A Wireless Quiz System using Low Power Microcontrollers

Suraj G. Swami, Onkar N. Raut, Ipsita Acharya, and James M. Conrad
University of North Carolina at Charlotte, Charlotte, NC, USA
{sswami, oraut, iacharya, jmconrad}@uncc.edu

Abstract --- **One of the many important parts of any multi-participant quiz game show is the Player Selection System. All participating groups are equipped with a selection button placed in front of them which can be used by them to give a response. The Player Selection System determines the group that gives the first response. Many of these systems used today are wired systems that consume a considerable amount of power. This paper describes an easily installable, expandable robust wireless quiz system using a low battery-powered microcontroller interfaced with a RF wireless transmitter.**

I. Introduction

In a multi-group quiz competition, a question is put forth to the players and the one who responds first is the one who gets the opportunity to answer the question. This is done by visual, acoustical or electrical means. The problem with visual and acoustical means is that they often are not accurate methods for determining the first response. The requirement to determine the first response accurately motivates the need to have an electrical system for accurately selecting the participant giving the quickest response. The quiz system described in this paper is an electrical system that fulfills all the requirements of any ordinary quiz system with the added incentive of being wireless, which provides for added benefits such as ease of installation, portability, and reduced power consumption. Number of participants can also be easily increased as per the requirement. The proposed system eliminates the drawbacks of currently used hard wired quiz systems.

II. Motivation

The objective of selecting the fastest response in a quiz game can be successfully achieved by means of a wired electrical system. However there are a number of drawbacks when such systems are used. These need to be addressed before one can actually start using the system. They are as follows:

1. All wired systems need to be physically disconnected and reconnected for every use, as all components are coupled together by means of wires.
2. Wired systems cannot be used outdoors or in extreme environmental conditions, unless specifically designed for it. This specification can incur a huge cost in the design of the system.
3. Numbers of participants within the game are required to be limited and every additional participant adds a significant cost to the overall system by increasing the cost for wiring, input to the player selection box, as well as power consumption. Therefore for adding more players into the game would require permanent physical changes to be made to the system and internal circuitry which increases the complexity of the selection circuit.
4. Another drawback of any wired system is that one needs to properly install each component and if any problem exists, there is always the possibility of a loose connection due to wires or improper wiring.
5. The final drawback of wired systems is that they utilize an appreciable amount of power thereby adding to the functional cost of the system.

We can eliminate all of the above mentioned drawbacks of the wired quiz system by replacing it with a wireless quiz system that is operated using low power, low cost microcontrollers that are portable, inexpensive and robust. The advantage of having a wireless system is that one need not worry about factors such as correctness of installation, power input, number of players etc. The only action that the user of this product needs to take is to just power up the system and start using it.

III. System Overview

The developed system provides a solution based on the system requirements. The components of the system are described below.

A. Access Device: Quiz Master module

The following steps describe the order of operation of the Quiz Master module.

1. The quiz master module acts as the Access Device for receiving responses from the End Devices.
2. Before asking a question quiz master needs to press the reset button which makes the system ready to receive response from the player.
3. The first response received from any player is displayed on the LCD screen.
4. After getting the first response the Access Device does not receive any other response.
5. The quiz master must press the reset button before asking the next question.

978-1-4244-5855-4/10/$26.00 ©2010 IEEE

B. *End Device: Participant Modules*

The following steps describe the order of operation of the Participant Modules.

1. Participants use the end device to indicate their interest to answer the current question.
2. By turning on the power switch the end device becomes ready to give their response to the Quiz Master.
3. After the Quiz Master module indicates that it is ready, participants can start give their responses using their respective push buttons.

IV. Hardware Design

The hardware used for this system consists of an Access Point microcontroller, available with the Quiz Master, interfaced with a LCD module and multiple End Point modules available with the participant modules.

Figure 1. The Quiz Master and End Point devices.

A. ***eZ430RF2500*** *by TI*

It is a ready to use RF development tool. It contains the **MSP430F2274** which provides an excellent low power solution for the system described in this system. The microcontroller provides for handshaking signals (interrupts) to be used along with the Serial Peripheral Interface present on board used to communicate with the CC2500, the digital RF transceiver module. All data to be transmitted through wireless mode of communication is generated by the microcontroller based upon the status of the On-Board push button and the current condition of transmission and is pushed on to the CC2500 transmission stack. Once placed in the transmission stack, the CC2500 starts transmitting the data over the selected wireless channel with a 2.4 GHz frequency with the set conditions of the channel. The SPI communication is initialized in the 3 wire mode as there are no other slave devices besides the CC2500 and transmission/reception is done at a 1MHz clock speed.

Two different set of codes are written in C programming language for the system, one for the Access Point which refers to the Transceiver that continuously monitors the status of the players within the game and a second one for End Points that refer to the modules given to the participants to give a response. The operation of these codes is described in the Software Design section of this paper.

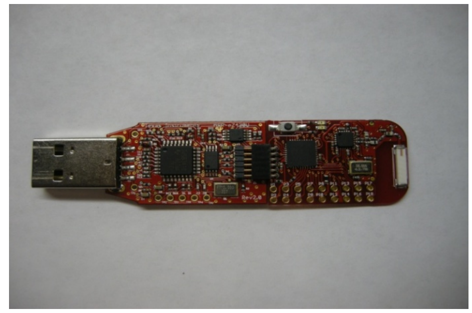

Figure 2. The Texas Instruments eZ430 RF Development kit.

B. *CC2500*

The CC2500, manufactured by ChipCon is a low cost RF transmitter and receiver used in many embedded wireless applications. It requires a minimum set of external components to be added to the pins in order to enable transmission and reception over a wireless channel. The chip has various special function registers (SFRs) that enable the user to modify the method of operation and communication. The baseband modem integrated into the CC2500 supports multiple modulation formats, data rates (up to a maximum of 500k Baud) and provides extensive hardware support for packet handling, data buffering, burst transmissions, clear channel assessment, link quality indication and wake-on-radio.

The major operating parameters, including the special function registers (SFRs) and the 64-byte transmit/receive FIFOs of the CC2500, can be controlled via an SPI interface. In a typical system, the CC2500 is interfaced with a microcontroller and a few additional passive components for successful communication.

In the case of the wireless quiz system, the Microcontroller used is the MSP430F2274. A ready to use RF development tool available in the market is the eZ430RF2500 by TI is used for the quiz system.

Before initiating transmission/reception, the CC2500 needs to be initialized to the desired transmission/reception parameters using the available 54 configuration SFRs configured by the SmartRF Studio Tool by TI.

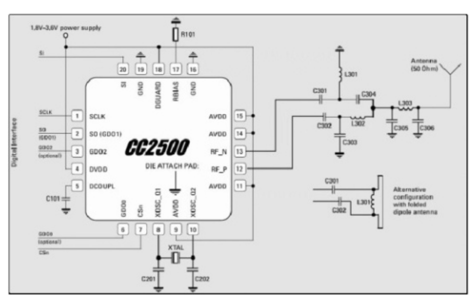

Figure 3. The Texas Instruments (ChipCon) CC2500 device.

C. SimpliciTI

SimpliciTI™ is a low-power RF protocol aimed at simple, small RF networks. This open-source software provides the network protocol for the MSP430 ultra-low-power MCU and a TI RF transceiver CC2500.SimpliciTi provides robust API to the services of the SimpliciTI protocol stack which is a low power proprietary network protocol architected by TI. It uses two communication modes, that is, peer to peer, broadcast and simple star with access point for store and forward to an end device. SimpliciTI even helps in making a device as range extender.

D. JHD162A LCD Screen

The JHD162A is 16 x 2 LCD module used to display ASCII characters. The LCD can display a total of 16 characters in a row and has 2 such rows.

The objective of having an LCD module within the system is to precisely determine the player id of the first responding participant, the instant after which any further transmission is restricted till the Access Point is reset manually. Hence it acts as a front-end for the quiz master.

V. Software Design

The software codes for the system were written with IAR Embedded Workbench for MSP430 microcontrollers.

All the running codes that were written include the standard definitions for the MSP430F2274. There are two different sets of codes that are required to run the system.

The first set of code was for the Access Point micro-controller (present with the Game Master) and the second one for the End Point microcontroller (present at the player end).

The code has SimpliciTI API's to communicate between the devices. For communication between devices a link is setup between the two communicating device. And then they communicate with each other using a generated Link ID during connection initialization. There exists an Unconnected User Datagram Link ID in SimplicTI which requires no connection initialization. All devices can send and receive data from this Link ID. We have used Unconnected User Datagram Link ID for system as it makes the end devices plug and play. And a new end device can be added to the system without any effect of functioning of the access device.

The SimpliciTI API also provides for switching off the radio when not required hence saving more power.

The pseudo codes described below:

A. Access Point

The following steps represent the pseudo code explaining the operation of the Access point:

1. Initialize Microcontroller and set desired port pin directions
2. Setup the interrupt.
3. Set address for the device.
4. Initialize the radio and SimpliciTI protocol stack.
5. Put radio to sleep
6. Run Infinitely
   - Go to sleep by turning the micro-controller in low power mode. (The controller wakes up on interrupt when the Quiz Master presses reset pushbutton)
   - Wake up radio
   - Wait for a message from the end device.
   - See Device number and display on LCD
   - Send the device number back to all devices. The device on which the device id matches will glow its LED.
   - Put radio to sleep

Interrupt Routine (push button): This wakes up the processor from sleep so that it executes one cycle of questioning.

B. End Point

The following steps represent the pseudo code explaining the operation of the Access point:

1. Initialize Microcontroller and set desired port pin directions.
2. Setup the interrupt.
3. Set address for the device.
4. Initialize the radio and SimpliciTI protocol stack.
5. Put radio to sleep
6. Run Infinitely
   - Go to sleep by turning the micro-controller in low power mode. (The controller wakes up on interrupt when the Quiz Master presses reset)
   - Wake up radio
   - Send self device ID as message on the Unconnected User Datagram Link ID
   - Wait for message from the Access Device.
   - If (msg_device_id = = self_device_id)
     - Glow LED
     - Delay
   - Put radio to sleep

Interrupt Routine (Push button): This wakes up the processor from sleep so that end device sends response to the access device indicating interest to answer the question.

C. LCD Driver

The LCD driver code is available with the Access Point. It is a standard code for 16 x 2 LCDs modified to be used with the MSP430.

VI. Low Power

The quiz system has one Access device and many End devices. Hence having low power end device is very important for this system, otherwise there will be a need to change the battery very frequently adding maintenance cost to the given system. We have reduced the power requirement by putting the radio to sleep and even switching the controller in low power mode when not in use. Before switching the device to the low power mode the radio is put into sleep mode using SimpliciTI APIs.

The MSP430 has one active mode and five software selectable low-power modes of operation. An interrupt event can wake up the device from any of the five low-power modes, service the request, and restore back to the low-power mode on return from the interrupt program. The following six operating modes can be configured by software:

1. Active mode (AM)
   a. All clocks are active
2. Low-power mode 0 (LPM0)
   - CPU is disabled
   - ACLK and SMCLK remain active
   - MCLK is disabled
3. Low-power mode 1 (LPM1)
   a. CPU is disabled
   b. ACLK and SMCLK remain active
   c. MCLK is disabled
   d. DCO's dc-generator is disabled if DCO not used in active mode
4. Low-power mode 2 (LPM2)
   a. CPU is disabled
   b. MCLK and SMCLK are disabled
   c. DCO's dc-generator remains enabled
   d. ACLK remains active
5. Low-power mode 3 (LPM3)
   a. CPU is disabled
   b. MCLK and SMCLK are disabled
   c. DCO's dc-generator is disabled
   d. ACLK remains active
6. Low-power mode 4 (LPM4)
   a. CPU is disabled
   b. ACLK is disabled
   c. MCLK and SMCLK are disabled
   d. DCO's dc-generator is disabled
   e. Crystal oscillator is stopped

When not in use and to have maximum power saving and longer battery life, we switched the controller to LPM4 low power mode. In our system the buzzer (push button) acts as an interrupt to the controller and wakes the controller.

VII. Security Issues

The security of the wireless quiz system is enhanced by the add-on security feature provided by the SimpliciTI protocol. This feature revolves around 5 important aspects for the designed system: A 32 bit Initialization Vector, a 32 bit counter, 128 bit key, one byte Message authentication constant and the counter window. The encryption scheme used for the system comes from the Extended Tiny Encryption Algorithm that produces a 64 bit encryption cipher stream from the 32 bit IV and 32 bit counter with the 128 bit long key. 8 bytes of the raw data to be sent from the application is then EX-ORed with the 64 bit cipher stream produced earlier. The encryption of data varies with each byte sent. This, however, is difficult for transmission over the UUD. Transmission over the UUD required us to set the first 3 bytes of the 32 bit counter to be kept zero and the control window which is the expected counter hint range is kept at 255. The counter hint is the least significant byte from the 32 bit counter that is transmitted at the head of the encrypted message. Also the message authentication constant for all devices is maintained common. This added a decent amount of security features to the system and prevents unauthorized access from rogue devices.

VIII. Testing

The current consumption of a unit, relates to the power consumed by the unit and also the battery life. We performed two tests to show the reduced power consumption by putting the radio in sleep mode and switching the controller to low power mode. In the first test, we put the CPU in Active mode and measured the current in the system when the radio was awake and when it was asleep (not in use).

Testing conditions and states	Radio in not in Sleep mode	Radio in Sleep mode
Waiting for push button press	21.28 mA	2.63 mA
One LED ON	24.80 mA	24.78 mA
Both LED's ON	26.47 mA	26.45 mA

It was observed that the system still drew some current waiting for press of push button. It is mainly because the controller was awake and polling for the port pin of switch. To show the reduced power consumption we observed the current drawn by the system when controller was polling for switch and when controller was in low power mode. In both reading the radio is in sleep mode.

Testing Conditions and states	Polling mode	Low power mode (LPM4)
Waiting for pushbutton press/interrupt	2.63 mA	0.1 µA

Hence to reduce the power consumption we put the radio to sleep and the controller into low power mode 4 (LPM4).

IX. Conclusion

This paper describes the successful development and implementation of a wireless quiz system using low power, low cost microcontrollers for usage in general purpose quiz applications. We tested the system for making a low power consuming wireless application. This functionality of low power and low cost can be used for a wide variety of wireless applications that run on battery and require long life time.

X. References

[1] Ivan Howitt, Wayne Manges, Teja Kuruganti, Glenn Allgood, Jose Gutierrez, James M. Conrad, "Wireless industrial sensor networks: framework for QoS assessment and QoS management". Transactions of the Instrumentation, Systems, and Automation Society (ISA), pp. 347-359, vol. 45, no. 3, July 2006.

[2] "Wireless Sensor Networks", edited by C. S. Raghavendra, K. M. Sivalingam, and T. Znati, Kluwer, 2004

[3] Datasheet of MSP430F2274, http://focus.ti.com

[4] Datasheet of CC2500, http://focus.ti.com

[5] SLAU227, eZ430-RF2500 Development Tool User's Guide (Rev. E)

[6] Documentation on SimpliciTI API's in packge "swrc099d.zip" available at http://focus.ti.com/docs/toolsw/folders/print/simpliciti.html