Design and Implementation of a General Purpose Transmitter Based on Microcontroller AT89C52

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Abstract

Design, implementation, and testing of a flexible and general-purpose transmitter is carried out. A simple structure for the transmitter is defined to meet the hardware functional requirements of sensing the process variables, commanding actuators, and communicating with other control elements. A personal computer represents a program development station and human interface to the transmitter so that it can be used to develop any application program on the RAM of a transmitter. The basic hardware parts of the transmitter are the single chip microcontroller (AT89C52), the associated logic circuit, and local operator interaction panel. However, the input and output structures may be changed according to the application requirements. The hardware design is minimized to a single board. The basic software functions comprise to two layers: the first is the system software, which turns the transmitter's hardware into virtual high-level machine. It includes basic driver routines (AI/O, DI/O...etc) , control, and management software routines. The second layer is the application layer, which depends on the transmitter's basic system software. Generally, the operating software of the transmitter is designed as a single-user system consisting of two programs one is as a foreground program (interactive), which is interrupt driven, and the other is a background program which is the main program of the transmitter.

الخلاصة

تم القيام بتصميم وتنفيذ وفحص مرسلة مرنة و متعددة الاغراض.تم تعريف تركيب بسيط للمرسلة لكي يلبي المتطلبات الوظيفية المادية لتحسس متغيرات الادخال والسيطرة على المنفذات و الاتصال مع اجزاء السيطرة الاخرى .الحاسبة الشخصية تمثل محطة تطوير البرامج و تداخل الانسان مع المرسلة لكي يتمكن من تطوير اي برنامج تطبيقي على ذاكرة الوصول العشوائية (RAM) للمرسلة.
ان الاجزاء المادية الاساسية للمرسلة صممت بالاعتماد على وحدة المسيطر الدقيق ذو الشريحة الواحدة **AT89C51** والدوائر المتعلقة به وواجهة تداخل مشغل الموقع.ان تركيب الادخال والاخراج ممكن ان يتغير حسب متطلبات التطبيق. التصميم المادي نفذ على لوحة واحدة.ان الوظائف الاساسية للبرامجيات تقسم الى شريحتين :الاولى هي برامجيات النظام التي تدير الاجزاء المادية للمنظومة الى مستوى الة عملي عالي. وتتضمن برامج فرعية لتشغيل الادخال والاخراج الكمي و الرقمي)، وبرامج السيطرة والادار البرمجيات الفرعية .الشريحة الثانية هي شريحة التطبيق و التي تعتمد على برامجيات النظام الاساسية للمرسلة .بصورة عامة برامجيات التطبيق للمرسلة صممت مثل نظام ذو مستخدم واحد.يحتوي على برنامجين واحد امامي(تداخلي) والذي يمثل سواقة التداخل والاخر البرنامج الخلفي(تزامني) الذي يمثل البرنامج الرئيسي للمرسلة.

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1. System Design

The system design represents the transmitter module that has single chip microcontroller Atmel 89C52 with a serial EEPROM of 256 Byte. The prototype has one isolated analog input channel and one isolated analog output channel, the input channel and output channel have 16-bit resolution. There are three digital inputs and three digital outputs. Also there is an optional card has been designed and implemented to be attached to the transmitter to reconfigure it for a new settings. Figure 1 shows the transmitter's hardware design.

1.1 The AT89C52 description

The transmitter is designed and implemented using single chip microcontroller Atmel 89C52. Its suitable for processing power and multiple on-chip resources minimize and simplify the design in a great deal. This microcontroller has a multiplexed address-data bus, which requires an octal latch to latch the lower address byte when address latch is enabled (ALE) signal goes low. This permits the same port (P0) to accept instruction from the Program memory (EPROM, EEPROM, Flash RAM) data lines when the Program Store Enable signal (PSEN*) enables the Program memory. The AT89C52 runs on a 12MHz clock which gives a basic instruction cycle of 1 microsecond. The external access signal (EA*) of the CPU is forced to low in order to execute an instruction from external Program memory, but when it wants the CPU to execute an instruction from the internal 4 Kbytes Flash EPROM, the (EA*) signal should be disable [1],[2].

1.2 System Clock and Reset Circuit

The transmitter system timing is provided with a crystal oscillator module, which has a frequency of 11.059MHZ. This clock frequency is applied directly through the clock pins.
The AT89C52 requires that an external reset must be applied to allow stabilization of the on-chip circuitry. Push-button reset circuit is employed to reset the system automatically to guarantee that the CPU behaves in a predictable fashion. In general the circuit consists of RC circuit which gives a time constant that determines both the power-on reset signal and the manually reset that is generated using push button switch. The watchdog timer signal and the RC signal are ORed together to generate the reset signal to the system [1,2].

1.3 Watchdog Timer

Microcontrollers are being used harsh environments where electrical noise and electro–magnetic interference (EMI) are abundant. In environments like this, it is beneficial if the system contains resources to help ensure proper operation. In many systems, a commonly used technique for verifying proper operation is the incorporation of a watchdog timer.
A watchdog timer is fundamentally a time measuring device that is used in conjunction with, or as part of, a microprocessor and is capable of causing the microprocessor to be reset. In a properly designed system, the watchdog will cause a reset when the microprocessor is not operating correctly, thereby eliminating the faulty condition.
In a typical application, the watchdog timer is configured to reset the processor after a predetermined time interval. If the processor is operating correctly, it will restart the watchdog before the end of the interval. After being restarted, the watchdog will begin timing another predetermined interval.

If the watchdog is not restarted by the processor before the end of the interval, a watchdog time–out occurs. This results in the processor being reset. If the system software has been designed correctly, and there has been no hardware failure, the reset will cause the system to operate properly again. Of course, the reset condition must be a safe state [3] .A programmable oscillator can provide different frequencies as it is programmed. The used programmable oscillator chip (PXO-1000) with built in laser trimmed quartz crystal. It generates 57 different frequencies from the single quartz crystal; the quartz crystal is 1MHz, it represents the base clock to generate the 57 different frequencies.

1.4 Memory Section

The memory section of the controller consists of two types of memories, which are Stack-RAM and serial EEPROM.

The stack-RAM includes 128bytes of the internal RAM that is residing in the AT89C52 package. It would be so called" stack-RAM" because the AT89C52 stack is built automatically in this RAM. It is addressed using one byte address; the space reserved for the internal RAM is physically separated from the space that the external data memory may use. The stack can be resided anywhere in the on-chip RAM. When the AT89C52 is reset, the stack pointer is initialized to 07h. When executing a "PUSH" or a "CALL" instruction, the stack pointer is incremented before data is stored, so the stack would begin at location 08h.

The used serial EEPROM memory is addressed using 16-bit data pointer register (DPTR) and the program counter (PC). Microchip Technology Inc.'s popular ST93C56 Serial EEPROMs feature a three/four wire serial interface bus. The attractive price and simple interface make it the ideal device for additional memory space. Since all I/O ports on the AT89C52 are configurable as input and/or output, a 4-wire interface makes optimum utilization of the I/O pins by having a connection for the DI and DO lines of the Serial EEPROM. The port pin on the AT89C52 connected to these pins, has a default setting as an output and is configured, when needed, as an input during program execution. In this work the EEPROM size was 256 Byte [2].

1.5 Analog Input Section

This section deals with the analog input that comes from sensor or from the plant. As the analog inputs enter the transmitter, they pass through the following stages:

1.5.1Analog to Digital Converter Stage

In this part, the analog readings are converted into their digital equivalent forms; the AD7705 does this. The AD7705 is chosen because it is a complete analog front ends for low frequency measurement applications. This device can accept low level input signals directly from a transducer and produce a serial digital output. It employs a sigma delta conversion technique to realize up to 16 bits of no missing codes performance. The selected input signal is applied to a proprietary programmable gain front end based around an analog modulator. The modulator output is processed by an on chip digital filter. The first notch of this digital filter can be programmed via an on-chip control register allowing adjustment of the filter cutoff and output update rate. The AD7705 features two fully differential analog input channels. Input signal ranges of 0mV to +20mV through 0V to +2.5V can be incorporated on both devices when operating with a VDD of 5V and a reference of 2.5V. They can also handle bipolar input signal ranges of ±20mV through ±2.5V, which are referenced to the AIN (–) inputs on the AD7705.

The AD7705 thus perform all signal conditioning and conversion for a two- or three-channel system. The AD7705 is ideal for use in smart microcontroller based systems. It features a serial interface that can be configured for three-wire operation. Gain settings, signal polarity and update rate selection can be configured in software.

1.5.2 Isolation Stage

The electric isolation is a very important stage in the transmitter. It protects the module from any abrupt voltage changes or non-linearity that occurs in the plant. ISO122, is the isolation stage used in this work, and provides up to 1500Vrms of galvanic isolation between its input to output section.

The ISO122 isolation amplifier uses input and output sections galavanically isolated by matched 1pF isolating capacitors built into the plastic package. Duty cycle is modulated and transmitted digitally across the barrier. The output section receives the modulated signal, converts it back to an analog voltage and removes the ripple components inherent in the demodulation. Input and output sections are fabricated, and then laser trimmed for exceptional circuitry matching common to both input and output sections [4].

1.6 Serial Analog Output Stage

This section represents analog output channel, the used serial DAC is low power ,voltage output,12-bit digital to analog converters(DAC),specified for single 5v power supply operation .It comes in 8-pin DIP packages so that it can minimize the hardware. An internal reset circuit forces the DAC register to reset to 000 hex on power–up. Additionally, a CLR* pin, when held low, sets the DAC register to 000hex .CLR* operates asynchronously and independently from the chip-select (CS*) pin.

The MAX539 DAC uses a three-wire serial interface. The DAC is programmed by writing two 8-bit words, sixteen bits of serial data are clocked into the DAC MSB first with the MSB preceded by four fill (dummy) bits. The four dummy bits are not normally needed. Data is clocked in on SCLK's rising edge while CS* is low. The serial input data is held in a sixteen bit serial shift register. On CS* rising edge, the 12 least significant bits are transferred to the DAC register and update the DAC register. the digital update rates is equal to 1.14µs.However the DAC settling time to 12 bits is 25µs,which may limit the update rate to 40KHz for full –scale step transitions.

1.7 Communication Section

The most widely used techniques on a digital communication system are to transmit serial data. In transmitting data over a serial link, synchronization between transmitter and receiver is of paramount importance. Data can be received either synchronously with reference to system clock, or asynchronously. Synchronous serial input /output is usually required for high (several Mbps typically) data communication links. Synchronous protocols are block oriented rather than character oriented. The block-oriented protocol provides more control and error checking than character oriented protocol [5].

In this work the communication is built with the aid of the on-board UART in

AT89C52. This serial port is internally interrupt driven it is programmed in the special multi-processor communication model hence enabling the interrupts in special packets. TTL output/input of RxD and TxD of the AT89C52 is converted to RS232 electrical standard with the aid of MAX232.

1.8 Front Panel Interaction

The front panel is constructed from three parts as explained below:

1.8.1 Alphanumeric Display

Four-digit displays modules complete with built in CMOS driving circuitry are used. In this alphanumeric IC (2416) has on-board integrated circuit contains an ASCII decoder, multiplexer, memory and LED driving. Inputs are TTL compatible, a single 5V is the only power required by the modules. It has an internal electronics on the RS intelligent displays to eliminate all the traditional difficulties of using multi-digit light emitting displays (segment, decoding, drivers, and multiplexing). The intelligent display also provides internal memory for the four digits. The approach allows the user to asynchronously address one of four digits, and load new data without regard to the LED multiplexer timing. In addition this IC chip contains 17 segment drivers, 4-digit drivers, 64 character ROM, four word*7bit RAM, oscillator for multiplexing, multiplexer counter (decoder, address decoder, and miscellaneous control logic).

1.8.2 Output Indicators Port

Three light emitting diodes (LED) indicators; they are: Prog, High, and Low are used to indicate the state of the output of the control algorithm. This means that when the output is greater than a certain value an alarm must be turned on whether it is high alarm or low alarm.

1.8.3 Keypad Part

A Three none latching toggle switches are used to represent simple keypad, all the three keys are connected to external interrupt (INT0) of the AT89C52. Each function of these keys is explained below:

- The first key is (up/down) which will increment/ decrement the displayed data by one each time this key is pressed.
- The second is (shift) key, to select the digit want to be reconfigured.
- The third is (page) key, types of sensors and the high, low ranges.

Note that the jumper must be set to program mode (configure) the parameters of the control algorithm, also there is a LED for each one of the explained keys.

2. Visual Basic Program

The reconfiguration, calibration and application programs can be developed under any Microsoft Windows operating system based on IBM personal computer. The implemented user interface designed in this work uses Microsoft Visual Basic (VB); also Figure 2 shows the Software Design on PC Side. The serial communication is based upon the Microsoft Serial Communication object (MSComm) library of Windows. This library can be accessed through VB to communicate with the outside world [6],[7].

The transmitter is connected to the PC through an RS232 interface between the PC and the transmitter. The 9pin connector of the serial connector is plugged to the RS232 port of the PC. The 4pin connector of the serial connector is connected to the transmitter.

The AT89C52 Assembler takes an assembly language source file created with a text editor and translates it into an Intel standard HEX file which can then be downloaded to the microcontroller device using the Windows Serial Downloader (WSD).
The Assembler also generates a list file (.lst), which displays any errors present in the original source code. The designed (WSD) is a windows software program that allows a user to download Intel standard Hex files into the on-chip FLASH/EEProgram memory via the microcontroller UART serial port. The WSD also incorporates the serial download protocols for downloading to Flash/EE data memory, setting of security bits and various RUN options.

2.1 Configuration of the transmitter

The VB program will always ask the user to enter his/her password in order to enter other pages of the VB program Figure 4 shows the prompt box.
When the communication is o.k. the first operation to be done will be "Upload" function to get the configuration of the connected transmitter. To reconfigure the transmitter, rearrange Calibration info parameters (Type, Zero, Span, Min. Output Current, Max. Output Current, Linearization, CJ-Comp, Sensor Break, Output and Filter) and then execute the "Download" function. "Download" function sends the configuration parameters to transmitter.

2.2 Output Calibration of transmitter

The designed Output Calibration page showing in figure3 .In order to calibrate the output of the transmitter, an ammeter must be connected to the output terminals of the transmitter. Using the up and down functions in Output Value window of Calibration Page, change the output value and monitor the ammeter reading. For zero calibration, output value should be set to "0" and MIN button is clicked. For 20mA (span) value, output value is adjusted by up and down buttons until the ammeter reading is equal to 20mA. Generally this value is around 4000. Output value corresponding to 20mA reading is set and MAX button is clicked.

2.3 Input Calibration of transmitter

A Calibration instrument must be connected to the input terminals of transmitter. The procedure for input calibration is as follows;

1. Select a thermocouple type and download the configuration.
2. Enter the Calibration Page and click the max and min button to set the new values, the result of the operation will be displayed in the message line window. This operation can be repeated several times until a stationary value is displayed in the message line.
3. Set the calibration instrument output.
4. Exit the Calibration page.

3. Communication Protocol

The communication protocol defines the functions needed to perform the communication by establishing connection, message transfer, and termination of the connection. So, there are functions responsible for communication between the PC and the transmitter through the serial link RS232, these functions resides in both PC and the transmitter.
For the transmitter side, a communication protocol based on one of the AT89C52 modes has been chosen. Mode3 has a special provision for multiprocessor or communications. An address byte differs from the data

byte in that the 9th bit is 1 in an address byte and 0 in data byte. An address byte will interrupt the transmitter, so that each transmitter can examine the received byte and see if it is being addressed, when it is being addressed, the transmitter will be ready to respond to the rest of the messages.
The execution of the new configuration will be in any location in the memory and there is a need to put the jumper into Prog mode to enable the execution[9].

4. The Software from the transmitter Side

Generally the software structure can be layered into two layers:
A- System software (near the hardware).
B- Application independent (independent of the hardware).
The first layer can be divided into two parts: the first one represents the application standard routine that includes: Analog input and output routines, Digital input and output routines and the control software required for application. So as this layer is located near the hardware so it must be written in assembly language and translated into object code to stand for the microcontroller.
The second layer represents all the routines that are used to create any application program without taking into account the hardware structure. It includes, the operating system of the transmitter (kernel software, user interaction and communication) usually this is a fixed layer.
Now, the main program of the transmitter is designed as a single-user system, which contains two programs. One is the foreground program, which interacts with the terminal and runs as long as it is able. The other one is the background program, which is assigned to the processor whenever the foreground program is unable to proceed [6].
The main program defines various constants, initializes ports and devices if needed, and enters an infinite loop. The main program is entered after applying RESET pulse to the AT89C52. Thus before calling INIT subroutine, it initializes the stack pointer, recall that the stack growing from the high address to the low address. The complete software may be partitioned into the following subroutines:

- INIT: for initializing program variables immediately after the system RESET. Several variables are to be initialized before the infinite loop in the main program begins. First initialize various I/O ports and timers by a subroutine named INIT.
- Keys ISR: This routine handles the depression of one of the three keys on the keypad; each one of these keys has a special function so when one of them is pressed a LED will be turned on each one.
- Download ISR: As mentioned before that there are functions responsible for the communication between the PC and the transmitter, so this routine is the communication driver for this mission.
- ATOD: Analog to digital routine, for getting analog input signals from the plant and processes the control algorithm on this signal.
- Database routine: This represents the DB area where all the processing parameters for the input data of the transmitter are found in DB area.
- Output the result signal to plant.

5. Conclusions

Through this work, a general-purpose transmitter module has been designed and implemented. The design is achieved through the use of a single chip microcontroller AT89C52. This chip is used because of its availability and all these kinds of this chip are proven and tested. They are run at speed up to 12MHz; internally it consists of 4KByte Flash EPROM that makes it ideal as development tool. So this single chip can handles data acquisition and data analysis between the transmitter and processes under control.

The transmitter also can communicate with IBM PC, through the serial port, which is used to reconfigure or test the transmitter module. However, it is attached with keypad and alphanumeric display on a separate card to provide the ability to set the control parameters of any input type. In this work the decision has been made to design the controller module using single board (S.B) because there is no extra components are required, and all components do not take up large space and power [7].

The biggest advantage of transmitter module is its isolation. The optical coupling devices completely separate the computer's signals from the factory signals, and because each module has a separate ground wire to the factory device it is connected to, it is completely isolated from other grounds. When several I/O devices share a common ground, ground loop currents can induce signal noise. Maintaining isolated grounds may be an important consideration in retrofitting older equipment.

The software of the transmitter was partitioned into two layers: Application independent layer, where the defined functions are: control, operator interaction and communication, all these are the backbone of a complete application program. While the system software layer represents: analog input/output, and digital input/output, this layer is located near the hardware and all the programs are written in assembly language and translated to object code.

In this paper the description of the microcontroller and Visual Basic programs that are required to communicate with each other through the serial communication protocol is also explained.

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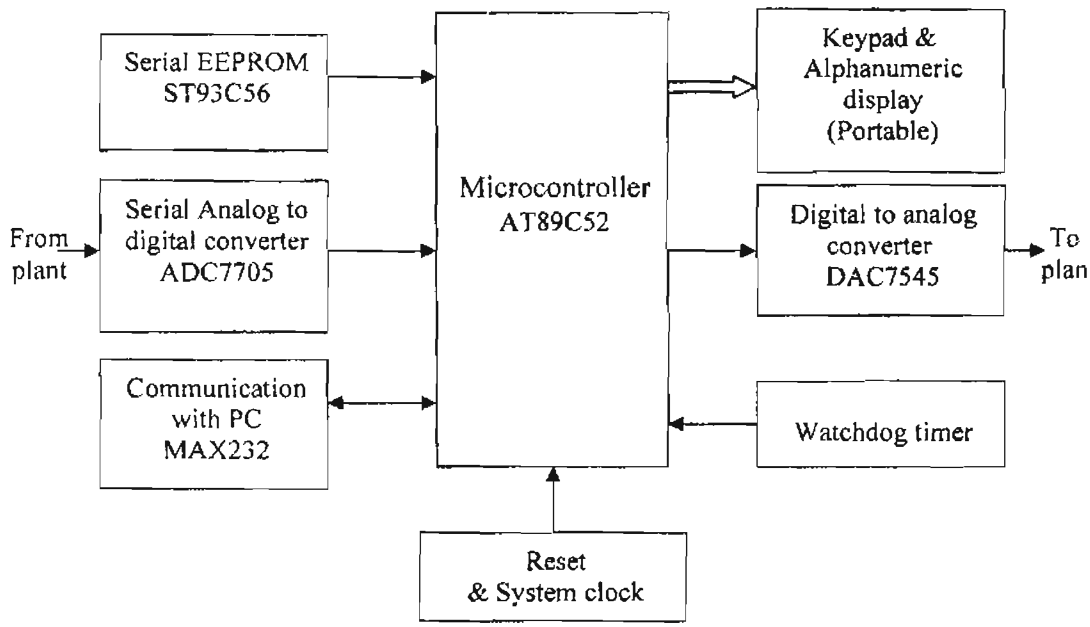

Figure 1: A block diagram of transimitter's hardware design

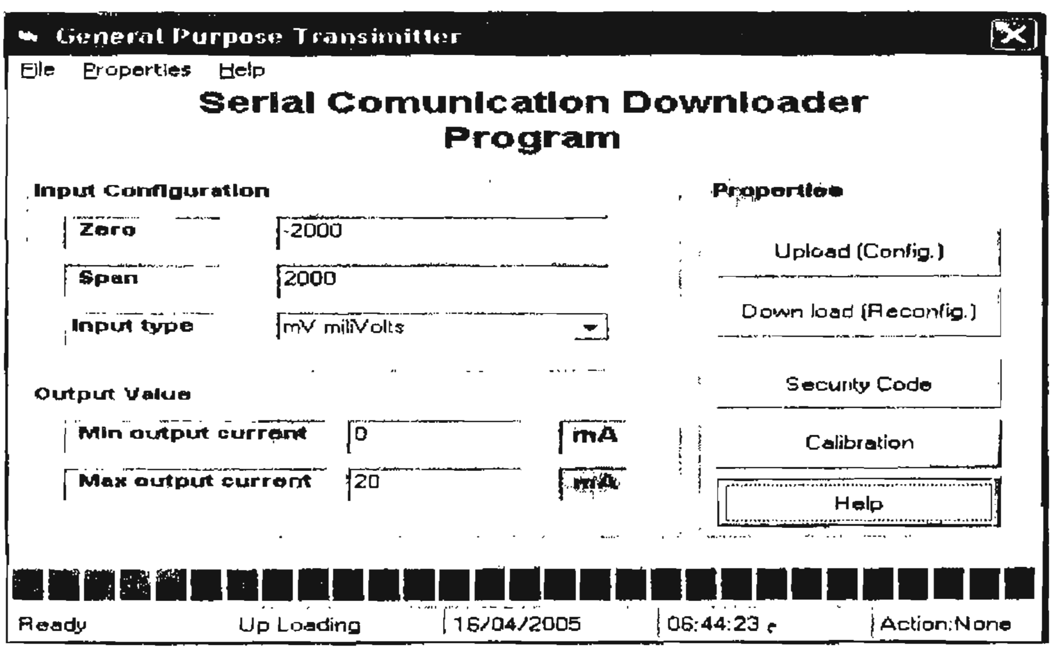

Figure 2: Software design of PC side

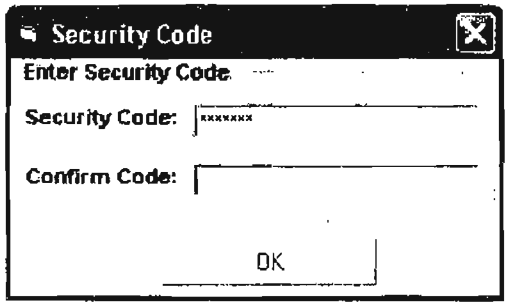

Figure 3: security code page

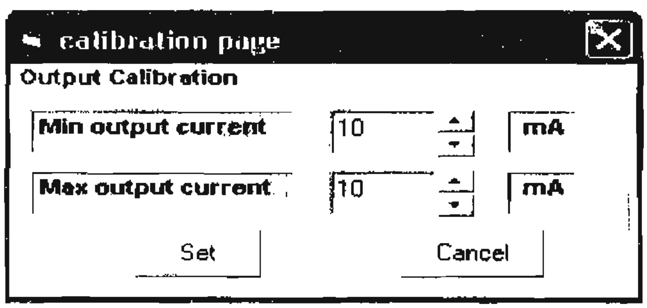

Figure 4: Calibration page of transmitter