UV-badge

Keychain-sized UV and environmental sensor

*System Design Document*

Designed by x-labz

TOC

Requirements

The device should fulfill the following requirements:

- UV Index measurement within ±1 UVI error
- Air temperature measurement
- Air relative humidity measurement
- Barometric air pressure measurement
- Small, 'keychain' sized
- Simple hardware
- Low power consumption, coin cell operation
- Should be 'nice'

Concept

The following system diagram shows the main modules of the device:
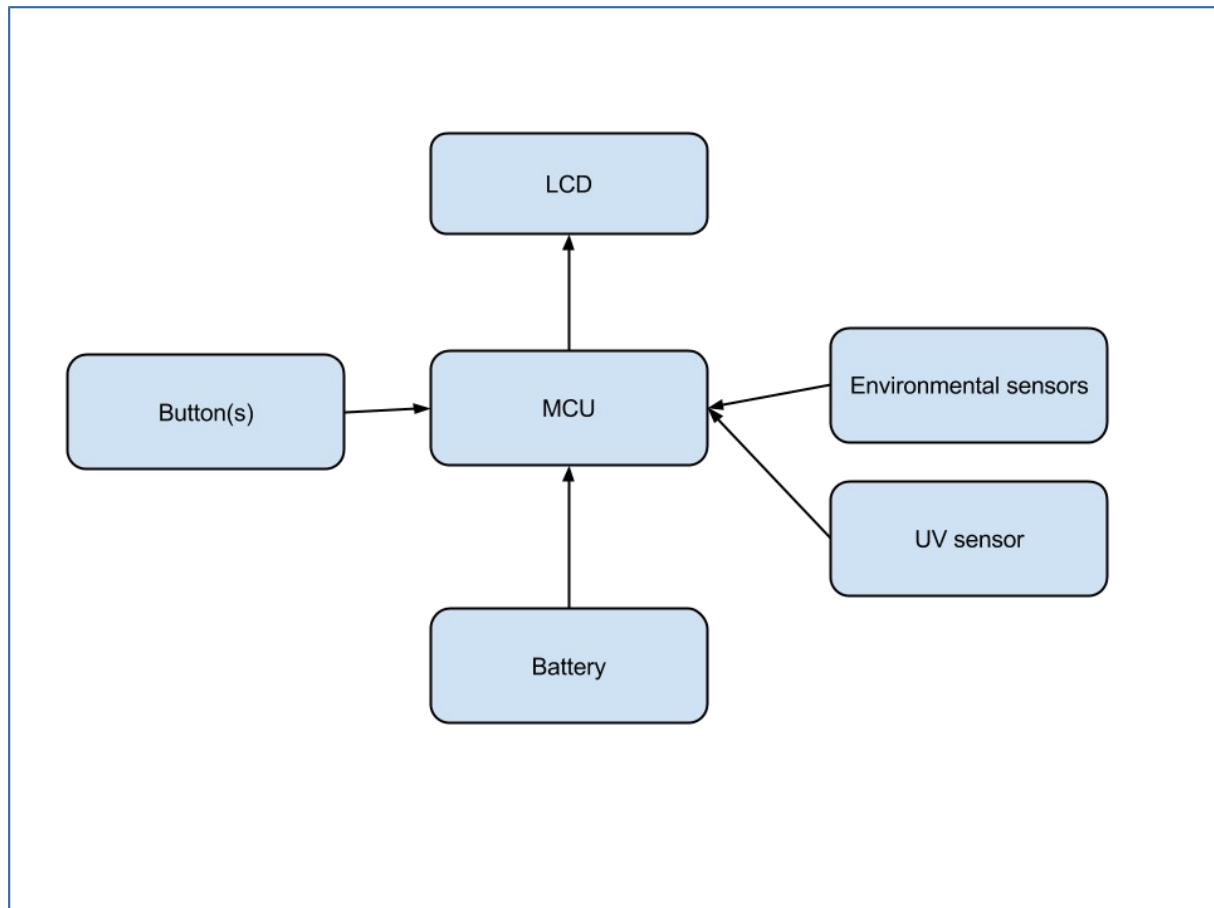
Function descriptions:

Component / module	System Function
Battery	The battery supplies the electrical energy needed
MCU	The μController reads the sensor data, displays on the screen, receives the user button interactions
Buttons	Buttons are used to control the device's

	functions
LCD screen	Displays the sensor data
UV sensor	Measures the UV intensity
Environmental Sensor	Measures the temperature, air pressure, humidity

Hardware

Schematic
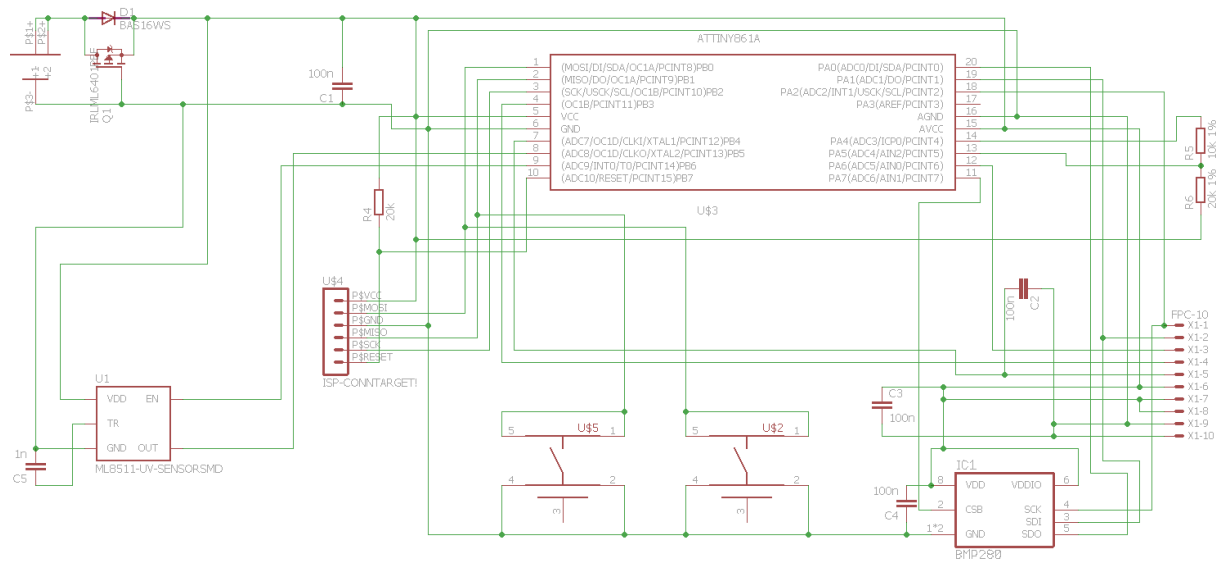
PCB

The PCB is two-layered 0.5mm thick panel.

The outline is CNC milled.

BOM

Bill of materials:

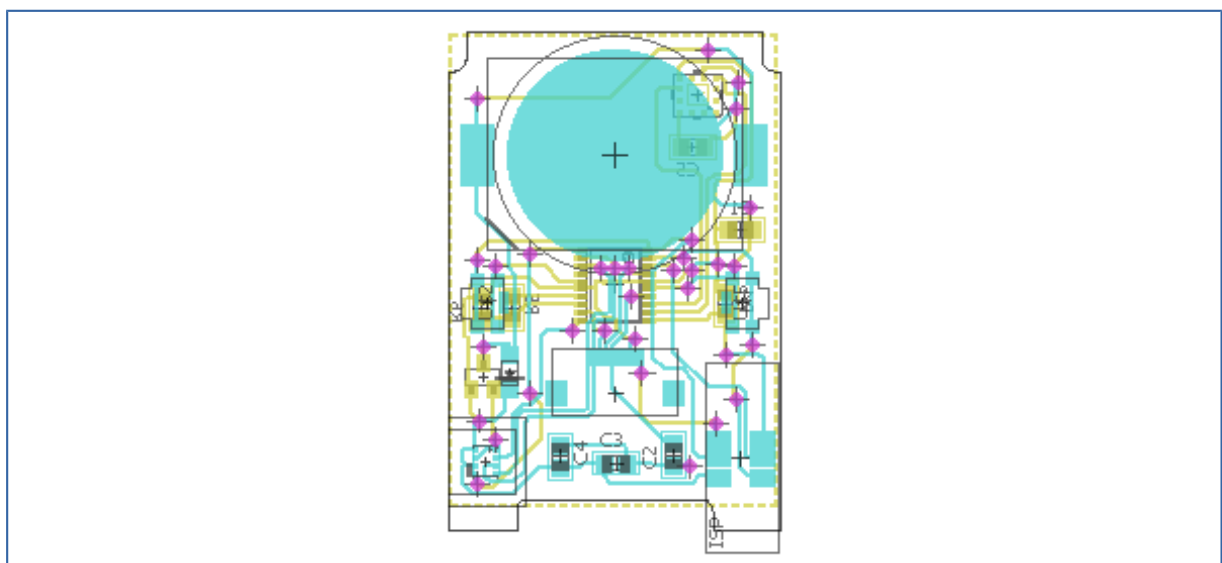| Qty	Value	Device	Package	Parts	Description	PROD_ID
4	100n	C-EUC0805	C0805	C1, C2, C3, C4	CAPACITOR, European symbol	
1	10k 1%	R-EU_R0805	R0805	R5	RESISTOR, European symbol	
1	1n	C-EUC0805	C0805	C5	CAPACITOR, European symbol	
1	20k	R-EU_R0805	R0805	R4	RESISTOR, European symbol	
1	20k 1%	R-EU_R0805	R0805	R6	RESISTOR, European symbol	
1	ATTINY861A	ATTINY861A	TSSOP20	U$3	MCU, ATMEL	
1	BAS16WS	BAS16WS	SOD323-W	D1	DIODE	
1	BME280	BME280	BMP280	IC1	Environmental sensor	
1	CR2016	CR2016	BAT-HLD-002	U$1	Battery holder	
1	FPC-10	FPC-10	FPC-10-BTM	X1	FPC Connector ZIF for SMT 0.5mm	
1	IRLML6401PBF	IRLML6401PBF	SOT23	Q1	MOSFET	
1	ISP-CONNTARGET!	ISP-CONNTARGET!	ISP-TARGET	U$4	6 x 0.1 inch Header	
2	KMSXXXG	KMSXXXG	C&K-KMS-SWITCH	U$2, U$5	Tactile button, C&K KMS Series	
1	ML8511-UV-SENSORSMD	ML8511-UV-SENSORSMD	ML8511	U1	UV sensor	IC-11927

Firmware

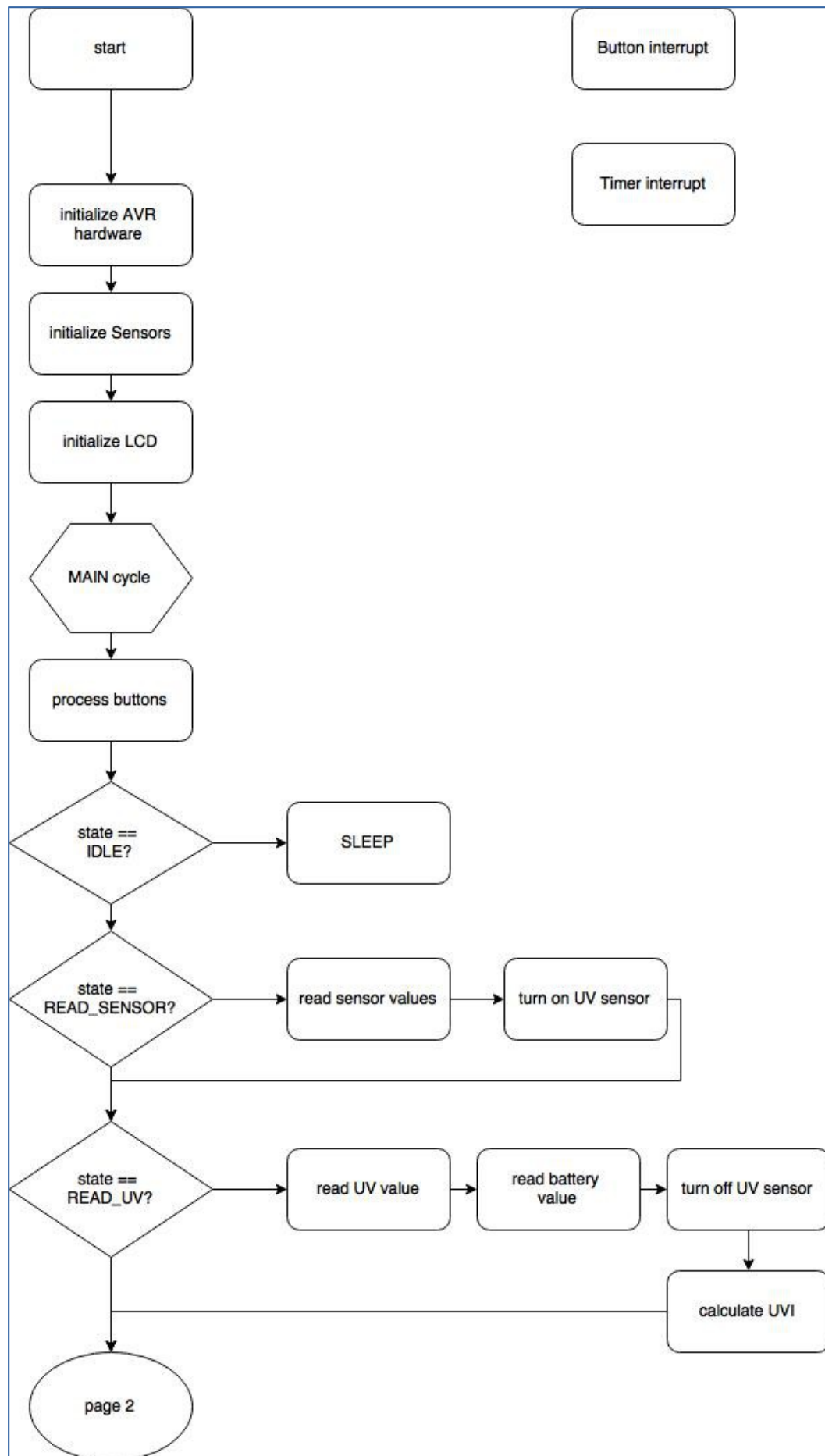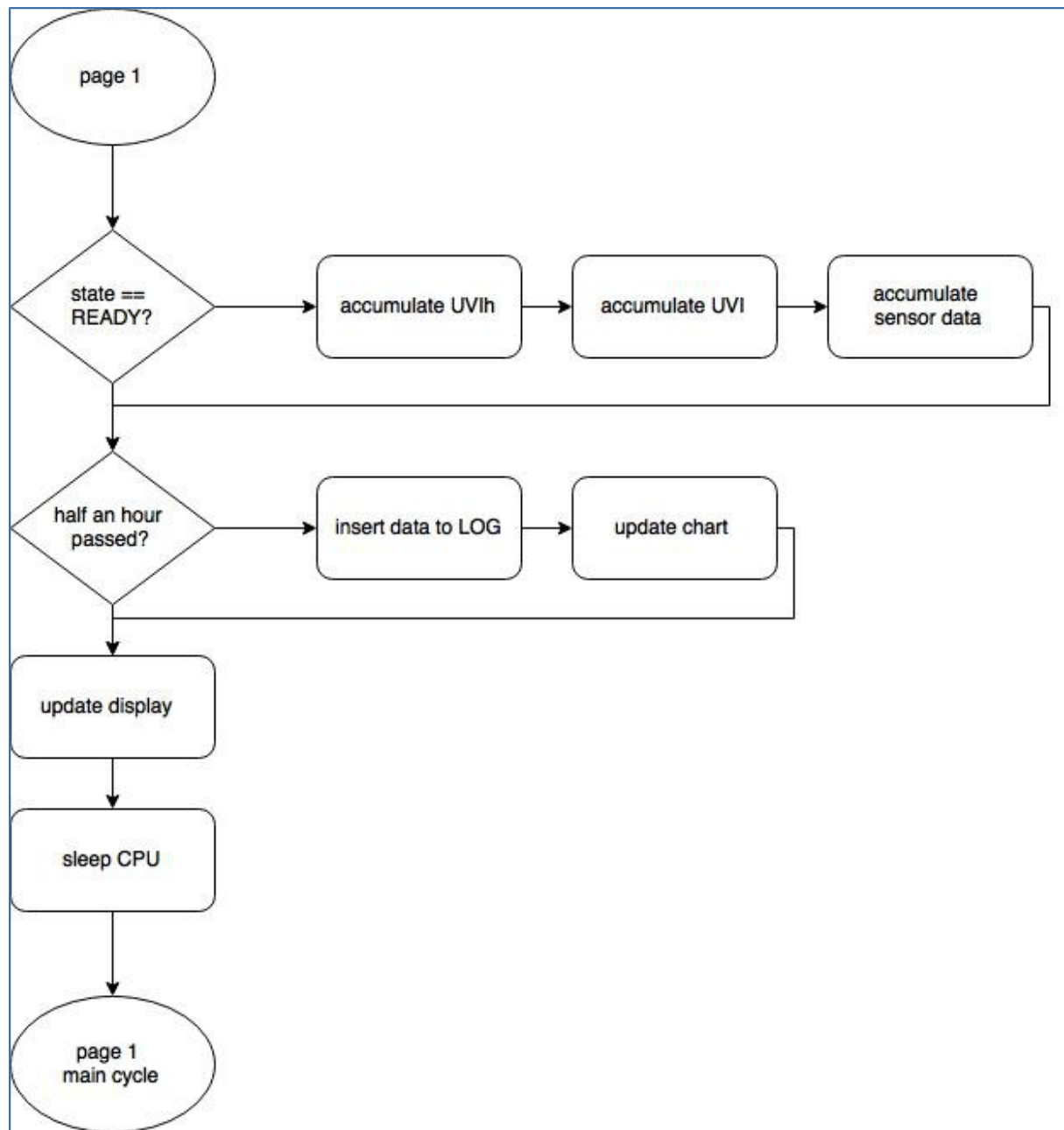## Logical model

The software functions are scheduled according the following rules:

- Battery voltage, UV, temperature, humidity and pressure values are measured approximately every two seconds
- The average values are stored in the log approximately every half-an-hour; this results in a record of measurements approximately six hours in length

The flow diagram of the software is as follows:

```
┌──────────┐                                    ┌──────────────┐
│  start   │                                    │Button interrupt│
└──────────┘                                    └──────────────┘
      │
      │                                          ┌──────────────┐
      ▼                                          │Timer interrupt│
┌──────────┐                                     └──────────────┘
│initialize AVR│
│  hardware  │
└──────────┘
      │
      ▼
┌──────────┐
│initialize Sensors│
└──────────┘
      │
      ▼
┌──────────┐
│initialize LCD│
└──────────┘
      │
      ▼
  ╱──────────╲
 ╱  MAIN cycle ╲
 ╲            ╱
  ╲──────────╱
      │
      ▼
┌──────────┐
│process buttons│
└──────────┘
      │
      ▼
   ◇─────────◇
  ╱ state ==  ╲       ┌──────────┐
  ╲   IDLE?   ╱──────▶│  SLEEP   │
   ◇─────────◇        └──────────┘
      │
      ▼
   ◇─────────◇
  ╱ state ==  ╲    ┌──────────────┐    ┌──────────────┐
  ╲READ_SENSOR?╱──▶│read sensor values│─▶│turn on UV sensor│
   ◇─────────◇     └──────────────┘    └──────────────┘
      │
      ▼
   ◇─────────◇
  ╱ state ==  ╲  ┌──────────┐  ┌──────────┐  ┌──────────────┐
  ╲ READ_UV?  ╱─▶│read UV value│─▶│read battery│─▶│turn off UV sensor│
   ◇─────────◇   └──────────┘  │   value   │  └──────────────┘
      │                        └──────────┘          │
      │                                              ▼
      │                                    ┌──────────────┐
      │◀───────────────────────────────────│ calculate UVI │
      ▼                                    └──────────────┘
  ╱──────────╲
 │  page 2   │
  ╲──────────╱
```

page 1

state == READY?

accumulate UVIh → accumulate UVI → accumulate sensor data

half an hour passed?

insert data to LOG → update chart

update display

sleep CPU

page 1 main cycle

Debugging

A custom ISP adapter is used to connect the board to the ATMEL ICE debugger. The ATMEL studio is used to compile and debug the firmware.

Housing

3D design

The housing is designed with FreeCAD. The housing consists of the following main parts:

- Top side of the case
- Bottom side of the case
- Buttons

The parts are connected with extraneous sections to be able to 3D print in one piece. After printing the parts should be separated.

3D manufacturing

The 3D model is exported to STL format. The 3D printing is panned to make by Shapeways with SLS technology. SLS technology produces much more accurate results than the more common ABS plastic printing technologies.

Plexi cover

The cover is made from 1,5 mm commercial water-clear extruded plexi sheet. The cover should be laser cut.

The laser cut plan is made by CorelDraw, because usually CDR file format is required.

Cover mask & graph

The plexi cover needs a solid white mask to hide the components, only the display and sensor area should be transparent.

Special UV cured printing can be used to print the mask and graphic on the plexi sheet.

Ideas for mass production

Housing

3D printing is not the correct technology for mass production because of its relatively high cost and limited accuracy. For the production of a plastic device case, injection molding technology is more suitable.

The design and manufacturing of injection molds would require some initial investment, but the cost per unit of the product can be quite low, depending on the volume.

Plexi cover

Laser cutting of the plexi cover is probably cost-effective even in medium volumes as well. The accuracy requirements should be taken into consideration in this case as well.

PCB

In larger production scales, PCB paneling can help to achieve a higher level of cost-effectiveness.

The mechanical design of the device needs electronic components to be placed on both sides of the panel. Normal reflow soldering should be adequate for this.

Firmware upload

The finished board is inserted into the custom programing device. The programmer downloads the firmware.

Successfully programing the CPU means that – at least – the CPU is operational and there is no short circuit on the panel.

Connecting LCD

The LCD module should be connected manually.

Testing

In general a manual inspection checklist should be adequate for testing this simple device, e.g.:

- Device turns on when the battery is installed

- Displays the required characters

- The displayed values are within the acceptable range (environmental sensor is factory calibrated)

- UV raw, offset value is within the acceptable range

- Button is working as expected

Calibration

To minimize the UV Index error the UV measurement should be calibrated. The simplest way can be the follows:

Prerequisites:

- Have a light insulated calibration chamber
- Have a constant light source with definite power in the UV spectral range.
- Use a reference meter to learn the level of UV exposure

Calibration of items:

- Record the UV sensor offset value in dark conditions
- Record the UV sensor output value with the UV emitter on.
- Use the programmer to load the calibration values into the eeprom of the MCU.

Packaging

Environmentally friendly cardboard packaging is planned. A printed user guide should be included, or the information could even be provided on-line.

The assembled coin cell battery should be inactivated using a cellophane tape, which should be pulled out to activate the battery.