Control of Industrial Robot via GSM Networks

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ABSTRACT - Controlling devices is one of the important fields in modern industrial control systems where robots do dangerous, precise and even boring work The study of embedded systems has the main role and contribution in making such control convenient, since it acquire measures, process readings and control of actuators. In this paper, the solution suggested is to realize control using three modes, as well as approaching the problem without using PC for processing of measurement and control signals. It aims also to overcome the limitation of the peripherals of AVR Atmega32 microcontrollers that can control only two servo motors. This limit has been overcome by utilizing SPI interface ports of microcontrollers. Results obtained are excellent and efficient performance achieved. However, there are some findings like rounds-up of some values that led to loose of few fractions in the position of motor due to shift in the instant of sending signal to the slave micro. A solution has been proposed, which was to send the value in two cycles. Another issue is how to put together the three modes in one program, which were not possible because of the blocking statement in the GSM mode.

Keywords: Robot; AVR; SPI; servo; humidity; irrigation; conditioning; GSM; blocking

المستخلص - يعتبر التحكم بالأجهزة واحداً من أبرز المجالات في نظم التحكم الحديثة ، حيث تقوم الروبوتات بالأعمال الخطر والدقيقة بل والمملة كذلك. كانت لدراسة الأنظمة المدمجة المساهمة الأكبر في تحقيق مثل وسائل التحكم هذه بصورة ملائمة ، حيث تقوم بالقياسات وتعالجها وتتحكم بالمشغلات. إن الحل المقترح في هذه الورقة هو تحقيق التحكم عن طريق ثلاث أطوار بدون الاعتماد على حاسوب شخصي لمعالجة البيانات أو إشارات التحكم. كما يعمل الحل على التغلب على محدودية منافذ الاتصال بالأجهزة الطرفية في المتحكمات الدقيقة من نوع AVR Atmega32 والتي تستطيع التحكم في محركين اثنين كحد أقصى. تم اجتياز هذه المحدودية بتوظيف عدة متحكمات متصلة بواسطة منافذ SPI . قد كانت النتائج المستخلصة ممتازة وكان الأداء عالياً ، إلا أنه كانت هنالك بعض التحفظات نتيجة لتقريب القيم العددية بغرض التخلص من الكسور ، الأمر الذي تسبب في خطا من بضع كسور في موضع المحرك نسبة للاختلاف في لحظة إرسال الإشارة للمتحكم التابع ، وقد تم اقتراح حل للمشكلة يتمثل في إرسال القيمة في دورتين. كما كانت هنالك مشكلة في تنفيذ الأطوار الثلاث بداخل نفس البرنامج ، الأمر الذي شكل استحالة نسبة لتعليمة الإيقاف في وضعية GSM .

INTRODUCTION

Acquiring the data for analysis and decision making is very important part of engineering. Earlier, data acquisition was being done through wire media, which have very good immunity against noise and interference and require less transmitter power. However, one of the clear limitations of wired communication that it requires cables which raises significant difficulties in case of longer destination. Wireless communication prosperity helped in linking longer destinations for multiple purposes. Most countries became able to access their remote sites using wireless communication, as well as hybrid communications. Embedded systems are a great addition to this domain, cost and size wise. In this paper a review is done to show the progress in the GSM based control specially using SMS.

Microprocessor based embedded systems is different from microcontroller based ones, as the first has greater capabilities on image processing and audio advanced applications. However, it needs peripherals, that is why it usually comes as development board, and programming memory and RAM as well. It applies variety of Real-Time operating systems and sometimes it even provides full TCP/IP network stack, USB, HDMI, etc. Moreover, it could have a device driver for any externally connected devices. While the second is used for simpler applications, having embedded programming memory, RAM and peripherals don't need high end processing.

The suggested solution is to achieve automation, whereas special type of actuators could be used to produce the required motion. In general, motors could be used as actuators to control artificial joints robots. Many types of motors are there such as DC, stepper and servo motors.

LITERATURE REVIEW

Control Systems

Typically, a servo system is a closed loop system such as what is shown in Figure 1. It accepts input, process that input and adjusts the position of a motor. It measures the actual position through a sensor, and applies a comparator to generate the difference or error signal, which is fed to the controller again so as to adjust the motor to the right direction accordingly [8].

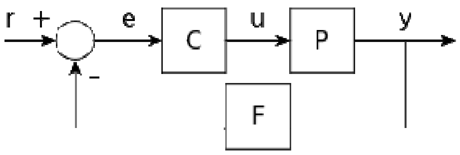

Figure 1: Closed Loop System

Pulse Width Modulation

Design influences which motor is better to be used and in which situation is the type of movement and nature of load. Servos are usually used to achieve movement of motor to specific angles, which leads us to talk about the nature of invoked supply used to control the movement through the Pulse Width Modulation (PWM) technique [7].

PWM is considered a quite well replacement to the use of continuous DC voltage that requires using inefficient amplifiers to supply power to the motor. On the other hand, PWM technique relies on switching the voltage rather than continuous. It is concerned about the duration of pulse and the duty cycle, which is defined as the ratio of the HIGH duration per cycle. For a DC motor, its rotor has a considerable inertia, and hence its speed is proportional to the average voltage across its armature, not the instantaneous voltage.

The maximum speed is achieved when the duty cycle is unity, i.e. using the whole duration of the PWM signal, and the voltage across the motor will be the supply voltage. Other values provide a percentage of the total supply voltage, thus the equivalent to DC voltage could be generated. Figure 2 below shows the PWM signal results across the motor [5].

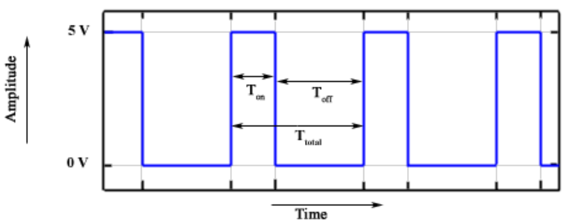

Figure 2: Voltage Across PWM Servo Motor

If the total pulse duration is expressed by T_{total} while T_{on} and T_{off} are the HIGH and LOW periods respectively:

$$T_{total} = T_{on} + T_{off} \quad (1)$$

The Duty Cycle [6] can be calculated by dividing the duration of the high period by the duration of the whole cycle, the result is percentage:

$$D = \frac{Ton}{(Ton+Toff)} = \frac{Ton}{Ttotal} \quad (2)$$

So to calculate the exact voltage the duty cycle is multiplied by the voltage:

$$Vout = D \times Vin \quad (3)$$

$$Vout = \frac{Ton}{Ttotal} \times Vin \quad (4)$$

The Global System for Mobile communications (GSM) network presents the wireless media component of the project. GSM is proposed to be used to send the control commands in one of its operation modes. In order to complete the picture, one should explain the architecture of GSM network. It is composed of Base Station Subsystem (BSS) and Network Switching Subsystem (NSS), which works as circuit switching for voice, as well as Packet Switching for data transfer.

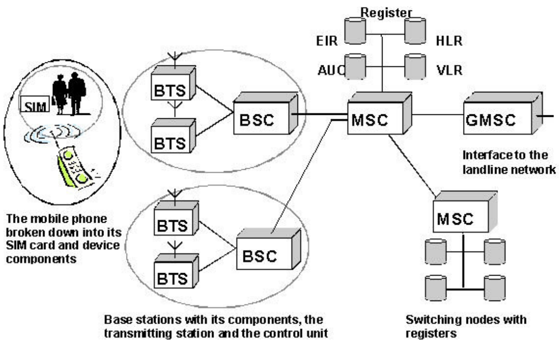

Figure 3: Basic Architecture of GSM Network

Short Message (SMS) is one of the services that are provided by GSM networks which is widely used by subscribers in all over the world. Hence, it can be efficiently used in control projects. In the Mobile Set side, there is a very effective line command tool called AT Commands (short for ATtention), which is also called Hayes Command Set that is developed in 1981 for Hayes Smart modems. Those commands are flexible text commands, and could be used to perform almost all mobile phone operations. SMS set of commands have been used here as the main drive for the robot.

PROPOSED SYSTEMS

In this paper, microcontroller-based broad use embedded systems are proposed. The first system is designed to measure and control humidity using SMS and an LPC2148 ARM microcontroller. The system works by measuring humidity using a humidity sensor that is connected to the controller using the ADC (Analogue to Digital Converter). It also includes a bulb indicator lights when humidity exceeds a predetermined threshold, in addition to SMS alerts.

The designed system is a flexible system that has track record as it sends the data frequently to the PC, which logs the data to a database and provides interface to the database using a program coded in Visual Basic [1], as shown in Figure 4 below.

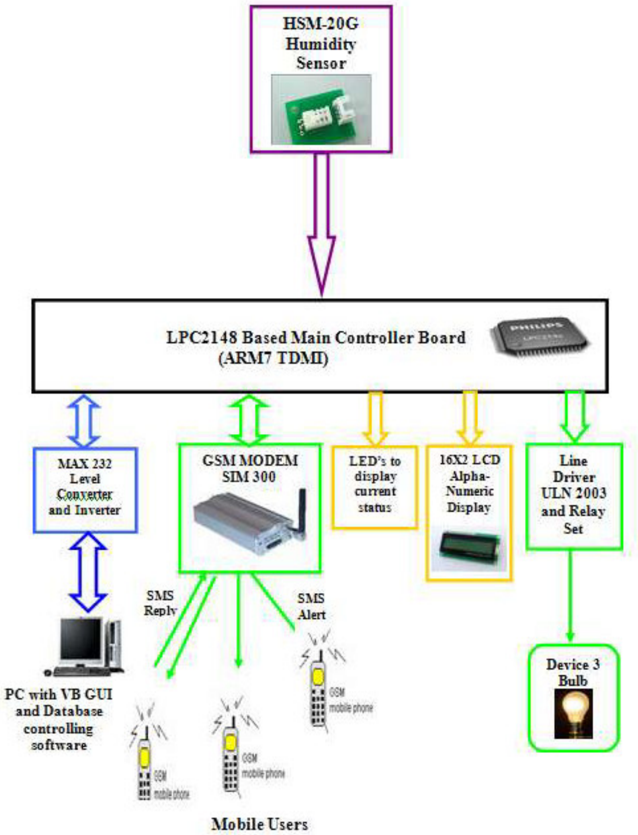

Figure 4: Low Cost GSM-based Systems [1]

The flowchart for the control process is shown in Figure 5, while Figure 6 shows the flowchart for monitor process, respectively.

The second system designed is for Home Appliance Control Systems (HACS). The objective of this research is to develop a new technique of home appliance control and monitor home thru SMS. The system is divided into two subsystems, the appliance control system was to remotely control home appliances, the second was to alert of any security breach.

The first subsystem was configured to advice the user via SMS to change the condition of the home appliance according to the user needs and requirements, while the security subsystem was mainly for intrusion detection. The obvious traits of this system are the dependence on a PC to process and generate SMS for decisions [2].

The third design is in the area of irrigation of the field, which resembles a very good example of applying embedded systems in the agricultural domain. It is used to sense the condition of the farm to evaluate whether it needs to be irrigated or not. It also checks the availability of the water in the field, controlled by the SMS to switch the water on or off. AT89V51 microcontroller is used along with motor driver, in addition to a SIM300S GSM modem and a moisture sensor.

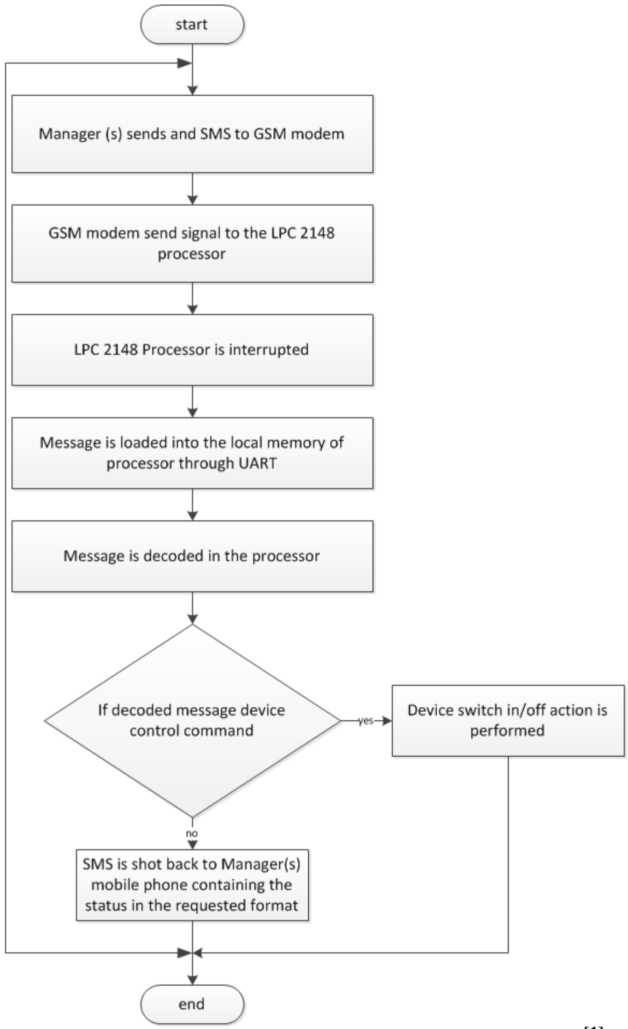

Figure 5: The Flowchart for the Control Process [1]

This system detects the status of the field using the sensor and sends alerts accordingly to the user, whom in turn can send a command SMS to switch on or off the pump or valve. This research has added a great value to agriculture field for some countries that their economy depends on agriculture. Moving around the field to control irrigation costs fuel and time as well, moreover such system helps scheduling irrigating [3].

In the fourth design, the SMS-controlled embedded system is used conveniently on E-notice Board, which is simple and nice project on controlling the displayed message on the board, instead of reprogramming the microcontroller every time the message needs to be changed. P89V51RD2 is a Philips microcontroller used along with 16x2 LCD, MAX232 level converter, and SIM300 GSM modem [4]. Figure 7 below displays the flowchart for the proposed E-notice Board embedded system, while Figure 8 shows block diagram of the system.

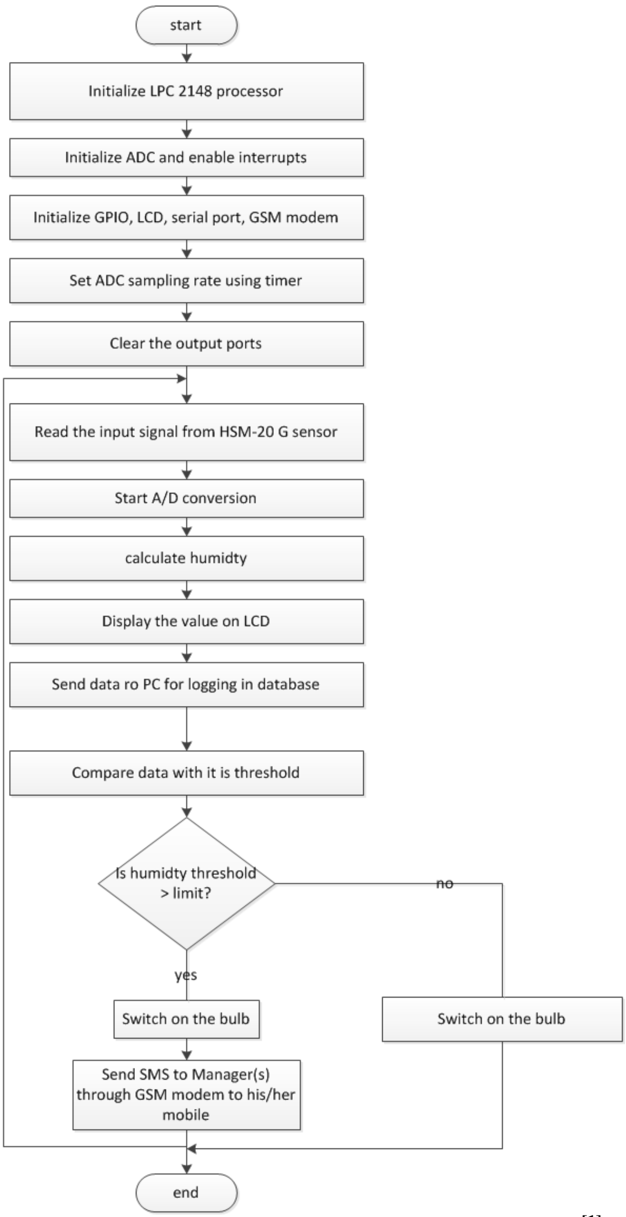

Figure 6: The Flowchart for Monitoring Process [1]

DESIGN MODEL AND SIMULATION

Most of PWM servo motors use pulse of duration from 1ms upto 2ms. So 1ms pulse produces the minimum 0 degrees angle rotation, while the 2ms produces the maximum 180 degrees angle rotation. Normally, 90 degrees is achieved by a 1.5ms pulse, supposing linearity. PWM could be implemented in a three ways:

- Non-inverted PWM (Fast PWM)
- Inverted PWM (Fast PWM)
- Phase correct PWM

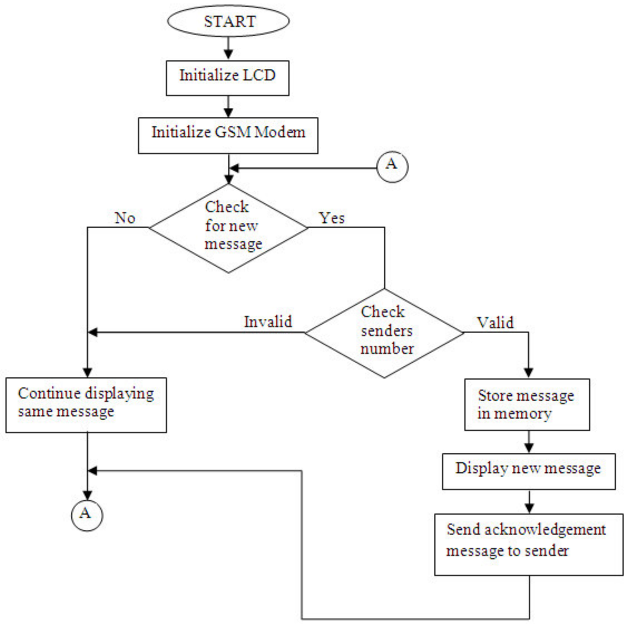

Figure 7: Flowchart of SMS-Controlled Smart eNotice Board

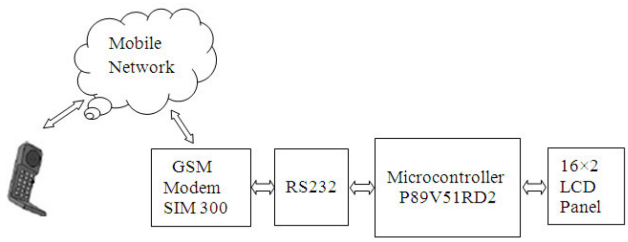

Figure 8: Block Diagram of SMS-controlled Smart eNotice Board

Non-inverted refers to the duty cycle, so it will be in the start of the pulse duration. And how it can be accomplished is fully depending on the counter/timer of the microcontroller, which will be counting bottom-up and then overflow directly to zero, this functionality is used for deciding when to set specific output and when to clear it. Hence, in our case model to control the servo motor, the requirements are 1 – 2ms pulse width and 50Hz frequency operation (from the datasheet).

Dividing 1 by 50 will produce 20ms which is the total duration. The microcontroller works on 1MHz clock, while the counter in the Atmega32 is 16-bit which can handle up to 65536 processor ticks only, then overflow occurs. Dividing 1MHz by 50Hz will result 20000, this will be the total duration, 20000 is definitely affordable to the 16-bit counter, which will be configured to work starting from 0 and end at 19999.

Also, 1-2ms of 20ms (1/50Hz) is 5% to 10% of the whole duration 20ms, Then 5% to 10% of 20000 is 1000 to 2000 (or actually 999 to 1999 as it starts from 0), the only remained value is the variable which determine the required duty cycle inside this durations that will be calculated based on the mode of PWM operation. In this non-inverted mode 19999 will be the top value and the duty cycle will be floating in the range between 999 and 1999.

Since it is a new implementation, robot controls required simulation. And sine Atmega32 is one of the most affordable microcontrollers in the local market, one can utilize as much as possible its full capabilities. The PWM functionality is provided through two channels, so in order to complete the design, one have to extend the functionality of the microcontroller by connecting it to another one to provide more PWM channels. Thus, a communication protocols for the microcontrollers has to come to the picture.

The reason behind using Serial Peripheral Interface (SPI) is the speed of the SPI (up to 10MHz) compared to I^2C (about 400kHz), which is more suitable to multiple higher number of microcontrollers applications. Also, there is no need for USART as it adds more complications such parity bit check. Moreover, USART doesn't allow the addition of many chips in case of functionality needed to be extended.

Proteus simulator has been used to test the design. GSM is used for general purpose data (internet), and after making some tests, 'AT commands' found to be 'unlocked' in that brand, in the same time this kind of GSM modems didn't work with the Proteus simulator. Investigating a lot in this issue has lead to an assumption that they were echoing issues as well as the mandate for using one of the two important modes (non-canonical mode). In general, there are two modes of operation canonical and non-canonical mode of operation, regardless of using Synchronous or Asynchronous. The first is line by line processing edition and deletion is granted, by default the line feed LF or the '\n' new line is the string terminator. The second type is the non-canonical mode which is character by character processing, or else to be more precise, this mode depends on two factors/parameters: the minimum number of characters and/or minimum timeout before returning the received data.

Canonical and Non-canonical mode; using this library canonical or non-canonical mode is chosen according to the requirements, actually it adds more complexity to serial communication as it doesn't work with the basic functionality like the embedded C programming libraries. For example to control general purpose GSM modem which is already a popular brand and has it is own user Application Programmable Interface (API), one had to redesign separate code for controlling this modem, as the already made interface to the modem will not do the work. The work needs to be added is the *command detection* and *process functionality*.

For instance consider moving the third motor to the left would be expressed with the SMS "$grab:1400#" which will be processed by specific function to split the motor position (which is the grabbing motor) from the movement degree (which is 1400 grabbing degree), the '$' and the '#' character are to define when to start and when the end of the command.

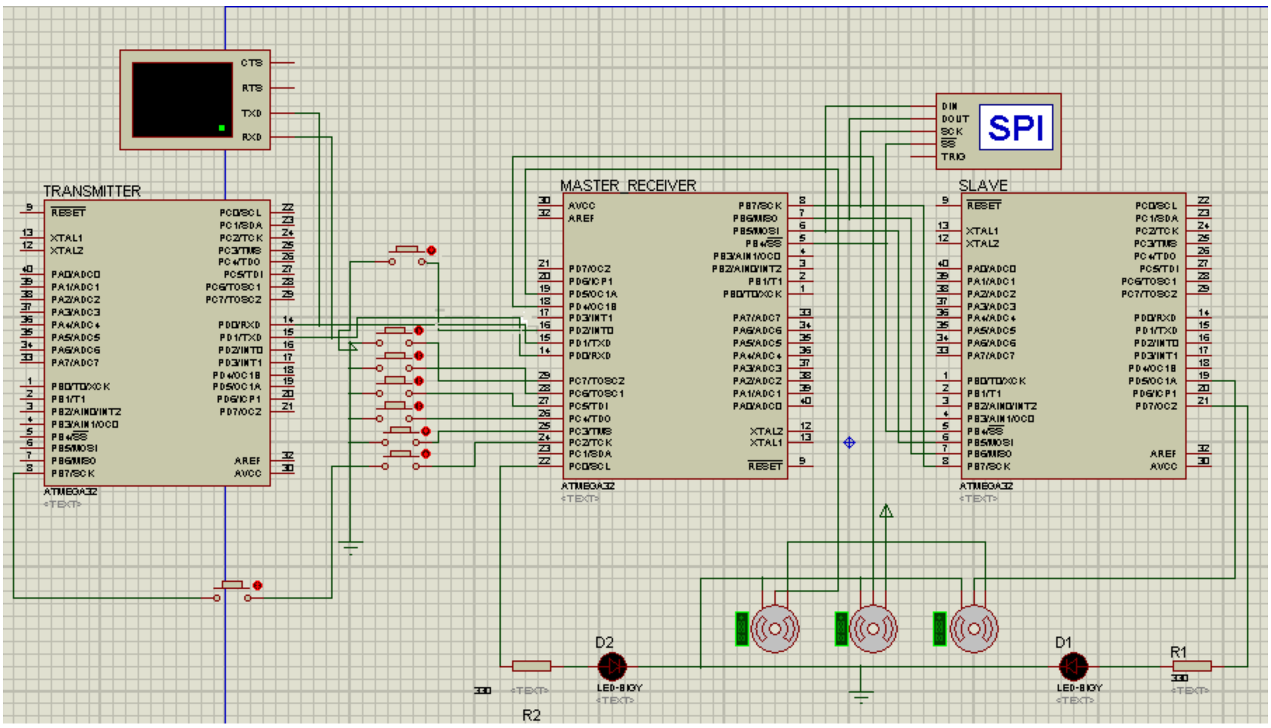

Figure 9: Micro serially connected to emulate GSM modem

To simulate; after the phase of testing using Linux and it is standard libraries, Proteus 7.8 is used as a simulator for the solution, so to test the HEX file in simulator before applying it in real hardware. In the simulator, one had to test each function separately, even he had to create a simulation and HEX files for each separate function. That is because merely some complexities have arisen when one tries to write the whole code once. So to identify the exact cause of the errors, one has to separate code based on functionality. Using any of the modes to control the third motor will require sending the degree though SPI to the slave microcontroller. This mode has been done in separate executable to provide fully automated control mode, hence it can be called preprogrammed mode.

Figure 9 below shows the connectivity of the two micros as well as the third microcontroller, which will represent the GSM modem as it sends data serially similar to that of the GSM modem.The three motors are set to specific angles according to the sent commands, which is 1200 for the first motor, 1300 for the second and 1400 for the third. The virtual terminal shows the notification message and the sent commands as well.

SPI protocol has some synchronization issues, when adding specific count of variables in the Master code, the Slave loose synchronization. The PWM control values are in the range 999-1999 and obviously these values cannot be assigned to one byte variable, in the same time the third motor has to be controlled via SPI which sends one byte by default. The proposed solution for this was to divide the value by 10 and send it, then after receiving it in the slave micro multiplying it by 10, but this will round up the values with fractions.

CONCLUSION AND RECOMMENDATIONS

There are some issues needs to be overcome. The first issue which has been partially overcome was the addition of variables in the slave code. That might affect the performance of the slave code, but with insignificant effect. Same problem could be avoided in the addition of headers, but couldn't be avoided when adding function in the master code.

The second issue is fixing the SPI limit of one byte. Two solutions were used; the first was to divide the value by 10 and multiplying it by 10 in the slave microcontroller. The maximum result will be 299 for 2999 though one byte can hold up to 255 only. The limitation of this solution is the loss of fraction as a result rounding up the value.

Another solution were examined to fix the limitation of the one byte and that was by creating another function to split the integer value into two characters and send them one by one, but again the SPI synchronization arisen. Of course, such problems are common when we use fixed-point processors such as microcontrollers, rather than floating-point processors.

I recommend I^2C to be used instead of SPI protocol in the communication between the microcontrollers. Also more work can be done to accomplish the function of sending and receiving the two bytes command to the third motor as the way used in this research is inefficient due to the drop of the fraction. Mixing the three modes together in one executable code will make it very efficient as there will be no need to reprogram it every time. Otherwise moving towards the boot-loader option is required.

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