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Design and Implementation of Customized Enhanced Patient Calling Device Using PIC Microcontrollers

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Abstract: *In both traditional and electronics based system of queue, queue management is still an issue for both customer and facility manager, especially in medical facilities. In the traditional queue, patients sit in chronological order and then continuously shift forward as early comers go into consultation with doctors. In this arrangement, order is usually disrupted when a queuee leaves and wanted to return to his former position. On it part, the electronics based queues call patient by means of dedicated electronic hardware but fails to account for absent queuee. While the problem of arranging patients in chronology order of arrival had been solved with the introduction of electronics queue management system, the issue of absent queuee is still beyond present technology even the most advanced system in which patient calling system is linked with patient database that solves the problem of physical file movement. The Enhanced Patient Calling Device [EPCD] is a microcontroller-based queue management system designed with the ability to handle absent patients from the queue in the form of a 'slot-back', using 'slot-back model equation' coded onto PIC18F45K22 and PIC16F877A microcontrollers. The developed device presented here is capable of electronically queuing patients for consultation with doctors, enables a doctor to send patient to pharmacy or other units within the facility, allows the doctor to slot-back an absent patient, and permits the doctor to attend to other issues like emergency via the use of 'busy' key.*

Key words: *Queue management, Slot-back model equation, Patient calling, absent queuee, and Microcontroller*

1.0 Introduction

The customized enhanced patient calling device (EPCD) is a microcontroller based electronics device, designed depending on the prevailing situation in a specific medical outfit in order to help medical workers to manage queues. It works by electronically queuing patient in chronological order with extra ability to take care of patient(s) that is/are absent on the queue when called (absent queuee) using the slot-back model equation in Aboaba , Abideen, & Dibal (2017). Thus, leading to drastic improvement in managing patient's queues. Traditionally patients that come to consult with doctor in the hospital sit in a chronological order, with patients facing the problem of lengthy queues and unpredictable waiting time. This situation is still in existence in the developing countries. This method of managing queue results in stress especially for seriously ill patients and even the facility staff related to queue management. In advanced situations, an electronics calling system is used where patients are tallied and the tally number is displayed on a screen when it is the turn of the patients to consult with the doctor, and files are collected manually at the record office and then arranged before the doctor. In a more advanced situation, the electronics tallying and calling system are linked with patients' electronics database in which a called patient medical record appears on the doctor's PC from where he reads and writes his observation and prescriptions and passes the record to the next location. However, all the aforementioned queue management systems do not take care of patients that are absent from the queue as at when called (absent queuee).

2.0 RELATED WORKS

Many research works had been presented aimed at addressing specific area in queue management in general and patient queue in particular. In Mucsi (2011) an Adaptive Neuro-Fuzzy Inference System for estimating the number of vehicles for queue management at signalized intersections was proposed. The main purpose of the work is only to count the number of vehicle approaching and leaving a traffic junction but work succesfully at the prototype level. It can also be expanded to work in real life. Basil & Aswin (2013) presented a novel intelligent System for Efficient Queue Management.The system was tested and the results show a lot of efficiency in managing queue for the public places but the system was unable to call out token numbers with speaker and can handle only 100 customers. Software based Queuing Model for Health Care Pharmacy was also proposed in Mohammed et al (2015). The main purpose of the work is to manage queue for outpatient pharmacy workflow in the hospital. But it only stops at the prototype and also does not have the capacity for slot-back which enables the patient to attend the call of nature and other exigencies. The use of GSM Technology in queue management was reported in the work of Arun & Priyesh (2013). The design was tested and found to be working according to the specification but the system cannot get location of the customer and cannot calculate distance between customer and the service area. Ramasamy & Chua (2012) advanced a new way of queue management which is electronics based with SMS notification. At the beginning, a queue management devise will issue a queuee with ticket and the device later announces the ticket number when service is available. This eliminates the need to stand in line while waiting. This work was design to manage queue in banks and does not have the ability to handle slot-back if a customer is absent. More so, the design stops at the prototype, cannot handle search function and does not generate customer information by range of date. Bhupender et al (2017) proposed a heterogeneous queuing system with reverse balking reneging but the limitation of the work is that it is limited only to two heterogeneous servers and does not have capacity for slot back. Bylayat et al (2011) designed a microcontroller-based systems aimed at maintaining queues with order and efficiency using two different queue control systems. The two systems were implemented with slight difference features resulting in EQC system-1 and EQC system-2. EQC system-1displays token number and service counter number whereas EQC system-2 display token number individually in each service counters with separate displays. However, the system cannot determine the total number of customers per certain time. The description of the implementation of paperless queue management system with the aid of Arduino UNO microprocessor board was presented in Jidin & Yusof (2016). The system has the potential to reduce paper usage at customer service premises. Furthermore, it also provides additional features such as SMS Reminder generation and ability to process remote ticket requests via SMS which allows more efficient queue management. However, there are rooms for improvement, to make the system more useful, more reliable and effective. It may contribute to green technology.

Furthermore, Rashid at el (2016) proposed a system called Automation of Queue Management System for organizing queuing systems; it works by initially analyzing the queue status and then takes decision as to which customer to be served first. The work focuses on the banks queuing system, and different queuing algorithm approaches which are used in banks to serve customer and the average waiting time. The queuing architecture model can switch between different scheduling algorithms according to the testing result. However, the work stops at prototype and camera is also needed for the bank manager to see customer from far away. An attempt to retain bank customers at the ATM points who are dissatisfied with lengthy queues and unpredictable waiting time was implemented only to the level of simulation by Rahman (2013). The work of Aboaba, Dodo, Umar, Samuel, &Amaza (2015) tries to solve the problem of inability of both the traditional and modern queue system in handling absentees. It is a microcontroller based system that tallies patients and displays the tally number on the LCD, and also has the ability to handle absentees in the form of slot-back model equation. However, the work only end at the prototype stage and the slot-back model equation is deficient. Nevertheless, the deficiency in the slot-back model equation was corrected in Aboaba et al (2017).

The current work is an improvement on Aboaba et al (2015) and Aboaba et al (2017) in that both the slot-back model equation and hardware implementation have been modified and implemented in real life. Thus, an absent patient would be slot-back into the queue owing to the slot-back position (SbP) equation already coded into the microcontroller, the equation is given as:

$$SbP = LAT\ A \times \frac{1}{(\frac{ACT}{NDD})} + C \quad \ldots\ldots\ldots\ldots\ldots\ldots..(i)$$

where: LATA is Longest Average Time of Absence
ACT is Average Consultation Time
NDD is Number of Doctor on Duty

3.0 Methodology

The focus of this study is to design and implement the enhanced patient calling system (EPCS) using parameters like LATA, ACT, and NDD derived from data collected from University of Maiduguri (UNIMAID) Medical Centre. Owing to the plan to enable EPCS to handle absentee patient (queuee) in the form of slot-back, the needs of a patient on queue that will warrant him/her to leave the queue were determined. These were found to be needs like snacking, and attending to call-of-nature (visiting conveniences), hence the needs were parameterizing into quantifiable units of action Aboaba et al (2017). As reported in Aboaba et al (2015), the methodology adopted for this work is to data collection and analysis, and resulting into mathematical model of the slot-back position (SbP) equation Aboaba et al (2017). These culminated into development of circuit for the implementation of EPCS.

a. **Field work**

To know the position to be reserved (known as slot-back) for an absentees' patients, there is need to know and record the average consultation time per patient, average number of patient that could be consulted per day, average number of Doctors present per day, the availability of conveniences within the medical centre, and the total time taken to go and return from the nearest snacking point to the medical centre owing to absence of one in the centre premises. Several days were spent recording the time spent by individual patient with the doctor (consultation time), and at the end, the average consultation time (ACT) per patient was determined.

b. **Survey**

For the survey, questionnaires were distributed among students and staff living on campus whose primary health care facility is the University Medical Centre to determine the time taken by individual to complete those activities deemed expedient while on queue. Eighty-eight percent (88%) of questionnaires distributed were returned and the received questionnaires were then analyzed and the average time it takes to complete any of the three (snacking, urinating, excreting) activities when sick was determined.

c. **Summary of Field Work Results and Data Analysis**

In this section, a summary of major indices in all data analyzed are presented in tabular form in table 1

Table 1: Summary of Major Findings

S/N	***ACTIVITY***	***TIME in Minutes***
1	Average Time for Snacking (ATS)	15
2	Average Time for Urinating (ATU)	7.5
3	Average Time for Excreting (ATE)	12.5
4	Average Time Taken to and fro from Snacking point (ATTS)	9
5	Average Consultation Time (ACT)	3

Based on the assumption that an absentee patient must have gone for the activity that takes the longest time, hence the average of the individual treks was found and added to the average time taken to snack. At the end, the longest average time of absence (LATA) of the patient called Longest Average Time of Absence (LATA) was defined

$$LATA = ATS + ATTS \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (ii)$$

3.1 The Model Equations

Based on the activities and time taken in table 1, a model equation was derived from the data analysis. The model equation was used to determine when next to recall an absent patient who has been queued before leaving, and invariably at what position he/she would be slot-back into the queue from the time his/her token number was displayed. This resulted into equation (i) called slot-back position equation derived in Aboaba et al (2017). It should be noted that equation (i) is a linear equation with NDD being the dependent variable that may vary from time to time even within a day. LATA and ACT are hospital specific, while C is a constant which could be zero (0) or one (1).

$$SbP = LATA \times \frac{1}{\left(\frac{ACT}{NDD}\right)} + C \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (i)$$

In which: LATA is Longest Average Time of Absence

ACT is Average Consultation Time

NDD is Number of Doctor on Duty, and

C = Ñ, & 0≤ C ≤1, in which C is 1 when mx is a natural number, and C is 0 when mx is non-zero real number round up to the nearest whole number.

3.2 Enhanced Patient Calling Device Design and Evaluation Algorithm

The Enhanced Patient Calling Device (EPCD) design algorithm is an outline of sequence of steps taken to actualize the device, the flowchart of the device design, and it also includes evaluation algorithm of the device.

3.5.1 EPCD Algorithm

Step one: The Slot-back Position (SbP) Equation is programmed into the Microcontroller in Assembly Language.
Step two: The two slave Microcontrollers were also programmed in Assembly Language.
Step three: The two slave Microcontrollers were linked to the Master Microcontroller via COM PORT.
Step four: In conjunction with other discrete components that supports the Microcontrollers, the device is first implemented in PROTEUS Environment.
Step five: The PROTEUS Environment version of the EPCD is simulated.
Step six: The EPCD was then assembled on Breadboard.
Step seven: Conduct specification test on the Breadboard version of the EPCD.
Step eight: Transfer the device onto Circuit board.
Step nine: Conduct specification test on the Circuit version of the EPCD.
Step ten: Evaluate the performance of the EPCD following the test sequence in section 3.5.3

3.5.2 EPCD Design Program Flowchart

Figure 1 shows the flowchart which described the working of the device.

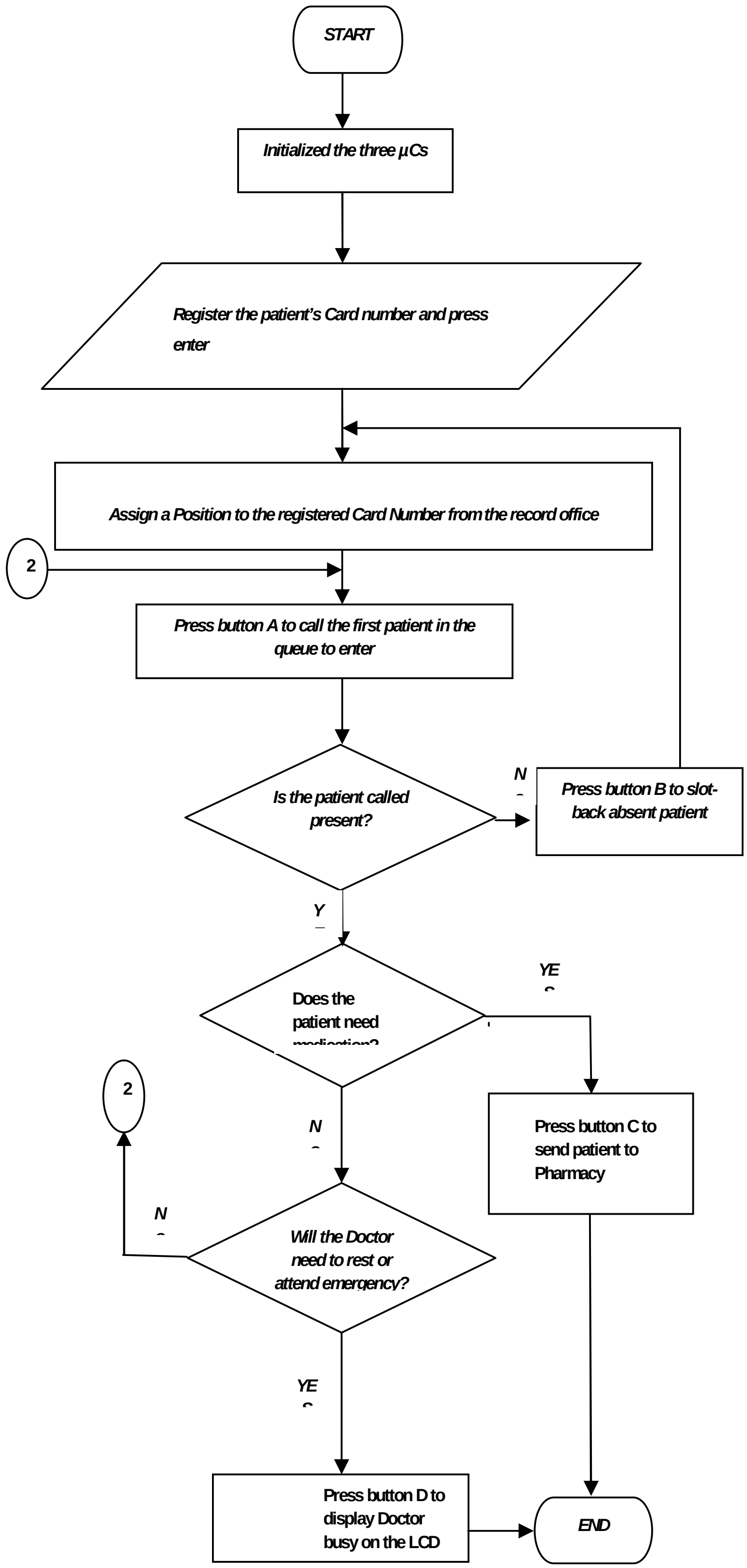


Fig.1: Flowchart diagram of EPCS

3.5.3 Enhanced Patient Calling Device Evaluation Algorithm

The evaluation algorithm is a sequence of steps to test for the functionality of the different parts/aspects of the device.

Step one: Microcontrollers of the EPCD were initialized.
Step two: Patients were queued on the EPCD using tally numbers according to arrival sequence.
Step three: The doctor pressed button A to call up the first patient on the queue; the tally number will be display on the LCD so that all the patients on the queue can see.
Step four: If patient is not around button B is pressed by the doctor to instruct the microcontroller to slot-back the absentee patient (queuee) by automatically inserting the absent queuee tally number in the queue using SbP Equation embedded into the Master Microcontroller.
Step five: Else, patient is present; the doctor will attend to him.
Step six: If the patient attended to needs medication, his tally number will be is sent to pharmacy unit by pressing button C.
Step seven: If the patient attended to does not need medication; meaning the patient need to leave from the consulting room, the Doctor calls the next patient by pressing button A.
Step seven: If the Doctor needs to rest, he presses button D; Doctor resting is displayed on the LCD.
Step eight: The Pharmacist presses button E to call up next patient in the pharmacy unit queue, and the patient tally number is displayed on the pharmacy unit LCD.

3.6 ENHANCED PATIENT CALLING DEVICE DESIGN

Since in the hospital there is only one pharmacy, one record office and even though there are more than one consulting room, only one consulting room is provided for in the design. The microcontroller in the Doctor's office served as the Master while the microcontrollers in the pharmacy and the record office will respectively serve as the slave2 and slave1. The medical record tallies the patients, and the tally number and the patient file number are saved in the memory of the Master. The Doctor then initiate call from his device, after consultation, he presses another button to send the patient to the next point or discharge him/her altogether. Microcontroller PIC18F45K22 was chosen as the Master, while PIC16F877A is slave1 and PIC16F877A is slave2 as shown in figure 2

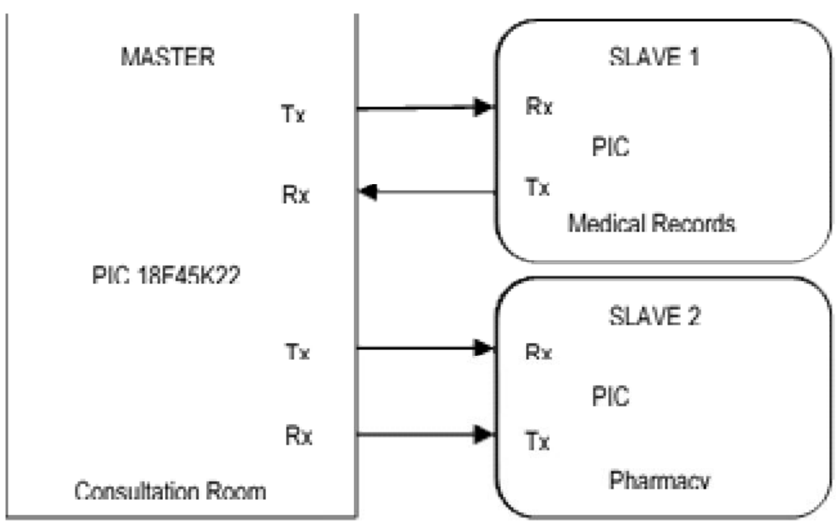
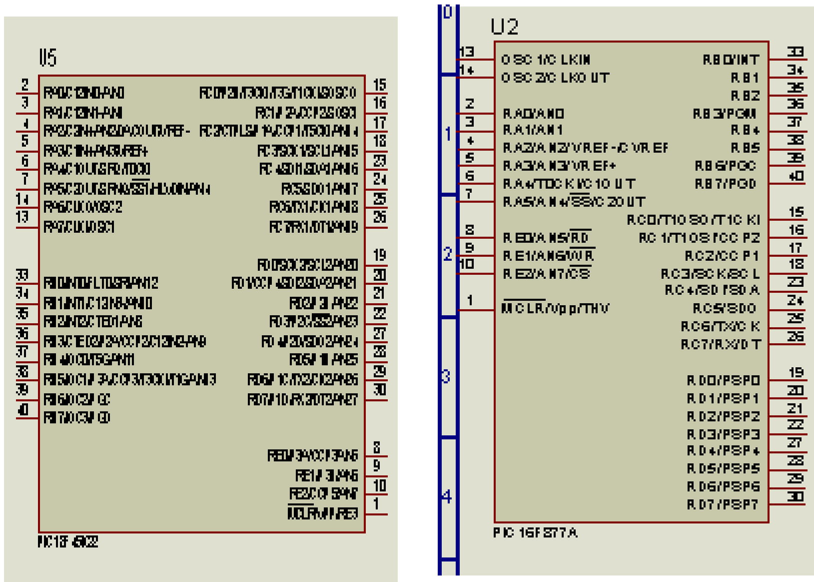


Fig 2: Design Block Diagram

The Master microcontroller (PIC 18F45K22) has two Universal Asynchronous Receiver Transmitter (UART) ports situated on pins 25 &26, and pins 29& 30 that is Tx1 & Rx1, and Tx2& Rx2 respectively. More so, the two Slave microcontroller used are of the same type (PIC 16F877A) having one UART port each. The port is on pins 25 & 26, that is Tx & Rx. Each one of the UART of the Master is connected to the UART of one of the Slave named Slave 1 and Slave 2 respectively. Figure three shows Master-Slave configuration.



As shown in figure 4, each of the microcontrollers is connected to their respective LCD Display to display patient's tally number and beside the LCD; the slave1 microcontroller is also connected to the keypad to enable the medical record officer to enter patient's card number on first-come-first-serve basis.

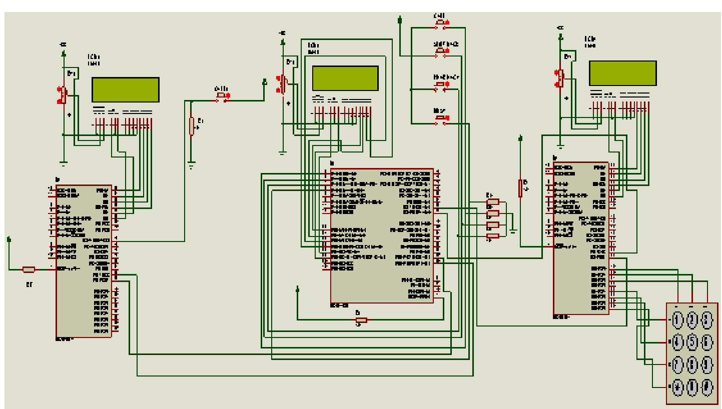
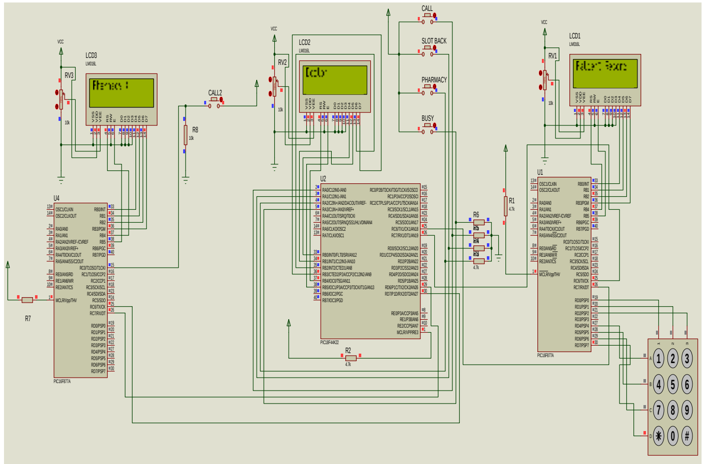


Figure 4: Interconnection of Master-Slave Microcontroller in Connection with LCDs

4.0 IMPLEMENTATION AND TESTING

Following the algorithm design and the flowchart, and using programmable microcontroller ICs (PIC16F877A and PIC18F45K22), the source code was compiled using micro C COMPILER. Proper consideration was given to the code during compilation in



order to avoid any logical errors. The test-run was done using interactive electronic simulation software called Proteus 8.5. The hex file was then generated and transferred to the PIC18F45K22 and the two PIC16F877A Microcontroller, using Kit3 USB programmer. The design was simulated on a computer to study and analyze the behavior of each stage before physical implementation was carried out, the implementation was finally assembled on Vero board after it initial assemblage on Bread board and tested.

4.1 SIMULATION RESULTS

Figure 5shows system initialization immediately after switching ON.While figure 6 Shows patient's number being inputted into the system via keypad.

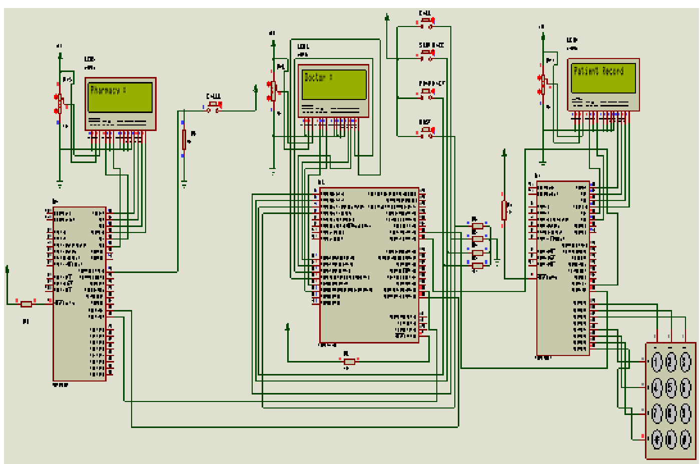


Figure 5: Simulation Results

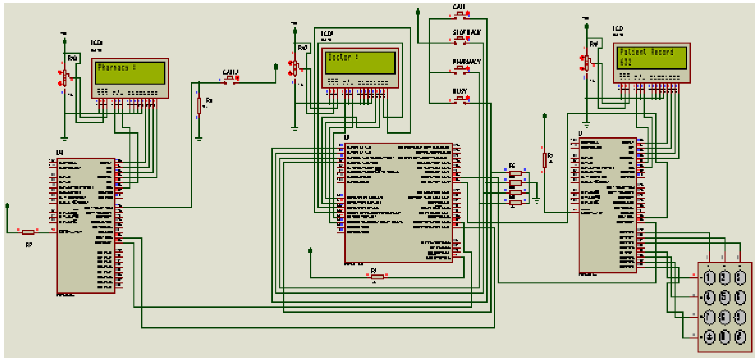


Figure 6: Inputting Patient's number into the system

In figure 7 and 8, the Doctor calls a patient by depressing the switch A (call button) and the recordedpatient number is shown on the LCD connected to the microcontroller controlling the consulting room devices. The card numbers had been previously stored in the system, and patients with card numbers 5 and 96 are called successively.

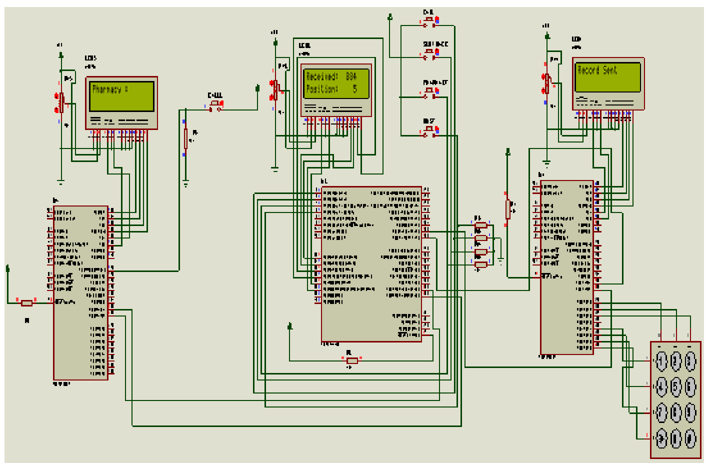


Figure 7: Doctor calling patient with card number 5

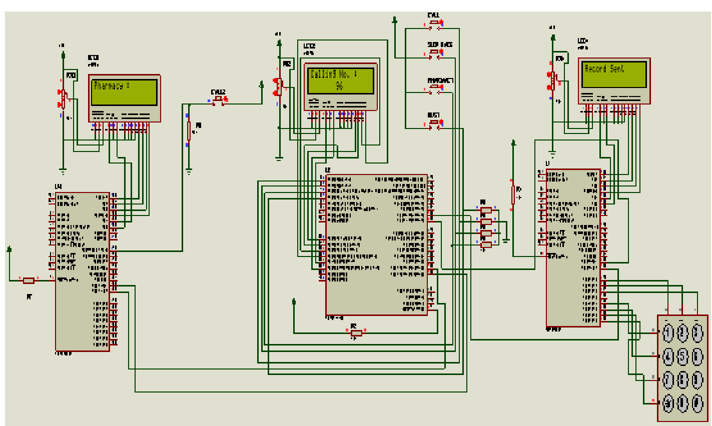


Figure 8: Doctor calling patient with card number 96

In figure 9, Pharmacist is shown calling patient with card number 057 sent by the doctor. The button for sending patients to the pharmacy from the consulting room is switch C.

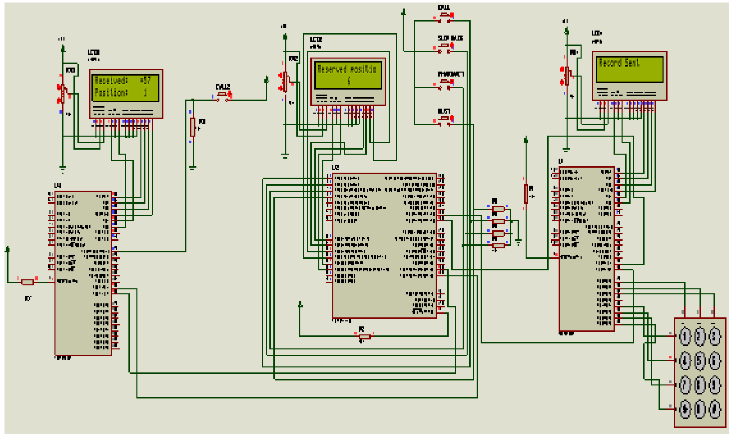


Figure 9: Pharmacy calling patient with card number 057

With respect to an absent queuee, the slob-back process is shown in figure 10 in which the absent queuee is slob-back into position 5 based on the slot-back position equation.

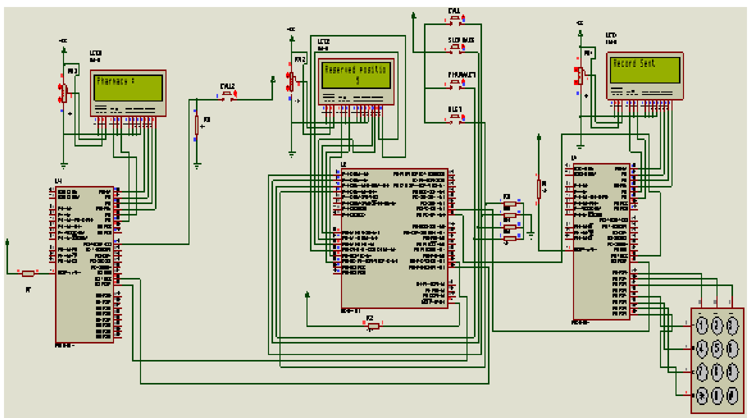


Figure 10: Absent patient (queuee) slot back into position 5

4.2 DICUSSION OF RESULTS

When the system is ON it will initialize the three microprocessors, then the clinic record office tallies the patients (the patient card number is registered on the system and it is automatically queued by the system and saved in the consulting room microcontroller) via the system's number keyboard connected to the microcontroller dedicated to the clinic's medical record office as shown in the simulations above. At the Doctors' side, four switches were provided labeled (A, B, C, and D) in which all the switches have specific functions to perform. The doctors switch on their stations devices when ready, and press the switch A to call the next patient. If the patient is absent switch B is depressed to slot the patient back into the queue based on equation 1. If the patient needs medication, switch C is pressed to send his/her card number to the pharmacy. When the Doctor is busy or attending immergence, switch D is pressed which indicates 'Doctor Busy' on the screen outside the particular consulting room. The doctor simply depresses switch A to call the next patient if the current patient is free to go home.

5.0 CONCLUSION

In conclusion, the sole aim of carrying out the design and construction of an Enhanced Patient Calling System has been achieved. The aim was to develop an efficient and reliable enhanced patient calling system, which was successfully realized at the end of the design and construction process. One factor that accounts for the uniqueness of the product is the ability to slot back an absent patient. The system was tested and found to be working to specifications and predictions. It is a model for cheap and reliable way of managing queues in public places, but the implementation of this produce is based on data collected from the university of Maiduguri Medical Centre.

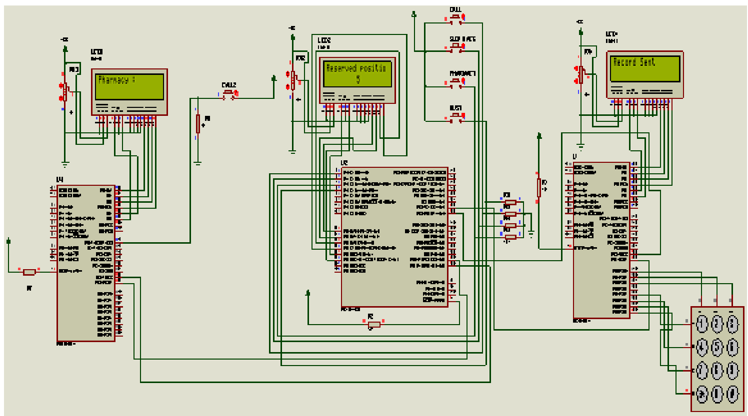


Figure 10: Absent patient (queuee) slot back into position 5

5.1 RECOMMENDATIONS

Although the aim and objectives of this work have been accomplished, there is still room for improvement on the work done as listed below:

(1) Provision could be made for GSM modem which could immediately send an SMS to alert an absent patient and inform him of the estimated time he would be called again.

(2) The EPCD presented here could, as a model be expanded to include more consultation rooms, laboratory test, radiology unit, ward, and all other sections the doctor may direct a patient to.

(3) The EPCD could be redesigned to interface with Computer system linked with the hospital database.

(4) The EPCD could be reconceived as an Application Software (Apps) to be installed on the Computer system linked to the Hospital database.

(5) Implementation of an intelligent QMS (IQMS) that learns the queuing pattern of the hospital and determines the peak periods and low period of activities thus providing the Hospital Management with the desired record to tackle and prepare in advance. In addition, using the cloud, the IQMS can learn more from various other IQMSs to optimize its performance.

(6) More importantly, it could be adapted to other areas where queue management is required such as banks, eateries, et cetera. Finally, the use of this device should be encouraged in our hospitals to engender order and increase efficiency.

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