implement speaker driver, implement USB serial driver and communication protocol (in various commands, out readings reports), implement ESP8266 AT Parser and communication support. Code architecture strongly OOP oriented, to keep code clean, and provide easier management. Implement a Data model to communicate between sensor layers and UI layers. Implement a GUI with modern interface elements. Implement a language file to make translations easy.

Future requirements:
Bootloader to allow firmware upgrade over USB and WLAN (OTA). Might require hardware changes (EEPROM to store new flash temporary).
SDCard support with hardware changes.

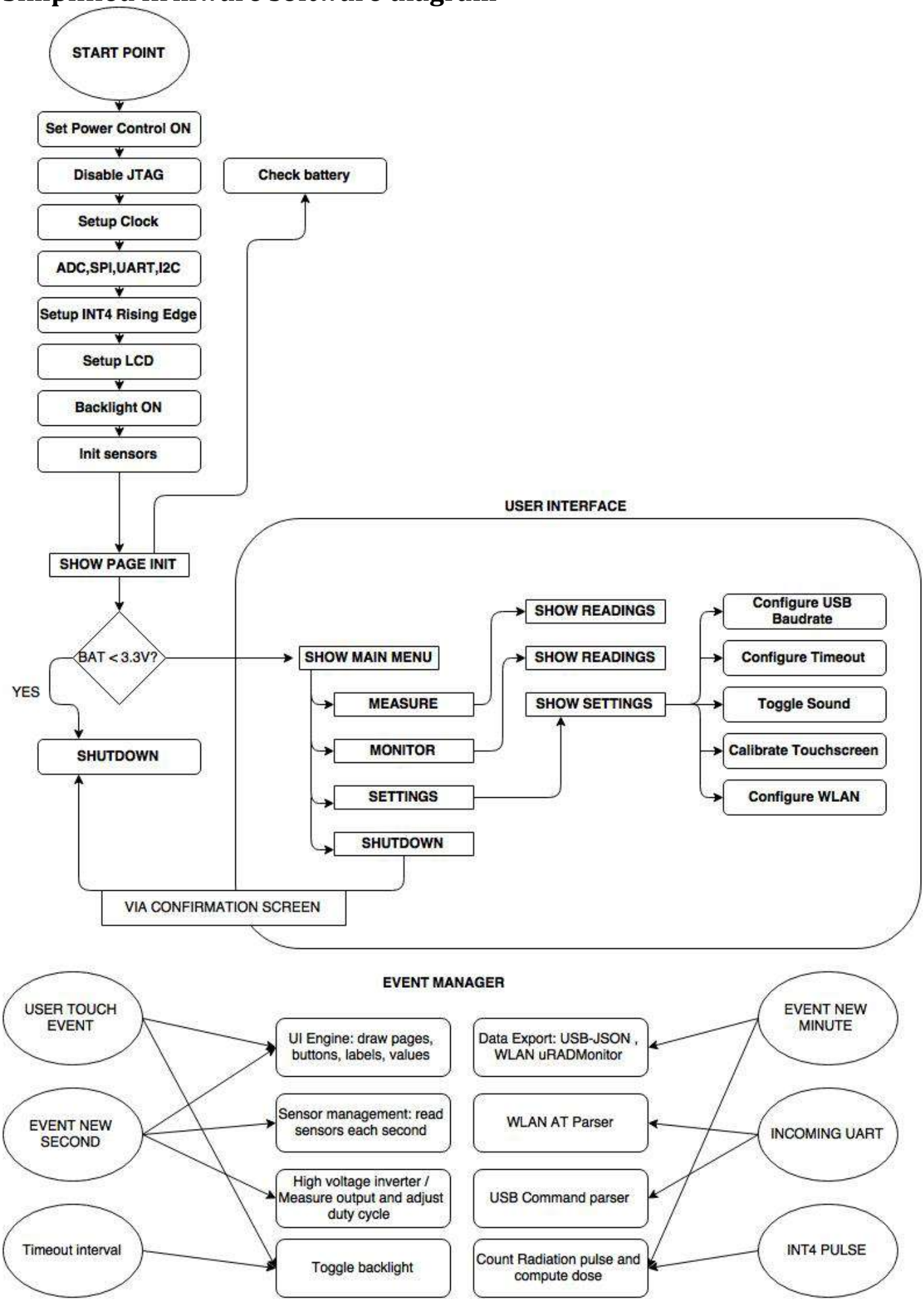
Implementation:
Dedicated classes for all components, from sensors to LCD, but also for microcontroller subsystems such as I2C, ADC or UART. Non blocking UI handling, allowing background sensor readings. Beta version totals approx. 3000 code lines of custom project code, with no external libraries.
An example of handling the Dust Sensor while relying on ADC and GPIO objects.

```
29 #pragma  once
30 #include "../adc/adc.h"
31 #include "../gpio/DigitalPin.h"
32 #include "../adc/adc.h"
33
34 class GP2Y10 {
35     DigitalPin *m_ledPulser;
36     ADC10b *m_adc;
37     uint8_t m_pin;
38 public:
39     // sets the pulser GPIO pin and the ADC converter, both to be used with this sensor
40     void init(DigitalPin *ledPulser, ADC10b *adc, uint8_t adcPin);
41     // does the probing and returns the 10bit ADC value representing dust
42     uint16_t readRaw();
43     // converting the raw value to dust quantity in mg/m^3
44     void readDust(float *dust);
45 };
```

The GUI uses a manager class, that implements various controls such as finger friendly buttons, popups and charts, for the AVR Atmega128:



Simplified firmware software diagram



USB Communication protocol

In Beta, the USB is used to send commands to the device and to receive sensor data. The final version will also allow firmware upgrades via USB and a dedicated bootloader.

Connecting via USB
Connect the device to your computer and open a serial terminal connection, or using any GUI based terminal window to the device's USB port. Configure the baudrate for 9600bps.

Commands in Beta
These are implemented *for testing purposes* and include:

beep<enter>
Will beep the built in speaker

shutdown<enter>
Will shutdown the portable environmental monitor without confirmation prompt

listwlan<enter>
will show a list of nearby access points

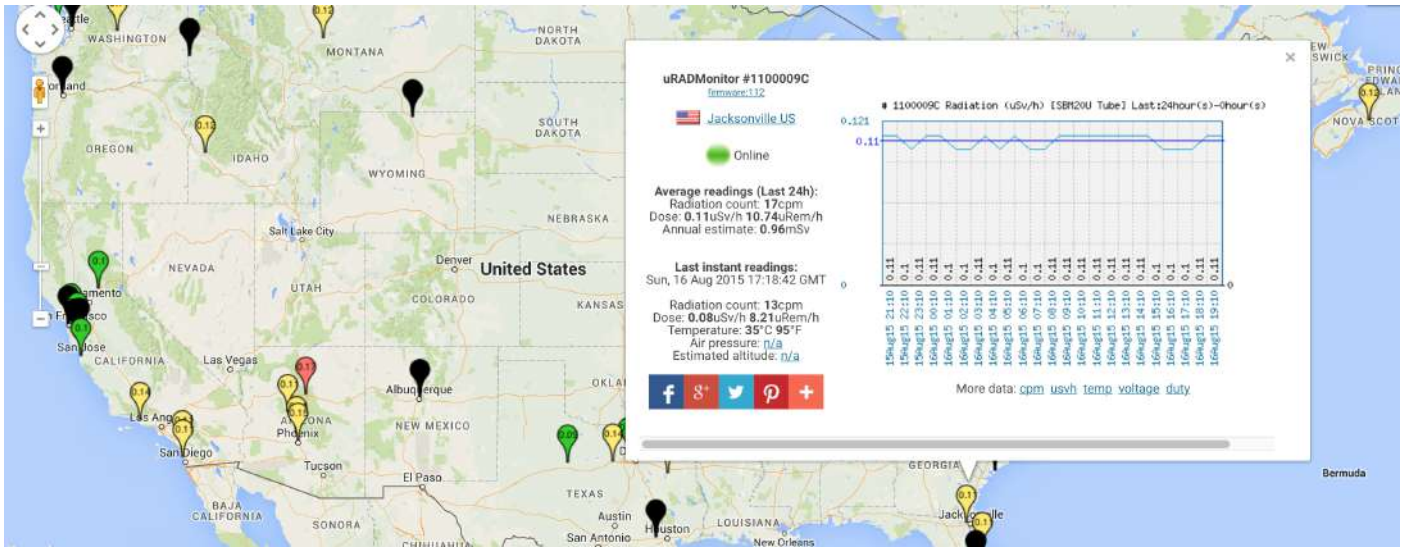
Data reports
The USB connection can be used to retrieve data reports that are sent each minute in a JSON format as follows:


```
{"data":{"id":"58000001","type":"5","detector":"LND712","cpm":
23,"temperature":22.50,"uptime":123,"pressure":100213,"dust":0
.01,"co2":400,"voc":10.00,"battery":3.79,"tube":450}}
```

The server software

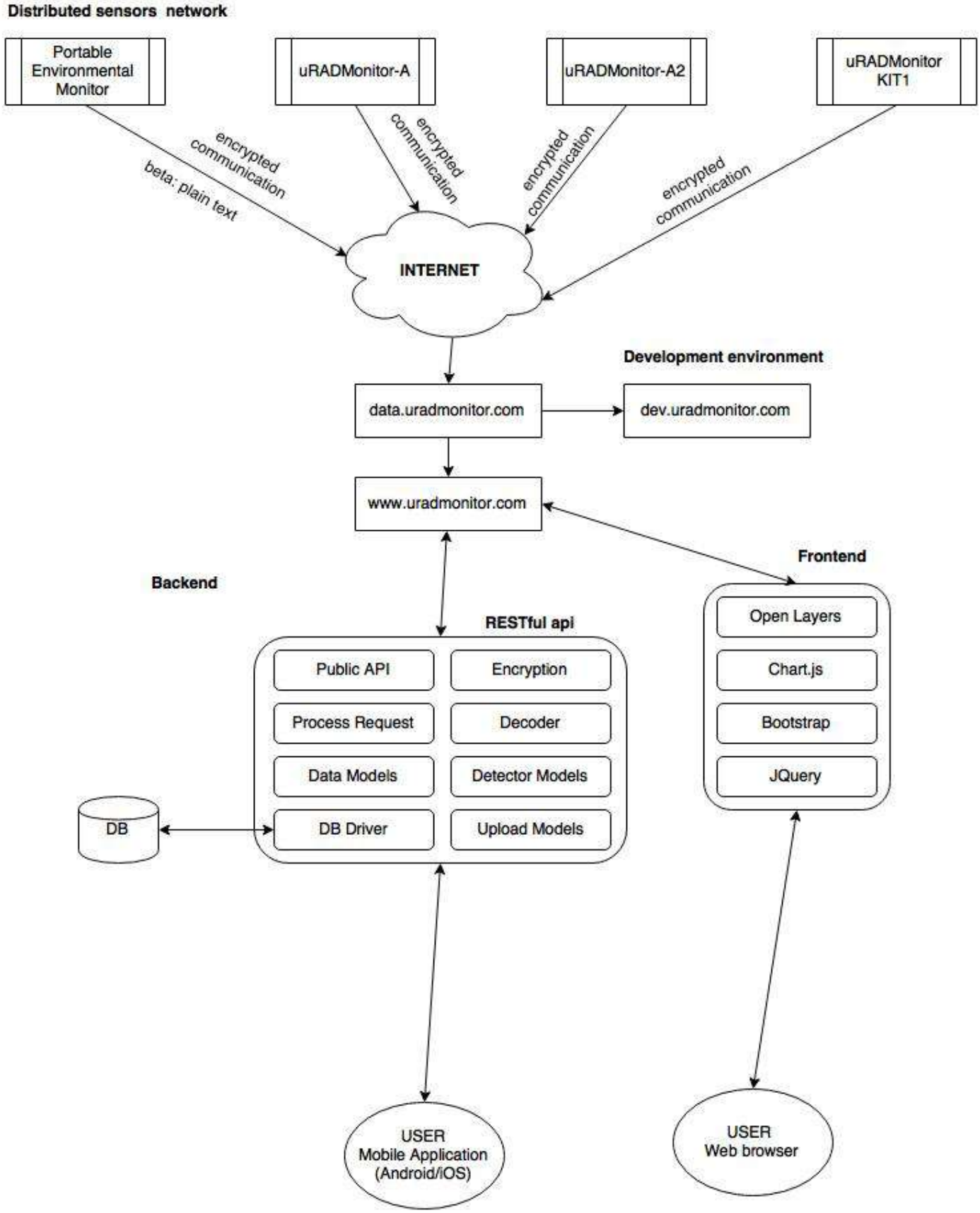
Requirements:
Implement a scalable server software to accept a high frequency, large number of input data packets, given the measurement resolution is set to 1 minute, the report data size is in the interval of tens of bytes and the number of distributed devices is in the interval of hundreds of stations.

Implementation:
Frontend based on Bootstrap, JQuery, Open layers and Chart.js / Highcharts and backend based on MySQL and RESTful API.



Server used:
2GB RAM, 2CPU Cores, 48GB SSD Storage
Database size:
57 million rows / 4.7GB / row length 55Bytes

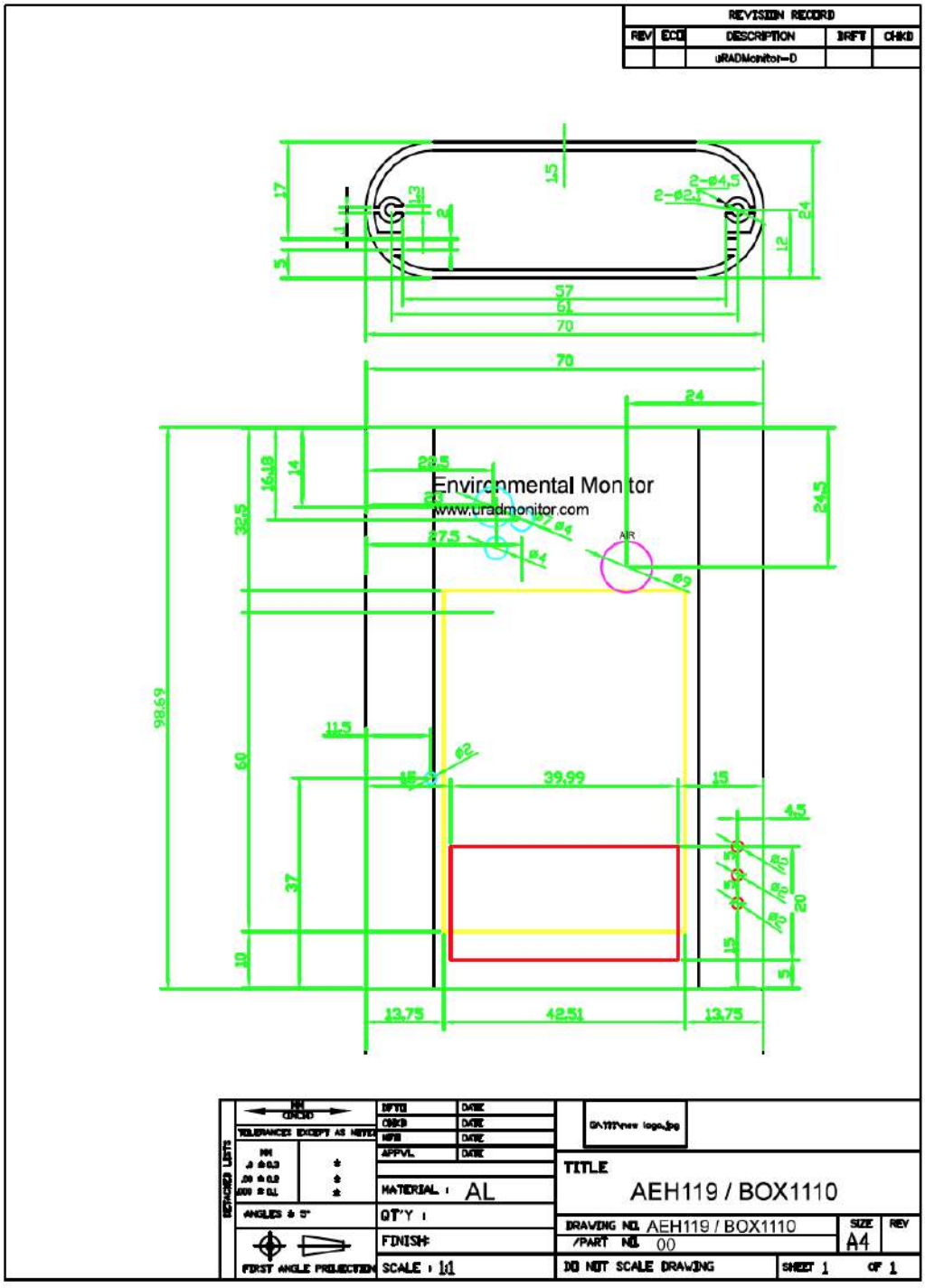
Basic server software diagram:

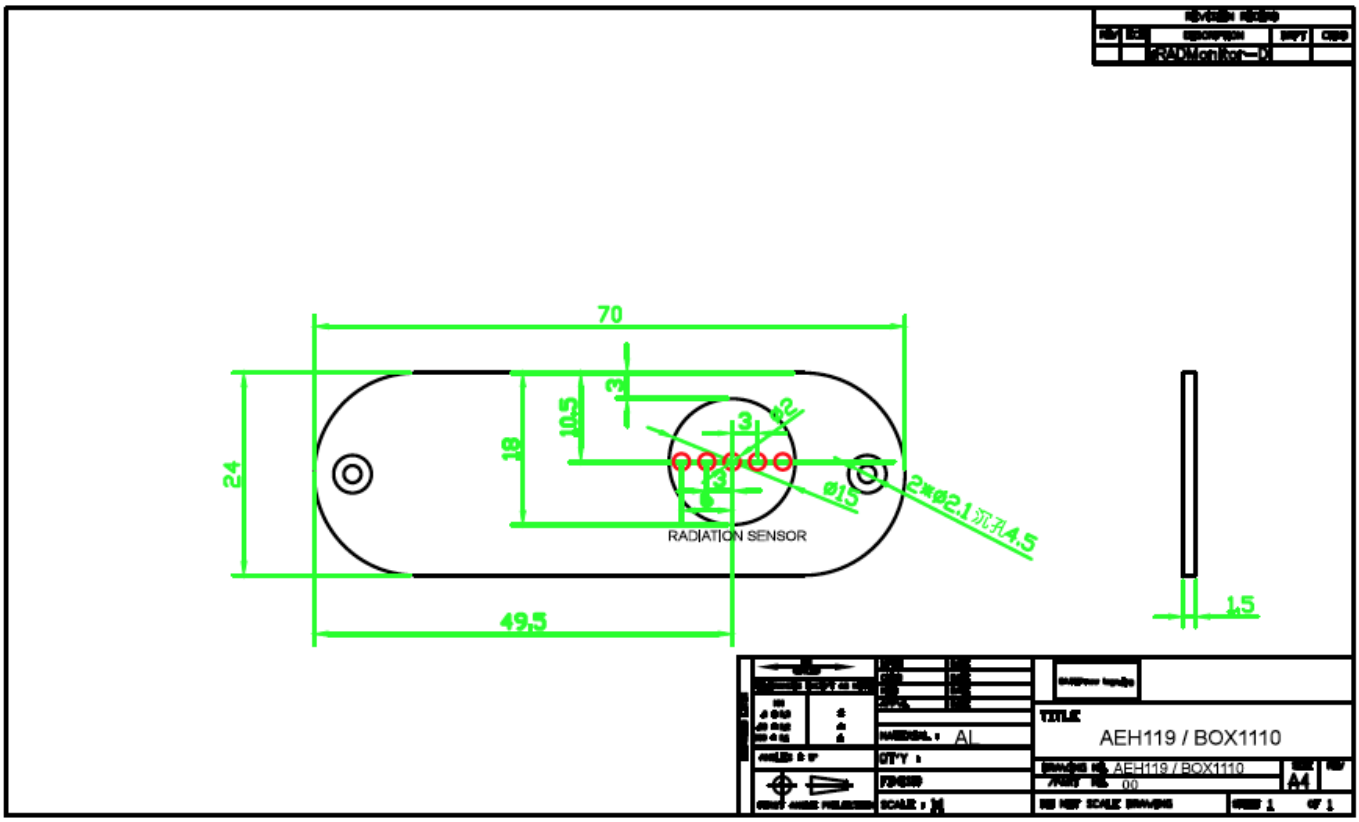


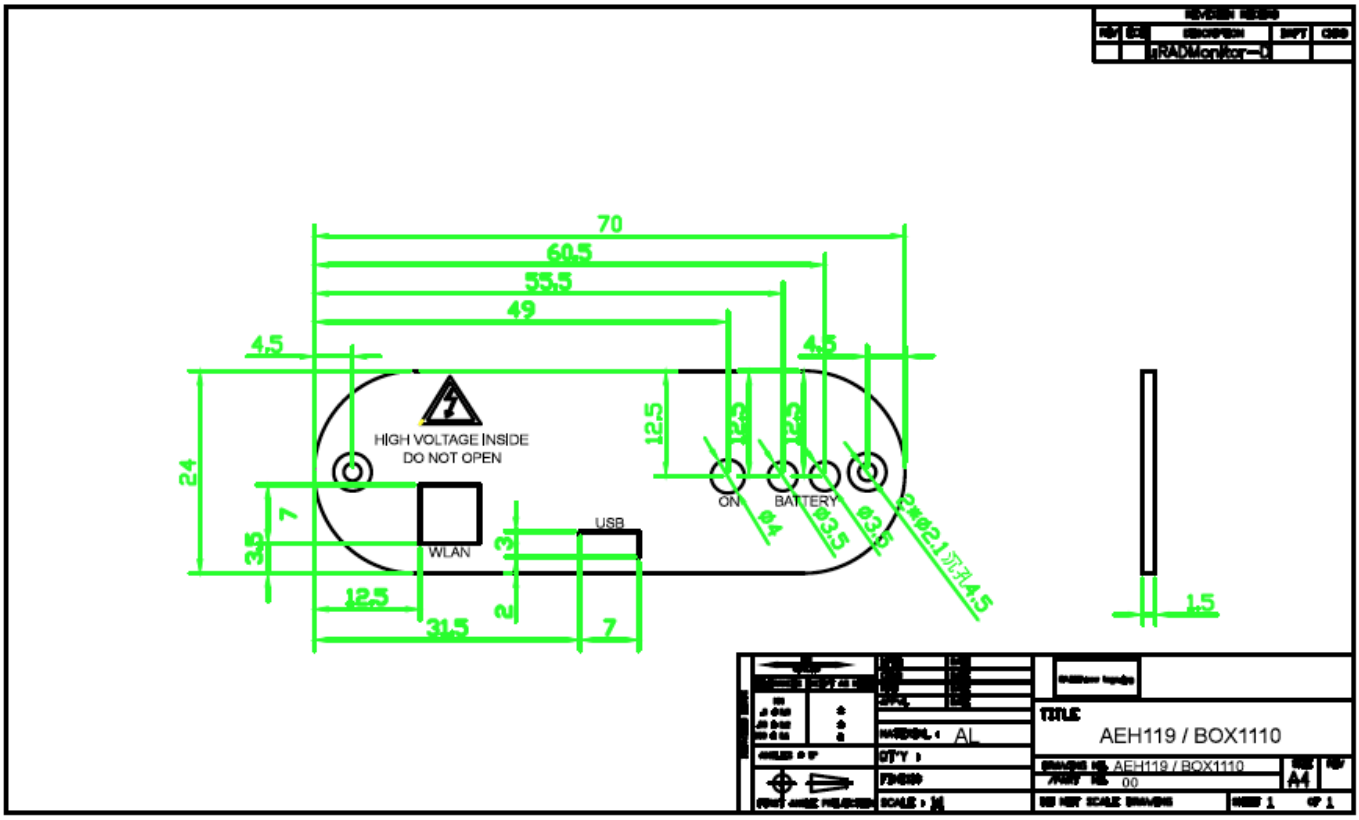
The Enclosure

Requirements:
Design and build a solid enclosure, to withstand heavy use, including on the field. Rainproof is optional, as it might not be possible given the sensors used. Make it confortable for handheld use.

Implementation:
Rugged aluminium enclosure was selected, and machine compatible design developed similar to uRADMonitor-A devices. Designed in AutoCAD.







Available on Github on: https://github.com/radhoo/uradmonitor_d

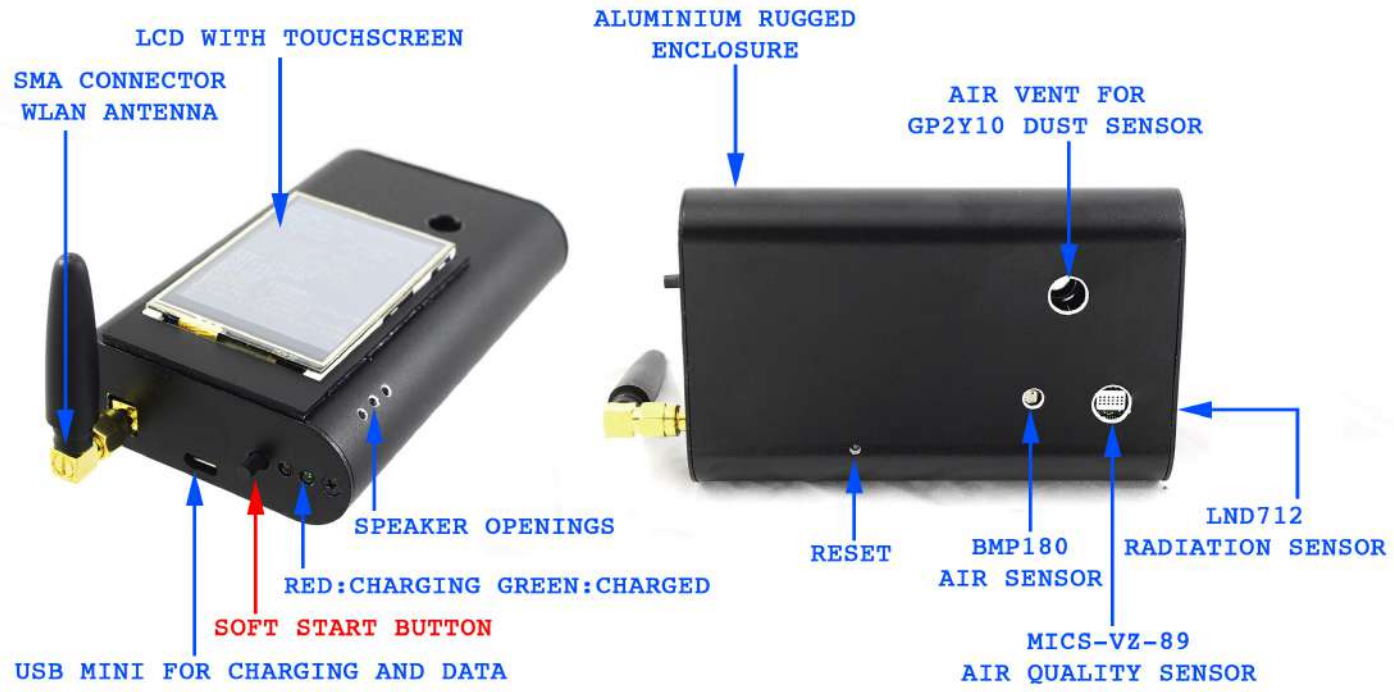
The user guide

As the current implementation is a Beta version, it will be further developed to reach a product candidate state product. At that point the firmware software should complement the sensor readings with sufficient visual indications to keep the user informed in an easy way. Displayed charts are to be compared with predefined minimal and maximal values. Standard deviation will also be involved in explaining the chart trend better.
Complementary a printed paper brochure will be also provided, to explain all device's functions in detail, from buttons to connectors and menu options. An electronic copy will also be available on the server side.

The Packaging

Cardboard packaging with polystyrene formers to protect the sensitive electronics and the LCD. Battery delivered pre-charged.

Beta Unit Preview



References

[1] The Influence of Primary Air Pollutants on Human Health Related Risk , *Sule, Tunde Usman Nurudeen, Alhasan, Abubakar, Z., Abdulasisi Titi Umoru,* http://www.iiste.org/Journals/index.php/JEES/article/view/6764/6876

[2] Global Radiation Monitoring Network, http://www.uradmonitor.com and http://dev.uradmonitor.com

[3] uRADMonitor-A HaD Semifinalist 2014, https://hackaday.io/project/1662-global-radiation-monitoring-network

[4] Portable Environmental Monitor construction log, http://www.pocketmagic.net/portable-environmental-monitor/

[5] Portable Environmental Monitor on Hackaday, https://hackaday.io/project/4977-portable-environmental-monitor

[6] uRADMonitor-D project summary https://docs.google.com/presentation/d/19o9m_u6T5lY1Vuw1UhByDP_UEonske0gD8dlyhWBAT0/edit?usp=sharing