Texas Instruments Innovation Challenge: Europe Design Contest 2015 Project Report

SHelmet

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Date:	[31.07.16]

Qty.	**TI Part Number & URL**	**Qty.**	**TI Part Number & URL**
2	MSP432P401RIPZ	3	OPA344NA
1	LPV7215	1	LM2622
1	BQ25570	7	LP5907
1	BQ24093	1	OPT3001
1	BQ25504	2	CC2564MODNEM

Project abstract: The main goal of this project is to design and develop an embedded system to transform a helmet into a smart, multi-sensor connected helmet (SHelmet) to improve motorcycle safety. The core idea of SHelmet is to implement a smart system, which can sense and take actions to improve driving personal safety. Thereby enhancing cooperation between man and machine in an automatic and smart way. Low power design and self-sustainability is key, to avoid continuously recharging the batteries. Hidden in the helmet structure, the designed system is equipped with a dense sensor network including accelerometer, temperature, light, and alcohol gas level, in addition, a Bluetooth low energy module interfaces the device with an on-vehicle IR camera, and eventually the user’s smart phone. To keep the driver focused, the user interface consists of a small non-invasive display combined with a speech recognition system. In addition, the system is designed with low power in mind, by including a low-power architecture that optimizes energy consumption, as well as providing ultra-low power wake-up radio, and software enabled isolating supply lines. Finally, a multi-source energy harvesting module (solar and kinetic) performs high-efficiency power recovery, improving battery management and achieving self-sustainability. SHelmet performs rich context awareness applications; breath alcohol control; real time vehicle data; sleep and fall detection; data display; wireless communication with the vehicle without any need of external power supply; and daily recharging. Two nodes were designed in this project, which have been tested and developed in real helmet and motorbikes to evaluate performance.

1. Introduction

According to European Commission, in 2014 almost 25700 road fatalities were reported in Europe, most of them involved motorcycles. During recent years, road safety work throughout the European Union led to a considerable decreasing trend for road accidents. In fact, considering the 2010-2014 window, the annual number of road deaths decreased by 18%. This means 5700 fewer deaths in 2014 than in 2010. However, there is still room for improvement. Therefore, we analysed the most common sources of road accidents in order to develop a wearable system aimed at reducing risks on the road. In Europe, distraction (27.38%), and speeding (16.34%), combined with driving while intoxicated (14.6%), are the most important. So we want help the driver to reduce these factors and other common sources of dangers. To achieve this result, we selected a specific vehicle (motorcycle) but the device is suitable and adaptable for cars, bikes, and trucks.

A feature-rich Smart Helmet…

Going from everyday applications to competitive automotive scenarios, every component of our SHelmet is designed to avoid fatalities and injuries on the road but also to increase awareness related to the driving experience. Figure 1 shows the most common causes of road accidents and the solutions using sensors or other electronics implemented to reduce risks related to them.

Cause	Solution
Defect in vehicle	ECU data, Infrared camera, Buzzer feedback
Distractions (cellular, inputs to system)	GUI on helmet, speech recognition, bluetooth
Overspeeding	Accelerometer, Buzzer feedback
Driving under alcohol effect	Alcohol Gas Detection, Buzzer feedback
Drowsy driving	Eye Blink Detection, Buzzer feedback
Reduced visibility	Infrared Camera, Display
Lack of roadside assistance	Falls detection, auto-call via Bluetooth

Figure 1 - Causes of accidents and solution in SHelmet

…and self-sustainable too!

Furthermore, the SHelmet is designed as a self-sustainable system which the driver can always rely on without the need for recharging. Due to the solar-kinetic energy harvesting module, the user will be always supported by the SHelmet on the street. To achieve this goal, energy harvesting is supported by aggressive hardware and software low power techniques to reduce the overall system power consumption. These features include a

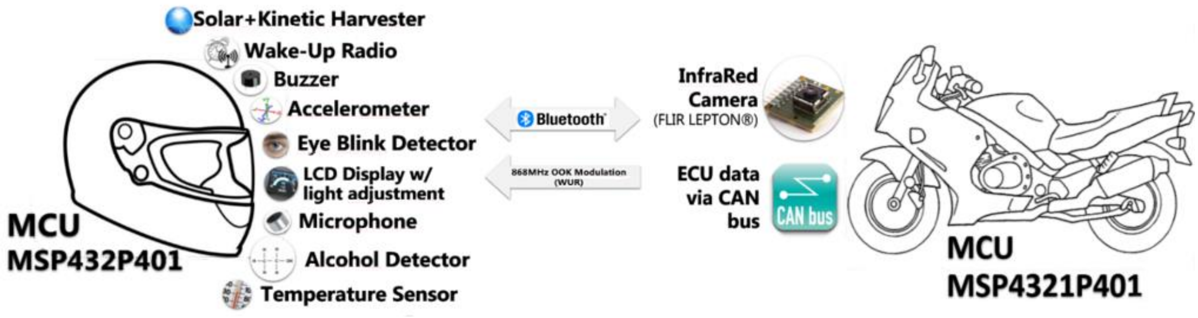

Figure 2 - System overview

dynamic switch on the unused peripherals and wake-up radio technology embedded in the design, to increase the wireless communication energy efficiency. For example, when the helmet leaves the vehicle's area, it is forced into a deep sleep mode waiting for a radio signal from the on-board module.

2. System Architecture

Figure 2 shows the overall architecture of the developed system that consists of two separate modules designed and developed in this project (one for the Bike and one for the Helmet). Figure 3 and 4 present the block diagram of the two modules respectively. The two modules host a microcontroller (MCU) to process sensor data and take actions, and a Bluetooth Low Energy (BTLE) interface allows communication. The microcontroller selected for both the modules is ***MSP432P401RIPZ***. This choice was made because the system needs both the computational performance to process on-board the data, and a low power profile. This MCU is able to manage all the sensors and external peripherals, the 14-bit internal ADC and eight serial ports interface. Moreover, with 57 DMIPS and 4.6 mA of power consumption, the computational resources and low power consumption are available to achieve the goal of self-sustainability. For a preliminary evaluation, the entire system has been set up using TI's evaluation boards. In particular, two ***MSP432P401R LaunchPad™ Development Kits*** were used as the core of the two nodes and a ***BOOSTXL-EDUMKII Educational BoosterPack™*** was used to extend the on-helmet board. Then, custom PCBs were designed for the helmet module shown in Figure 5. The MPS432P401 LaunchPad was equipped with the camera, wake up radio and Bluetooth radio for the bike node (Figure 5 right). As the Bluetooth module, two ***CC2564MODNEM*** were used to interface the two modules and it allows the SHelmet to be connected with the bike node and user's smart phone.

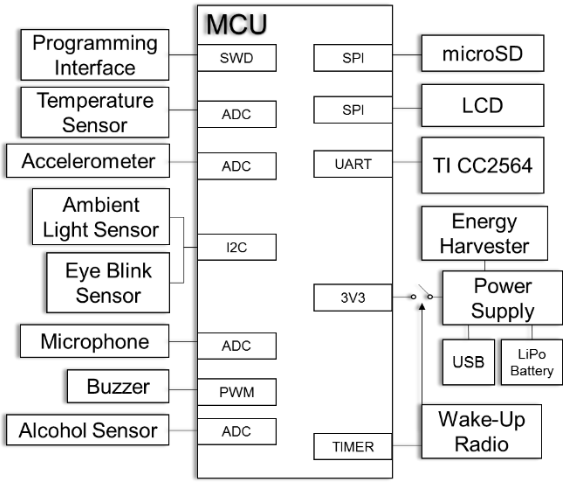

Figure 3 – Helmet block diagram

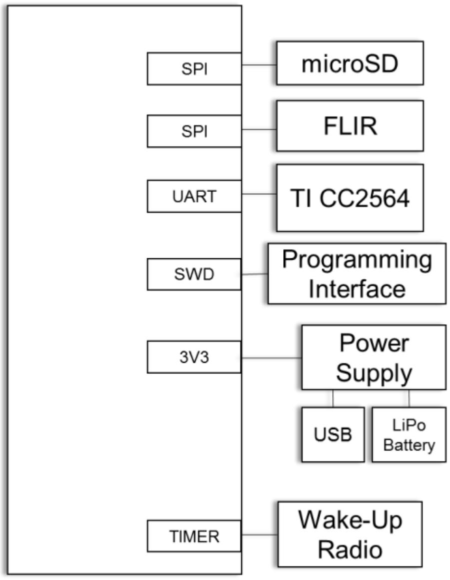

Figure 4 – Bike block diagram

2.1 SHelmet node:

Figure 3 shows the block diagram of the developed node that is mounted on the helmet. This manages the sensor's acquisition and elaboration, as well as the user interface, which is graphic (LCD Display) and audio (buzzer feedback and microphone). As one goal is to have a device that does not need to recharge its batteries continuously, the main node includes a dual source (solar and kinetic) energy harvesting circuit that provides continuous energy to supply the system and recharge the LiPo battery that is used as an energy buffer.

2.1.1 Multi-Sensor Network for on-board processing

Our smart helmet assists the driver in augmenting the probability of undertaking safe behaviour. To achieve this goal, we embedded a series of sensors to detect dangerous situations and a MCU to process the sensor data to alert the driver quickly.

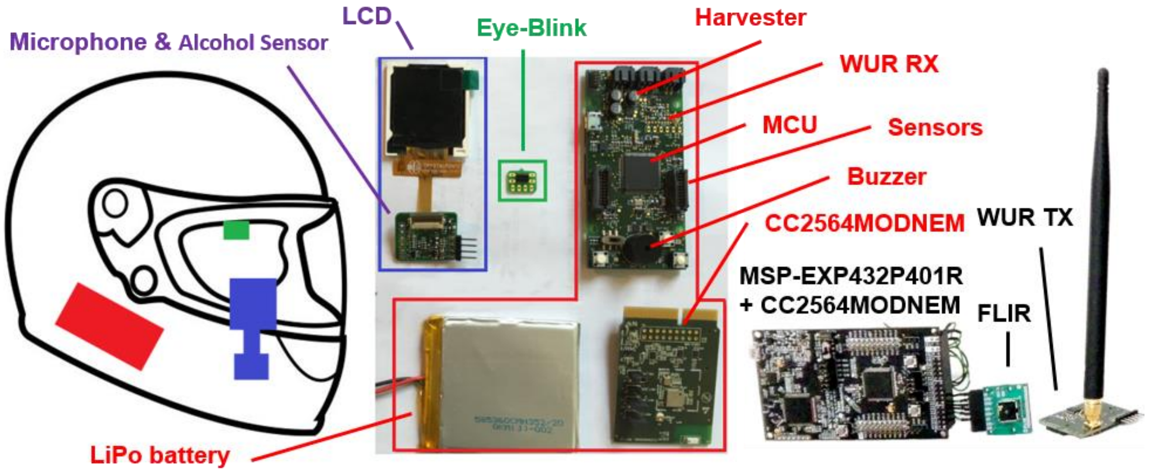

Figure 5 - On-helmet developed modules for the SHelmet (left) and the motorbike module using the TI LaunchPad

The sensors implemented are as follows:

2.1.1.1 Accelerometer

The ***Kionix KXTC9-2050*** is a high-performance, tri-axis accelerometer with analog outputs, a factory-programmable low-pass filter and g-range from ±1.5g to ±6g. The sensor is directly connected with the MSP432 microcontroller through three channels of the Analog Digital Converter. This sensor provides very useful information on motion g-forces as well as fall detection, and the small packaging (3x3x0.9 mm 10-pin LGA) eases the tricky PCB layout needed for the board to fit in the helmet. Furthermore, it has low current consumption (5 µA in standby, 240 µA at full power) which is very important in terms of power management. With regards to safety, this sensor is used to detect unexpected g-acceleration associated to a fall during driving. In this case, the system will wait for a user confirmation and, if that is not received, it will call ICE contacts with the phone connected via Bluetooth.

2.1.1.2 Ambient Light Sensor

The ***OPT3001*** is a digital ambient light sensor (ALS) that measures the intensity of light as visible by the human eye. Its digital output is reported over an I2C interface; in addition, its low power consumption and low power-supply voltage capability enhance the device's self-sustainability. The main function of this sensor is to provide information about light levels in order to modify the system behaviour. For example, the LCD backlight is continuously adjusted by PWM depending on light measurements; thereby, useful power is saved and the user is not disturbed.

2.1.1.3 Temperature Sensor

The ***MCP9700A*** is an analog temperature sensor connected via MSP432 ADC channel. It is a low-cost, low-power sensor with an accuracy of ±2°C from 0°C to +70°C while consuming 6µA (typical) of operating current. This sensor was selected for low-power consumption and the fact that it does not require an additional conditioning circuit.

2.1.1.4 Alcohol Detection System

In order to detect alcohol traces in the driver's breath, SHelmet includes the ***MQ-3 Gas Sensor****.* This device has high sensitivity to alcohol and small sensitivity to benzene, which is not to underestimate in automotive applications. Moreover, it has a very simple drive circuit. Figure 6 shows the *MQ-3* drive circuit: a 5V line supplies both the heating and the sensing resistance of the

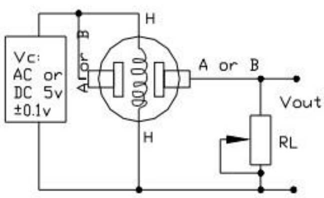

Figure 6 - MQ-3 drive circuit

sensor, the latter changes its value depending on alcohol gas levels in air and determines the voltage drop on a load resistance. In the SHelmet, the MQ-3 is designed to be sampled using the 2.5V MCU ADC internal reference so both a 5V supply line and an output de-amplification circuit were required.

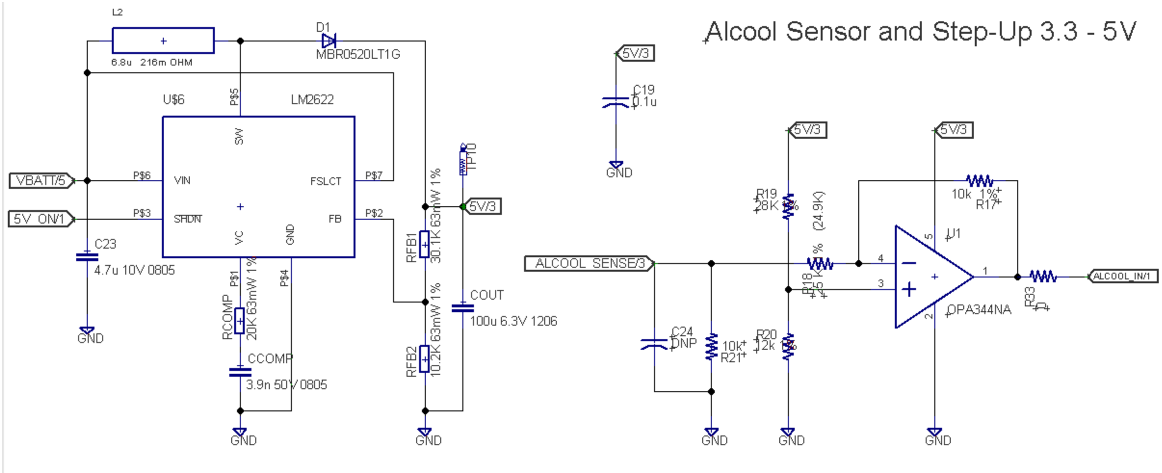

Figure 7 - MQ-3 conditioning circuit schematics

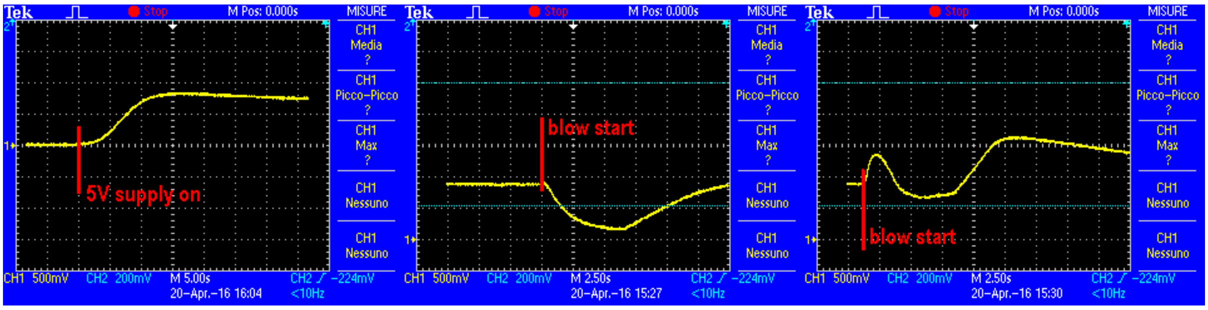

Figure 8 - MQ-3 voltage trends, in order, (a), (b) and (c)

Figure 7 shows the conditioning circuit for the MQ-3, including a ***LM2622 Step-up DC/DC Converter*** which generates the 5V line from the 3.3V and a ***OPA344 Low Power Operational Amplifier*** used to reduce the output voltage swing from 0-5V to 0-2V. OPA344 (same of BOOSTXL-EDUMKII) was selected mainly for its low power consumption, compact package, and very low offset voltage. The MQ-3 acquisitions requires a 20 seconds of pre-heating time, this is necessary for the output to be stable. Then the signal rises or falls depending on alcohol concentration in air. Figure 8 shows voltage trends for pre-heating (a), breath with alcohol (b) and breath with no alcohol (c). The voltage drop in (b) e (c) scenarios is due to the fact that the more you blow the more the heating resistance cools, causing its resistivity to rise. When the MCU detects a dangerous situation, an alert is sent to the motorbike module that prevents ignition of the motorbike.

2.1.1.5 Eye-Blink Detection

This feature has been included to avoid drowsy driving, by sending an alert to the driver when the eye is closed for too long. To enable the SHelmet with this capability, we used the **VL6180X Proximity Sensor**. This component is based on patented FlightSense™ technology allowing absolute distance to be measured independent of target reflectance. Moreover, combining an IR emitter, a range sensor and an ambient light sensor in a three-in-one ready-to-use reflowable package, the VL6180X is easy to use as a one dimension gesture detector. This is a digital sensor connected through I2C directly to the MSP432. The pupil and the eyelid have different reflectance. Combining the ambient light sensor with a threshold in distance (time domain) and in amplitude (signal and noise), an algorithm that detects eye swipes is easily implemented. Figure 9 describes an eye pulse that can be processed to extract information about gesture detection (input commands to system) and driver alertness.

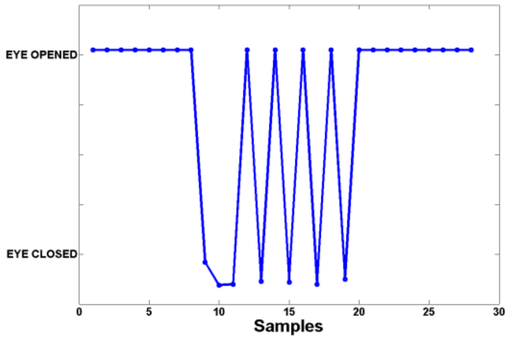

Figure 9 – Eye blink sampling

2.1.2 User Interface

SHelmet is also a hands-free device, as the driver needs to focus on the street. To target this goal, the user interface consists of the following input/output subsystems:

2.1.2.1 System Output : both visual and acoustic output are included to interact with the driver. The ***Crystalfontz CFAF128128B-0145T*** is a display that features the *EDUMKII Booster Pack* and it is a colour 1.44” 128x128-pixel TFT LCD with a colour depth of 262K colours and a contrast ratio of 350. The choice to keep this component as part of the project is the result of a trade-off between performance and power management as well as dimension with respect to the overall system. The low efficiency framerate of 20 FPS is balanced by its low power consumption of 6.6mW @ 3.3V (no backlight) but that is not a big deal since thermal images are only available 10 times per second. To generate acoustic alerts the ***CUI CEM-1203(42),*** a 2 KHz piezo buzzer, is selected. Figure 10 shows a standard SHelmet screen: the main toolbar gives information about battery, Bluetooth, Wake Up-Radio antenna signal and Push-To-Talk recording; while on the rest of the screen are drawn peripherals measurements.

Figure 10 – LCD screen during the tests

2.1.2.2 System input: SHelmet is capable of taking voice commands. A ***CUI CMA-4544PF-W*** is used as that implements an OPA344 operational amplifier to boost the output of the microphone with an operating range from 20 Hz to 20 KHz and -44 dB of sensitivity. After the OPA344 the signal goes to the MSP432 trough the ADC. The main function of this component is to allow efficient speech recognition strategy. Many samples of different command phrase models are stored in the microSD card to be recognised by SHelmet. Using a push-to-talk system via user button, the driver speaks his command, which is compared to the sampled ones. The command with the highest number of matches is then picked and a scheduler consequently updates the system.

2.1.3 Energy Harvesting Subsystem

This subsystem has been designed to make the main node self-sustainable and fully embedded in a motorcycle helmet. The energy harvesting circuit includes both a solar (or as further option thermal) and a kinetic path to exploit the combination for the two energy harvesting sources. Both are used to recharge a single LiPo battery that supplies the node as presented in Figure 11. The adopted storage element is a 2000mAh – 3.7V lithium-polymer (LiPo) re-chargeable battery. For supporting the energy harvesters to recharge this battery, a highly integrated Li-ion and Li-Pol linear charger device targeted at space-limited portable applications was included. The devices operate from either a USB port or AC adapter. This component is the ***BQ24093***.

2.1.3.1 Solar Energy: the solar energy harvesting is designed around a ***BQ25570*** ultra-low power IC. For high efficient energy harvesting, the BQ25570 features maximum power point tracking (MPPT) capabilities. Moreover, it integrates an ultra-low power buck converter with programmable output voltage. The BQ25570 consumes less than 500nA in active mode. The power source of our system is on the top of the helmet, which embeds four solar cells with a 40 cm^2 area. The developed system provides a maximum power of 2mW under low room light conditions (250lx) and 45mW under sunlight (50000lx) (Figure 12).

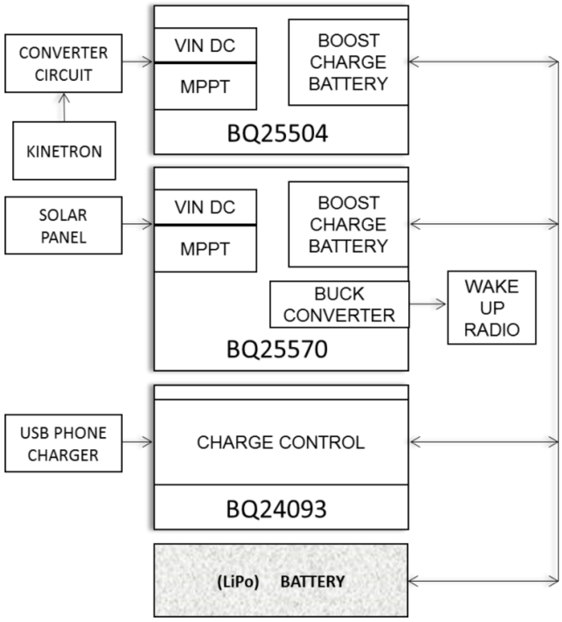

Figure 11 – Battery management architecture

2.1.3.2 Kinetic Energy: The kinetic harvester generator used is the Micro Generator System 26.4 (MGS26.4) produced by Kinetron (Figure 13); it is an electromagnetic generator with a 26.4mm thickness and a 4.3mm diameter. The kinetic energy harvesting has at its core the ***BQ25504***. It contains a Boost Converter with an ultra-low quiescent current of 330nA. However, the Kinetron generates an alternating waveform (AC), which is not directly accessible from the BQ25504, then a rectifier is needed. Figure 14 shows the ac-dc doubler voltage converter (D3-D4-C43-C42) circuit we needed to insert before the BQ25504. The total efficiency of the whole circuit (AC-DC+BQ25504) has been measured to be 64%.

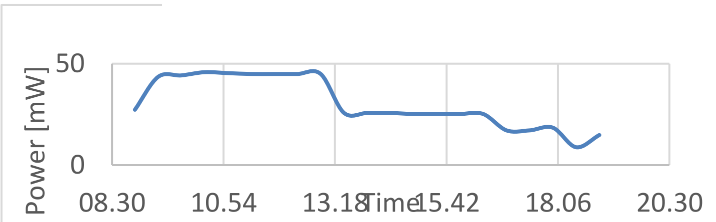

Figure 12 - Application scenario during a day

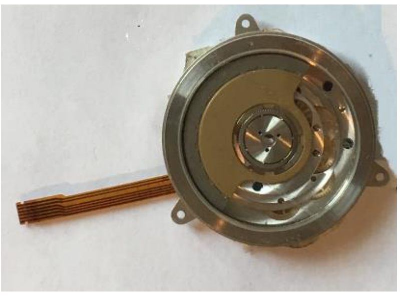

Figure 13 - Kinetron

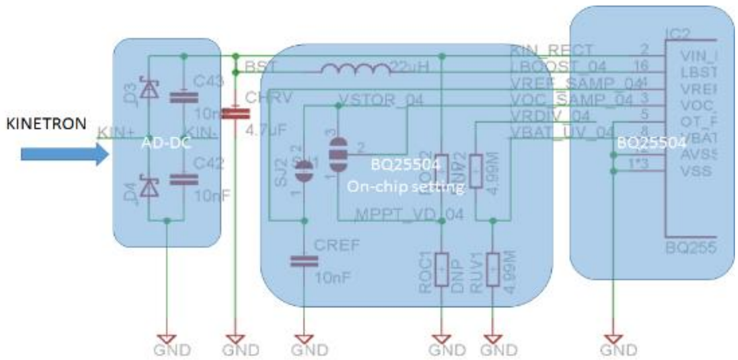

Figure 14 - Kinetic AC-DC converter connected with the BQ25504

We also tested the energy harvesting circuit in realistic condition when the driver is wearing the helmet and the energy acquired is reported in the following table.

Kinetron	Stored Energy [µJ]	Acquisition Time [s]	Average Power [µW]
OnBoard	16500	100	165
Walking	2400	100	24

2.1.4 Wake-Up Radio

This section presents the design of a nano-Watt wake-up radio receiver (WUR) that uses only a comparator as active component. In order to reach the best usability of the SHelmet, WUR was added to automatically switch on/off power for all electronics, keeping an ultra-low power receiver always powered to minimise the latency time. We use a low power OOK transmitter placed inside the motorbike to wake up the helmet when it is nearby. When a driver switches off the motor, the transmitter stops to send the "KEEP ON" message and the SHelmet switch to deep sleep mode after few seconds.

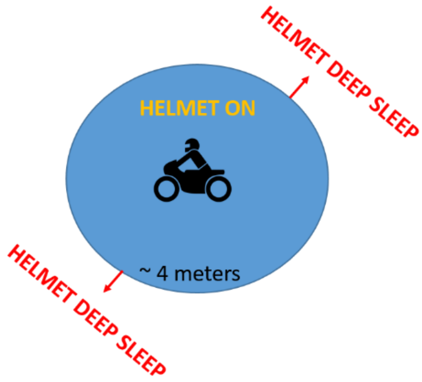

Figure 15 - Wake Up Radio Operation

The characteristics of this receiver are: ultra-low power (around 1 μW), high sensitivity -55 dBm, reactivity (less than 200 μs), performs addressing and receive wireless commands.

The starting point for the design of the receiver is the demodulator (Figure 16). Avago Technologies provides the optimal diodes in terms of sensitivity and radio frequency optimization: HSMS-2852 and HSMS-2852. The comparator for the data detector is the ***LPV7215*** that combines an ultra-low quiescent current (700nA) with only 250uV input voltage offset. The voltage offset affects the sensitivity of the wake-up radio receiver directly, as the lower voltage offset the lower input voltage can be detected. The circuit (Figure 16) uses an adaptive threshold mechanism (R22-C26-R32) that keeps the inverted input of the comparator at half of the input signal level. With this approach, the power consumption of the circuit is reduced, as, instead of a voltage divider, the signal from the antenna is used for generating the threshold. Following the comparator, there is the preamble detector, which generates the interrupt and the digital data. The entire system uses only 880 nA @3,3V with a typical sensitivity of -55 dBm.

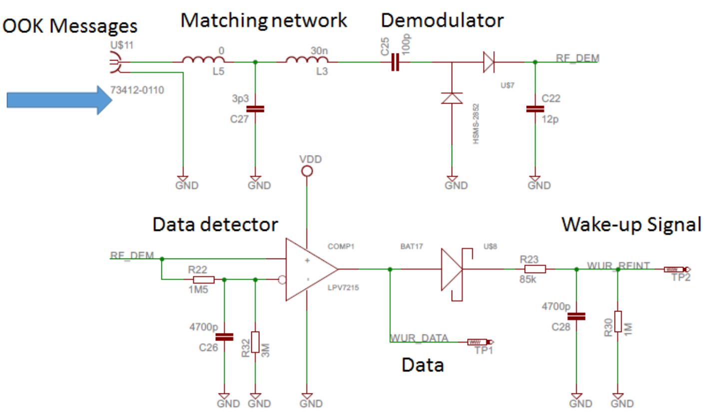

Figure 16 - Wake Up Radio system

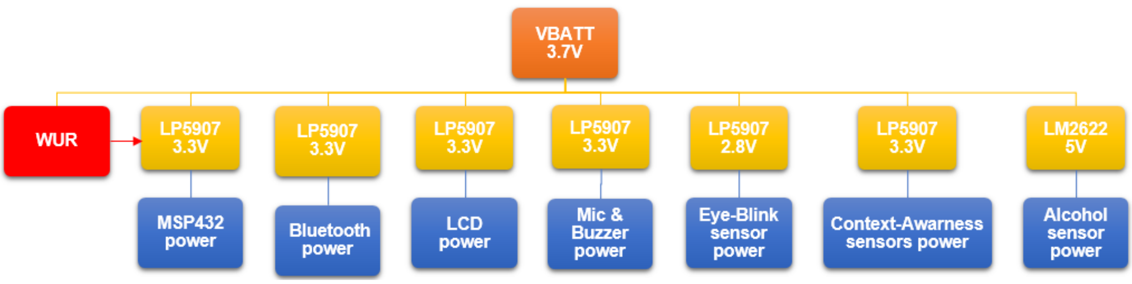

Figure 17 – Power Management

2.1.5 Low power and flexible architecture

In addition to low power operation, sleep modes provided by the MCU, and wake up radio, power consumption in the SHelmet is also optimised at architecture level. In fact, as shown in Figure 17, the board mounted on helmet is divided into different sub-systems, each with its own independent supply line. To make it possible, ultra-low power LDOs were needed, so between board's and sub-system's supply line five ***LP5907 Ultra-Low-Noise LDO*** were connected in addition to one ***LM2622 Step-up DC/DC Converter***. The reason why *LP5907* was selected is its very low quiescent current (200nA) when disabled and a low dropout voltage that permits low battery voltages. On the other hand, a 5V supply line was needed for the MQ3 Alcohol Gas Sensor which was achieved using the LM2622, selected for its compactness, with only 10 components and 90 mm^2 Total Footprint Area. However, the main feature was its ability to convert 3.3V to 5V with an 84% of efficiency and a high switching frequency for easy filtering and low noise. This way, the sub-system's supply lines are software selectable so that energy consumption is deeply reduced enabling the different sub-systems only when they are needed.

2.2 Motorbike Node

In contrast with the SHelmet that is worn by the user, the motorbike node (Figure 4) is on-vehicle mounted and its main function is the infrared camera acquisition. This solution was selected to reduce the computational power on the helmet processor and the energy consumption of the camera on the smart helmet. Then, the bike node can be supplied directly by vehicle's battery and send alarms to the user in case of mechanical defections the infrared camera on the bike node is able to detect via hot spots analysis and it is possible to process ECU (Engine Control Unit) data running on the CAN bus too.

2.2.1 Infrared Camera

The Infrared Camera is one of the most interesting features of our system. The device used is the ***FLIR Lepton®*** a complete long-wave infrared (LWIR) camera module designed to interface easily into native mobile-device interfaces. Mounted on the vehicle and interfaced with the MSP432, it captures infrared radiation input in its nominal response wavelength band (from 8 to 14 microns) and outputs a uniform thermal image. Its small size (8.5 x 11.7 x 5.6 mm) makes the camera versatile (8.5 x 11.7 x 5.6 mm) so it can be located in every section of the vehicle. Looking at the entire SHelmet system, the on-board microcontroller acquires thermal images from the camera using the SPI interface, then they are sent via Bluetooth (4800 bytes per image, 10 frames per second) to the main module where they are drawn on the LCD Display at 20 fps with a 80x60 resolution. This thermal vision can improve the safety in a low visibility environment so that this system can be a lifesaver not only for the driver but also to pedestrians. Figure 18, shows thermal images taken from the developed node and the benefit in terms of safety. In fact, an almost invisible object at night is easily detected from the camera, so the driver can promptly react to the situation. Furthermore, thermal imaging has another interesting application: aiming the camera at the engine, mechanical defects can be found detecting hot spots. Thereby, the system can instantly alert the driver preventing unexpected and unsafe scenarios.

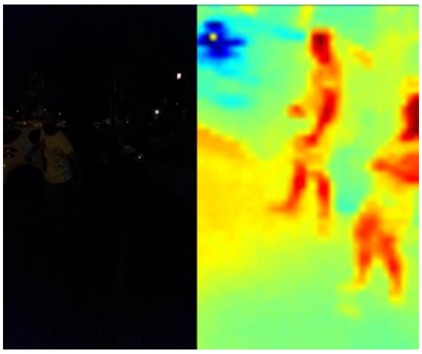

Figure 18 - Thermal images at night

3. In-field experimental Results

All of the functions presented above have been tested, in particular: data acquisition from sensors, input/output interface, processing the data and testing the communication, and wake up radio. Experimental measurements have also been conducted to evaluate the self-sustainability of the SHelmet under realistic circumstances. Figure 19 shows current consumption in the most used configurations of the device. When the system is in sleep

I_{sleep} @3.3V [µA]				
BQ24093	BQ25504	BQ25570	WUR	5 * LP5907
1	0,33	0,49	0,88	1
TOT		3,70		
$I_{MCU+MULTI-SENSOR+LCD+LED+BUZZER}$ @3.3V [mA]				
		17		
$I_{MCU+MULTI-SENSOR+LCD+LED+BUZZER+BLUETOOTH}$ @3.3V [mA]				
		58,2		
$I_{MCU+MULTI-SENSOR+LCD+ALCOHOL}$ @3.3V [mA]				
		270		

Figure 19 - Current consumption in SHelmet

mode with the harvester on and waiting for wake-up signal, the power consumption is ultra-low (3,7µA). The second configuration is the standard one and only draws 17 mA current, with the context recognition sensors powered and analysed, ensuring a fully operational user interface. This configuration allows self-sustainability when energy is harvested. The other two scenarios are referred to tasks performed only in particular situations. In fact, the Bluetooth module is on when the system requires infrared camera thermal images and that only happens in low light environments. Alternatively,

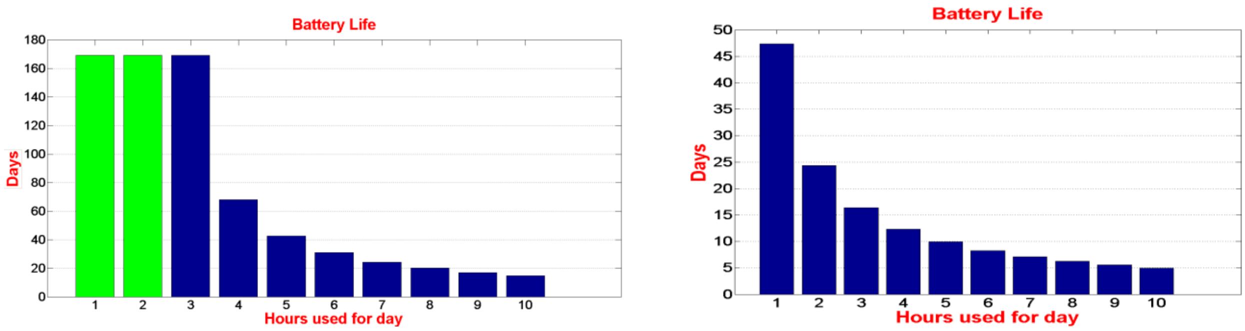

Figure 20 - Battery life during day light (left) and night

alcohol sensor acquisition is required a couple of times a day at most. Based on these results, predictions were made on battery life. That is explained by the bar graphs shown in Figure 20. In particular, the first is referred to an under-daylight application scenario supposing the infrared camera working for a third of the time the device is used and an alcohol acquisition per day. Green bars go to infinite on the "days" axis in scenarios where the SHelmet is self-sustaining. The last graph (Figure 20 right) is based on battery life predictions during night time. As you would expect, with no solar energy source and Bluetooth module always on (receiving thermal images), battery life evidently drops and self-sustainability is lost, despite this, the duration is still high with respect to commercial wearable devices.

4.Conclusion and Future Plans

We presented SHelmet that results as a life-saving, self-sustainable, smart helmet, which the user can always rely on during the driving experience. Context-aware sensors, in addiction to infrared camera, eye-blink detection, alcohol detection, on-board processing, and non-invasive user interface empower the driver to avoid dangerous situations. The wearable device has dual-source energy harvesting to guarantee self-sustainability. Wireless communication trough Bluetooth Low Energy enables communication between vehicle and user guarantying fast alerts and flexibility of the solution. Starting from TI's demo-boards allowed fast development of a platform to test several subsystems (sensors, power converter, display, and camera) both of the bike and helmet prototypes were developed to test in-field the performance. The whole system is at a mature level and ready to be shown as a demonstration. Further improvements can be done such as: the use of a transparent display instead of the LCD one, adding sensors, block of motors and so on.

5. Bill of Materials

Component List					
Manufacturer	**Part number**	**Qty**	**Manufacturer**	**Part number**	**Qty**
Helmet			Diodes Inc.	MMBT2222A	1
TI	**LPV7215MF**	**1**	Fairchild	S2B-PH-SM4-TB	3
TI	**BQ25570RGRR**	**1**	Vishay	Res. 4.99 MΩ	2
TI	**BQ25504RGTT**	**1**	Vishay	Res. 6.34 MΩ	1
TI	**MSP432P401RIPZ**	**1**	Vishay	Res. 3.83 MΩ	1
TI	**LP5907MFX-3.3**	**6**	Panasonic	Res. 1 KΩ	4
TI	**LP5907MFX-2.8**	**1**	Panasonic	Res. 10 KΩ	2
TI	**BQ24093DGQT**	**1**	Panasonic	Res. 100 KΩ	8
TI	**LM2622MMX**	**1**	Panasonic	Res. 6.8 Ω	1
TI	**OPA344NA/250**	**3**	Panasonic	Res. 47 KΩ	1
TI	**CC2564MODNEM**	**1**	Panasonic	Res. 91 KΩ	1
TI	**OPT3001DNP**	**1**	Vishay	Res. 4.32 MΩ	1
Avago	HSMS-2852	1	Vishay	Res. 5.23 MΩ	1
Kionix	KXTC9-2050	1	Vishay	Res. 5.49 MΩ	1
Molex	Antenna 868 MHz	1	Vishay	Res. 7.87 MΩ	2
Battery-2000mAh	PRT-08483	1	Panasonic	Res. 715 KΩ	1
CUI	CEM-1203(42)	1	Vishay	Res. 15 MΩ	1
Murata	Cap. 10 nF	4	Panasonic	Res. 1 MΩ	1
Murata	Cap. 4700 pF	2	Panasonic	Res. 16 Ω	1
TDK	Cap. 100 nF	29	Panasonic	Res. 110 Ω	1
Murata	Cap. 3.9 nF	1	Panasonic	Res. 33 Ω	3
AVX	Cap. 22 pF	2	Panasonic	Res. 24.9 KΩ	1
Murata	Cap. 12 pF	2	Panasonic	Res. 85 KΩ	1
Murata	Cap. 100 pF	2	Vishay	Res. 1.5 MΩ	1
Murata	Cap. 3.3 pF	1	Panasonic	Res. 2.2 KΩ	1
Vishay	Cap. 4.7 uF	10	Molex	73412-0110	1
Murata	Cap. 1 uF	1	NXP	BAT17	1
TDK	Cap. 10 uF	6	C&K	JS202011SCQN	1
Harwin	M50-4901045	2	Panasonic	Switch Tactile NO	3
Harwin	M50-3500542	1	Microchip	MCP9700A	1
Hirose	FH12-20S-0.5SH(55)	3	Microchip	PIC12LF1552	1
FCI	SFV10R-2STE1HLF	1	**Bike**		
TXC	AM-48.000MAGE-T	1	**MSP-EXP432P401R**		**1**
ON Semi.	MBR0520LT1G	1	**EM Adapter BoosterPack**		**1**
Fairchild	1N4148WS	1	**CC2564MODNEM**		**1**
ON Semi.	RB751V40T1G	2	Molex	Antenna 868 MHz	1
Murata	BLM18AG601SN1D	1	Murata	Cap. 1 nF	1
Hanwei	MQ-3	1	Murata	Cap. 1 pF	1
ST	VL6180XV0NR	1	Murata	Cap. 2.7 pF	1
Murata	Inductor 30 nH	1	Murata	Cap. 1 uF	1
Murata	Inductor 4.7 uH	1	Murata	Cap. 100 nF	1
TDK	Inductor 10 uH	1	Epson	FA-20H	1
TDK	Inductor 22 uH	1	Murata	BLM18AG601SN1D	1
TDK	Inductor 6.8 uH	1	Murata	26 nH	1
Everlight	R6GHBHC	1	Murata	12 nH	1
Molex	104031-0811	1	Panasonic	Res. 10 KΩ	1
Hirose	ZX62R-B-5P	1	TE Conn.	5-1814832-1	1
CUI	CMA-4544PF-W	1	FLIR	FLIR lepton	1
Fairchild	FDN302P	1	Microchip	PIC16LF1824T39A	1