Designing and Development of a Low Power Electronic vending machine using PIC 16F877A controller

Manish Kumar, Vinay Kumar Deolia

Department of Electronics and Communication, GLA University, Mathura

manish.kumar@gla.ac.in, vinaykumar.deolia@gla.ac.in

Abstract – In this paper we present a Low Power 'Pay Power' Automatic Electronic Vending Machine design. A simple coin detection mechanism is employed to detect a coin of a single type and taking appropriate action using a PIC 16F877A microcontroller (switching a 230V power supply in this case).The programming process has been accomplished using standard application MPLAB IDE v7.60. PROTEUS v6.9 is used for simulating the entire system. The mechanical prototype to accept a coin has been ingeniously designed using a rectangular fiber case with metal detection terminals. The PIC microcontroller goes to low power 'sleep' mode when not in use there by conserving power. An experimental study at the end of the paper shows the amount of power saved.

Keyword: PIC, low power, vending machine, microcontroller.

1. Introduction

The demand for unmanned sales machines with enhanced security measures and reliable counterfeit detection procedure is growing all over the world especially in the small and medium sized business firms where the major concern is cost of operations to ensure maximum profit. A vending machine provides snacks, beverages and other similar products to customers without a cashier or a salesman. It accepts payment either in the form of coins or bills or both. Other general applications include initiate Pay-n-Use services like, issuing tickets, public call offices, Photo booths, arcade gaming, books and DVD vending, etc. Ours is an automatic, low power coin collection 'Pay Power' system for payloads like battery chargers, lamps, air-conditioners etc. Such a system finds use at paying guest houses, lodges, trains, mallsetc. The number of machines in the world is expressed in millions and the largest market share countries are U.S.A, UK and Japan. According to Japan Vending Manufacturers Association (JVMA), in Japan there are 5.5 million vending machines and the amount of money used in this machine is over 56 billion dollars. This value is around 33 billion dollars in USA. In European countries there are nearly 2-4 million vending machines and the value is around 15 billion £. Recently, the usage of vending has increased because of low cost of operation without salesman and the users beginning to use these systems more commonly. As the number increases, proper power saving mechanisms should be implemented to save wastage of power when the system is not in use.

2. Problem Definitions

In a typical vending machine, the entire system consumes energy even when not in use. Because of this there is enormous amount of power wasted. This impacts not only the cost but also the environment. In the

proposed design we try to reduce the energy consumption by using existing special features of the microcontroller. Though there are various ways for reducing energy consumption, in this paper we concentrate on using the low-power operation mode of the microcontroller [1].

3. Block Diagarm

Fig .1 shows the block diagram of the design. The major blocks are the coin collector, PIC and the switching circuit. Each of the blocks is briefly explained in the following sub- sections. The prototype consists of a coin dispenser which is a 35 x 3 x 2.5 cm cubical fiber case which acts as a passage for the inserted coin. The coin travels through the tunnel at the end of which, two metallic strips are attached that are actually the two open ends of the coin detection circuit. When the coin reaches the end of the tunnel and comes in contact with the two strips simultaneously, the detection circuit is completed which triggers the external interrupt line of the microcontroller. The microcontroller, in turn, activates the switching circuit that consists of a 6V relay which provides 230V power supply to the user. This supply will be un-interrupted till the preset limit is reached. Once the preset time expires the system goes back to the initial state and is ready to process the next request
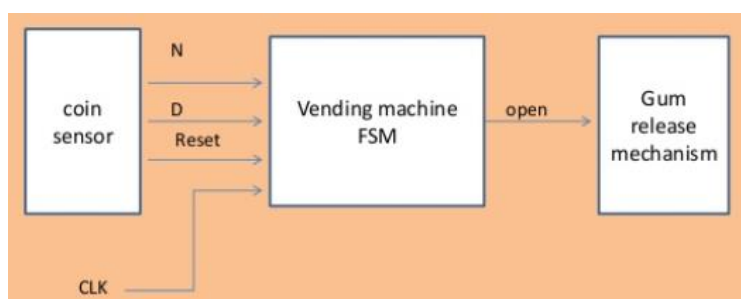

Fig.1 Block diagram 'Pay Power' vending machine.

A.   *Coin Collector*

It is a cubical tunnel as shown in Fig 2., whose one end is the opening slot through which the coin is has to be inserted. The apparatus is fixed at proper inclination to avoid wobbling motion of the coin through the tunnel. This will also ensure proper time delay for the coin to be in contact with the metal strips so that the detection circuit is completed. The insertion slot is of exact width (i.e. the diameter of a 2-rupee coin). The surface of the tunnel is smooth enough to avoid frictional interference. The metallic strips at the end of the tunnel are placed symmetrically and they are positioned in such a way that they do not interfere with the downward motion of the coin. The coin is collected at a repository beneath the collector setup.

B.   *Coin Detection Circuit*

The coin detection circuit is a simple electric circuit whose purpose is to generate a 5V signal used as an external interrupt to the microcontroller. As mentioned earlier, the two metallic strips at the end of the dispenser are the two open ends of this circuit. When the coin comes in contact with the two strips simultaneously, the circuit is completed for a very small instance at which a 5V signal is generated and is observed as an external interrupt by the microcontroller.

C.   PIC 16F877A Microcontroller [1]

It is 40 pin microcontrollers from Microchip Inc. The datasheet from the Microchip website has been used as the standard reference. The microcontroller is programmed in such way that the external interrupt generated by the detection circuit is observed at the RB0 pin of PORTB. The microcontroller activates the switching circuit after accepting four coins. This event occurs only when the user has inserted 4 coins (assuming that 1hour of 230V power supply cost Rs.20). This counter will not increment if the user inserts more than four coins as the maximum duration of per request is 15 minutes only. A seven-segment display is used to show the count of inserted coins. PORTD of the microcontroller is used to drive the seven-segment display.

D.   Amplifying Circuit

Even though we expect a 5V signal as output from the output pin of the microcontroller, the output current (25mA) is insufficient to drive the relay. Hence an amplifying circuit is employed to strengthen this signal to the required level. The amplifying circuit basically consists of a transistor appropriately biased to work as an amplifier.

E.   Switching Circuit

A 6V SPDT relay is used to switch the 230V power supply. The output from the microcontroller is amplified aptly before it is fed to the primary switch of the relay. This induces a magnetic field in the relay coil which, in turn switches on the secondary circuit which makes the 230V power supply available at the output interface.

F.   Output Interface

The output interface mainly consists of the 230V power supply line-out and a seven-segment display that displays the count of the coins inserted. The maximum value of count is preset as four. The user is expected to insert only four coins at a time.

4. Implementation

The system is implemented as six separate parts that are assembled together to form the prototype as described in the block level description. The entire circuit is designed and simulated using the simulation software Proteus v.6.90. Then the circuit is implemented over a circuit board and favorable output is obtained. The coin collector is crafted out from a left-over piece of window frame. The two ends are fitted with metallic strips for contact.

The coin acts as the medium that completes the detection circuit. A 5V power supply is used to drive the microcontroller. The event of coin detection is morphed as an external interrupt to the microcontroller and is received at pin RB0 by the microcontroller. The microcontroller is programmed in such a way that this interrupt increments a counter which indicates the number of coins inserted by the user. But the maximum number of coins to be inserted has been limited to four (two-rupee coins). Therefore, the system will serve a request for maximum of 15 minutes (which has been preset in the program) for a charge of Rs.8 only(2x4). The microcontroller is also programmed to drive a seven-segment display that would display the number of coins inserted. PORTD has been used to drive the 7-segment display. Here also the display will show a

maximum count of four even if the user inserts more than four coins for a single request. If the user has multiple requests, i.e. requires more time to draw power, another set of four coins has to be inserted again. When the microcontroller encounters four external interrupts, it sends out a 5V signal through the RB1 pin-out. BC 547 transistor connected to RB1 amplifies the signal and is fed to the primary circuit of 6V relay which induces a magnetic field in the relay coil. This field drives the secondary circuit of the relay which acts as the 230V power supply line-out.

Low Power Mode: The microcontroller has been programmed to go to low power mode if it is idle for at least 15 seconds by using the 'sleep' feature. This saves huge amount of power used to drive the microcontroller when it is idle. The PIC 16F877A microcontroller consumes 9mW of power when in operation. While in sleep mode, it consumes only 100nW of power. As there is a huge difference between the operational mode power and sleep mode power, putting the microcontroller in sleep mode when not in use leads to enormous amount of power saving. Sleep mode in PIC16F877A is designed to offer a very low current power- down mode. The INT interrupt can wake-up the processor from Sleep if bit INTE was set prior to going into Sleep. The status of global interrupt enable bit, GIE, decides whether or not the processor branches to the interrupt vector following wake-up [1].

Fig 3 shows the entire system simulation using Proteus software [3]. The assembly code for the entire design is written and simulated using the MPLAB IDE from Microchip [1]. The program to be downloaded into the PIC in real time circuit is downloaded into PIC shown in the system simulation diagram. Fig 2 shows the circuit setup as we tested in the lab. The cubical coin collector is shown placed over the bread board in the figure. The switching circuit is placed near the power supply.

5. Experimental Study

A case study is conducted to arrive at the power consumption amount. In this case, a typical 'Pay Power' system is assumed to be used from 6am until 6pm which is considered as peak hours in a day. The system is assumed to be idle in the remaining hours. The peak twelve-hour duration is divided in 48 slots each of 15 minutes. Each slot is available to the user after inserting four coins. During week-ends, the usage might be as low one user. During week days, the usage might be as high as 48 users. Based on this assumption, the power consumption and power saving estimation are given in Table I.
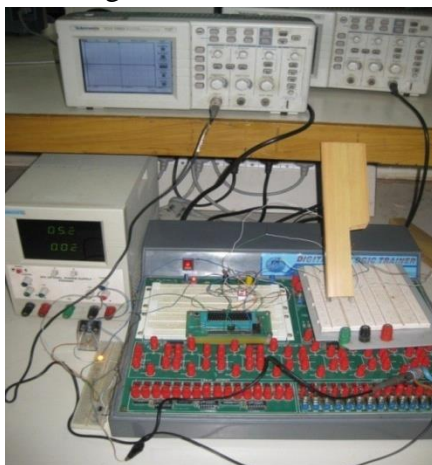

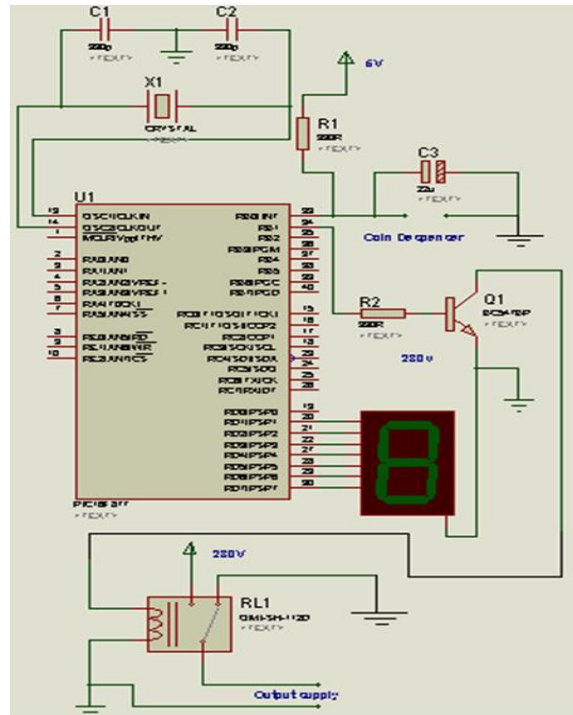Fig.2 The Set-up showing the Experimental Vending machine

Fig.3 System Simulation in Proteus.

The first column in Table I shows the number of users ranging from 1 to 48. The second column gives the total time in minutes varying depending upon the number of users each of 15 minutes slot. If the PIC microcontroller's sleep feature is not enabled then the amount of energy consumed by the PIC for twelve hours is given in the third column. This figure will not vary as it is independent of the number of users. The fourth column shows the energy consumption when the PIC's sleep feature is used. For example if the number of users in only one, then the PIC will be in full power mode for 15 minutes only. Remaining 715 minutes of the 12 hours duration, it will be in sleep mode leading to 96.83% of energy saving.

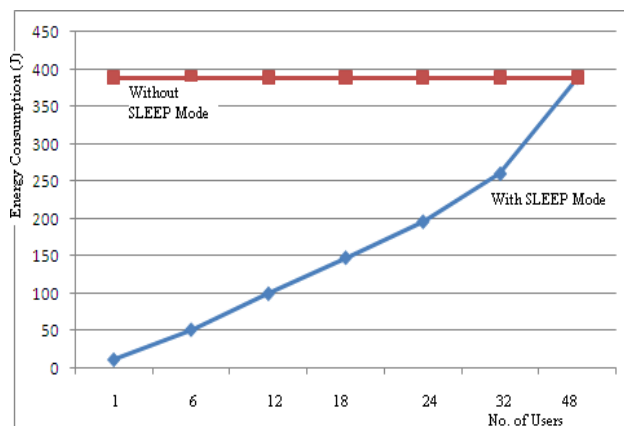   TABLE I. ENERGY CONSUMPTION COMPARISON OF THE VENDING MACHINE WITH AND WITHOUT SLEEP MODE

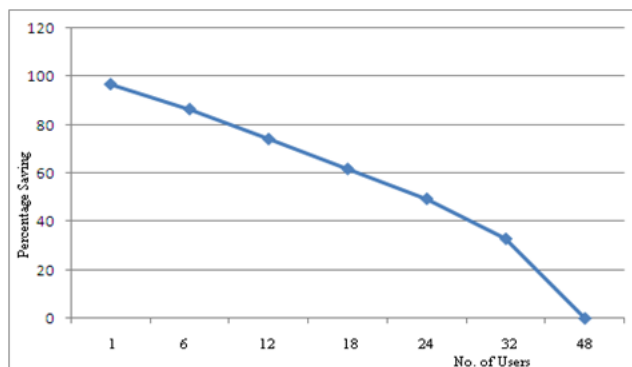Fig.4 Graph which shows the comparison of Energy consumption

Fig.5 Graph showing the relationship between Energy saving and no. of Users

Fig 4 shows the graph of energy consumption versus no. of users. We see here that, as the number of users increase the energy consumption also increases during the sleep mode operation of the microcontroller. When the sleep feature in not enabled the energy consumption is a flat line which is constant even when the system is not in use. Fig 5 shows the graph of% saving of energy consumption. The % saving is high when the number of users is low. Any generic case where the system is in use for about 50% of the time, the % energy saving is still around 50%.

There were quite a few challenges that came in the due course of the implementation of the prototype. They are discussed below in the chronological order of their occurrence:

A. Designing the setup

The team members came up with different ideas that were either too complicated or were error prone. There were some designs that incorporated complicated circuitry and components like laser diode and LDR etc where light interruption is used for coin detection. But the idea that has been taken up for the prototype is much simpler and also acts as a metal detector. Even this setup might face problem as the distance between the metal strips must be very accurate to pass the coin. Otherwise the coin will get stuck in between the metal strips.

B. De bouncing of switch

We used the inserted coin to complete the detection circuit or in other words it acted as a mechanical switch that provided the interrupt. But initially, even a single contact of the coin with the metal strips resulted in multiple interrupt generation. We found that this was because of bouncing which is general in mechanical switches. This was overcome by implementing de-bouncing mechanism in the firmware.

C. Amplification

As mentioned before the output current from the microcontroller was not strong enough to drive the relay. Amplifying circuit was employed to overcome this issue.

D. Spike generation

After the completion of a request, when the coin counter is being reset a spike is observed which increments the counter even before the insertion of next coin. This was due to an unwanted interrupt generated by the

504

spike. The issue was solved by introducing a 22µF in parallel to the RB0 pin which is the pin for accepting the external interrupts.

6. Conclusion

A simple, yet efficient low-power 'Pay Power' electronic vending machine has been developed. It is very economical and ideal for small and medium scale business firms that are looking at economically efficient and reliable system to expand their functionality. The system is capable of acting as a 230V power supply unit whose services can be utilized on a Pay-per- use basis. It can be installed at common public places such as railway stations and trains, bus stations, shopping malls, banks, hospitals, convention centers and other such places and can be utilized to charge laptops and mobile phones and could also serve as charging-station for hybrid automobiles in future that would run on electricity. The experimental case study showed that there is huge amount of power saving using this system.

References

[1] T.R Padmanabhan 'Introduction to microcontrollers and their applications', Narosa Publication.

[2] Arun Kumar Singh, 'Microcontroller and Embedded System', 1st Edition.

[3] Programming and Applying of the Multiple Product Disrtibution System by using PIC16f877A Microcontroller', Özcan Varul and Melih İnal, International Confe

[4] Manish Kumar and Vinay Kumar Deolia, "Performance Analysis of Low Power LNA using Particle Swarm Optimization for wide band Application", Vol. 111, pp.152897, International Journal of Electronics and Communication, Elsevier, 2019.

[5] Aasheesh Shukla, Vishal Goyal, Manish Kumar, Vinay kumar Deolia, and Munesh Chandra Trivedi "MMSE based beam former in Massive MIMO IDMA downlink systems", Journal of Electrical Engineering.71(1), march 2020

[6] Kalra D., Kumar, M., Shukla, A., Singh, L., & Jeffery, Z.A, "Design Analysis of Inductor less Active Loaded Low Power UWB LNA using Noise Cancellation Technique" Journal of RF Engineering and Telecommunications.74(3-4), Jan 2020

[7] Manish Kumar and Vinay Kumar Deolia "A wideband design analysis of LNA utilizing complimentary common gate stage with mutually coupled common source stage" Analog Integrated circuits and Signal processing, Springer, **volume 98**, pages575–585(2019)

[8] Vishal Goyal, Puneet Mishra, Aasheesh Shukla, Vinay Kumar Deolia, Aarti Varshney, "A Fractional order Parallel Control Structure Tuned with Meta-Heuristic Optimization Algorithms for Enhanced Robustness". Vol 70 (1), pp. 16-24, *Journal of Electrical Engineering, 2019.*