

Wireless Acceleration and Impact Recording Chips

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ABSTRACT

This paper presents an overview of a new class of wireless acceleration sensor chips being developed by Evigia Systems and Air Force Research Laboratory (AFRL) that can record the magnitude and duration of exposure to external impact without requiring any battery or any other external power source. The combination of the magnitude and duration of the acceleration event provides the information needed for quantification of the impact energy after extracting the recorded data from the sensor array. The light-weight, small form-factor, and wireless link features of these chips enables them to be readily inserted in earplugs, helmets, protective gear, on sections of vehicles. Further, their low cost, make them well suited for the Go-Kart, Sprint Car, Rally and Motocross races where the budgets are lower than IRL or NASCAR.

INTRODUCTION

An increasingly important issue in protection of civilians in sports activities and accidents, firefighters on duty, and military forces in combat is to quantify injury causation resulting from impacts to the body and weapons effects and to design appropriate protection gear and strategies. What is not always known is the relationship between the local insult and the resulting injury. This is especially true of traumatic brain injury caused by physical impacts and blast waves from Improvised Explosive Devices (IEDs). In order to design effective protection systems knowledge of this cause and effect relationship is critical [5]. The first steps in this direction have been taken by instrumenting race car drivers in the Indy Racing League and Champ cars with earplugs containing miniature accelerometers [1-4]. More than sixty crashes have been documented thus far showing how the drivers' heads accelerate during the impacts while the resulting injury is documented by the medical staff. Boxers at the Air Force Academy have also been instrumented with earplugs containing accelerometers. Recently a select number of the combat troops in Middle East have been instrumented

with helmet mounted acceleration recorders by US Army. All these systems require batteries with limited life, have a noticeable weight and form-factor that affects the instrumented person, and would require wiring for data transfer.

The objective of the initiative by the AFRL has been to fund development of a new class of wireless sensors that are very small, operate without requiring any batteries, and can be embedded in all military and civilian protective gear without encumbrance during all operations. With the new sensors very comprehensive prospective epidemiological studies could be carried out in all military and police operations and in helmeted sports where the recorded insult could be correlated with the resulting injury documented by medical staff. The resulting data could then be used to optimize protection through changes in protective equipment and tactics. The ultimate goal is to be able to identify impact exposures that can result in potential TBI.

This paper introduces the wireless acceleration chips being developed by Evigia Systems and AFRL that meets these requirements. The light-weight, small form-factor, and wireless link features of these chips enables them to be readily inserted in earplugs, helmets, protective gear, on sections of vehicles. Further, their low cost, make them well suited for the Go-Kart, Sprint Car, Rally and Motocross races where the budgets are lower than IRL or NASCAR.

ACCELERATION CHIP

The acceleration sensor array chip performs acceleration measurement in 6 degree of freedom (DOF) over 30g to 1000g range, and provides digital output that is directly stored in the system non-volatile memory. The acceleration sensors are formed using micro electro mechanical systems (MEMS) technology, atop of integrated circuitry needed for sensor interface, memory, and wireless communication. The sensor chip includes integrated energy source for its operation. The overall sensor module integrated on a chip, measures less

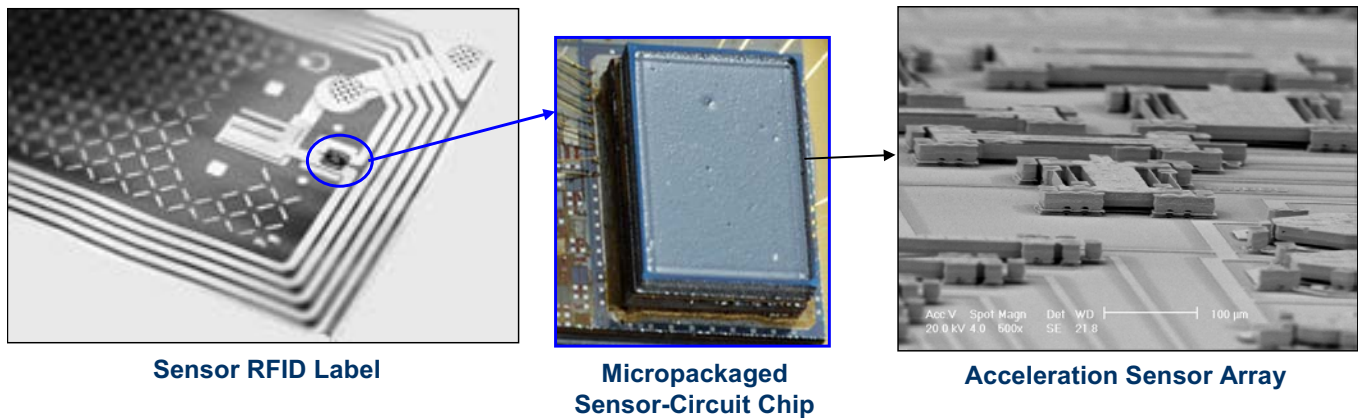


Fig. 1: Batteryless wireless acceleration recording chip will work in conjunction with a standard RFID-label after development. The chip detects impact events and records the magnitude and duration. The stored data on chip will be transferred over a wireless link to a RFID reader.

than 3 millimeters on a side, weighs less than 0.1 grams, and is micro-packaged with a low profile of less than 1 millimeter. The sensor chip assembled with a standard radio frequency identification (RFID) antenna label can transfer its sensor data as well as any other on-chip information through a wireless link to a handheld or fixed interrogator (Fig. 1). The chip detects impact events and records the magnitude and duration. The stored data on chip will be transferred over a wireless link to a RFID interrogator (reader).

The first generation of these sensors operates on ISO15693 RFID protocol that employs 13.56MHz wireless carrier frequency and has a range of a few feet. The acceleration sensor chip also has an electronic reset, which can be applied after the chip data transfer to the reader. The wireless sensor chip cost is competitively low as it is manufactured employing mass volume semiconductor production infrastructure and techniques.

of an array MEMS acceleration switches. Each element has a predetermined switching threshold and is made sensitive to one of the 6-DOF primary axes by the geometrical design. The chip includes its energy unit that powers the circuitry when an impact event detected. This energy unit is integrated with the sensor module and can be recharged when the sensor is in its wireless reader field. The circuitry resolve the state of their input sense switch array, and detect the amplitude and duration of the impact, and store on-chip digital non-volatile memory. Once the acceleration chip is in the field of its wireless reader, the communication block of the chip and additional digital control circuitry will be powered up by the remote power coupling similar to a standard RFID system, and the stored data can be read over a passive wireless link to the reader. The reader also can issue reset command. It is worth noting that the chip can support a finite number of impact events, which can be incorporated into to the chip design and activated by the post-manufacturing configuration at the factory.

Figure 2 shows the block diagram of the chip. It consists

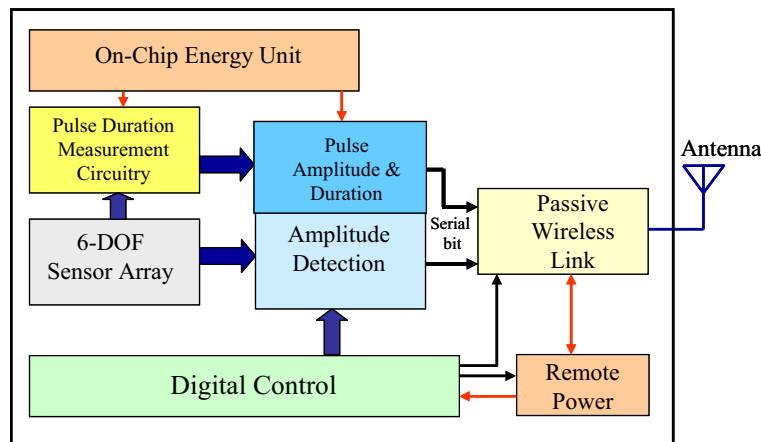


Fig. 2: Block diagram of the wireless acceleration impact detection and recording chip.