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SpeedMed: device for measuring velocity in track sports

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***Abstract*—**Everyday, industries make use of economic resources to carry on research studies of products to improve the athletic performance of people. This is the main reason why it is believed that the development of an inexpensive and portable device capable of measuring times and speeds in track sports in general will provide useful information to study the performance of not only sportsmen, but also of ordinary people under stress situations allowing them to determine their weaknesses. In this project, two very simple sensors (photocells) are used to develop a device capable of measuring speed. A microcontroller was programmed to measure the time between the interruptions of two laser beams which lighten the surfaces of photocells, and it was also programmed to calculate velocity for a given distance. These values are sent to a Liquid Crystal Display (LCD) where they can be visualized and interpreted.

***Keywords*—**Laser, Photocell, Portable device, Track sports, Training.

***Resumen*—**El desarrollo de productos e investigaciones relacionadas con el mejoramiento del desempeño atlético ha sido impulsado por el apoyo económico de las crecientes industrias deportivas. Así, la construcción de un dispositivo económico y portátil que permita medir los tiempos y velocidades en deportes de pista proporcionará información adecuada para cuantificar el progreso de los deportistas relacionados e identificar los aspectos para fortalecer. Su uso podría extenderse a personas ordinarias bajo condiciones de estrés. En este trabajo se utilizaron fotoceldas para desarrollar un dispositivo capaz de medir la velocidad en los escenarios mencionados. Para esto se programó un microcontrolador que mide el intervalo de tiempo entre las interrupciones de dos haces de láser que impactan la superficie de las fotoceldas, y luego calcula la velocidad para una distancia dada entre los sensores. Finalmente los valores se envían a una pantalla de cristal líquido (LCD) para su visualización e interpretación.

***Palabras Clave*—**Láser, Foto-celda, Dispositivos portátiles, Deportes de pista, Entrenamiento.

I. Introduction

Measurement of locomotor velocity is important in many sports analyses and human movement studies in general. Technology choices for linear velocity sensors include cable extension, magnetic induction, microwave, optical or laser, piezoelectric, radar, or radio frequency, strain gauge, and ultrasonic sensors [1]. However, the use of SpeedMed-like devices, (i.e optical sensor timing gates) may provide a convenient and, most importantly, rapidly accessible source of information on velocity [2]. For these reasons, photocells timing systems are used routinely to measure speeds in athletic performance testing [3].

When focus on track sports, it is important to analyze the behavior of the athlete in the different segments of the track to recognize the difficulties the athlete has according to his abilities and physical contexture. This way, when the areas of decreasing or low speed are determined, they can be emphasized on a newly designed training program based on the results of the test to ensure a harder work where the athlete needs to develop strengths and make bigger efforts. Likewise, determination of high velocity areas allows the trainer to characterize the biomechanical behavior of the athlete during the most demanding segments of the track in order to understand his enhanced performance on that specific segment.

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In Colombia, the need of such devices is confirmed by local institutions which support sports as Indeportes Antioquia and Antioquia's Cycling League. They report that the equiptment to measure their athletes skills and difficulties is quite limited and very expensive forcing them to use it in very specific situations because any damage to this equipment could have very serious consequences. Moreover, many tests can not be done in a laboratory because the results would not be the same as if they were made outside on the track. The difficulties to recreate the conditions of the outside due to the lack of technology to simulate ground and environment characteristics have made the use of this equipment even tougher because they have to expose them to climatic changes and inappropriate conditions for working.

A. Description of the problem.

Track athletes generally have an outstanding performance on some specific segments of the track and a fair performance on the rest of it. There is no such thing as a perfect athlete, because they always have better performance in a determined part of the track. The best athlete is the one who has an uniform performance during the entire competition, maintaining his high level [4].

The use of devices to help improving the quality of the training process and competition itself is widely known. Industries have become interested on financially support research studies on the area looking forward to provide athletes with products that allow them to use their capabilities to the maximum, overcome fatigue and push their own physical limits during competition. Political and social involvement on some sports as football (soccer), presented among others, has presented large industries an opportunity to advertise through sponsoring and while doing so they acquire a responsibility towards their consumers to work on the improvement of the products they offer. This way, research becomes an economic interest for the industries that have attempted to specialize on sports and athletes.

Athletic performance testing equipment and systems have lately become of special interest since testing and measurement are the means of collecting information upon which subsequent performance evaluations and decisions are made by both coaches and athletes to determine the success of the training program [5]. The Chronomix Precision Performance Timing Systems is one of the photocells systems available for purchase worldwide. It is designed to provide accurate and consistent measurements of an athlete's speed and agility, for comparing or qualifying athletes or for tracking improvement in performance [6]. Since, this type of technology is not easily affordable for regional institutions and sport leagues; it has to be replaced with less expensive devices.

To prove the behavior of our device, two basic track sports were considered. The first one is Bicycross (BMX) and the other one is cycling.

On the latter one, there are several characteristics to be considered during a performance test:

To measure the maximum speed that an athlete can obtain during a velocity test, the athlete must travel at least 200m before taking a measure in order to get appropriated and veridical data.

To measure reaction times, the measure must be taken 60m after the start line.

Strength resistance can also be measured; this measurement indicates the fatigue tolerance of the athlete during a 250m laps test.

On the other hand, using SpeedMed to measure speed and time in BMX has several advantages. Basically because it is necessary to measure reaction times on very short distances. Since in this sport, what really counts is reaction time, instead of velocity, it is appropriated to focus the test measurements on the initial segment of the track. There is where the athlete has to make bigger efforts and gets a position that may allow him to finish the race in a good place. It is very difficult to gain positions during the competition because after the initial segment the space is too limited between competitors and maintaining a position is just a matter of technical skills.

As we will show further on this article, the sensors used with SpeedMed can only be 4m apart from each other, therefore it may not be very useful for cycling due to the requirements mentioned earlier, but it is good enough for BMX.

On this paper an apparatus which uses photoelectric means for measuring velocity is designed and developed. In the following sections it is first described the elements that will be used on the design of the circuit, and then it will be described the circuit, which includes the PIC microcontroller that had to be programmed, the signal processing and finally the signal visualization via a LCD.

II. Materials and Methods

A. Design Process

To obtain a device capable of measuring velocity, several aspects have to be considered. It is evident at first glance that a specific and distinguishable type of signal is required. For this purpose an interruption of some kind when the person passes by may be a proper signal, but it is not clear which type of sensor would give more accuracy and faster response for this particular application.

Using a LED-phototransistor pair, presents several difficulties. First, it is very difficult to align both of these components, and second, it is not fully determined how far apart from each other could they be to still work adequately.

It was also considered using a laser beam with a phototransistor, but the latter ones work with infrared light, which means non visible light, so they do not have an adequate response to laser signal.

Finally, it was used a photocell, which is a very economic device but it also responds to the light in the environment, so when the beam hits its surface, it did not respond much and the change in the voltage is barely perceived. In consequence the photocell has to be isolated. A PVC tube was used to overcome this difficulty with very good results. The photocells have a range of about 4 meters, and the distance interval between the two adjacent photocells can be freely chosen [7].

B. Basic Design of the device

The fundamental principle behind the design is the combined functionality of photocells, laser beams and a simple timer, to create a system that essentially calculates and displays the motion velocity as the distance between two photocells divided by the recorded time interval between two consecutive beam-broken signals, in real time [8].

As shown in Fig. 1, the basic components of the SpeedMed are:

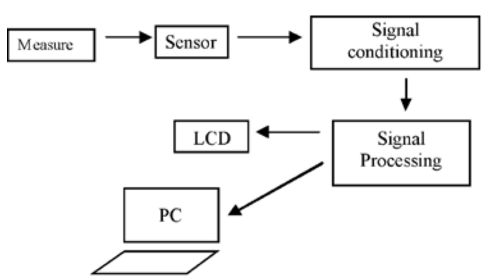

Fig. 1. Block diagram illustrating the basic design of the project. The sensor determines the time when the light beam is interrupted, then the elapsed time is defined to calculate the velocity by signal processing (PIC) the LCD is used to show the results.

Measurand: movement of the athlete in the bicycle. The exact moment when the front part of wheel cuts through the laser beam is measured in two different points which stand from 1 meter to 4 meters apart, depending on the measurement requirements.

Sensing element: the sensor used is a photocell. A laser beam pointing to the surface of photocells. This laser beam is the one that is interrupted when the bicycle passes by. The advantages of photocells include low cost and ease of calibration [9].

Signal conditioning: there is no need to do any kind of signal conditioning, because the signal will only be used to create the interruption.

- Signal processing: the only signal processing implemented is the use of operational amplifiers to compare a reference voltage with the voltage on the photocell which varies depending on the amount of energy it receives from the laser source.

Visualization: for this stage of the process, it was used a LCD. To be able to visualize the speed and time, a routine has to be developed in the microcontroller. The PIC programming will be discussed in a topic.

C. Circuit design

The electrical components of the circuit are shown in Fig. 2. On the left, there are two isolated photocells which receive a laser beam. When this beam is interrupted by the bicycle, a counter inside the PIC will count the time until the next interruption in the second cell. The time that was obtained will divide the value of the distance. This value was previously selected by the user with the Dip-Switch. The circuit also has an LM324 operational amplifier which acts as a comparator; it gives an output voltage of 5V when the beam is interrupted in each one of the sensors. This voltage goes to the PIC and starts, or ends, the interruption, according to the sensor activated.

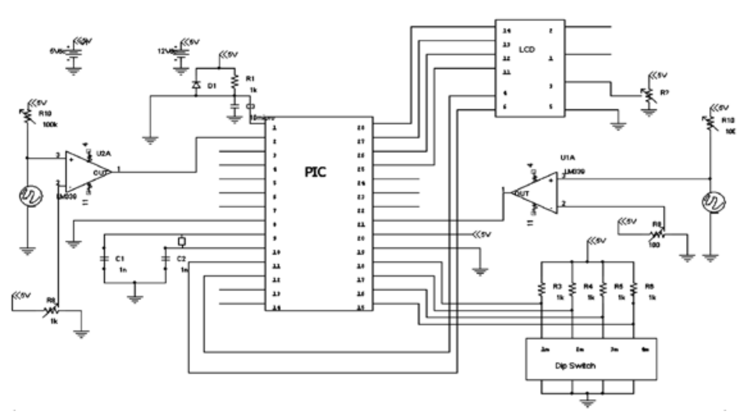

Fig. 2. Complete circuit. Description of the hardware used, showing the sensors, operational Amplifiers, electronic devices and their operating configuration, the interface between the PIC and the LCD and the input voltages required for the adequate functioning of the system.

The PIC has a master clear circuit which resets the entire circuit and it is mostly used to re-start the entire process.

Finally, the LCD shows the data that corresponds to the time, distance and finally, velocity.

D. Brief description of the microcontroller program

The program can be described by the flux diagram shown in Fig. 3.

The implementation of this device is based on a principle called polling, which means that the microcontroller is constantly checking in a cyclic way if the interruption has already taken place and when it does, it executes the program.

There is a very important aspect that has to be taken into account and it is the fact that the microcontroller works at very high speed, in the order of microseconds, this is why it has to saturate to be able to count times larger than one second.

If the pre-scaler of the register timer zero (TMR0) is set to 1:256, the microcontroller can only count 65536µs, which is much less than one second. First, TMR0 is initialized in a value of six and set the pre-scaler to 1:32. The timer is set to count 8000 microseconds and then it saturates. This happens 125 times to complete one single second.

Although it may be possible to calculate the velocity as a single value, two values are separately calculated and sent to the LCD, making the binary division implemented a much simpler process.

III. Results and Discussion

The SpeedMed, as basic as it is, is a powerful tool to reveal several aspects of the athlete's development because it can tell how he is behaving under normal or stressful conditions; yet, there are some problems that have to be taken into account when using this device, which can affect its efficiency and accuracy. These are:

- The SpeedMed allows seeing only one decimal digit. This is mainly because operations with binary numbers bigger than two digits require a 16 bit routine, which was not implemented. The LCD has a limited amount of space to display the information; therefore it is not possible to visualize all the information at the same time and in some cases it may be required.

- Because of the saturation of the microcontroller it can only count for 255s approximately, which is equivalent to 4min and 15s due to the register's capacity. This is enough time for the athlete to complete an entire lap, but it does not allow the SpeedMed to be used on a long competition to measure different velocities.

The design of our device has some advantages such as:

- The unique characteristic of letting the user choose the distance between the sensors allows him to be able to measure many different characteristics, not only velocity but also reaction times and how the speed decreases after several laps. Although the maximum allowed distance is 4 meters which is viable for BMX but not enough for cycling.

- The low cost devices used on this prototype may lead to a very inexpensive design that could be commercially distributed in the future.

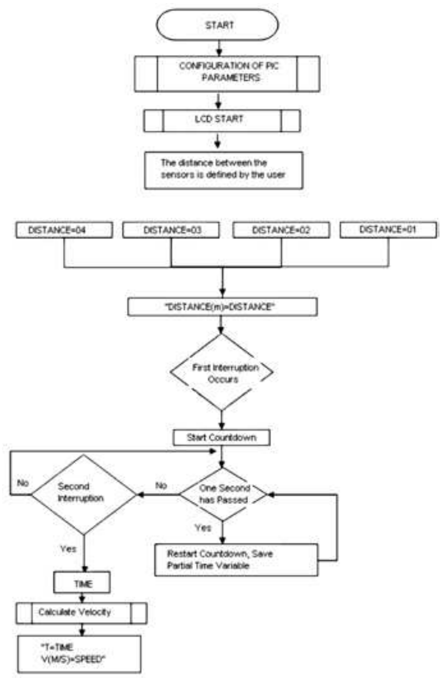

Fig. 3. Flow diagram for the microcontroller program. Indicating the sub programs [10].

Despite all of these pros and cons, the use of SpeedMed for measuring velocities on cycling should not be discarded; because it can provide valuable information about the different "stages" an athlete goes through on a competition because of the physical wear.

IV. Conclusion

There are several sensors which can be used to measure velocity in an indirect way, but it has been proved that the simplest of these sensors, the photocell, has many advantages over other sensors. By using laser, it is possible to work with visible light, which is of great importance because it makes the alignment of the sensor easier. By implementing very simple devices, equipment that has many applications can be obtained, not only for use in sports, but also in biomechanics. This is the main reason why this device will have a big field of application in the future, and could be considered in many other fields.

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