



Texas Instruments Innovation Challenge: Europe Design Contest 2016 Project Report

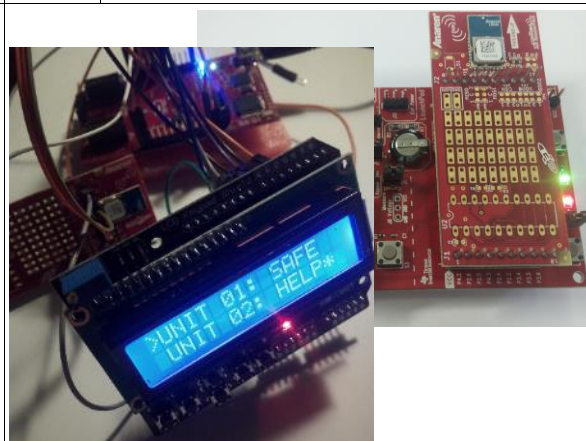
Safe, Search and Emergency

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Qty.	TI Part Number & URL	Qty.	TI Part Number & URL
1	MSP-EXP430FR5969	1	430BOOST-CC110L
1	MSP-EXP430FR5739	1	TPS54231EVM-372



Photo of the team



Project abstract: This project presents a novel system to give support for rescue teams by providing means of visual and remote alerting mechanisms. Each element of the team is equipped with one portable station which allows to set their own condition, or state, e.g. Safe, or Help. At the command centre, the base station receives the information from all team members and displays it. The project concerns the development of a low-cost, low-power, reliable, scalable and modular embedded system. At the heart of the developed system there are TI's MSP340FR ultra-low power micro-controllers, which allow for significant power savings, when compared to competitor technologies. Moreover, TI's hardware portfolio and tools facilitated the quick development of the system's prototype to validate the design without delving into all the details of all components and producing a custom PCB.

Introduction

We have invented a novel system (pat. pending) to equip rescue teams. It is to be applied on a backpack or jacket, to indicate the presence or emergency state of rescue

team personnel. Any team member is then able to notify the central command of their condition with a simple push of a button. The module emits a bright light, with a specific blinking pattern, and sends a message over an RF link to the command centre, depending on the user status.

The system is constituted by two modules. One of the modules is referred as **Mobile Signaller (MS)**. The mobile signaller equips the end-user (fire-fighter) which sets one of the three user status by pressing a push button. It sets and communicates one of the 3 possible user status: **Safe**, **Search** and **Emergency** sending messages through RF to a central module referred as **Base Station (BS)**. This module converts the received data into a text message displayed on an LCD screen. This unit is meant to be on a fixed location and enrolled as a central unit gathering the information from all the MS on field is showed on a text display.

This system cycles through three possible states: SAFE, SEARCH and EMERGENCY, as illustrated in figure 1.



Figure 1 - Possible operation states.

- **SAFE:** This is a state when the person who carries this module is not in a particular task, or the section where he is at the moment, is not distressed by anything. It is considered to be in a zone without need for help, which is the opposite of search or a panic states.
- **SEARCH:** In the search state the module lights up the LEDs with a slow blinking pattern so that they can serve as presence indication to other team elements. This enables the proper formation of the team, when search activities are taking place, or for the identification of a group dispersed due to executing different tasks.
- **EMERGENCY:** For emergency the module flashes the LEDs fast so they can easily be identified. Simultaneously the module sends a message, via RF, transmission support for a centre that is coordinating the operation.

The mobile module is fitted with a small battery, a microcontroller, a RF module and a wireless charger. The change of states depends solely on a press of a push-button to facilitate the user interaction.

It is our concern to create a system that is as cheap as possible, useful and top of all which can contribute to society by saving lives.

So far there's no solution that resembles the proposed system. Typical alarming are PASS (Personal Alert Safety System) devices which usually consist of inertial sensors that sound a loud alarm after a couple of seconds of users' inactivity.

Motivation for project

In catastrophic scenarios every life counts and every second matters. The evolution of technology has made a contribution to the development of tools that make our lives safer, which is greatly appreciated. However, in some situations when our safety is no longer guaranteed it is time for the big heroes to step forward. They are human beings with all the fears and chills, with a lot of courage and skills to overcome them. We are talking about those who risk their lives for ours... the fire-fighters!

Every story will have, most of the time, a happy ending, but what about those who had difficulties, at a field without any help? It can be because it was dark, because the smoke would not let him to get any field of vision, because this fireman had a collapsed structure on his back or leg, so he just passed out and couldn't scream for help. Or just because he was saving someone...and couldn't reach for any help...

Not every country, or city has a squad of fire-fighters with resources or even a financial situation to gather the latest novelties on life-saving devices, which can ensure their security, or at least, reduce the risk of dangerous situations like in fire control, search and rescue operations, or even a loss of communication on field due to panic or crisis situations.

Here in Portugal, our country, the fire-fighters are faced with very short budgets, therefore they need have to find creative ways to come around such limitations, and still manage to do their job safely. One element of our group spends a part of his time as a volunteer fireman, which participates in the control of fires and also in rescue and salvage operations. After an investigation that we made with the Professional Fire Department of Setúbal, we realized during search and rescue operations that in conditions with poor lighting and communication, the squad uses a hanging lantern in the backpack or jacket, as signalization, in order to maintain the proper formation. However, the use of these instruments are not suitable for this purpose, as they cause glare for the remaining group elements or affect the visibility of the site and others issues.

System Overview

The system here presented is comprised of two modules: one or more mobile signaller (MS) units and one base station (BS).

The mobile signaller unit is the module that equips all fire-fighters, used to indicate their condition; and the base station is the module that receives information about the fire-fighters and is at the centre of operations, as illustrated in figure 2.

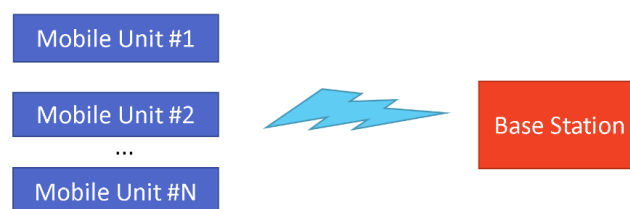


Figure 2 - System overview

In terms of requirements gathered from the end-users, the system has to support the following features: at least 8 working hours, placed inside a sealed container to protect from harsh environments, easy to operate, reliable and low-cost.

Mobile Signaller

This module provides the ability to the user to transmit the necessary information in 3 status, just by pressing a push-button will advance to current mode:

SAFE: The micro-controller (MCU) will send data to the board LEDs and the RF module. LEDs will blink in longer intervals which informs the other fire-fighters that this user is not on a mission or a danger situation. Also and very important this information will also be sent through RF to the BS and the message displayed in the LCD alerting the central.

SEARCH: The MCU activates the board LEDs and sends data to the RF module. LEDs will blink in shorter intervals which informs the other fire-fighters that this user is on a mission/tracking situation. Also and very important this information will also be sent through RF to the BS and the message displayed in the LCD alerting the central.

EMERGENCY: The MCU activates the board LEDs and sends data to the RF module. LEDs will blink alternatively fast which informs the other fire-fighters that this user is on a danger/SOS situation. Also and very important this information will also be sent through RF to the BS and the message displayed in the LCD alerting the central.

The MCU is programmed so that it consumes the least power possible.

The MS is assembled with a MSP430FR5969 connected to a RF module from Anaren Integrated Radio (AIR) A110LR09A, present on the 430BOOST-CC110L BoosterPack, a battery, and a wireless power supply unit to charge this circuit.

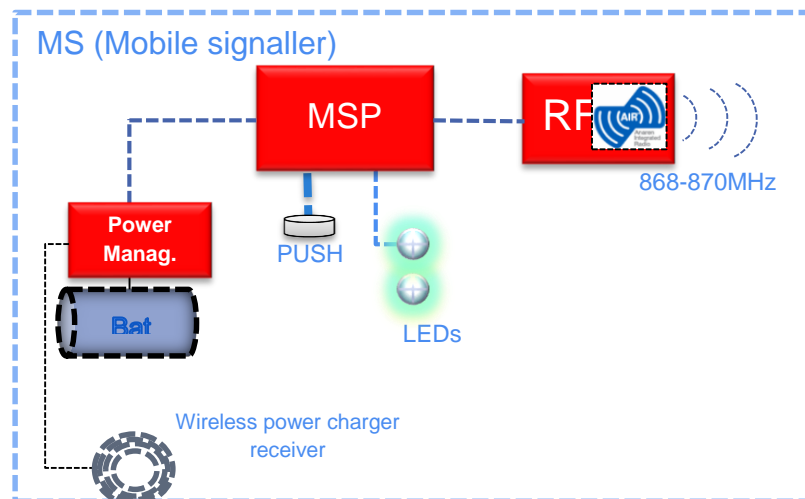
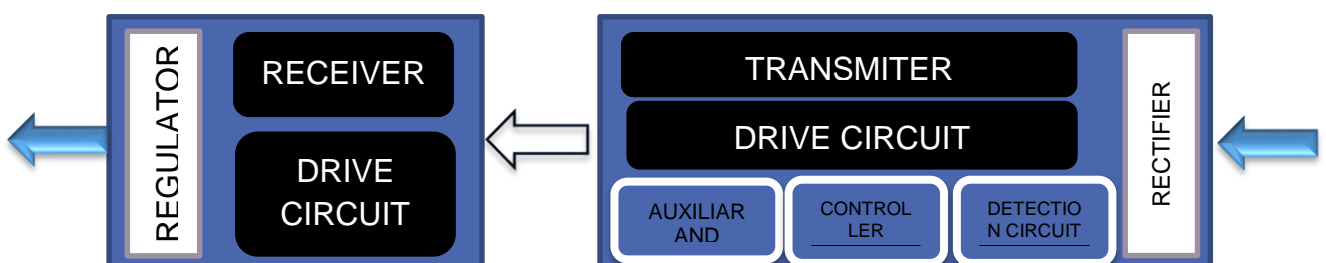


Figure 3 - Mobile Signaller architecture.

Wireless Charger

The wireless charger is used to charge the MS as it is the only way to charge the circuit without having to have exposed contacts or any openings on the module.



Base Station

This module receives the information sent by the multiple MS on field and displays the messages on an LCD screen. The LCD has a couple of buttons that provides interaction with the user to read the next message or go back to the previous and check the status of the required.

The BS was assembled with a MSP430FR5739 TI board attached to a 430BOOST-CC110L RF module and a micro USB cable to provide the 5V to run the circuit. Here, the DC/DC converter TPS54231 is important to offer a wide range of input voltages to allow power to be supplied from different sources, such as batteries.

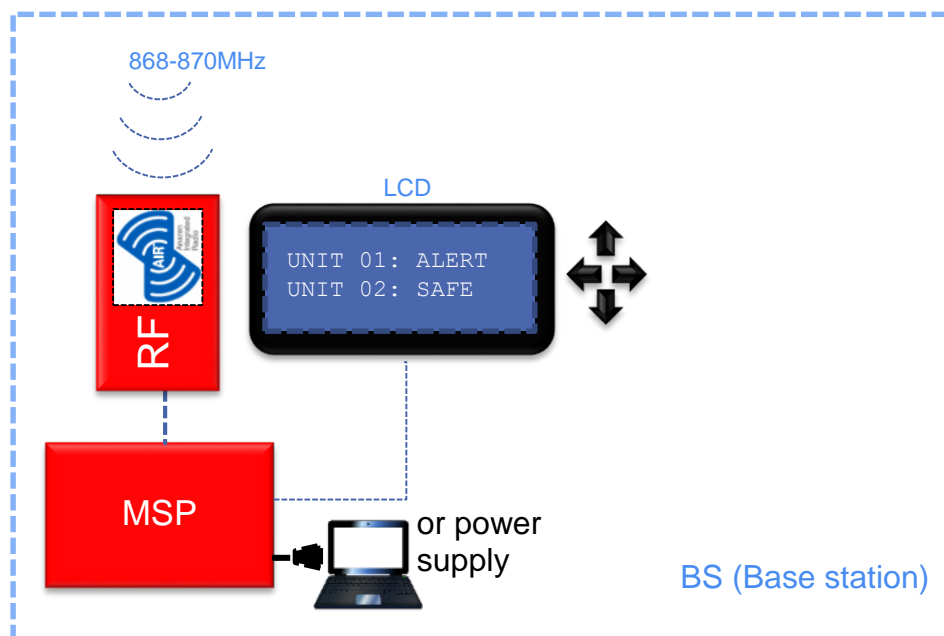


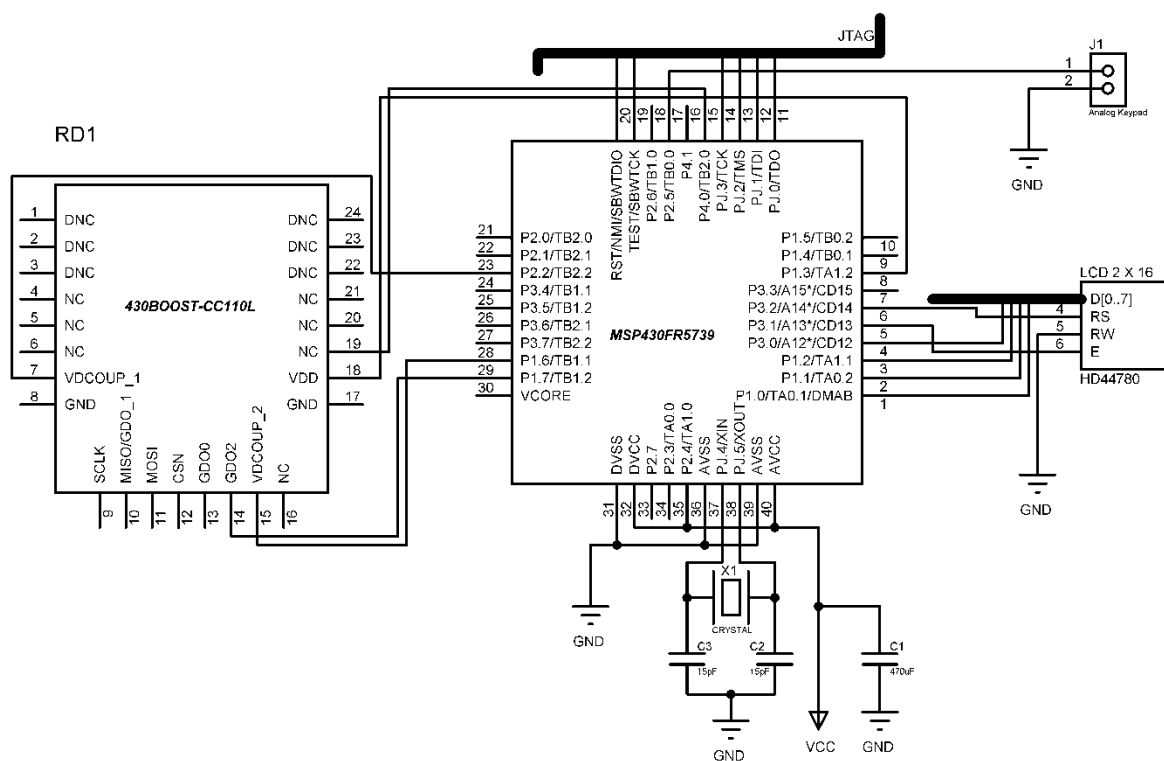
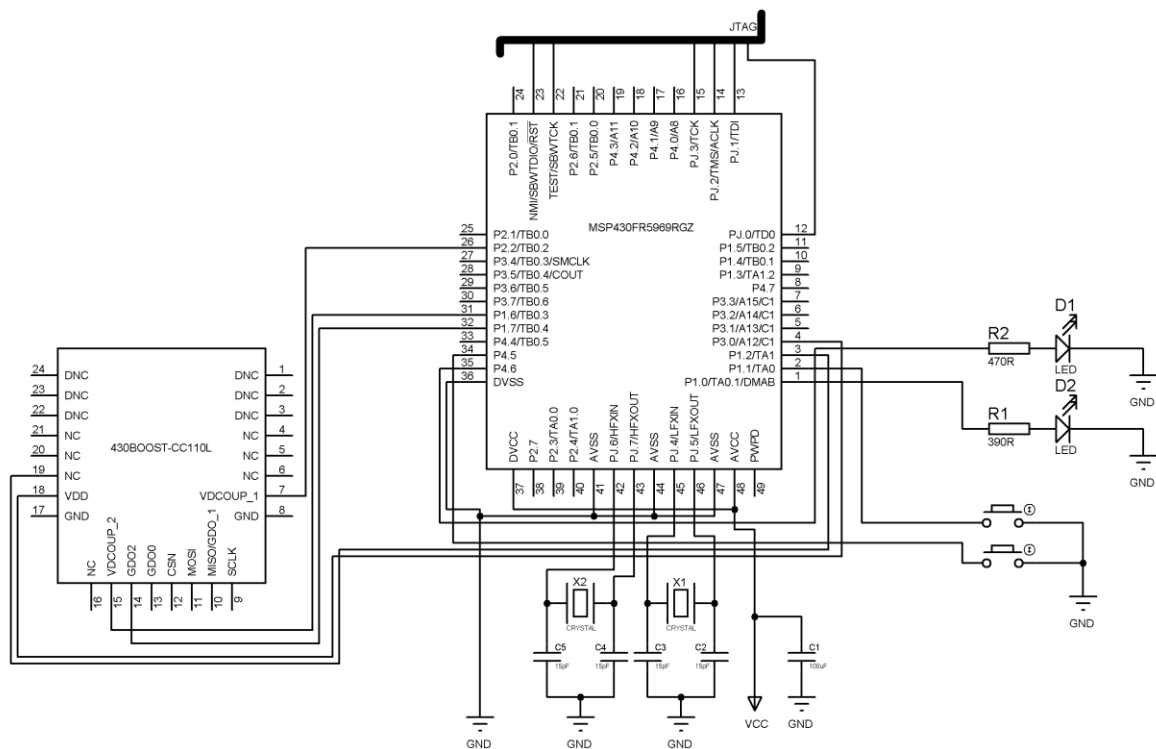
Figure 4 - Base Station architecture.

Implementation

This project was thought to exploit the main features of the Ferroelectric RAM (FRAM) MCUs, such as ultra-low-power, low-voltage, embedded peripherals and small footprint. Hence, two MSP MCUs, MSP430FR5739 and MSP430FR5969, were used to extend battery life and to allow future implementation of any additional functionalities. The use of Texas Instruments technology guarantees to our project an excellent performance to support multiple MS on the field and minimize power consumption thanks to the sleep mode, and the use of other specific coding techniques (as described in [slaa294a](#)).

Controllers

Figure 5 shows the schematic of the Mobile Signaller module using the microcontroller MSP430FR5739. Figure 6 shows the schematic of the Base Station module using the microcontroller MSP430FR5739.



RF Communication

The two RF modules 430BOOST-CC110L provides the standard European 868-870MHz frequencies to support the communications from the mobile signallers (transmitters) to the base station (receiver). At the moment they are operating in simplex mode using a proprietary protocol described next.

Main Features:

- 1.8 to 3.6 V operation
- Low power consumption
- SPI interface between RF module and MSP430
- Ability to change radio settings locally and/or remotely

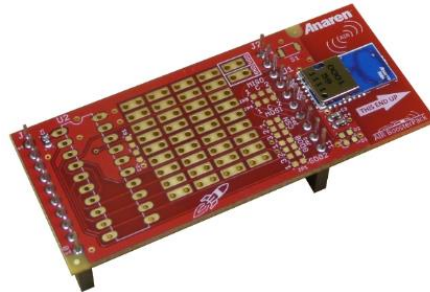


Figure 7 - Photo of the RF transceiver AIR module.

LCD

The LCD is used to display human-readable information about the status of the members of the rescue team.

The information on the LCD display is organized as follows:

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>UNIT 01: SAFE
UNIT 02: HELP*
UNIT 03: SRCH
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The character > represents the currently selected message. The character * indicates anew message. Each unit is identified with a unique number, and each one can be in one of the 3 possible states.

LEDs

The LEDs are used to indicate the state of the user to the rest of the team and control centre. For this reason they need to be very bright. In our development stage we have used the built-in LEDs on the development board. For the final implementation we're planning to introduce OSRAM's Golden Dragon LEDs, and their respective driver. Contrary to conventional (low-power) LEDs, these ones are pulsed with high current for a short period of time.



Figure 8 - Photo of a Golder Dragon LED from OSRAM, off (left) and on (right).

Wireless Power Supply

The need to use a wireless power supply is driven by the necessity to have the module on a fully sealed container. To understand and experiment the features and capabilities of this sub-system we have tried an off-the-shelf system.

Specifications:

- Input Voltage: DC 5~12V;
- Output Voltage: DC 5V;
- Output Current (max): 600mA;
- Transmitter Coil Inductance: 30uH;
- Transmit-receive distance: 1~20mm;
- Coil Diameter: 38mm; Coil Height: 2mm

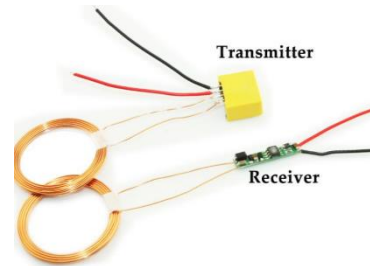


Figure 9 - Photo of the wireless transfer modules

It was our intention to use TI's "Small 5W Wireless Power Transmitter Reference Design", as presented in <http://www.ti.com/tool/TIDA-00623>, but it was outside our budget.

Power Management TPS54231EVM-372

The TPS54231 DC/DC converter is designed to provide up to a 2A output from an input voltage source of 3.5V to 28V. This power management board is used in our BS module equipment to guarantee the best performance and protection of the circuit and respective components.

Specifications:

- Input Voltage: 3.5V to 28V
- Output Voltage 3.3V
- Output current: 2A
- Adjustable Slow-Start limits inrush currents
- Overvoltage transient protection

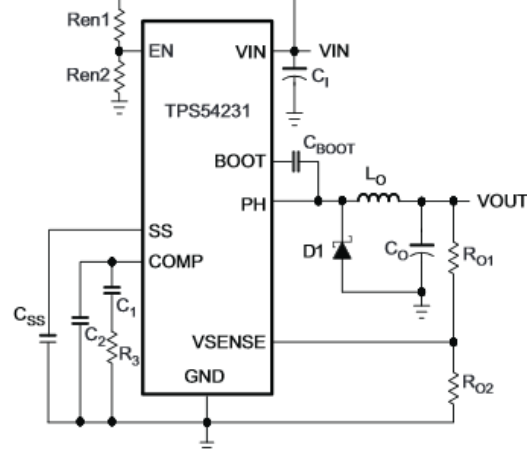


Figure 10 - Circuit schematic for the DC/DC converter (from TI)

Communication Protocol

To establish the communication between the Mobile Stations and the Base Station, a basic protocol was defined. The protocol was thought to be as short as possible to minimize the transmission power per sent packet. Due to its simplicity we have created a fixed-length packets with a start, data and checksum bytes, as exemplified in the figure below. In this protocol, the data information that needs to be passed is the identifier of the Mobile Station (6 MSbits) and its current status (2 LSbits). The checksum byte is given by the sum of the first 2 bytes and is intended to validate the

packet.

In this protocol there's no acknowledgement from the base station, as it operates in simplex mode (one way). Moreover, to account for any possible packet losses the MS resend the packets periodically.

Start byte	Mobile ID + Status	Checksum
0x7E	$(0x00-0x3F) \ll 2 + 0x00-0x03$	0x00-0xFF

Figure 11 - Communication frame.

Experimental results

For the evaluation of the system, and given the resources available, we have produced one prototype for each unit, using TI's development boards, and tested them. In terms of peripherals considered for the demonstration, the LEDs from the development boards were used as they can easily be replaced with any others. Furthermore, the experiments were focused on validating the control logic to demonstrate the proposed circuit design. Even though the power sub-systems are not attached to the development boards, they were experimented independently.

The Mobile Station of programmed to emulate 2 stations, so that the Base Station could receive information for more than one unit.

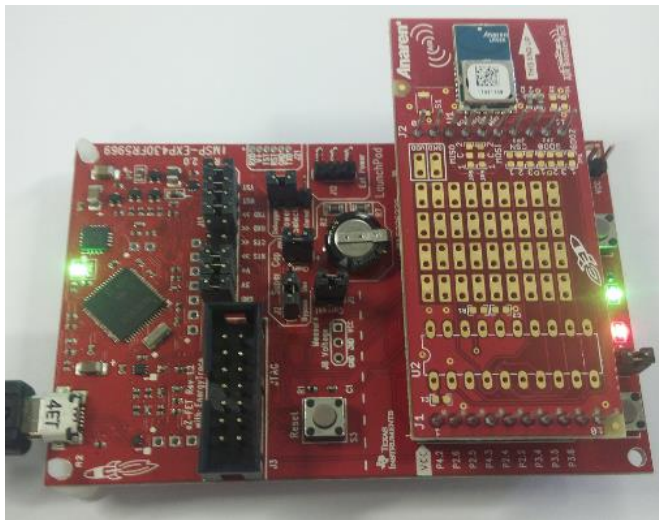


Figure 12 - Photo of the MS.



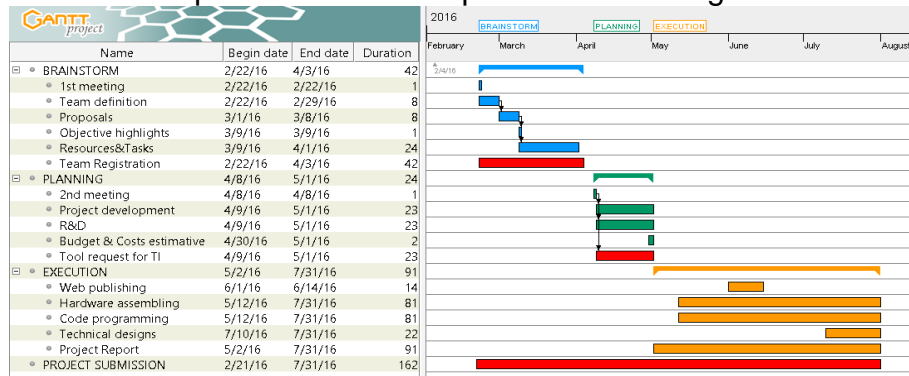
Figure 13 - Photo of the BS.

In terms of power consumption, which is one of our main concerns, in the worst case scenario, where all components are drawing current constantly and no low-power considerations taken into account, the mobile station draws a total of 9mA.

This means that, the autonomy of the Mobile Signaller, when powered by a 1000mAh battery, it is possible to offer an autonomy of approximately 100 hours, which is far beyond the initial requirements. Next steps involve using the [EnergyTrace](#) tool available on the MSP430FR5969 LaunchPad Kit to tweak the source code in order to reduce the power consumption.

Project Execution

The project evolved as planned within the period of the design contest.



Conclusions and Future Work

A novel signalling system to help rescue and search teams has been invented. We started from a set of specifications from the actual users of the system, designed the system and made a prototype to validate our solution.

The first part of the project was straightforward as we've had benefited from TI's broad range of development systems to assist us in the definition of our system, without the necessity to actually produce a custom system. The main difficulty was integrating all the components under one embedded design tool (Energia and Code Composer). Both tools have great features to "speak" with the MSP430, however some compatibility issues between components made them difficult to use, considering our entry level knowledge. However, our motivation was pressing forward and every step conquered was a check point marking our goals and pushing our team to this very end and satisfactory results.

The initial solution thought for this project, had to be changed and optimized for more simplicity but still committed to the idea of producing a system to help society with a simple and economic tool. Our team already made a live test of the system with the squad of the fire department, which can be accessed through the following link: <https://www.youtube.com/watch?v=X-DtaeGQIPU>

Regarding the fact that TI hardware is perfect to guarantee power savings and increase battery life, it may be worth exploring alternative RF solutions in the future, such as LORA, to support long range operation, and a larger LCD at the BS to improve readability. It is also foreseeable to add duplex (bidirectional) communication between the MS and BS to improve the system's capabilities.

Bill of materials (main modules)

Part Number	Price €	Quantity	Total Price €
430BOOST-CC110L RF BoosterPack	donated	1x	19.00
MSP-EXP430FR5969 LaunchPad Evaluation Kit	24.00	1x	24.00
MSP-EXP430FR5739 LaunchPad Evaluation Kit	donated	1x	35.00
TPS54231EVM-372 Evaluation Module	donated	1x	10.00
Wireless Charging Transmitter + Receiver modules	9.27	1x	9.27
LCD 2x16 44780 w/ keypad DFRobot	9.90	1x	9.90
		Total	107,17