Electronic system for net touch detection for table tennis

Arturo Méndez Patiño[1] and Juan J.D. Delgado Romero[2]

[1] Department of Electronic Engineering, Instituto Tecnológico de Morelia, Morelia, México
(Tel.: +52-443-326-2916; E-mail: ampatino@prodigy.net.mx)
[2] Department of Electronic Engineering, Instituto Tecnológico de Morelia, Morelia, México
(Tel.: +52-443-312-1570; E-mail: ampatino@itmorelia.edu.mx)

Abstract: The design of an electronic system to detect the touch of the table tennis ball on the net during the service is shown in this work, just like in tennis. The design was done taking into account the simplicity to use (to achieve a friendly system), small size and low power requirements to be used with batteries.

Keywords: Net touch detector system, electronic system, umpiring.

1. INTRODUCTION

The laws of table tennis [1] state in section 2.9.1.1: “The rally shall be a let if in service the ball, in passing over or around the net assembly, touches it, provided the service is otherwise correct …”.

The detection of the touch of the ball on the net during the service in a table tennis match requires the full attention and some skills of the umpire and assistant umpire. On some occasions none of both umpires noted the touch of the ball on the net, and the players are those who report it. In tennis, there are already systems for net touch detection, doing easier the umpires work.

This work shows an electronic system designed specially for table tennis, to be used in real matches as well as in training sessions. The work of the umpires in a match will be easier. In training sessions it will help to improve the steering of shots.

2. THEORY OF OPERATION

When the ball touches the net, it produces a slight displacement or movement of the net in 2 of 3 axes:

- In the horizontal axis that runs across the table from side of one player to the side of another player (Z axis) and/or

- In the vertical axis that runs between the floor and ceiling (Y axis),

- Along the transversal axis that runs from one end of the net to another, or between left and right (X axis), the displacement that occurs is minimal.

The displacement or movement of the net involves a change of position (millimeters) at a certain time (seconds), which implies a speed (mm/s). When the ball touches the net, it is applying a force through its mass, which finally produces an acceleration (a = f/m) in each of the axes mentioned before. This acceleration produces a velocity (v = a*f), and also produces a displacement (d= v*t).

Therefore, we can detect when the ball touches the net taking the measurements of the net acceleration in the Y and Z axes.

There are several integrated circuits for detecting acceleration in each axis, as required here; these circuits are called MEMS (Micro Electro-Mechanical System) or accelerometer [3]. They give the measured value of acceleration relative to the acceleration of gravity. So when the circuit provides a value 1 on any axis, it means that there is an acceleration of 1 gravity or 9.81 m/s^2 on that axis.

Fig. 1 shows a graphical representation of the MEMS integrated circuit used in this design.

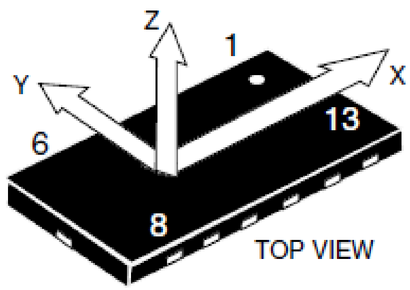

Fig. 1: MEMS Integrated Circuit or Accelerometer used

This design uses a MEMS circuit to precisely detect these accelerations and therefore detect the touch of the ball on the net. The MEMS integrated circuit was selected considering its presentation or package of small size so that it did not represent an additional mass to the net, without changing the ability of the net to move with the touch of the ball.

The names of the axes were chosen as the names mentioned before, because the integrated circuit was placed with his Y axis pointing to the ceiling, the X axis aligned along the net and the Z axis pointing to the players, as shown in Fig. 2.

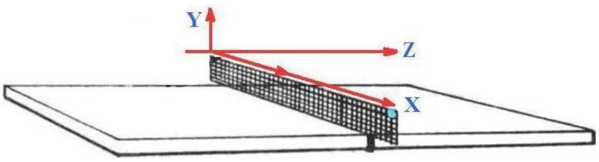

Fig. 2: Axes orientation used.

With this placement, only Y and Z axes are required in our application. In this way, in steady state, the Z axis will have an acceleration of value 0, the Y axis will have an acceleration of -1 (gravity).

The MEMS utilized has a sensitivity determined by the number of bits used to deliver the reading and for its full scale value. The number of bits used for each measurement is 8 and the full scale can be chosen between ±2 g and ±8 g.

In order to detect smaller accelerations and, therefore smaller displacement of the net we used the ±2g scale, so it had a sensitivity of 0.015g (0.1532 m/s^2 or 153.28 mm/s^2), as shown in Eq. (1).

$$\pm 2g \Rightarrow 4g/2^8 = 0.01562g$$
$$0.01562x9.81 \frac{m}{s^2} = 153.28 \frac{mm}{s^2} \qquad (1)$$

There are other integrated circuits with sensitivities of ±1g with 8 bits (76.64 mm/s^2). If we estimate that the ball touches the net during 0.1 s, any displacement of 1.5 mm will be detected (or 0.76 mm using a MEMS of ±1 g of sensitivity). This is shown in Eq. (2)

$$a = v/t = d/t^2$$
$$\Rightarrow d = a * t^2 \qquad (2)$$
$$153.28 \frac{mm}{s^2} * (0.1s)^2 = 1.53mm$$

3. DETECTION ALGORITHMS

When the axes "Y" or "Z" have a change in their initial value of acceleration (stable value, when the net is without movement), it was considered that the ball touched the net, as shown in Eq. (3).

$$g_Z - g_{Z_{INI}} \neq 0$$
$$g_Y - g_{Y_{INI}} \neq 0 \qquad (3)$$

In order to avoid the normal noise in the sensors, it was considered that only changes bigger than a programmable minimum value, were caused by the touches of the ball on the net. Since the changes can be either positive or negative, we took the absolute value of the change, as shown in Eq. (4).

$$\left| g_Z - g_{Z_{INI}} \right| \geq \Delta g_{Z_{MIN}}$$
$$\left| g_Y - g_{Y_{INI}} \right| \geq \Delta g_{Y_{MIN}} \qquad (4)$$

When we use only Eq. (4), we have a proportional detection system (P).

In order to reduce the probability of incorrect detections, several measurements can be taken and then calculate the average of these values. In this way we implement a detection system that is proportional and integral (PI). This is shown in Eq. (5).

$$\sum_1^N \Delta g_Z \Big/ N$$
$$\sum_1^N \Delta g_Y \Big/ N \qquad (5)$$

A more sophisticated detection technique takes into account the change in acceleration over time (rate of changes of acceleration or the derivative of acceleration), as shown in Eq. (6). In this way, it is implemented a proportional-integral-derivative (PID) detection system.

$$(\Delta g_{Z_2} - \Delta g_{Z_1})/\Delta t \rightarrow d\Delta g_Z/dt$$
$$(\Delta g_{Y_2} - \Delta g_{Y_1})/\Delta t \rightarrow d\Delta g_Y/dt \qquad (6)$$

Each part of this equation (proportional, integral and derivative) can be weighted using a constant coefficient, in order to get the best detection system, with minimal error. The adjusting of these constants is often called system tuning.

4. IMPLEMENTATION

The MEMS used gives the measurements in digital form, through a serial interface I2C or SPI, which can be chosen by software. Fig. 3 shows a picture of the MEMS used, mounted on the printed circuit. The size of this board is of 1 x 0.8 cm, with a mass of less than 20 g, and therefore in a practical form, it is not affecting the total mass of the net and it is not changing the ability of the net to move with the touch of the ball

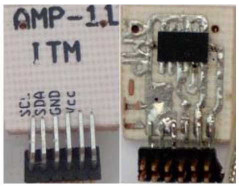

Fig. 3: Back and front view of MEMS sensor.

To achieve the communication with the MEMS and to implement the detection algorithm, we used a low power microcontroller, in order to energize it with a battery. The microcontroller chosen was from MSP430 family of Texas Instruments. From this family we selected the MSP430F2274IDR [2], because in our application we want to have:

- I2C serial port;
- Output pins for a 7-segment display with 3 digits, to show additional options;
- Output pins for light indicator;
- Input pins for the enable of sensing;
- UART serial port for future options.

We choose all the integrated circuits in Surface

Mount Technology (SMT) package, also the passive components that were used are in SMT package. With these packages, the printed circuit board (PCB) built is of 2.5 x 4 cm in size. Fig. 4 shows pictures of the prototype circuit.

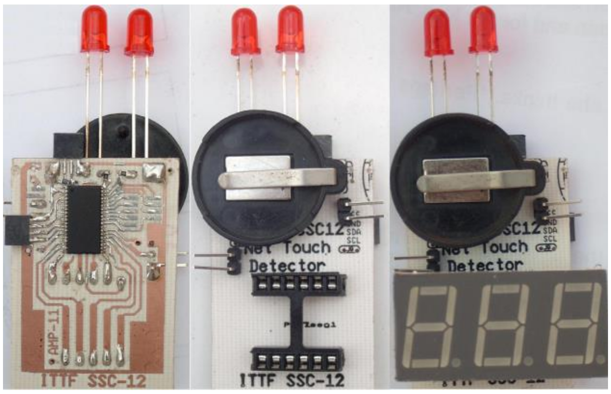

Fig. 4: Back and front view of the system and front view with a display.

For the programming of this application, we used C language because we wanted to have a portable software or easy to transport to any microcontroller.

To indicate when the ball touches the net, we used a light indicator, placed in a visible position, in a way that any player and any the umpire can see it. A sound indicator also can be used, but in noisy environments it will be difficult to hear it.

We used a light emitter diode (LED) as light indicator, because they need lower current than other indicators, allowing longer life of the battery.

To avoid that the indicator light works during a normal rally, we decided to use a push button switch, controlled by the auxiliary umpire. In this way, only when the auxiliary umpire is pushing the switch, the detection system will work. Therefore, the auxiliary umpire will push the switch just during the service.

Any time during the service when the ball touch is detected, the indicator light will stay turned on, although the auxiliary umpire stops pressing the switch, and it only will be turned off pushing and releasing the switch twice in a row. This sequence was chosen to avoid accidental erasure of the indicator, when naturally the umpire stops pressing the switch after the return of the service.

Fig. 5 System mounted on the net assembly.

The sensitivity of this system can be modified by software, modifying the minimal change required in each axis; and changing the constant coefficients of the PI or PID system. Also the sensitivity can be increased using other MEMS sensor with more resolution.

With the goal of using this system not only in matches, but also in training sessions, we put a display of 3 digits (7 segments and 3 digits) in order to show the counting of "events". Putting the MEMS in any place on the table and adding a sheet-pad over the MEMS, the "events" will be the touches of the ball on any specific position over the table. This can help in training sessions to improve the steering of the shots, and the display will show the count of successful shots.

The seven segments display was placed over a socket, in this way we can select to use it or not. Without the display we are saving battery power, and therefore we will get longer life of the battery, this is the case when we are using it for a real match. In training sessions, using the display we can show the counting of ball touches.

5. CONCLUSIONS

This application shows that with small electronic devices applied to table tennis, there is a wide range of possible applications that can make us enjoy our sport in a better way.

Implementations can be easily multi-purpose; in this way, a design can be used both in a real match and in training sessions, giving added value to the system.

The low power consumption and small size of electronic devices allow us to have systems quite small and portables, powered by batteries.

More options and improvements will be added to this system in the future based on experience of use, suggestions and advices received.

6. ACKNOWLEDGEMENTS

We thank the support of Instituto Tecnológico de Morelia, Dirección General de Educación Superior (DGEST), Asociación Michoacana de Tenis de Mesa (AMTM), Michoacán State Government through the Comisión Estatal de Cultura Física y Deporte (CECUFID) and UVAQ.

REFERENCES

[1] Handbook of the International Table Tennis Federation, "The laws of table tennis", chapter 2, 2010-2011.

[2] TI Inc., *MSP430xx22x2, MSP430xx22x4, Mixed Signal Microcontroller datasheet*, TI Inc., July 2008.

[3] ST Microelectronics, *LIS302DL MEMS motion sensor datasheet*, October 2008.