University of Colorado Boulder
10-27-2016

A

Project Report on

# *Al fresco*

Submitted under the course work of ECEN 5023

*By*

**Sai Raghavendra Sankrantipati**

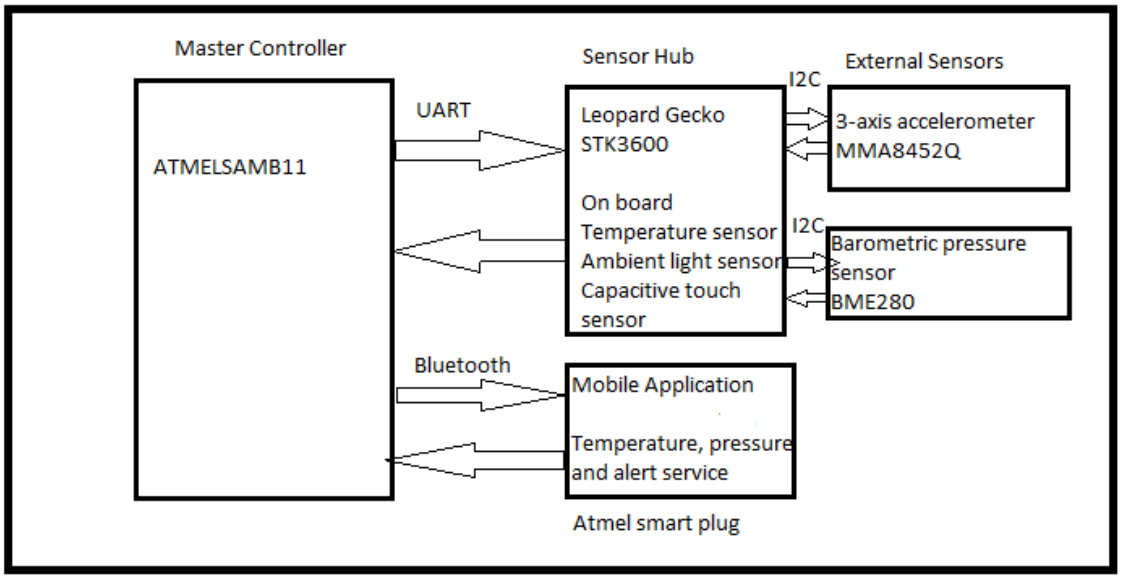
**Project Overview**

Home automation is the control and automation of security, light, air conditioning etc., of home appliances such as washers, ovens, or refrigerators. The internetworking of these automated devices with electronics, software, sensors, actuators, and network connectivity is Internet of Things.
Al fresco means “in the open air” in Italian. Our Al fresco is a sensor hub that is placed on a door which monitors temperature, pressure, ambient light, letter counts and a mimic for pattern access to the door. For the implementation of the project EFM32 Leopard Gecko is used as sensor hub and ATMEL SAMB11 is used as master for the sensor hub. An ATMEL designed mobile phone application ‘ATMEL Smart’ is used to track these changes. Three profiles run in the application which monitors temperature, pressure, and letter count. Along with 3 on board Temperature, Light and Touch sensors 2 extra sensors for Pressure and mail count are implemented using I2C protocol. Transfer between master and slave is done using UART protocol and transfer between client and server is by Bluetooth.

## Solved Problems

- In countries like India where every citizen has a smart phone or a phone with minimum Bluetooth service and doesn't have a proper internet connection, Al fresco is used for these basic purposes.
- On-board ambient light sensor is used to turn light on when its night and turn it off during morning in the front garden.
- On board temperature sensor monitors the temperature and sends its information to the mobile application. User can decide on taking a jacket or not by this information.
- Barometric pressure sensor is used to monitor pressure in the front yard and during low pressure days it helps to decide on taking an umbrella while going out or decide on turning sprinklers on or off.
- Accelerometer is attached to the mail box's lid. When a letter is dropped in it, it's count is recorded and can be displayed on ATMEL Smart application and LCD
- Capacitive touch sensor is used to check pressure, temperature and letter count in LCD. .
- Touch sensor is also used to mimic a pattern for door opening.

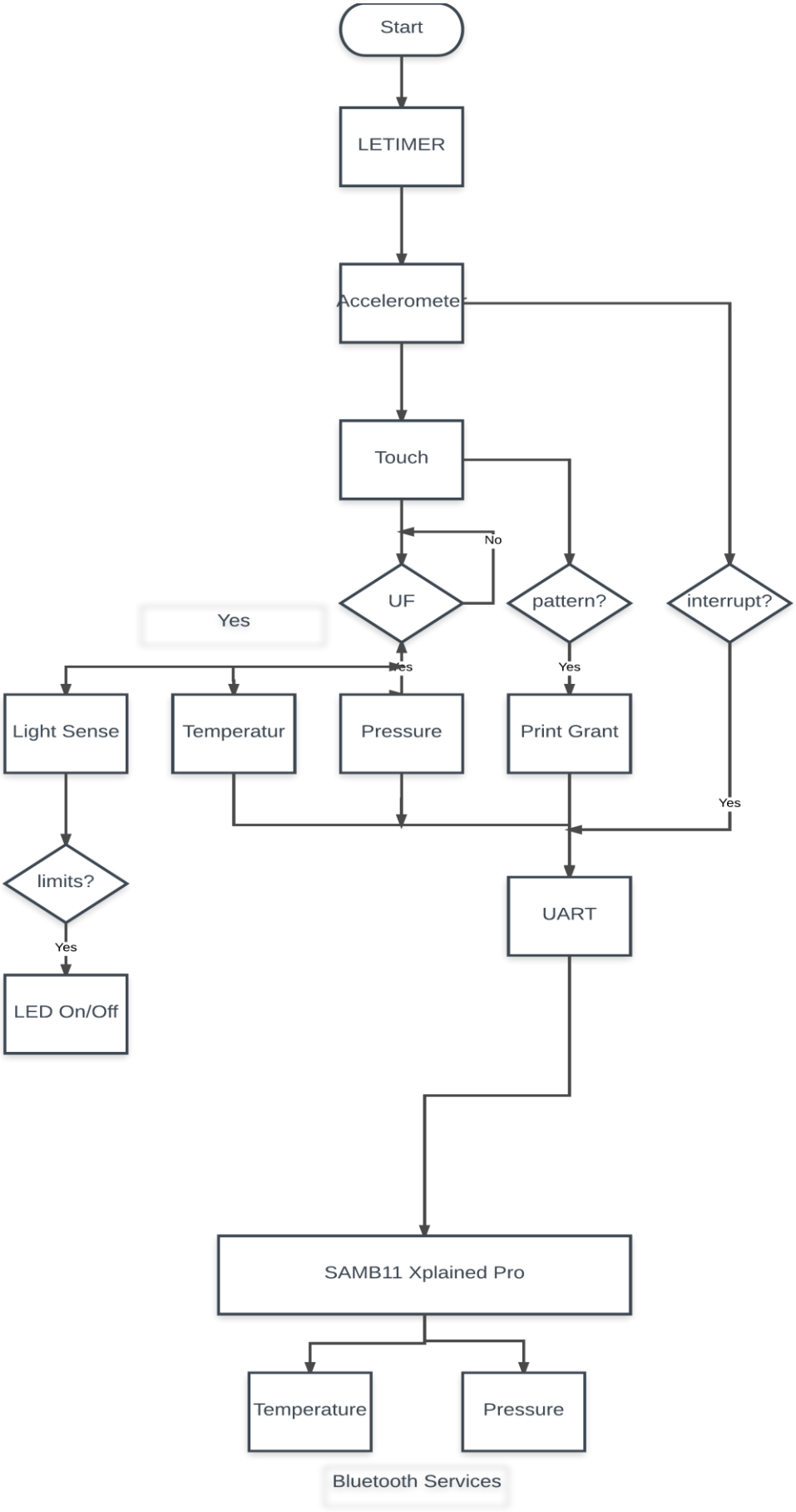
## Hardware Block Diagram



## Key Components

1. **EFM32 Leopard Gecko**
    - LETIMER
    - LESENSE
    - LETOUCH
    - Temperature Sensor
    - ADC
    - DMA
    - Ambient Light Sensor
    - UART
    - I2C
2. **SAMB11 Xplained Pro**
    - DMA
    - UART
    - Bluetooth
3. **MMA8452Q 3-axis accelerometer**
4. **BME280 – Pressure Sensor**
5. **ATMEL Smart Mobile Application**
    - Temperature service
    - Pressure in Battery Service.
    - Letter count in Heart Rate Service

## Software Flow Chart



**Functions used in code:**

- CHIP_Init();
- CMUConfiguration();
- LETIMER0Setup();
- accelerometer();
- LETOUCH_Init(sensitivity);
- pattern_check(channels_touched);
- ACMPlowSetup();
- ACMPhighSetup();
- LED1off();
- LED1on();
- ADCSetup();
- DMASetup();
- ADC_Start(ADC0, adcStartSingle);
- BMEI2CSetup();
- BMEEnable();
- BMESetup();
- DataCalibration();
- BMEDisable();
- `CircBuff();`
- LCD_off();
- LEUARTSetup();

**Risk parts**

- Capacitive touch pattern as a shared key – I'm not sure how robust could this key be and the patterns that could be made using just 4 sensors would be very less.
- Accelerometer has been configured for an interrupt with little movement. What if there were more than a single movement for a single letter input.

**Trigger Points**

- When the LETIMER Underflow flag is set all the sensors would start working and a spike is seen in Energy profiler.
- When there is a change in ambient light and if it exceeds a limit, it triggers LED0.
- Temperature is recorded every 10 seconds and on pressing channel 8 of LESENSE its value should be visible. A constant tracking of temperature is done on Atmel Smart App.
- When there is a change in accelerometer an interrupt is seen in energy profiler. Letter count increments and its value is displayed in LCD. On pressing channel 8 of LESENSE letter count can be seen.
- When the pattern on the capacitive sensor matches "GRANTED" is displayed in LCD.
- When capacitive touch sensor is pressed on channel 8 it should display temperature, pressure, and letter count. Spikes are visible in the energy profiler.
- Pressure is recorded every 10 seconds and on pressing channel 8 of LESENSE its value should be visible. A constant tracking of pressure is done on Atmel Smart App.

**Timeframe**

| | Description of Work | Date | |
|---|---|---|---|
| Status report I | Work on LETIMER, ADC, DMA, Temperature Sensor, Circular Buffer and LEUART | 11-08-2016 | Done |
| Status report II | Work on Pressure Sensor, capacitive sense, ambient light sensor and LCD. | 11-29-2016 | Done |
| Phase Three | Work on Temperature and pressure services on ATMEL Smart Application. Taking care of project's energy score and updating conn interval and slave latency | 12-6-2016 | Done |

**Test methodology**

| Component under test | Test condition | Verification for success | Result |
|---|---|---|---|
| LETIMER | Running in a condition with two interrupts | An interrupt should occur when comp1 and comp0 values have reached their limits | verified |
| ULFRCO Calibration | Calibrated in the very start of program | ULFRCO should be calibrated and a logical ratio should be observed | verified |
| I2C1 | Send commands to read status pressure sensor in route 1 | Status should be visible in EFM32 | verified |
| I2C1 | Send commands to read status accelerometer sensor in route 0 | Status should be visible in EFM32 | verified |
| Ambient light sensor | Cover ambient light sensor | LED0 should turn or remain on | verified |
| Ambient light sensor | Flash the ambient light sensor | LED0 should turn or remain off | verified |
| ACMP0 | Cover ambient light sensor | LED0 should turn or remain on | verified |
| ACMP0 | Flash the ambient light sensor | LED0 should turn or remain off | verified |
| ACMP1 | Touch any channel of cap sensor | A spike is visible in energy profiler which resembles an interrupt | verified |
| Temperature Sensor | Touch channel 8 of LESENSE for 2 times | LCD should display temperature | verified |
| Temperature Sensor | Use cold spray and Touch channel 8 of LESENSE for 2 times | LCD should display change in temperature | verified |
| Temperature Sensor | Use cold spray | temperature value should be visible on Atmel Smart | verified |
| ADC | After every 10 seconds | temperature value should be visible on Atmel Smart and LCD | verified |
| DMA | After every 10 seconds | A call back should be called after the transfer | verified |

| | | | |
|---|---|---|---|
| DMA | Use cold spray | temperature value should be visible on Atmel Smart and LCD | verified |
| Accelerometer | Read and write to the registers | Read the config registers and status registers after writing to them | verified |
| Accelerometer | Move the sensor | LCD should display count | verified |
| Accelerometer | Touch channel 8 of LESENSE for 1 time | LCD should display number of accelerometer interrupts | verified |
| Circular Buffer | Send series of bytes to UART with no significant time difference | In SAMB11 they should be read in the same order without any overlap | verified |
| LEUART/EFM32 | Send data to SAMB11 | Check data in SAMB11 | verified |
| USART / SAMB11 | Send data from EFM32 | Check data in SAMB11 | verified |
| USART / SAMB11 | Send data from EFM32 | Data should be visible in BLE services | verified |
| Barometric Pressure Sensor | Read and write to the registers | Read the config registers and status registers after writing to them | verified |
| Barometric Pressure Sensor | Touch channel 8 of LESENSE for 3 times | LCD should display count | verified |
| Barometric Pressure Sensor | Blow air to the sensor putting in a closed environment | Read temperature and pressure raw values and calibrated value is read in EFM32 | verified |
| Barometric Pressure Sensor | Blow air to the sensor putting in a closed environment | Pressure value should be changed in Atmel Smart Plug | verified |
| Capacitive touch sensor | Touch channel 11 and 10 and 8 and 9 | It mimics a key and should display access granted | verified |
| Capacitive touch sensor | Touch channel 8, first time | LCD should display number of accelerometer interrupts | verified |
| Capacitive touch sensor | Touch channel 8, second time | LCD should display temperature | verified |
| Capacitive touch sensor | Touch channel 8, third time | LCD should display pressure | verified |
| LCD | On touching channel 8 of LESENSE | Either Temperature or pressure or letter count is visible | verified |

| | | | |
|---|---|---|---|
| Sleep mode | Disable accelerometer | Current should be below 1.7 uA | verified |
| Temperature Service | Connect to SAMB11 using ATMEL Smart | Temperature calculated in EFM32 should be visible | verified |
| Pressure Service | Connect to SAMB11 using ATMEL Smart App | Pressure calculated in BME by EFM32 should be visible | verified |

**Difficulties Encountered:**

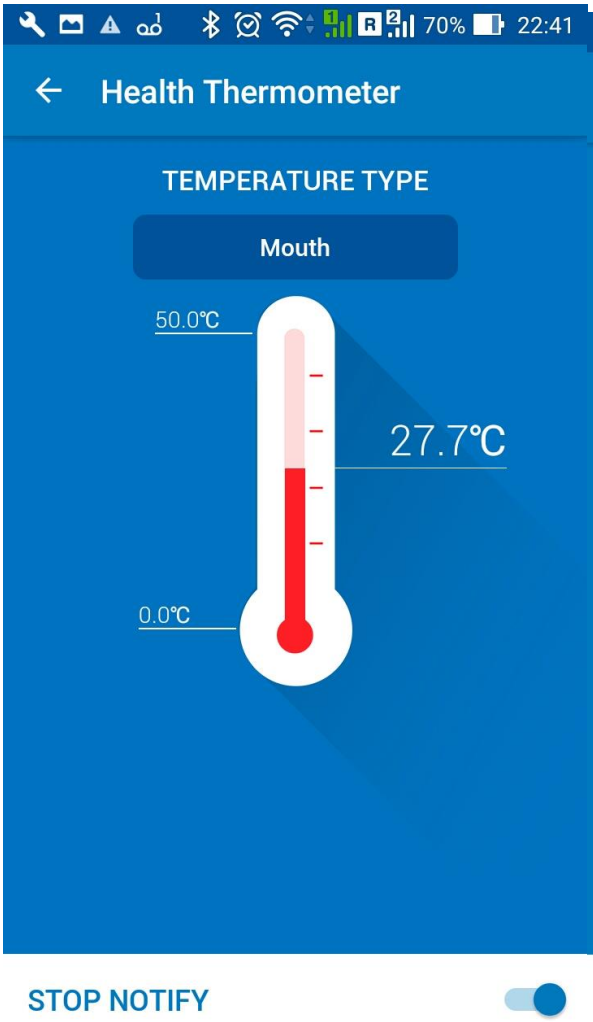
- For the challenge to integrate two sensors using I2C, different cases were tried like using route 2 for one sensor in I2C1 and other on route 0. Finally Route 0 and Route 1 have worked fine.

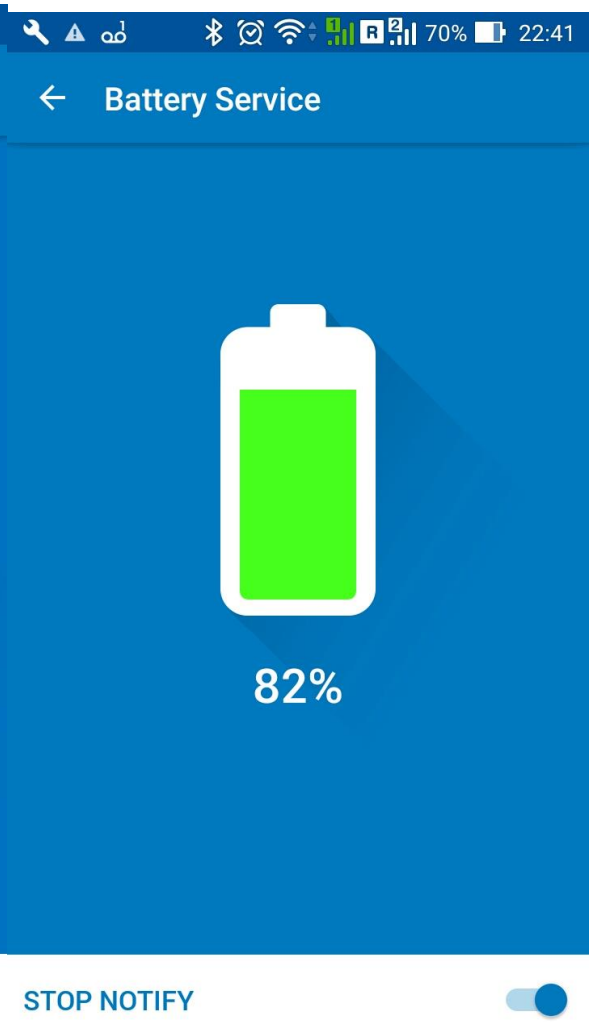
Making a pattern, which is channel 11, channel 10, channel 8 and channel 9, has taken a lot of time for logic to get framed.

- Integrating more than 1 service on the Bluetooth is another difficulty came across the work.
- Implementing Light Sense while Capacitive touch is active is one more difficulty I came across.

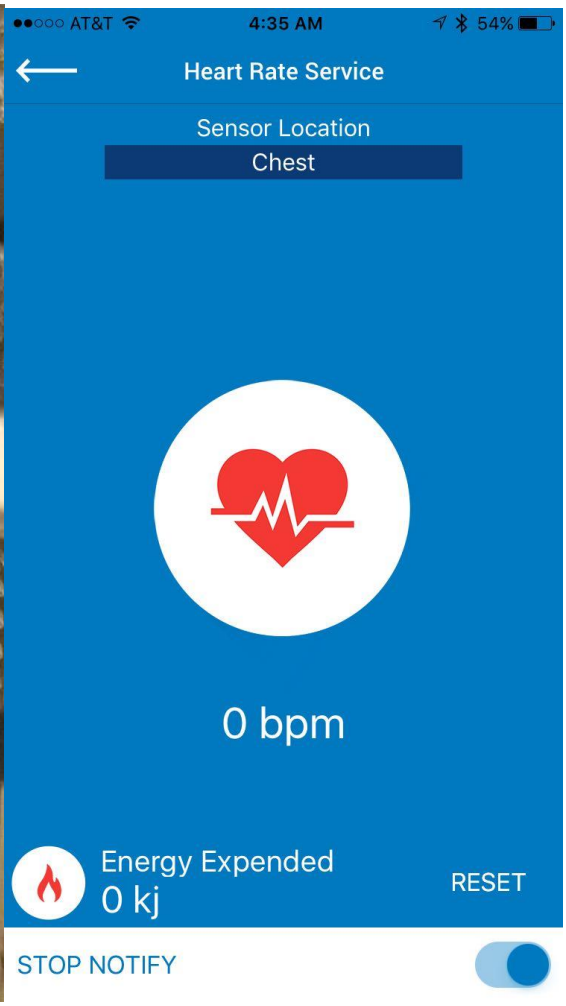
**Functionality of Project:**

1. LFXO oscillator is enabled and sleep counter is set
2. ULFRCO is calibrated using TIMER 1 and TIMER 2 by using HFRCO and LFRCO.
3. LETIMER0 is enabled and underflow flag is set for every 10 seconds. An interrupt occurs when COMP1 flag and UF flag set.
4. LESENSE is initialized with channel 8, 9, 10 and 11 for scanning. ACMP1 is used by LESENSE and interrupt occurs when any of the channel is touched.
5. Accelerometer Is turned on and all the control registers were configured for motion detection using I2C1 in Route 0 position. SDA and SCL ports are disabled.
6. A function for pattern is called in while loop. It checks for channel 11 interrupt, then for channel 10 interrupt, then for channel 8 interrupt and finally for channel 9 interrupt. If any of the case fails EFM32 goes into EM2 mode.
7. When the COMP1 interrupt occurs, Light Sense is turned on which stands for 0.04 seconds.
8. When Underflow interrupt occurs ACMP0 status is recorded twice with both high and low ambient light values. LED0 is turned on and off per the status of ACMP0. ACMP0 and light sense is turned off.
9. Pressure sensor is configured and uncalibrated readings were recorded and appropriate calculations were made to generalize pressure. BME 280 is configured using I2C1 on route 2 position. After pressure being calculated SDA, SCL and Vdd input for BME is disabled.
10. ADC is initialized with temperature sensor as input. 1000 readings were recorded and transferred using DMA. Average of these values were calculated.
11. Finally, all these values are sent to a circular buffer. After all the values being added LEUART is enabled and transfer begins.
12. These values were read in SAMB11 and first 4 bytes were for temperature service and another four for pressure service.
13. After connecting to SAMB11 using ATMEL SMART Temperature Service and Battery Service would be visible which displays temperature and pressure respectively.
14. When channel 8 of LESENSE is touched once, number of interrupts were displayed on LCD. If its pressed again LCD should display temperature and on pressing channel 8 again LCD should display pressure.
15. If the channels of LESENSE were pressed in the following order 11, 10, 8 and 9 “GRANTED” would be displayed on LCD.
16. LCD is turned off in LETIMER0 IRQ handler.


70%
22:41
Health Thermometer
TEMPERATURE TYPE
Mouth
50.0℃
27.7℃
0.0℃
STOP NOTIFY


70%
22:41
Battery Service
82%
STOP NOTIFY


EFM32
LEOPARD GECKO
PB0
PB1
RESET
DEBUG
BU CAP
SENSE


AT&T
4:35 AM
54%
Heart Rate Service
Sensor Location
Chest
0 bpm
Energy Expended
0 kj
RESET
STOP NOTIFY

**Lessons Learned:**

Mainly, this project is done in the most professional way. From giving proposal to updating statuses, everything is happened in the corporate style. Secondly, 5 sensor's value were used using 2 transfer protocols and peripherals like ADC, DMA, ACMP and TIMERS were used. Most importantly, this project is developed in lowest possible energy which makes it a direct consumer product.

**Conclusion:**

Successful implementation of Alfresco by 5 sensors using several peripherals in the low energy mode is implemented. Both Silicon Lab's Leopard Gecko and ATMEL SAMB11 are implemented together in a Bluetooth Smart device application where ATSAMB11 is the master of the system and Leopard Gecko is the sensor hub.

It was a wonderful learning experience and gave me a real insight into Internet of Things.

The project is further extendable.