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### DESIGN OF AN ELECTRONIC SCOREBOARD FOR TABLE TENNIS

*This paper talks about a design of Table Tennis electronic scoreboard, with multiples functions and benefits, like: automatic server indication; automatic change of side indication for the last set and change of score side; Time-out indication; time for rest between sets; at the end of match, it shows scores and times for each set. The table tennis rules are embedded in the scoreboard.*

*This design has non-volatile memory in case of loss of energy, it keeping the current score in memory. A battery can be used for continuous use even if the main energy source is lost.*

*Many electronics scoreboards can be network connected, in order to shows in several places the same score ("mirror" scoreboard). Also many electronic scoreboards (to 255 scoreboards) can be network connected for several match scores and they can be monitored from a main computer (PC) for scores concentration. All the scores sequences for each match with the time (hour: minutes: seconds) for each point can be filed and used for statistical. Internet displaying of the scores can be done by the PC used for monitoring.*

*This scoreboard can be used in table tennis instruction for easy learning of scoring. It has the option of to place pads in the table for training and counting the balls hitting over the pads.*

*The scoreboard can be used in tournaments, clubs and home; for professional use and for entertainment (recreational) use.*

*It is based in a microcontroller using CAN bus for network communication, it use LEDs for display the score (Points, Sets, Server and End of match). It uses a serial EEPROM to save the scores; configuration and other important information. The keyboard uses only 4 keys for an easy management.*

**Key words:** *electronic scoreboard, microcontroller, network, CAN, learning, training, embedded rules.*

## 1- Introduction

In a table tennis match, it is needed to take the score, in order to make it easy, pre-printed scoreboard are used. In general, electronic scoreboards are used only in national, international or in professional tournaments or in first world countries.

The introduction of electronic scoreboards in local tournaments implies higher costs and problems to obtain the scoreboards. The commercial scoreboards are designed thinking in its use in other sports with more demand, like basketball, volleyball, football, etc., in consequence its design takes into account others needs, different from table tennis.

Even that some commercial electronic scoreboards are for multi-sports use, they don't full fit the table tennis special requirements.

The present work is about the design of an electronic scoreboard it thinking on full fit all the table tennis specific requirements, for tournament applications also as for teaching and learning the sport and its rules; also as it helping in the training. A key point of this design is the easiness of use, it reducing to the lowest quantity the number of keys of the control keyboard.

The design here presented it takes into account the expansion possibility, for interconnect several scoreboards and to have a network of scoreboards. Inside of this network we can have several use options; like that some group of scoreboards show the same information of a match, it placing them in different places for better vision of players, judges and spectators. Also a network node with a personal computer (PC) can

be used to read all the scoreboards in the network and write all the information of a tournament into a file. In the event of a power fail, the information of each scoreboard is stored in a non-volatile memory inside of the scoreboard and in the PC.

The implementation of this work takes into account the modularity, and it can be removed some parts in order to reduce the cost, without the loss of basic functions.

The next section will talk about the hardware needed and the optional parts. The third section will describe the considerations taken in the design of the software and its modular structure. The fourth section will show the installing way and wiring for a correct use of the scoreboard. The fifth section shows the applications of this work. The sixth section will show some comparisons with commercial scoreboards. Finally the last section will show the conclusions of this work and the improvements to implement in the future.

## 2- Hardware

The implementation of an electronic scoreboard for any sport needs the use of digital electronic devices; programmable devices are best suited in order to have a versatile and reprogrammable design.

The digital electronic devices can be classified in two large groups: The Processors and the Programmable Logic. Inside of the first group are the microprocessors (uP), the microcontrollers (uC) and the DSP (Digital Signal Processor). In the second group are the SPLD (Simple Programmable Logic Devices), the CPLD (Complex Programmable Logic Devices) and the FPGA (Field Programmable Gate Array).

The use of programmable logic and in special the FPGA gives an enormous versatility to the design, because that all the pins can be used for any function in any direction. Also the processing power that can be achieved is higher than with other options because all the work is done in hardware and it can be done in parallel, only limited by the quantity of gates available in the chosen device. There are device with several millions of gates. The design with FPGA is little more complex than with microprocessors, because that the start point is the use of basic elements like gates and the use of some pre-designed blocks, named Cores. There is also the option of implement a processor inside of the FPGA, it using cores or it using a real processor integrated from factory in the FPGA, like the PowerPC in some Xilinx FPGAs.

The microcontrollers are microprocessor integrated with RAM and ROM memory and common used peripheral, like timers; analog to digital and digital to analog converters; serial ports; etc. The DSP are microcontrollers with the hardware and the instruction set needed for digital signal processing, where multiplication and accumulation is a basic operation.

The control of an electronic scoreboard do not require the power processing of a DSP but RAM, ROM and peripherals are needed, then the use of a microcontroller is a good and enough option for this application.

There are a large number of microcontrollers available with different quantities of integrated RAM and ROM memory; with several types of ROM; and with spread type and quantity of integrated peripherals devices.

For the control of an electronic scoreboard is not necessary a high power of processing, but the following elements are required:

- Enough quantity of RAM memory for storing the variables of table tennis scoring (points in each set for each player; server order; time of match, etc.) and for the stack used in subroutines. At least 128 bytes of RAM are needed. If the software is written in a high level programming language 1 K byte is recommended.

- Enough quantity of ROM memory to hold the control program. If the software is development in assembler, 2 K bytes of ROM are needed. If the software is written with a high level language more than 8 K bytes are recommended. The ROM memory suggested is Flash, in order to have an easy and quickly change in the control program when updates are needed.

- One timer (at least) with interrupt generation. The timer is useful for measuring game time; rest time; and for timing the multiplexing in the LED (Light Emitter Diode) display.

- Three parallel ports are required, two for a seven segments LED display control and one port for connecting a control keyboard.

- A serial port for add special peripherals. There are several types of serial ports, but SPI (Serial Peripheral Interface) and UART (Universal Asynchronous Receiver Transmitter) are recommended.

- A type of network connection, in order to have intercommunication between the scoreboard and others scoreboards and/or a personal computer.

Also the price and availability is an important factor to take into account in the selection of the microcontroller, and even if the chosen uC does not have some peripheral needed, we need to consider the option of add it externally.

The microcontroller chosen for this work was AT89S53 from Atmel. This is an uC compatible with the Intel 51 family. It has 12 K bytes of Flash ROM; 256 bytes of RAM; 4 8-bits parallel ports; 3 16-bits timers; 1 UART Serial Port; 1 SPI Serial Port; 9 interruption sources. The maximal work frequency of this circuit is 24 MHz.

For displaying the score a 7-segments LEDs array was chosen, with 6 digits: two pairs of digits are for display the points of the current playing set for each player. Another two digits are for display the sets won for each player. Additionally there are LEDs to show which player is serving and for indicate the end of set; change of side and end of match. The six digits are multiplexed in the time, and for their control they require 2 8-bits parallel ports of the microcontroller. With these two ports we would be able to have to 8 digits of 8 segments with time multiplexing. The figure 1 shows the LED array of the scoreboard display, indicating the function of each digit.

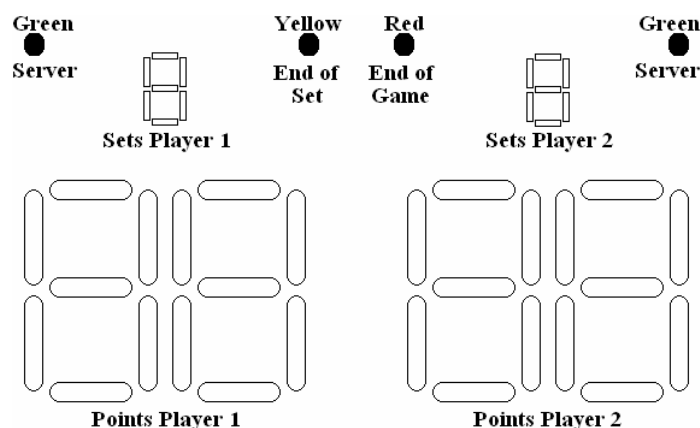


Figure 1 Scoreboard Display.

For the scoreboard control a keyboard with only 4 keys was chosen. For connect this keyboard to microcontroller, it is needed a 4-bits input port. Using an 8-bit input port it can be connected a keyboard with 16 keys. A 4 key keyboard was chosen in order to facilitating the use to the judge and avoiding confusions. The figure 2 shows this keyboard with the names of each key.

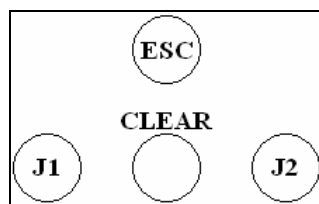


Figure 2 Scoreboard Control Keyboard.

For the network connection of the scoreboards a CAN (Controller Area Network) bus was chosen. This standard was selected because its simplicity of wiring, its noise

immunity and the availability of drivers and controllers with SPI interface, reducing the number of wires for interconnecting the controller with the microcontroller. In CAN standard mailboxes are used, it identifying them by an 11-bit number or address using Standard Data Frames, but in this design only 8-bit are used, therefore only 255 scoreboards can be connected in the network. A node of the network can be used to capture the information from all the mailbox addresses, and therefore it taking all the scores from all the scoreboards. This node can be used by a personal computer.

An external EEPROM memory was added to the design in order to not lose the scoring in case of power fail, when there is not a backup battery. This memory has SPI interface and therefore does not it need additional terminals that the used by the CAN controller.

The figure 3 shows a block diagram of the scoreboard.

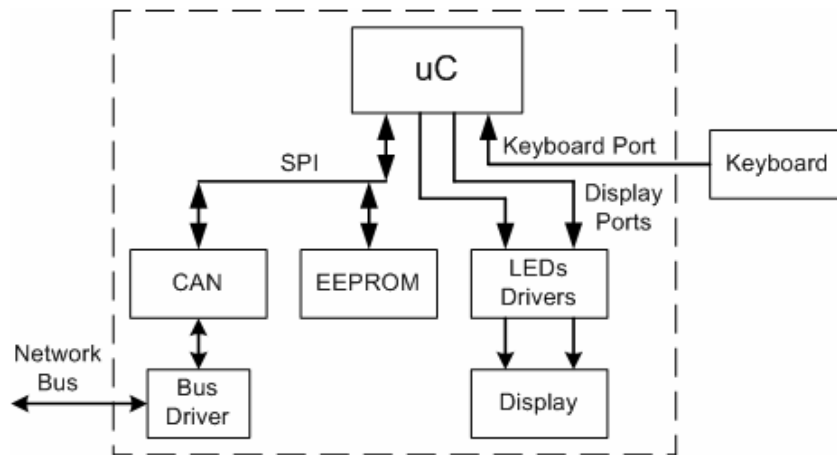


Figure 3 Scoreboard Block Diagram

The EEPROM memory is optional, because it is not needed when a backup battery is used, and therefore it can be or not connected, without any loss of functionality of the scoreboard. In the same way, if we do not wish the network interconnection, the CAN driver and controller can be removed without alteration of the scoreboard performance. Then the cost of the system can be reduced.

With all the options included and without battery, the scoreboard consumes 0.1A at 110v of AC. It has a weight of 1.2 Kg when an acrylic box is used to hold the system. The dimensions are 34cm x 22cm x 15cm.

### 3- Software

With the purpose to reduce the quantity of RAM and ROM required by the software and taking advantage of my experience writing programs in assembler language for several microprocessors and microcontrollers, I wrote the software in assembler. For future versions I will write the software in "C", it thinking in the option of changes of microcontroller used and because a high level language like "C" need less changes to use in other uC, but requiring more quantity of RAM and ROM.

One of the objectives when the software was designed, it was simplifying the management of the scoreboard, it integrating and complying the table tennis rules, like the order of the services, the rest times in a set (under request of each player) and between sets (automatic), it showing the time in descending form, so that the players be aware. At the end of a match the software hold the partial results for each set also as the total and partial time duration.

The software design was modular, structured and generic, and easily the main parameters can be modified, as the points by set; services by turn for each player, etc.

The software has many routines; some of them are mentioned in the next lines:

- Updating the display: This routine is responsible of showing the data for each digit during a period of time avoiding that the blinking (caused by time multiplexing of the digits) be seen. This routine is executed by timer interruption.
- Keyboard read: It is responsible of to read the keys pressed in the control keyboard.
- Keys Decoder: This routine takes the decision of which routine should be executed in function of the key pressed.
- Routines for each basic function: Increment or Decrement of points for each player; verification of player that should have the service; end of set and end of match verification; time update; time of game update.
- Start of Game: Routine used to clear all the counters and to choose the maximum number of set to play (3, 5 or 7).
- Network communication: Routine needed to send and receive the scores to or from the network.
- EEPROM communication: Routines for write and read the scores to or from the external backup memory.
- Initialization routines: It is used for programming and configuring all the internal and external peripherals.
- Change of parameters: Routine used to modify the numbers assigned to the scoreboard in the network, for broadcast and for reception (CAN mailbox addresses).
- Time routine: It is for display time (min:sec) in descending form for 1, 2 or 3 minutes in time-out.
- Work in Stopwatch mode: It is to shows the time (hour:min:sec), it is useful for training.
- Work in reception or mirror mode: This routine is used to show the score received from other scoreboard in the network, from the address chosen.

#### 4- Wiring

The scoreboard needs 3 sets of cables for its use. One of these sets is for power supply; another is for the control keyboard and another one optional is for the network interconnection.

For the power supply is needed a pair of wires that provide 110v of AC with 0.2A of current.

For the control keyboard connection is needed a telephonic or network cable, with 5 wires (or 3 pair of wires). The maximal current in these wires will be of 5 mA. The maximal length is of 50 meters.

For the network connection is needed a cable with a pair of wires to interconnect all the scoreboards. The maximal length for this bus is 500 meters. In the extremes sides of this bus a 120 ohms at  $\frac{1}{4}$  w termination resistors are needed.

The figure 4 shows an example of the wiring for several scoreboards.

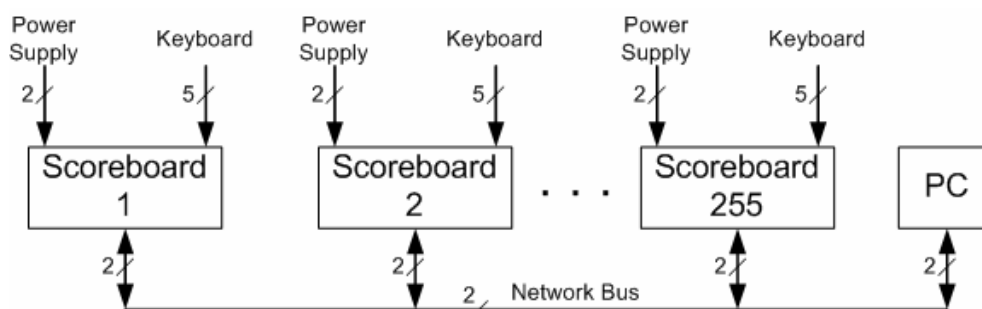


Figure 4 Scoreboard Wiring.

## 5- Applications

This scoreboard can be used in table tennis matches in tournaments, connecting a network of several of them; selectively some of them can be configured in reception or mirror mode to show the same score from a match, it placing them in various places for better vision of players, judges and spectators. For different tables the scoreboards work in independent form, it assigning them the same number that the tables.

Since the scoreboard shows automatically the time of rest between sets, the players, coaches, judges and public are aware of the remaining time.

A personal computer can be connected in a network node to concentrate and to register the information of all the tables (scoreboards). A computer file will have the point sequence of each table, along with the time (hour:min:sec) in which each point occurred. With this information, statistic can be generated also as a "replaying a game" can be done subsequently.

In table tennis clubs the scoreboard can be utilized with a third player carrying the count, or placing the keys of the keyboard under the table in each side, so that the players carry its own count.

Also it can be used for teaching to children, since the operation is very simple, once explained this, the children can carry their own count and the sequence of services.

With the use of additional pads placed over the table in specific places, training exercises can be done.

In fact, this scoreboard is useful for family use; in clubs; in training also as in tournaments. It can be used alone or to 255 scoreboards connected in network, it concentrating the information in a PC.

## 6- Comparisons

The majority of the commercial electronic scoreboards that have been found utilize screen of LEDs, generally with a greater quantity of digits (necessary for other sports) and some with wireless remote control and with sounds.

But none has the table tennis rules embedded, as the automatic indication of the player serving; the change of side in the last one set; the option of connection in network of to 255 scoreboards; the option of configuration in reception or mirror mode. These characteristics are special and unique in this design.

The cost of a commercial electronic scoreboard is greater than 300 USD. The cost of this design manufactured in small quantities is of less than 260 USD.

Because this design is specific for table tennis, it was done putting the useful indicators for this sport, avoiding showing more information that would cause confusions.

The keyboard was organized with the smaller quantity of keys in order to do it less confused and easy to use.

Although this version does not include sounds neither wireless keyboard, these are improvements to include in future versions.

## 7- Conclusions and Future Improvements

An electronic scoreboard specifically designed for table tennis facilitates its management and clarifies the information shown. In this work the table tennis rules were embedded.

The options added to this scoreboard are unique and they are not available in other commercial electronic scoreboards. They do it ideal for tournaments (the network connection; reception or mirror mode; the use of a PC to register and to monitor to all the scoreboards) also as for use in clubs (for teaching and training) and for family or recreational use.

This design is ready for the evolution and improvement. Already it is in test of a wireless remote control. Also sound will be added to indicate or to call the attention of

players and judges in situations that require it. Also it is considered to include a blinking in the display when occurs a change of the scoring.

In the training mode, the option of pauses will be added, as well as the count of these pauses, for the count of exercises repetitions.

The observations and criticisms of the users are welcomes and they are taken into account to improve the operation of this design.

To future also an intelligent control (judge console) will be implemented, in order to show the score with a small LCD display to the judge or person who carries the scoreboard. This console would communicate with the scoreboard through CAN, in such a way that the scoreboard will need to be in reception or mirror mode to show the score of the judge console. Because it use the CAN bus then the console can control all the scoreboards that be desired, showing the same information and allowing a better view to the spectators and to the players.

## **8- References**

- [1] Atmel 8-Bit Microcontroller with 12K Bytes Flash, Rev. 0787D-06/00.
- [2] Atmel SPI Serial EEPROMs 8K, 16K, 32K, 64K, Rev. 0675F-08/01.
- [3] ITTF Handbook, Chapter 2: Laws 2001-2002.