Low Power Microcontroller Based Simple Smart Token Number Display System

Rajesh Kannan Megalingam, Sreenath P S, Devidayal Soman, Jessin P A, Srikanth S
Amrita Vishwa Vidyapeetham, Kollam, Kerala, India.
Email: rajeshm@amritapuri.amrita.edu, sreenathpsmallan@ieee.org, dayal3656@gmail.com, jessinrules@gmail.com, srikanth.chelsea@gmail.com

***Abstract*: The inconvenience encountered in many public dealing places like restaurants, banks, canteens etc. where people normally follow queue system has called for many solutions to speed up and ease the dealings. In this paper we show a low power microcontroller based smart token number display system to overcome the inconvenience mentioned above. This system is used to display two digit numbers from 0 to 99 using two sets of display units, one being user display and the other, customer display. Using this system the customers need not wait in the queue but come to get their order once their token number is displayed in the large customer display. It consists of two portions: a display unit and a processing unit. The software design in the processing unit is accomplished using PIC16F877A microcontroller. The power saving mode is achieved by putting the microcontroller in sleep mode. A peripheral keypad is interfaced with the microcontroller. Each set of display unit consists of two seven segment displays which get input from a BCD decoder/driver operating in open collector configuration. The token number display system with low power mode mentioned here is unique in the sense that it is controlled by software to go in sleep mode to save power.**

***Keywords*: Sleep, Low power, Token number display.**

I. INTRODUCTION

In our university campus canteen token numbers are announced using microphone. It causes lot of confusion due to similarity in phonetics; such as 'seventeen' and 'seventy' sounds alike. Moreover customers sitting far from the counter are unable to hear the numbers being announced vocally. It is always observed that visuals catch attention immediately and clearly than acoustics. The present situation demands a token number display system. Tokens are distributed on 'first come, first serve' basis and as soon as the service is ready for the customer, the attendant has to just enter the token number which will be displayed on a large seven segment display with an alarm. The customer need not wait in the queue once their order is placed. They can have a chat or ease, till their token number is displayed and then can get their order.

Our system is unique in the sense that we put the entire system in the low power mode when the system is not in use, to reduce the power consumption. In the first part of the paper, the overview of the system is given which is followed by the brief working of each of the blocks in the system. In the final part of the paper we give the testing method, tools used, debugging and the experimental results. Also the estimated power consumption is tabulated.

II. GENERAL OVERVIEW OF THE SYSTEM

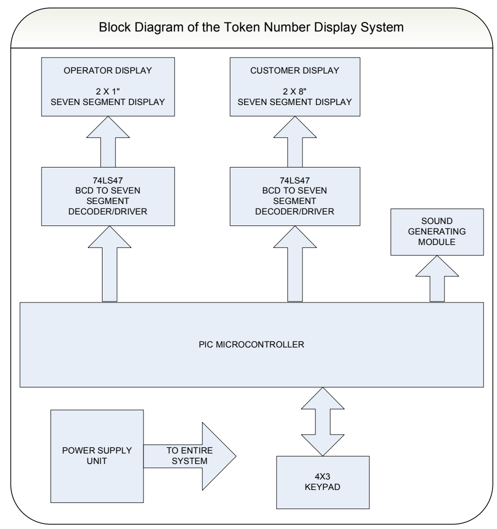

Fig 1. Block diagram of the PIC microcontroller based token number display system

The token number display system basically consists of six blocks as shown in Fig 1. They are as follows: PIC microcontroller – 16F877A, keypad, display units, 74LS47 BCD to Seven segment decoder/driver, and a 5V/12V power supply. A detailed description of each block is given below.

A. Microcontroller – PIC16F77A[1]

PIC16F877A is one of the most commonly used microcontrollers especially in automotive, industrial appliances and consumer applications. We use 40-pin DIP package of PIC16F877A which operates at a supply voltage of 5V and a frequency of 4MHz. Here we utilize the SLEEP instruction of the microcontroller to enter the power down mode.

1) Low power or Power down mode

Low power or power down mode is entered by executing SLEEP instruction. The I/O ports maintain the status they had before the SLEEP instruction was executed (driving high, low or high-impedance). For lowest power consumption in this mode, all the I/O ports are placed at either V_{DD} or V_{SS}, ensuring that no external circuitry is drawing current from I/O pin. The active low MCLR pin is kept at a logic level high. The device wakes up from SLEEP through external input on MCLR pin or PORTB change interrupt.

978-0-7695-3938-6/09 $25.00 © 2009 IEEE
DOI 10.1109/ICMENS.2009.42

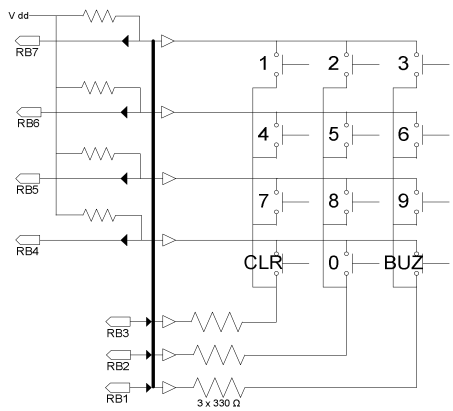

Fig 2. Circuit diagram of Keypad

B. Keypad

In this system we use 4x3 matrix keypad which reduces the I/O pin count to 7 which otherwise would be 12. Larger keypads show an even greater efficiency.

The internal circuitry of a 4x3 keypad is as shown in Fig 2. The four rows are read in via RB7:4 with internal pull-up resistors enabled. The three columns connected to RB1:3 can be individually selected in turn by driving the appropriate pin low, thus scanning through the matrix. The switch contacts are normally open and, because of the pull-up resistors, read as logic 1. If a switch connected to a low column line is closed then the appropriate row line is low. This means that once the closed key row has been detected the column: row intersection is known. The 330Ω resistors limit the current through the switch.

1) Debouncing

A key is a mechanical device with spring action. When a key is pressed/ released it takes a few milliseconds to settle to ON/OFF state. In the interim period, the contact may be made and broken repeatedly due to the vibration of the moving mechanism. The duration of the bounce and the high frequency of vibration associated with it depends on the key structure. During the bounce period the status of the key is not clearly defined. The effect of bounce can be nullified either using dedicated hardware or software.

Here the debounce is handled by the software program. One way of filtering out bounce and noise induced in the connections between keypad and the electronics is using a debounce subroutine. It scans the state of the keypad by keeping the previous reading in memory. It returns the key pad state only if no change occurs over a short period of polling. Usually a delay period is assumed over which the level of the key press signal should not change. The delay period depends on the quality of the keypad, ambient noise and processor speed.

C. Display

One of the most popular methods for displaying numerical data which can be understood readily by the user or operator uses a 7-segment configuration to form the decimal characters

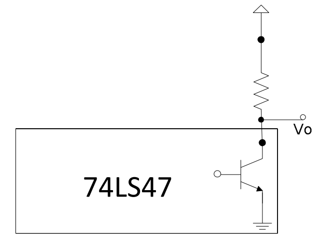

Fig 3. Schematic representation of open collector configuration of 74LS47

0 through 9. The display unit comprises of BCD-to-7-Segment Decoder/Driver and two sets of seven-segment displays.

1) 74LS47-BCD to seven segment decoder/driver

The PIC microcontroller can be directly used to drive the seven segment display. Due to the limited number of ports and limited current output of PIC give rise to the need of driver ICs. Another advantage of using the driver IC is that PIC can be programmed to output the BCD of the number resulting in interfacing two seven segment displays with PORTC and PORTD. The BCD code of the number is sent to 74LS47 BCD to seven segment decoder/driver [2] which provides the outputs that passes through appropriate segments to display the decimal digit.74LS47 has 25mA sink current in open collector configuration.

Fig 3. shows the BCD-to-7-Segment Decoder/Driver (74LS47) being used to drive a 7-Segment common anode LED readout. Each segment consists of one or two LEDs. The anodes of the LEDs are all tied to Vcc (+5V/+12V). The cathodes of the LEDs are connected through current–limiting resistors to the appropriate outputs of the decoder/driver.

a) Open collector configuration

The term open-collector typically refers to a transistor output where the collector (output) of the transistor is not connected to a positive voltage. Since a transistor used in outputs is a saturated switch, the collector needs to be connected to a positive voltage to complete the transistor circuit. This positive voltage need not be any specific value as long as it is above the transistor saturation level. Because of this, an open collector output can be connected to a range of voltages using a pull-up resistor. This resistor is required for the output to function as it completes the transistor's circuit. Many logic chips and circuits use open-collector outputs for reasons such as creating hardware logic and interfacing different voltage levels.

2) Display units

Display module consists of two sets of displays: operator display and customer display. When the user enters the token number to be displayed in the large seven segment customer displays mounted high on the wall, the same can be viewed by the user in the small 1'' seven segment displays placed next to the keypad. The 8" seven segment display is constructed by

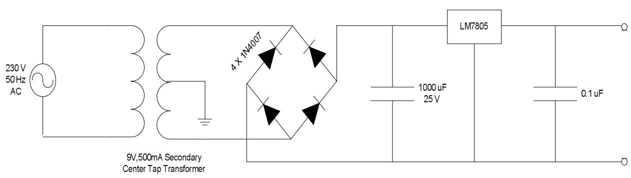

Fig 4. Circuit diagram of 5V power supply

mounting seven individual segments on a mica sheet. Both the displays are driven by the 74LS47 BCD-to-seven segment decoder/driver, which is interfaced to the common anode operator display through 330Ω current-limiting resistors. The open collector configuration of 74LS47 decoder is utilized to drive the large customer display, which requires an operating voltage of 8-12 V.

D. Power Supply

A 5V/12V DC supply is all that required for the working of the circuit. The microcontroller requires 5V supply for its working. The display driver ICs and the seven segment displays require the 5V/12V power supply for their proper working. The circuit diagram or the 5V power supply is shown in Fig 3.

A microcontroller based system requires a power supply which provides constant DC power. A transient on the power supply could result in system failure. The power supply unit designed is 5V DC and is not affected by variation in the AC serving as input to the transformer. A 230 V transformer is used with output voltage of 9V.

Four 1N4007 diodes are arranged to form a bridge rectifier, which converts the AC to DC and satisfies the charging current demands of the filter capacitor. The DC voltage varies above and below an average value. This variation is called ripple voltage. In order to reduce ripple voltage to a very small value, the DC voltage needs to be filtered. Filter capacitors of capacitance 1000 µF were chosen to reduce the ripple voltage contained in a rectified voltage, to a relatively filtered voltage which resembles a smooth DC voltage as much as possible.

The regulator receives the input of a fairly constant DC voltage and supplies, as output, a somewhat lower value of DC voltage, which it maintains fixed or regulated over a wide range of load current or input variation. The LM7805 regulator maintains a 5V DC supply voltage to the system. The main circuit diagram of the system is shown in Fig 4.

III. WORKING OF THE SYSTEM

The number entered through the keypad is given as input to the PIC microcontroller. The keypad is matrix 4x3 telephonic keypad. The microcontroller identifies the key with the help of a keypad scanning algorithm described later in the paper. Initially both the operator and customer displays are set to 00. It sends the corresponding BCD equivalent of the entered number to the 7447 BCD to seven segment decoder/driver which drives the operator display. When the 'BUZ' key is pressed, the numbers in the operator display are exhibited in the large customer display with a pleasant sound indicating the availability of service. The system takes care of the false triggering of sound system without entering token number. If the system remains idle, that is, no number is entered for a certain amount of time; the system enters the low power mode. To resume, the system is reset. The power supply unit provides the required power for the entire system.

IV. EXPERIMENTS AND RESULTS

The construction and implementation of the system was carried out in different stages in order to obtain the expected results. Overall system design was divided into modules which were individually designed and tested before the integration of the various subsystems. Software design was started in MPLAB IDE. A series of program was written in PIC assembly language. It was then compiled and simulated in the MPLAB environment. The MPASM assembler (the assembler) is a command-line or Windows-based PC application that provides a platform for developing assembly language code for Microchip's PIC microcontroller families. The version we used was MPLAB IDE 7.3. After satisfactory result was obtained the interactive simulation was carried out in Proteus. This software is a revolutionary interactive system level simulator developed by Labcenter Electronics. The version we used was Proteus 6.9 SP5 with Advanced Simulation. This product combines mixed mode circuit simulation, micro-processor models and interactive component models to allow the simulation of complete microcontroller based designs. The circuit diagram of the Token number display simulation in Proteus is shown in the Fig 5.

Initially the keypad was tested with a few set of LEDS. The connections and the conditions of keypad was thus verified. The seven segment displays were interfaced with 74LS47 BCD to seven segment decoder/driver to which the

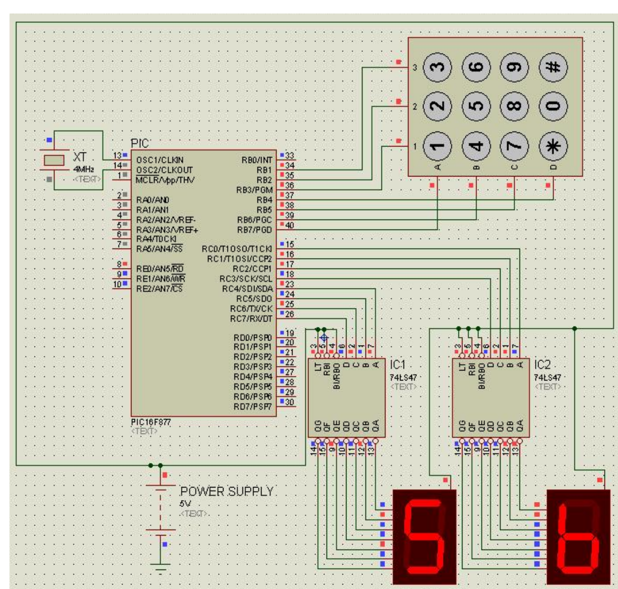

Fig 5. Proteus Simulation output

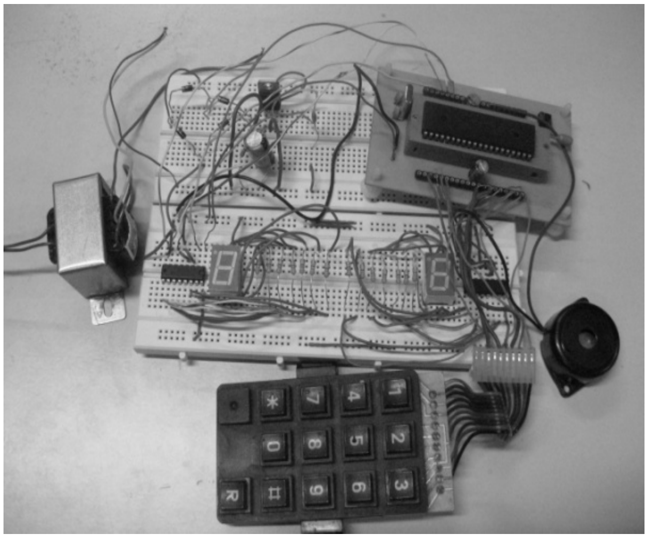

Fig 6. Testing of the system on a breadboard

BCD inputs were manually set to test the various conditions of the common anode seven segment display. The PIC was mounted on special base with oscillator embedded in it. The keypad and one set of display were assembled and tested with various input combinations. Before the results were obtained, the count for polling the keypad was obtained by trial and error. Fig 6 shows the bread board connections with PIC microcontroller, keypad and a set of displays driven by 74LS47 driver/decoder.

The larger operator display was mounted on a mica sheet. It is operated in open collector configuration with 74LS47 decoder/driver. Later a sound system driven by relay was interfaced with the PIC microcontroller to alert the customer.

V. SURVEY

Our university has three campuses. For this research work a survey was conducted in the university campus canteen at Amritapuri Campus. The canteen having a dimension 15m x 15m, has a capacity to accommodate 170 people at a time. It functions from 8:00am to 6:00pm, which can be classified as peak and non peak hours. The Table I illustrates findings of the survey.

TABLE I. DISTRIBUTION OF CUSTOMERS IN PEAK TIME AND NON PEAK TIME

	Duration	Average no. of customers
Peak time	8:00am – 10:00am	100
	11:30am – 1:00pm	150
	3:30pm – 5:00pm	100
Non – peak time	10:00am – 11:30am	20
	1:00pm – 3:30pm	40
	5:00pm – 6:00pm	30

TABLE II. ENERGY CONSUMPTION OF PIC16F877A AT V_{DD} = 5V, FOSC = 4 MHZ

Mode	Time in seconds	Order count	Energy consumption kWh	Total consumption kWh
Active	7500	300	4.17×10^{-4}	4.18×10^{-4}
Sleep	28500	nil	6.33×10^{-7}	

VI. POWER CONSUMPTION ESTIMATION

A. Power consumed by PIC microcontroller

The power consumption of the PIC16F877A microcontroller for supply voltage (V_{DD}) 5V at 20MHz clock frequency (P_{max}) is 1.0W. To find the power consumption at 4MHz clock frequency the following formula is used [3].

$$P = V_{DD}{}^{2} * f * C \qquad (1)$$

Substituting the values for P = 1 W, V_{DD} = 5 V and f_{max} = 20 MHz we obtain capacitance C = 2nF which when substituted in same formula with V_{DD} = 5 V and f = 4 MHz results in P = 0.2W. If only one token is issued the number will be displayed for 25 seconds when the order is ready. If more than one token is issued and more than one order is ready at a time, the time for which a token is displayed is reduced to 5 seconds. The PIC microcontroller remains active for 25 seconds before it goes into low power sleep mode for the worst case. As a worst case about 300 tokens are to be displayed at an interval of 25 seconds for one day, the PIC remains in active mode for 7500 seconds. The power consumption of PIC in sleep mode is 80 µW. The Table II shows the total power consumption of the PIC is active and sleep modes.

B. Power consumption of 74LS47 BCD to Seven segment Decoder/Driver

Typical power dissipation of 74LS47 BCD to seven segment decoder/driver is 35mW. it remains active until the system is switched off. Normally it remains active for about 10 hours. The Table III shows the total power consumption of 74LS47 BCD-to-seven-segment decoders/driver.

C. Power consumption of Seven Segment Display

The large seven segment display requires 8V and 36 mA per segment which is operated in open collector configuration of 74LS47. It dissipates 288mW per segment. In worst case where all the seven segments are switched on for it consumes 2016mW for each display which remains active until the PIC goes into sleep mode. The power consumption of the display unit in the sleep mode is zero since all the segments are turned off by applying logic level low to the zero blanking input to the 74LS47 BCD-to-seven-segment decoders/drivers. The Table IV shows the total power consumption of seven segment display.

TABLE III. POWER CONSUMPTION OF 74LS47 BCD-TO-SEVEN-SEGMENT DECODERS/DRIVER

Time in seconds	Power consumption (mW)	Energy consumption (kWh)	Total consumption (kWh)
36000	35	3.5×10^{-4}	1.4×10^{-3}

TABLE IV. ENERGY CONSUMPTION OF SEVEN SEGMENT DISPLAY AT VDD = 8 V AND ISEGMENT = 36 mA

Mode	Time in Seconds	Energy consu-mption one segment kWh	Energy consumption one display (7 segments) kWh	Total consumption (kWh)
Active	7500	6×10^{-4}	4.2×10^{-3}	8.4×10^{-3}
Sleep	28500	0	0	

TABLE V. TOTAL ENERGY CONSUMPTION OF THE LOW POWER TOKEN NUMBER DISPLAY SYSTEM VS CONVENTIONAL SYSTEMS

Sleep feature enabled	Total consumpt-ion of PIC microcon troller kWh	Total consum-ption of 74LS47 decoders/ drivers kWh	Total consum-ption of seven segment display kWh	Total consumption of the system kWh
yes	4.18×10^{-4}	1.4×10^{-3}	8.4×10^{-3}	1.022×10^{-3}
no	2×10^{-3}	1.4×10^{-3}	5.6×10^{-2}	5.94×10^{-2}

D. Total power consumption

The Table V shows the total power consumption token number display systems with sleep feature enabled and the system without low power mode.

From the Table V it can be inferred that a low power token number display system with sleep mode enabled consumes only about 7% of the total energy consumed by the conventional token number display systems.

VII. FUTURE WORK

The main limitations of this device are use of only two digit numbers from 0 to 99. Speech processing capabilities can be included to make announcements of the number being displayed using ICs like SP0256. The system can be interfaced with computer using USART (Universal Synchronous Asynchronous Receive Transmit) module of the PIC16F877A eliminating the telephonic keypad and thus making it suitable for the future scenario.

VIII. CONCLUSION

This is a unique microcontroller based token number display system which enters a low power state when kept idle for certain amount of time, reducing power consumption which is a great advantage in the times of energy crisis. This system consists of a 4x3 telephonic keypad to enter the token number which is identified by microcontroller and drives the display driver which in open collector mode drives the large seven segment display. The low power state of the system is attained using the *'sleep'* instruction which shuts down the module clocks while transmission/reception will remain in that state until the device wakes from Sleep. A customized seven segment display was assembled from individual segments which can be seen even from a few meters. When sleep mode is enabled this system consumes only about 7% of the total energy consumed by the conventional token number display systems without sleep mode.

ACKNOWLEDGMENT

We would like to acknowledge the Almighty GOD who gave us strength and health to successfully complete this venture. We also wish to express our heart-felt gratitude to Amrita Vishwa Vidyapeetham, in particular the Digital library, for access to their research facilities and for providing us the laboratory facilities for conducting the research. The authors wish to express their deep gratitude to all persons who helped them directly or indirectly towards the successful completion of this paper.

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