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GSM REMOTE CONTROL HEATER

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ABSTRACT

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In the Nordic winter, a car users need to warm their cars in order to start up the frozen engine of the car. Usually, it takes around 5 minutes for him/her to wait outside for warming the frozen engine. Thus, car users suffer a lot to warm their cars in the cold environment.

To deal with this issue, a remote control system was designed in this thesis to remotely turn on/off the heater of the car by sending an SMS. The whole process of the thesis project lasted two months, and it was conducted in the Technobothnia laboratory. The remote control system is an application based on a GSM modem, serial communication, and MCU technology. The GSM modem was used to transmit and receive SMSs between the system and the user's phone through a GSM network. MCU was used for switching the heater through a relay, and it was also used for receiving the detected temperature through a digital thermometer.

As a result, in the system test phase, the remote control system could successfully remotely control a lamp by sending an SMS, and the actual temperature could be reported through the SMS. However, the power of the heater limited the usage of the remote control heater; and the security risk would be another main issue in the future.

In conclusion, the initial objectives of the thesis project were achieved, and the whole process run well according to the project plan.

Keywords: GSM modem, MCU, SMS, Remote Control

CONTENTS

LIST OF FIGURES AND TABLES

ABBREVIATIONS

ASIC	Application Specific Integrated Circuit
BPS	Bits Per Second
CR	Carriage Return /11，11/
CPU	Central Processing Unit /11，11/
DCE	Data Circuit-terminating Equipment /11，11/
DSR	Data Set Ready
DTE	Data Terminal Equipment
DTR	Data Terminal Ready
DQ	Data Input/output
EEPROM	Electrically-Erasable Programmable Read-Only Memory
EGSM	Enhanced Global System for Mobile Communications
GND	Ground
GSM	Global System for Mobile Communication
LED	Light Emitting Diode
LF	Linefeed
IGT	Ignition
I/O	Input/Output
ISP	In System Programming
ITU-T	International Telegraph Union-Telecommunication Standardization Sector
mA	milliampere
MCU	Microcontroller
ME	Mobile Equipment
ms	millisecond
MT	Mobile Terminal
NUM	Number

PDU	Protocol description unit
RI	Receive Index
RxD	Received Data
SBUF	Serial Buffer
SMS	Short Message Service
TE	Terminal Equipment
TA	Terminal Adaptor
TI	Transmit Index
TxD	Transmitted Data
UART	Universal Asynchronous Receiver/Transmitter
ZIF	Zero Insertion Force

1 INTRODUCTION

In the Nordic countries, there are a lot of car users who confronting the following tough situation: in the cold six-month-long winter period, they warm their car by the heating system in order to start the frozen engine. Currently, they set up the timer of the heater for two hours in the night before the day when they want to drive. However, some of them might forget to set the timer up. Or the car might be still cold when they want to drive, since they could not exactly estimate the driving time.

The purpose of this thesis project was to solve the problem by designing a remote control system. The system was designed to remotely turn on/off the heater of the car by sending a short message. The system is based on the Global System for Mobile Communication (GSM) technology, the serial communication technology, and the microcontroller (MCU) technology. One GSM modem is used to transmit and receive the signal between the control devices and the user's phone. The control devices consist of one microcontroller (MCU), one digital thermometer, and one relay. The MCU is used for switching the heater through the relay, and it is also used for receiving the detected temperature through the digital thermometer.

Basically, the system has two main functions. Firstly, the system allows car users to warm their car by sending Short Message Service (SMS) messages at any time and any location. Secondly, the system can report the actual temperature of the car by sending SMSs back to the phone of car users. Compared to the current heating system, there are certain benefits of this remote control system.

Firstly, it can improve the performances of the heating process. For instance, it would increase the operating security by monitoring and reporting the temperature of the car. Conversely, the current heating system occupies the potential risk to

burn the car without any notification of overheating. In addition, it is easy to access. It allows car users to control the heater from remote locations, which makes it available to warm the car at anytime and anyplace. Thus, car users will not suffer a cold environment in order to wait for warming a car.

Secondly, it could save money and energy. For instance, if a car user was to use this system to switch on a 3kW heater in a car, it would take at most 30 minutes to warm the car. Thus, it would reduce 1.5 hours operating time of the heater per day. The lifetime of this system is 10 years. Therefore, the calculation of saved electricity is: 10 years * 20 weeks/year * 5 weekdays/week * 1.5 hours/day * 3kWh=4500kWh. In Vaasa, Finland, the average price of electrical energy is 7.04 cent/kWh, and the average price of electricity transmission is 8.71 cent/kWh. /14/ Therefore, the calculation of saved electricity cost is: 4500 kWh * (7.04 cent/kWh + 8.71 cent/kWh) = 708.75 Euros. The cost of the system is around 30 euros. Thus, the car user could save at least 678.75 Euros of electricity fee. Thus, it would not just save money, but also save energy, which is beneficial for environment.

Thirdly, this project could be the expansion of exercise “GSM SMS” in VAMK’s Telecommunication Laboratory Exercises. The thesis project shows a possible example to integrate the telecommunication technology and embedded technology.

Lastly, in addition to control a heater in the car by the GSM remote control system, the high compatibility of the system offers more opportunities to extend its appliances. For example, it could be used for remotely control a rice cooker. Therefore, the GSM remote control system is not just a promising solution for car users to remotely control the heater, but also owns highly scalable and wide future extensions.

The thesis has the following structure:

Chapter 2 briefly illustrates how the system works and how the signals transmit during the process.

Chapter 3 states related theories, which are used to support the practical section in the thesis project. It mainly includes seven parts: GSM SMS, AT commands, encoding and decoding of GSM SMS, GSM module, Microcontroller, Relay, and Temperature sensor.

Chapter 4 describes how the hardware and software of the system are designed and approached.

Chapter 5 states how the system test was implemented. The key performances of the GSM remote control system and the analysis of the results are presented.

Chapter 6 concludes the implementation process of the thesis project and discusses the potential future extension of the system.

2 PURPOSE OF THE PROJECT AND SYSTEM STRUCTURE

How the system works and how signals transmit during the process will be briefly introduced in this chapter.

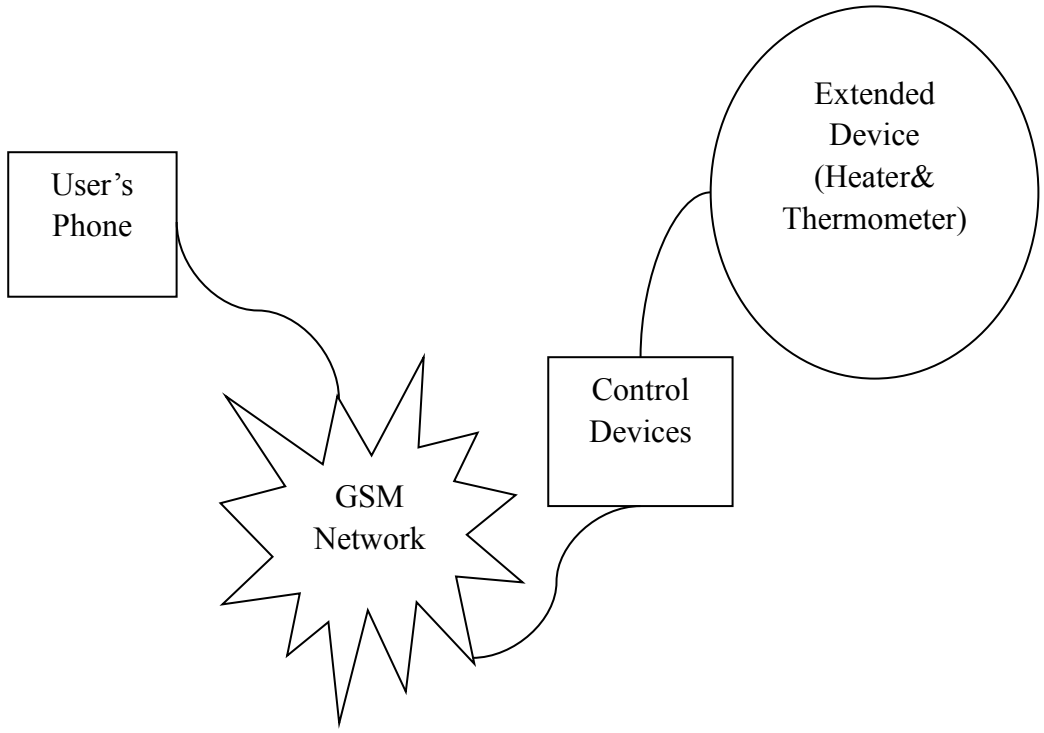

Figure 1. Block diagram of GSM SMS remote control system

As shown in Figure 1, without any other applications or terminals, a car user can use a regular phone to send a SMS to control a heater. The process of transmitting the SMS is: the SMS from the user's phone transmits to a SMS center through the GSM network; then, the SMS center forwards it to the control device. After the SMS is decoded in the control device, the control device will take actions to the extended device. The system schematic diagram of the control device is shown in Figure 2. The relay status is always under control of the MCU and can be reported to the user directly. By connecting with a digital thermometer, the control device can also report the temperature of the car engine to the users' phone.

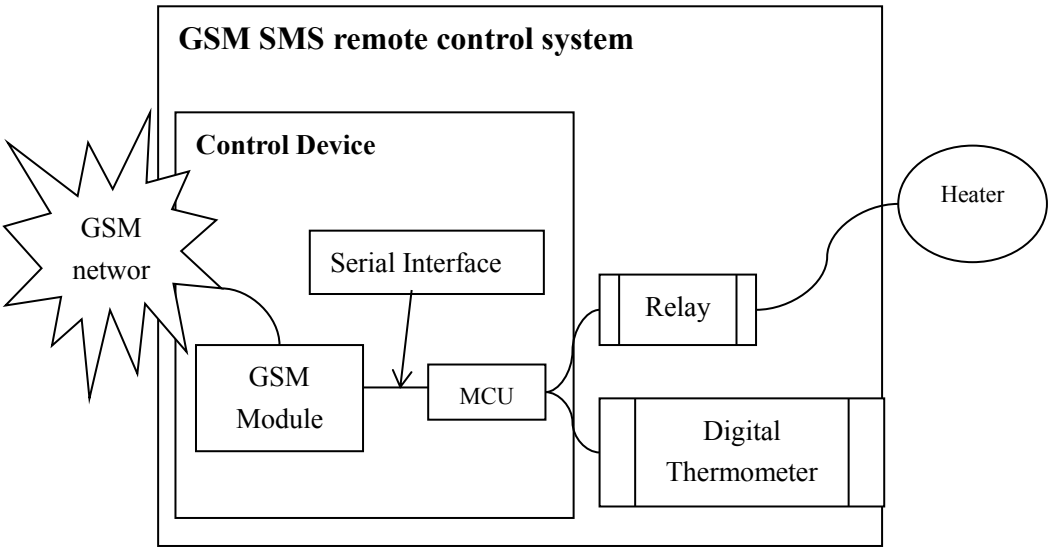

Figure 2. Control device in the system

In this thesis project, several components needed to be used, including a GSM module (TC35i), a MCU, a relay, and a digital thermometer.

There are two main functions of the GSM remote control system, including remotely switching the car block heater and reporting the temperature of the car engine temperature through SMSs.

As can be seen from Figure 2, the operating process of the first function is: the car user sends an SMS from his/her phone and the SMS is received and decoded by a GSM module. The decoded signal of the SMS is transmitted to a microcontroller. Then, the microcontroller switches ON/OFF the relay according to the decoded signal. In addition, when the relay is ON/OFF, the heater circuit would be open/close.

The second function is to send SMSs to report from TC35i after the car engine temperature reaches the default set temperature. The implementing process is: the MCU reads thermometer value and if it is below or over a threshold, the MCU would organize a SMS and send it via GSM modem to a dedicated number.

3 THEORETICAL STUDY

In this chapter, the related theories of the thesis project are discussed in detail in order to introduce the applied technologies of supporting the practical section. The theoretical background in introduced in 7 subheadings, including serial communication, GSM, SMS, GSM AT commands, microcontroller, relay, and Temperature sensing.

3.1 Serial Communication

Serial communication is the process which sequentially transmits data one bit at a time through a communication channel. There is one important serial communication standard: RS232 standard. It is the series of standards for serial binary single-ended data and control signals connecting between a DTE (data terminal equipment) and a DCE (Data Communication Equipment). /3/

A DTE, such as a computer, is an end-equipment that converts users' information into signals or reconverts received signals. Usually, the DTE device is a terminal, and the DCE is a modem performing functions, such as line clocking, signal conversion, and coding. In RS232 standards, a line that is an output to a DTE device is an input to a DCE device and a DCE device can be connected to a DTE device with a straight wired cable. /3/

In this project, a serial interface is used to connect a GSM modem with a microcontroller. The GSM modem can be regarded as the DCE and the microcontroller could be regarded as the DTE.

3.2 GSM

GSM stands for Global System for Communication, which is the protocol for second generation digital cellular networks applied for mobile phones. It offers

high telecommunication quality based on low service cost and basic physical requirement. It could offer mobile phones multiple services including voice features service, data transmission service, and short message service. In this project, the short message is the core function to fulfill the tasks. /5/

Compared to other telecommunication standard, there are some advantages of GSM system: the first advantage is the huge amount of users whose phone supported GSM network. It domains the mobile communication market holding 80% market share. The second advantage is that there is no limitation of the amount of users, no need for establishing a special network system and it leads to low cost of R&D and maintain. The third advantage is less signal deterioration inside buildings. It has no co-channel interference, better performance of security problems, and high speed of mobile communication. The fourth advantage is a larger cover area. GSM covers almost everywhere in the world; therefore, no matter domestic or international communication are available. /6/

3.3 SMS

SMS stands for Short Message Service. It is the application service of GSM standard between GSM terminals, such as mobile phones. It is used to send/receive text messages through a service center; and the service center fulfills the function of storing and transmitting data.

The stability of dual transmission function of GSM SMS provides a strong platform for the transmission of remote data and the communication of monitor devices.

There are three formats of encoding SMS, including Block mode, Text mode, and PDU mode. In this project, Text mode and PDU mode will be applied to implement the tasks. The sections 3.3.1 and 3.3.2 describe what Text and PDU mode are.

3.3.1 Text Mode

The Text Mode is a character-based interface based on “AT” commands; and it is suitable for unintelligent terminals or terminal emulators. A SMS message can include the maximum of 160 characters with 7-bit- coded each or 140 characters with 8-bit-coded each of text in length. In the text mode, those characters are the plain text, which can consist of numbers, alphabet, or the combinations of the former two. An example of a text mode message could be “Relay1 is open”. By default the text mode is meant for ASCII-based text. It is a terrific choice to use the text mode to send or receive English SMS messages. It can also be used to send or receive SMS messages in other languages than English, but some modems do not support the character set. /1/

3.3.2 PDU Mode

The Protocol Description Unit (PDU) Mode is a character-based interface with hex-encoded binary transfer of message blocks. It is suitable for software drivers based on AT command structures which do not understand the content of the message blocks. It can only pass them between the Mobile Terminal (MT) and “upper level” software resident in the Terminal Equipment (TE). In the PDU mode, not only English but also other languages, such as Finnish and Chinese can be supported to be sent through SMS. /2/

3.4 GSM AT Commands

The applied AT Commands of GSM modem TC35i is referred to the GSM 07.05 document and the GSM 07.07 document; and they are designed by the European Telecommunications Standards Institute.

The GSM 07.05 is the technical specification, which focuses on the technical instruction and application of the SMS service including the coding method of

SMS. The GSM 07.07 is the DTE-DCE interface standard, including AT commands set for GSM Mobile Equipment. The GSM 07.07 specifies the AT command set for control Mobile Equipment (ME) or Data Terminal Equipment (DTE), such as a MCU from a Terminal Equipment (TE) through Terminal Adaptor (TA) or Data Circuit Terminating Equipment (DCE), such as a GSM modem TC35i ; and it also includes some instructions for the GSM functions and GSM network services. /12, 12-13/

The AT commands described in this standard may be observed on the link between the TE (Terminal Equipment) or Data Terminal Equipment (DTE) and the TA (Terminal Adapter) or Data Circuit Terminating Equipment (DCE) in Figure 3. /7, 7/

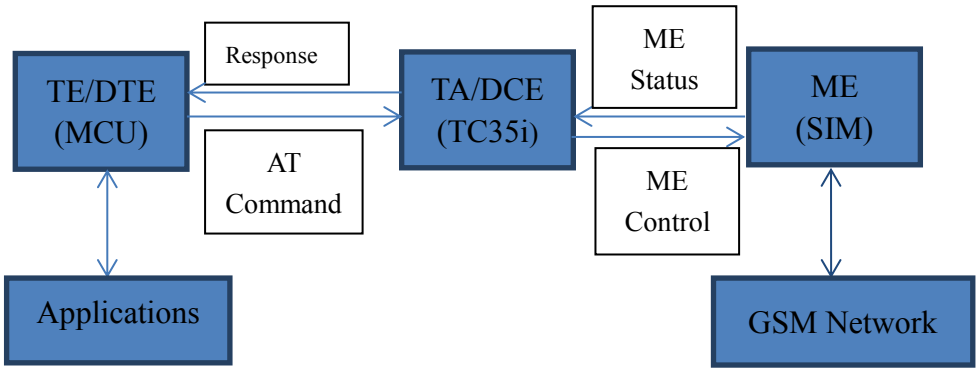

Figure 3. The operation link between TE, TA, and ME

Sending AT commands from TA or TE could control the ME (Mobile Equipment) to communicate with GSM network, such as sending SMS, receiving SMS, calling, and hanging up calling, and so on. After sending AT commands to ME, it will return the related values to TA or TE in the specific formats which are set by the GSM 07.07 and GSM 07.05. However, most of the commands retrieve information about the ME, not about the TA. /7, 7/

The interface between TE and TA is intended to operate through the serial cables or other types of links with similar behavior. In this project, MCU, TC35i, and

SIM card can be regarded as TE, TA, and ME correspondingly. Eight bit data is required for many of defined commands in order to operate correctly. Therefore, it is recommended that a TE-TA link is set to eight bits mode. The interface between TA and ME is dependent on the interface in the ME. /7, 7/

The AT commands defined in the GSM 07.05 document and the GSM 07.07 document have the constant format and return value. In general, there are four formats of AT commands:

The first format is no parameters commands. They are the simple and pure operation order. The symbols “+” and “&” do not have any functional meanings but AT commands have the defined format to combine the symbols with other characters to control and act. The frame of the first format of AT commands should be: AT (“+” or “&”) <command> For instance, “AT&F” stands for factory Reset. /13, 16/

The second format is query commands. They are used to query the value of the related settings. The frame of the first second format of AT commands should be: AT (“+” or “&”) <command>? For instance, “AT+CPIN?” means to read the pin code. /13, 16/

The third format is test commands. They are used to list the possible related parameters. The frame of the first third format of AT commands should be: AT (“+” or “&”) <command>=? For instance, “AT+CMGL=?” means test if the status of pin code is correct. /13, 16/

The fourth format is with parameters commands. They are the most widely used commands with strong flexibility. The frame of the first fourth format of AT commands should be: AT <“+” or “&”> <command>=<value1>, <value2>, <value3>… For instance, “AT+CMGF=1” means that set the SMS format as TEXT messages. /13, 16/

Regarding the return values from TA, there are numerous formats of them. But, they almost all apply to the following frame: <CR><LF><OK/ERROR> [: ERROR number]. CR stands for the Carriage Return character, which is used as the Terminal symbols of commands; and its default value is 13. <LF> Linefeed means Linefeed character, which is used after the Carriage return; and its default value is 10. The AT commands which were used in this project are shown in Table 1. /13, 26-27/

Table 1. Applied AT Commands /13, 26-27/

AT Command	Function
AT	Handshake
ATE1	To switch on the local echo
AT+CPIN	Set the pin code of SIM card
AT+CPMS	Preferred SMS message storage
AT+CNMI	New SMS message indication
AT+CMGF	Choose SMS message format
AT+CMGD	Delete SMS message
AT+CMGR	Read SMS message
AT+CMGS	Send SMS message
AT+CLCC	Incoming calling indication
ATH	Hang up the calling
ATD	Dial

In this project, AT commands are used to perform the following functions to communicate with GSM network: set the pin code; set the storage place of SMS; set the incoming calls and new SMS indication, set the SMS format; delete, read and send SMS; dial and hang up the calling.

The format of AT commands for DTE to achieve the above tasks and the return values from DCE are:

a) Input pin code:

AT Commands Format: AT+CPIN=<NUM> <CR>

Return value: OK

NUM stands for the pin code of SIM card; and in this project, it is 1234. /13, 109/

b) Set SMS storage place: AT+CPMS="","","" <CR>

E.g. Set SMS storage place in the MT (Module Terminal), which stands for all available storage location in the TC35i module:

AT Commands Format: AT+CPMS="MT","MT", "MT"

Return Value: +CPMR: 8, 75, 8, 75, 8, 75 OK

The value “8” in the above return value stands for the number of messages currently in MT. The value “75” in the above return value stands for the number of messages storable in MT. /12, 297/

c) Switch on the new SMS indication. /13,293/

AT Commands Format: AT+CNMI=2,1 <CR>

Return Value: OK

d) Set up the SMS format. /13, 281/

i. Set TEXT format

AT Commands Format: AT+CMGF=1 <CR>

Return Value: OK

ii. Set PDU format

AT Commands Format: AT+CMGF=0 <CR>

Return Value: OK

e) Delete SMS

AT Commands Format: AT+CMGD=<*INDEX*> <CR>

Return Value: OK

INDEX is the index number of the message in the storage place. /13, 280/

f) Read SMS

AT Commands Format: AT+CMGR=<*INDEX*> <CR>

Return Value: +CMGR: "REC UNREAD","PNUM","TIME" CONTENT

PNUM stands for the phone number of SMS's sender

TIME means the time stamp of SMS's transmitting. E.G. "*13/05/30, 23:46:46+12*"

CONTENT stands for the content of the SMS. /13, 284/

g) Send SMS in Text mode

AT Commands Format: AT+CMGS=<*PNUM*> <CR>

After receiving return value ">", the SMS message content is sent firstly. The hexadecimal number "1A" is sent immediately. The correct return Value should be: +CMGR: *INDEX* OK

PNUM stands for the phone number of SMS's receiver.

INDEX is the number of the total SMS has been sent. /13, 286/

h) Set incoming call indication. /13, 171 /

AT Commands Format: AT+CLCC

Return Value: OK

i) Hang up

AT Commands Format: ATH

Return Value: OK

j) Dial

AT Commands Format: ATD<*PNUM*>;

Return Value: BUSY/ NO CARRIER

BUSY: the phone hang up the dialing

ATH: send "ATH" to hang up the dial /13, 154/

k) Other Return Values. /13, 434-439/

Return Value: RING //alert of incoming calling

Return Value: +CMTI: "MT", 1 //alert of new coming SMS and the storage place is the first SMS in MT; number 1: first SMS

3.5 Microcontroller

A typical microcontroller is a chip-size computer with an integrated circuit, including a main processor, memory, and programmable input/output peripheral equipment. /9/

In this project, the microcontroller acts as the main control unit. Its main functions include controlling of the relay, communicating with the thermometer, and communicating with the GSM modem.

Firstly, in order to switch the heater, the microcontroller connects to the relay through its one bi-directional programmable input/output pin; and it controls the output voltage of the pin to control the relay. Secondly, in order to read the temperature from the thermometer, the microcontroller is connected with the thermometer through another bi-directional programmable input/output pin and its temperature data are transmitted through the pin. Thirdly, the microcontroller sends an IGT signal to ignite the GSM modem through one bi-directional programmable input/output pin. Lastly, the microcontroller sends AT commands to the GSM modem and receives return values from the GSM modem through a full-duplex serial port.

The microcontroller used in this project is STC11F08XE. It is one of the 8051-based MCUs. 8051-based MCUs have an integrated serial port: once the operation mode and baud rate of the serial port is properly configured, receiving or writing data to the serial port can operate directly through a serial buffer register. Besides, the serial port of MCU STC11F08XE is a full-duplex serial port; and it can send data, while it receives data. /11/

The operation mode of the serial port can be set with the Serial Control (SCON) register. TI and RI are the name of bit 0 and bite 1 of the SCON register. When the serial transmission is completed, the TI flag value is set as 1. Similarly, when the data is received, RI flag value is set as 1. Whether the RI or TI flag value is 1, as long as the serial port interrupt is in the open state, the microcontroller will enter the serial interrupt service routine. /16/

3.6 Heating Control: Relay

In terms of the control of the heater, the relay was used to switch OFF or ON the heating circuit, which is controlled by the output pin of the microcontroller. Basically, the relay is an electrical switch, which is usually used to control a high-power circuit by a low-power signal. In addition, the control part and the controlled part are completely isolated. The basic principle of the relay operating is: when there is enough current passing through the electromagnet in the control part, the contactor in the controlled part will be propelled by the electromagnet. Thus, the current will be through the controlled part. Otherwise, the contactor is connected and the controlled part stays off. Thus, the current is big enough to trigger the relay to switch on the heating circuit; otherwise, it will stay off. /10/

3.7 Temperature Sensing

In terms of temperature sensing, the digital thermometer was used to sense monitor, and report the temperature of the car. The digital thermometer is a temperature measurement device used to state values to be used in processing an electronic signal to convert it to a temperature. There are two important elements of digital thermometer: temperature sensor and the mean converting the physical value into numerical value. The temperature sensor is a device that gathers data concerning the temperature from a source and converts it to a form that can be understood by another device.

4 APPROACH AND IMPLEMENTATION OF THE PROJECT

In this chapter, how the system are designed and approached are described from the hardware and the software two aspects.

4.1 Hardware Design

The main objectives of this project was to establish the remote control system, which could send/receive the SMS, remotely control the heating system based on the received SMS, and report the temperature and statue of heating device. The structure of the remote control system is shown in Figure 4.

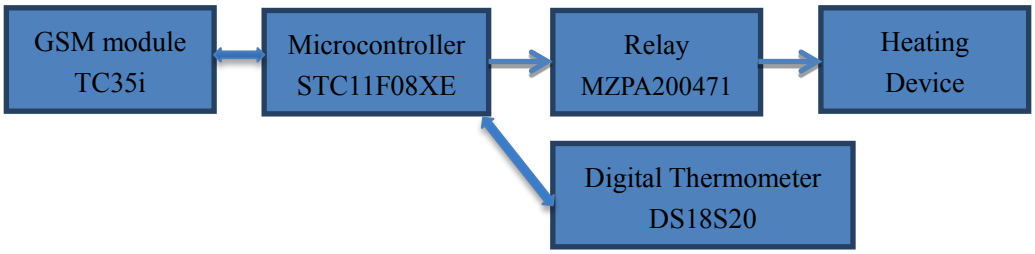

Figure 4. GSM remote control system structure

It mainly contains GSM module TC35i, MCU STC11F08XE, Relay MZPA2004710, and Digital Thermometer DS18S20. Basically, the process of designing hardware was: after selecting appropriate components, Altium Designer 10 was used to design circuit schematics and the PCB board of the system. Then, the PCB board was printed out and the components were connected.

4.1.1 GSM Module TC35i

The chosen GSM module is TC35i from Siemens Company. It is an OEM module, which is based on GSM900 system and made for wireless data transmission, voice transmission, and developing future products. In addition, it combines radio frequency circuit and baseband together; and offers standard GSM AT commands interface with the open interface protocol. The other main features of TC35i are shown in Table 2. /12, 17-18/

Table 2. Main features of TC35i /12, 17-18/

Features	**Implementation**
Power Supply	Single supply voltage 3.3V-4.8V
Frequency Bands	Dual Band EGSM 900 and GSM 1800
SMS	MT, MO, CB, Text and PD SMS storage: SIM card and 25 additional SMS locations in mobile equipment
SIM Interface	Supported SIM card: 3V
Audio Interface	Two analog audio interface (balanced microphone I/O)
Serial Interface	2.65V level bi-directional bus for commands/data using AT commands Supports RTS/CTS hardware handshake and software XON/XOFF flow control Multiplex ability according to GSM 07.10 Multiplexer protocol Baud rates from 300 bps to 234000 bps Autobauding supports baud rate: 4800, 9600, 19200, 38400, 57600, 115200, and 23400bps 8 bits data 1 stop bit with No parity

TC35i has an 8-wire serial interface which is asynchronous and it complies with the ITU-T V.24 protocol DCE signaling and ITU-T RS232 standard. Therefore, the data I/O interface can be treated as a Serial Asynchronous Transceivers. In addition, TC35i is designed for use as a DCE (Data Terminal Equipment). Based on the principles for DCE-DTE connections, Port/TXD sends data to the module's/TXD0 signal line, and Port/RXD receives data from the TC35i's RXD0 signal line.

Figure 5. GSM module TC35i

Regarding the pins of TC35i, it has 40 pins in total, which are led by a ZIF (Zero Insertion Force) connector shown in the red box of Figure 5. The pins 1-5 are the power voltage input pins Vbatt+; and pins 6-10 are power GND. Plus, pin 13 is the external voltage output for the power supply of the external circuit and pin 15 is the ignition pin IGT. In order to start the module, low voltage lasting greater than 100 ms should be given to the IGT pin. Pins 16-23 of TC35i is the data receive/transmit pins, which are DSRO, RINGO, RxDO, TxDO, CTSO, RTSO, DTRO and DCDO correspondingly. /12, 46/

According to the datasheet of TC35i, the application of TC35i connected to the microcontroller is the signal connection of serial interfaces. Figure 6 shows an example of the serial interface connections between TC35i and MCU. /12, 45/

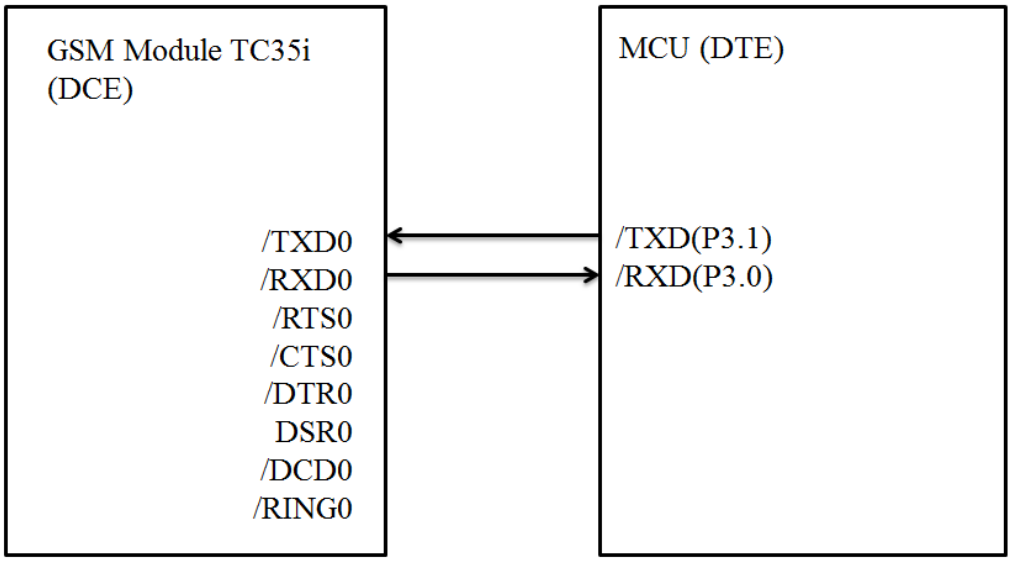

Figure 6. Interfaces connected TC35i with MCU

Thus, in this project, in terms of the serial interface of TC35i, there are two wires used to communicate with MCU's serial pins: TXD0 and RXD0. On the one hand, TXD0 connects with P3.1 of MCU which is the TXD of it. On the other hand, he RXD0 connects with P3.0 of MCU which is the RXD of it. In black box of Figure 5, the RXD0 and TXD0 are the pins connected to MCU.

The data input/output interface of TC35i is actually a serial asynchronous receiver/transmitter, and it meets the ITU-T RS232 interface standard. In addition, it has fixed parameters: 8 data bits, and l stop bit, no parity, baud rate from 300bps to 115kbps, CMOS level and they support the standard AT command set. The default baud rate of TC35i is 0, which stands for autobauding. In this project, the baud rate was set as 9600. Through this interface, an AT commands can be used to switch the operating mode, including voice, data, SMS, or fax mode.

4.1.2 Microcontroller STC11F08XE and External Devices

In this project, the microcontroller is mainly used for igniting TC35i module, controlling the input voltage of the relay, and communicating with digital

thermometer. The microcontroller used in this project is STC11F08XE. It is an 8-bit enhanced 8051 microcontroller with Watch Dog Timer, internal oscillation EEPROM, and reset circuit. Plus, it is compatible with standard 8051 in binary level. The main features are shown in Table 3. /11, 7/

Table 3. Main features of microcontroller STC11F08XE

Features	Implementation
Power Supply	4.1V - 5.5V
Frequency	0-35MHZ
Flash Program Memory	8K
EEPROM	32K
Timer	T0 and T1
UART Serial Port Baud Rate Generator	2
Interrupt Priority Level	2
Internal low interrupt	YES
40 PIN	36 I/O

For the pins shown in Figure 4, there are 40 pins in total and 36 of them are I/O pins. In this project, the used pins of the serial port are P3.0 RxD and P3.1: TxD connected with TC35i and pin P2.4 IGT is used for the Ignition signal line of TC35i. For the I/O pins, pin P1.1 connected with relay control side and pin P1.7 connected with the signal interface DQ of the digital thermometer.

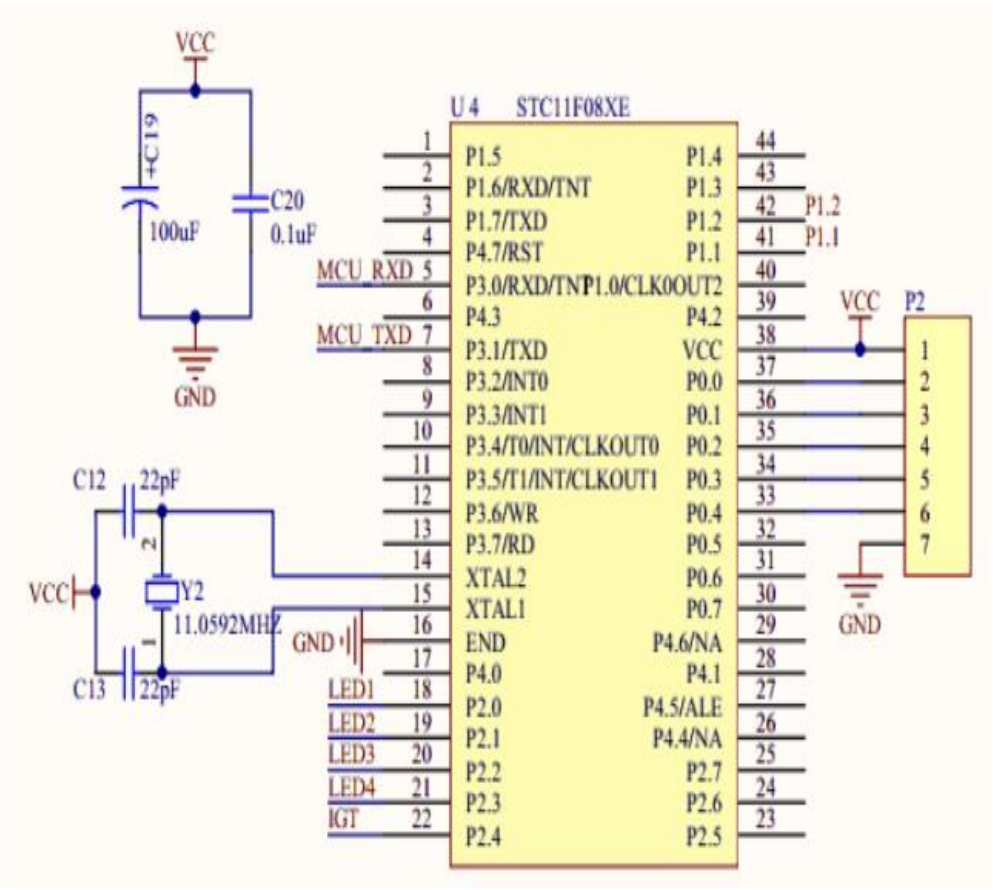

Figure 7. The schematic of microcontroller STC11F08XE

The MCU board was purchased from Tianxiang Electronic Company with the price 278 RMB. The interface of MCU STC11F08XE is shown in the red box in Figure 8.

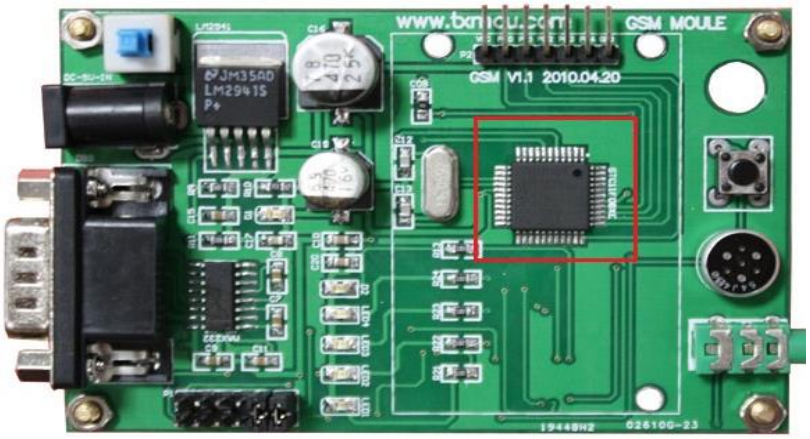

Figure 8. Interface of MCU STC11F08XE

For the Relay MZPA2004710 , basically, the microcontroller pulls the voltage of pin P1.2 to high and the relay(switch) would be ON; then the heating system would be connected with power and be ON. Conversely, the low voltage of pin P1.2 leads to the OFF of heating system.

In this project, MZPA2004710 was chosen as a relay. The driven and protection circuit of relay is as below. The input control voltage is from 16,3V to 28,6 V and output switching voltage range is from 48 V to 280 V and the load current range is 100 mA to 14 A. The maximum turn-on/off time is ½ cycle plus 1ms. /8/

The schematic of the relay is included in the red dashed box in Figure 6. Regarding the driving circuit of the relay, the Darlington transistor array ULN2803A was chosen to drive the relay since the output voltage is not enough to drive the relay directly.

There are 8 Darlington transistor pairs in ULN2803A and one pair of them was used to drive the relay. The schematic of the driving transistor is included in the green dashed box in Figure 9. /14/

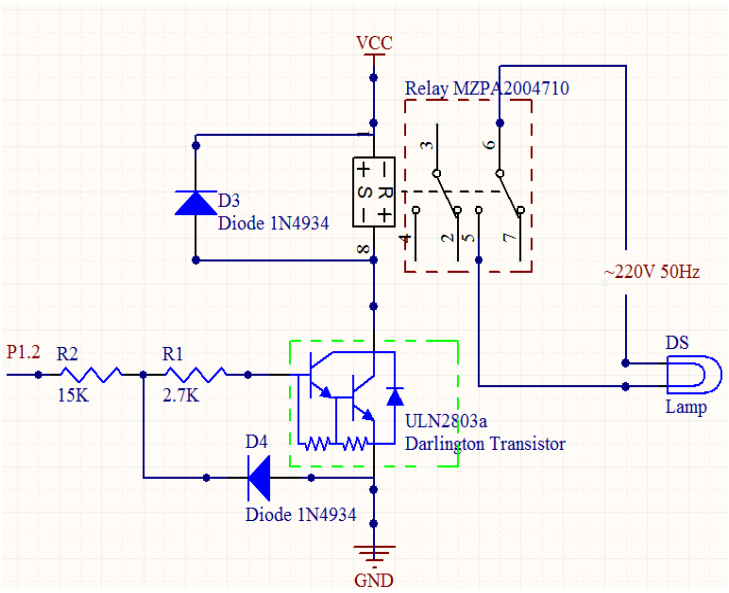

Figure 9. Relay driven application circuit

For the digital thermometer DS18S20, it offers 9-bit Celsius temperature measurements through one-wire interface required with only one port pin DQ communication with microcontroller. The application circuit of DS18S20 is designed as shown in Figure 10. /4/

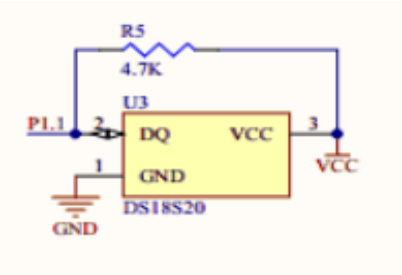

Figure 10. The application circuit of DS18S20

For the parameters of it, it can be powered by the data line with the power supply range from 3.0 V to 5.5 V and the valid measured temperature range is from -55 to +125 Celsius degree with +/- 0.5 accuracy and 750 ms conversion speed. In addition, there is one 2-byte temperature register in DS18S20 (TH and TL) which stores the digital output from the temperature sensor. The 1-byte upper and the lower registers are TH and TL correspondingly, which are nonvolatile (EEPROM). Thus, they will store data when the DS18S20 is powered down. In this case, its direct-to-digital temperature sensor output has 9-bit resolution, which corresponds to 0.5°C steps. "The DS18S20 powers-up in a low-power idle state; to initiate a temperature measurement and Analog-to-Digital conversion, the master must issue a Convert T command. Following the conversion, the resulting thermal data is stored in the 2-byte temperature register in the scratchpad memory and the DS18S20 returns to its idle state. After the Convert T command, the DS18S20 will respond by transmitting 0 while the temperature conversion is in progress and 1 when the conversion is done." /4/

4.1.3 The Structure of Hardware

The structure of hardware system is shown in Figure 11. It illustrates how the

main components are connected.

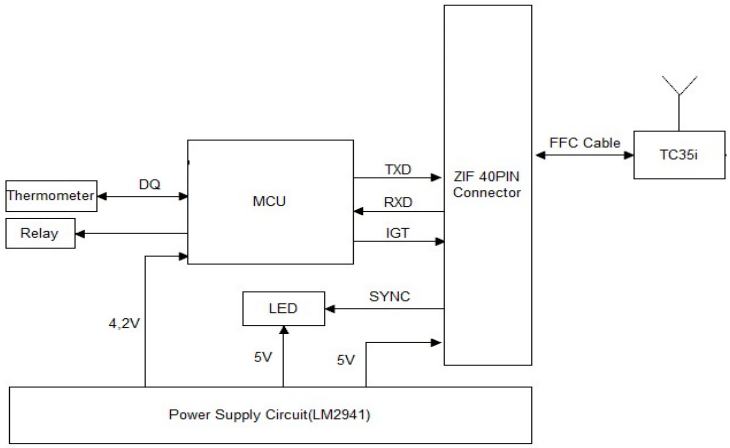

Figure 11. The block diagram of hardware system's connections

Through the serial port, the microcontroller receives and transmits data with GPRS module by AT commands in order to initialize TC35i module and send/receive data. After the system is powered, firstly, it starts TC35i; and then transmits an AT command to query the status of SIM card. If the SIM card is properly installed, the TC35i module returns the command. Then the TC35i module completes the initialization by the commands from the microcontroller. When a new SMS is received by the TC35i, AT command will sent from the TC35i module to the microcontroller; and microcontroller decodes the content of SMS and controls the voltage of I/O port to switch the relay according to the content of SMS. On the other side, the microcontroller receives the data (temperature value) from the digital thermometer through one single port pin P1.7; and by using an AT command, the value is sent to TC35i module through serial port pin P3.1. Then, the temperature is reported in the content of SMS from TC35i.

4.2 Software Programming

The program language is the C language, and the programming tool is Keil 2.0.

The burner tool is ISP-1.3.6 to download hex file to the microcontroller. There are two main parts, main function and serial port interrupt functions.

4.2.1 Main Function

The flow chart of the main funciton is shown in Figure 12. It includes I/O initilization, values initialization, set up the TC35i, and processing the data with TC35i.

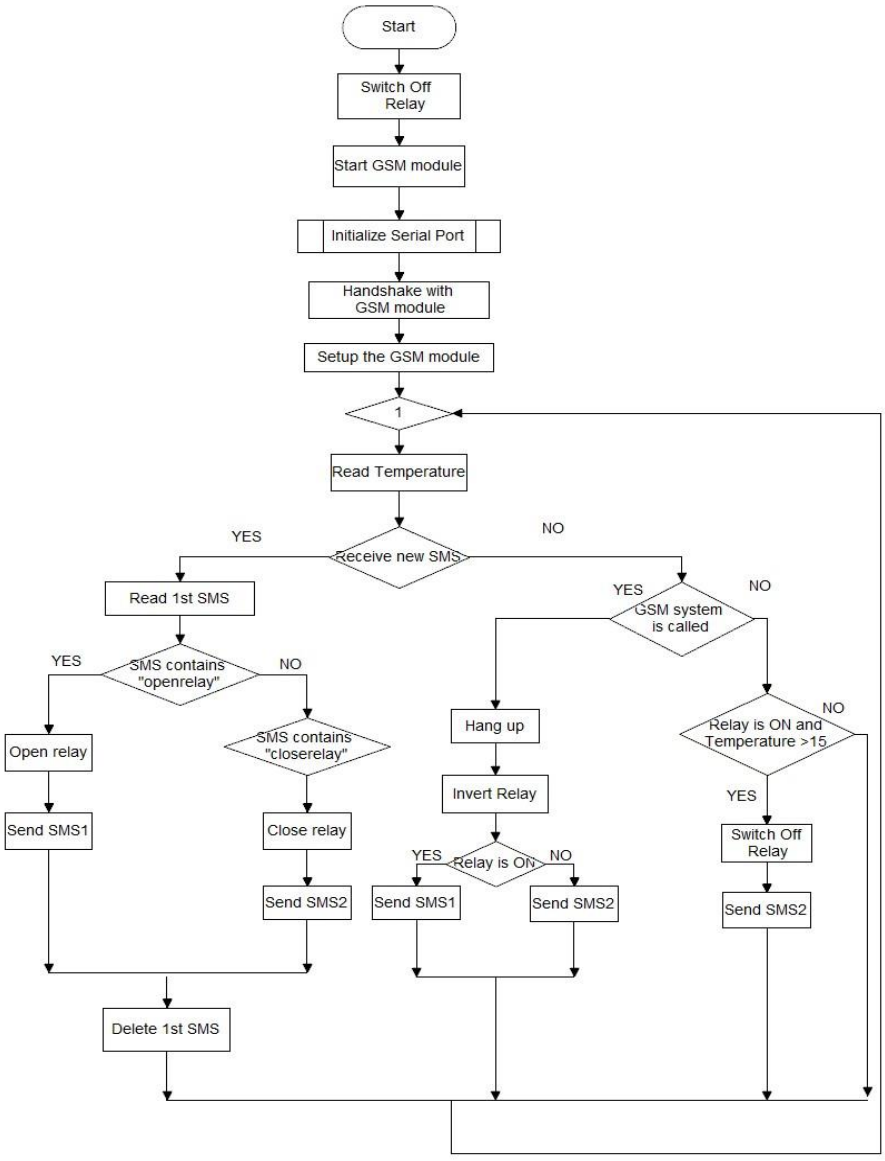

Figure 12. Main function flowchart

4.2.1.1 I/O Initialization

In the parallel port initialization setting step, in order to turn the relay OFF the output pin P1.1 was enabled to stay in the low voltage level.

Regarding the serial port setting, 9600 bps baud rate, none parity, none flow control, 8-bit data, and 1 stop bit was set in the serial initialization function. In the timer initialization, the Timer1 was used and set as auto-reloaded mode to offer bard rate of serial port.

Therefore, for the serial control register SCON, it was set as 0x50 in order to set it work in mode 1 with 8 variables and with no parity. In addition, for the timer control, we used Timer 1 to generate the baud rate in mode 2 with 8-bit auto-reload mode; then TMOD was set as 0x20. Timer 1 gives interrupt every 1/9600 second. Timer register 1 consists of TH1 and TL1. TH1 will be set a reload value which is loaded to TL1 when interrupt occurs. The value is calculated by the clock rate of the system and division value set in TMOD register. In order to get the baud rate 9600, we set the reload value of timer register 1 as 253. The calculation of the reload value is: TH1 =256-(CF/384)/baud rate. In the function, Cf stands for Crystal Frequency; and STC11F08XE has crystal frequency with 11059200 Hz. Thus, TH1=256-(11059200/384)/9600=256-3=253=0xFD. /16/

4.2.1.2 Variables Initialization

There are two important steps related to variables initialization, empty the buffer and the relay state. In order to confirm that the received SMS always is stored in the first position in the buffer, the buffer is set to write only mode in the variable initialization step, which allows the received serial data put into the buffer. Regarding the relay state, after the system's startup, the relay must be in the OFF state for safety. Thus, the variable for the state of the relay is set to 0 (OFF).

4.2.1.3 Processing the Data with TC35i

This part is mainly about judging and processing the data received from or transmitting to TC35i module.

When the SMS is received, the microcontroller reads the content of SMS and takes actions according to the content of SMS. The actions could be opening/closing the relay and sending an SMS back to report the statue of relay plus the temperature of the environment.

The microcontroller sends AT commands to TC35i and will get related echo from TC35i to indicate the result of the actions. The sending of AT commands from the microcontroller and the related echo from TC35i are shown in Appendix 1.

4.2.2 Serial Port Interrupt Functions

Regarding the serial port of microcontroller, the receiving/transmitting data was realized by the serial interrupt function and the timer interrupt function.

For the serial control of microcontroller, 8 data bits with no parity and 9600 baud rate were set to communicate with TC35i module. Therefore, for the serial control register SCON, we set it to work in mode 1 with 8-bit data format and with no parity.

In addition, for the timer control, Timer 1 was used to generate the baud rate (9600 bps) in mode 2 with 8-bit auto-reload mode.

Once the configuration of the serial port has been properly set, the serial port of MCU can communicate with TC35i. The SBUF register is the serial data buffer, which acts as an output when data is written to serial port. Or it acts as an input when data is read from the serial port.

In order to write a byte to TC35i, SBUF should be set as the value of the byte. The

received data from TC35i through the serial port were stored in the SBUF buffer. In order to read a byte from TC35i, the stored value in the SBUF should be read.

The flowchart of serial interrupt processing function is shown in Figure 13. The flow chart of sending characters from the serial port function is shown in Figure 14.

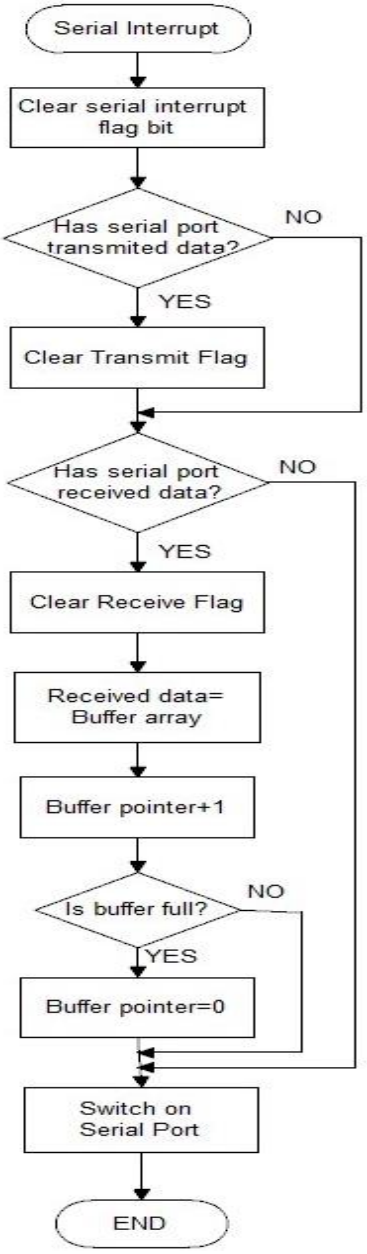

Figure 13. Serial interrupt processing function

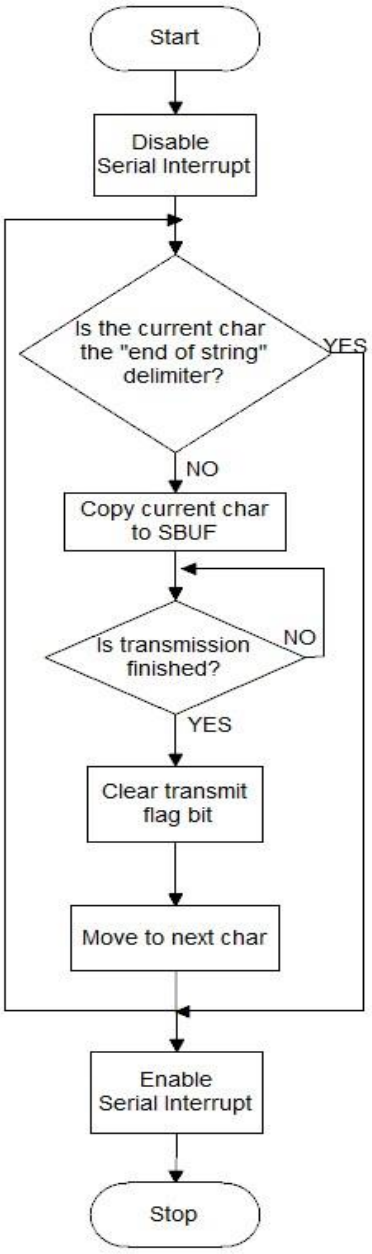

Figure 14. Serial ports send characters

5 SYSTEM TEST

In this chapter, the test of the remote control system is illustrated, including its arrangement, result, and analysis. The aim of this phase was to measure the key performances of the GSM remote control system.

5.1 List of Instrumentation and Equipment

GSM Remote Control System with SIM card which phone number is: +358465927406

Mobile Phone with number +358400571017

Voltage Transform: 220V AC to 24V DC

24V DC Lamp

5V DC Power

One mercury thermometer 50 °C to – 50 °C

5.2 Test Arrangements

The connection of the system test is shown in Figure 15. The white box in Figure 14 is the voltage transform.

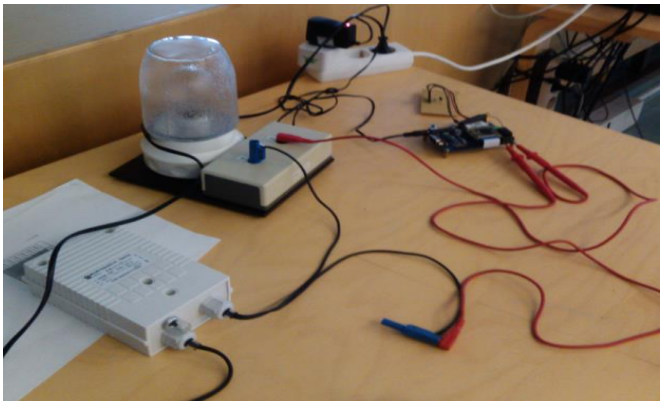

Figure 15. The connection of system test

In the test phase, the lamp replaced the heater to show a direct illustration of switching the heater. When the relay was in the ON state, the lamp was lit; otherwise, it was dark. In addition, taking the safety of the system test operation into consideration, the transfer connected with the 220V AC power in order to transfer the 220V AC to 24V DC. One red cable was used for the connection between one side of the DC lamp and one pin of the relay. The other red cable was used for the connection between the other pin of the relay and the positive electrode of the transfer. The black cable was used for the connection between the other side of the DC lamp and the negative of the transfer. The 5V DC power source was connected with the GSM Remote Control System.

After the connections had been completed, the ignition button of the system was pressed; and the indication LED would indicate the statues of the system. After the system completed configuration by itself, the indication LED would be ON for 30ms and be OFF for 1ms in a cycle.

5.3 Operations and the Results

In order to test the stability and the key functions of the remote control system, there were two testing operations, including sending SMSs to switch the lamp and testing the temperature report function.

Firstly, a mercury thermometer was used to test the actual temperature to compare with the measured result of the digital thermometer. It showed that the actual temperature was 10 °C in Figure 16.

Secondly, the mobile phone with phone number “+358400571017” sent the “openrelay”. Then, the lamp was lit. In addition, the GSM system sent back the SMS to the mobile phone with the content: “Relay is open. The temperature is 9.5 degree now”, which can be seen in Figure 17.

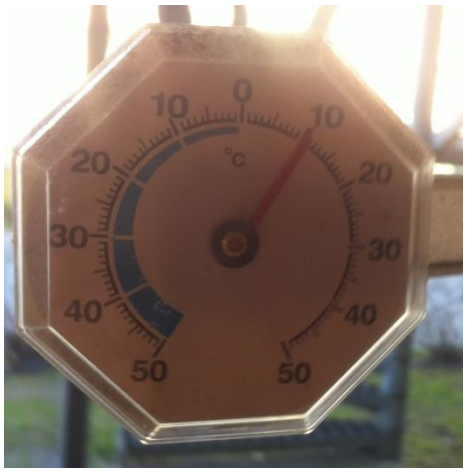

Figure 16. The temperature measured by mercury thermometer

Thirdly, the mobile phone with the phone number "+358400571017" sent the "closerelay". Then, the lamp was dark. In addition, the GSM system sent back the SMS to the mobile phone with the content: "Relay is close. The temperature is 9.5 degree now", which can be seen in Figure 17.

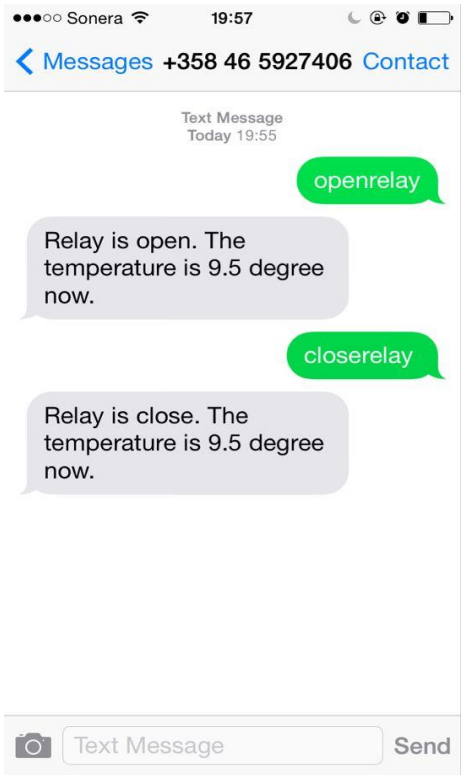

Figure 17. The SMSs between the system and the mobile phone

5.4 Analysis of the Results

"SMS remote control" and "SMS reporting" functions of the remote control system worked quite well and were stable in different time of period and environments:

Regarding the "SMS remote control" function, sending an SMS with the content "openrelay" could remotely switch ON the lamp. Relatively, the GSM remote control system sent back to the mobile phone to report the temperature and the status of the lamp as "open". In addition, sending an SMS with the content "closerelay" could remotely switch ON the lamp. Relatively, the GSM remote control system sent back to the mobile phone to report the temperature and the status of the lamp as "close".

The actual temperature is 10 °C, which is measured by the mercury thermometer. The temperature reported in SMSs is 9.5 °C. Thus, the difference between them is 0.5 °C. When the difference between the temperature shown on the mercury thermometer and the temperature reported in SMS is not above 0.5 Celsius degree, the measurement is accurate and successful. Therefore, the test of temperature sensing was successful.

Even though the remote control system was tested to run in a very good condition, the main problem of making the GSM remote control heater come true is the power supply of the heater. To put it in the other angle, the lamp would be switched ON/OFF by SMS; however, there might be some potential risk to use the power of engine without anybody around the car.

This problem could be solved using an external power supplier to power the heater. Therefore, this GSM remote module could be used as a remote switch to control the connection between the heater and external power supplier.

6 CONCLUSIONS AND FUTURE EXTENSION

The remote control system run properly and stably and it could implement all the desired and planned functions. This is because the software was designed in a proper way, and the test process run step by step.

The planned functions were done with the system: the relay in the system could be remotely switched ON/OFF by SMSs, and the temperature as well as the status of the relay could be reported through SMSs. As the theoretical knowledge from the previous study supported the practical study a lot, the process of approaching the result went almost smoothly. But, some mistakes happened in the software designing and test section. For instance, the reported temperature through SMSs was all the same in different environment; in the end, it was proved that in the code, the function of calculating the measured temperature was wrong.

It is a practical topic that car users do not need any other applications or terminals to remotely control the heater of a car; the car users just need to send SMSs to warm their cars with a regular phone. However, there are some realistic problems to deal with in the future. For instance, the power of supplying the car block heater is really a big issue. Also, there are potential risks of remotely controlling the car block heater.

For the future extension, this system could be combined with the Wi-Fi/3G module and specialized phone application for this system could be made. And the system could be modified to save the energy by auto-selecting heating time based on monitoring the outside and side temperature.

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APPENDICES

APPENDIX 1. AT commands and echo

Function	Microcontroller (DTE)	TC35i module(DCE)
Handshake	AT	OK
Input pin code	AT+CPIN=1234	OK
Set storage place	AT+CPMS="MT","MT","MT"	+CPMS: 8,75,8,75,8,75
Set new SM indication	AT+CNMI=2,1	OK
Set TEXT mode	AT+CMGF=1	OK
Delete the first SM	AT+CMGD=1	OK
Indication of a new SM	+CMTI: "MT",1	
Read the first SM	AT+CMGR=1	+CMGR: "REC UNREAD","+358400571017",,"13/05/30,23:46:46+12"
Send SM in TEXT mode	AT+CMGS=0400571017	>
	"Relay is open"+"\x1a"	→, +CMGS: 70 ,OK
Set PDU mode	AT+CMGF=0	OK
Send SM in PDU mode	AT+CMGS=40	>
	"0791535880770101110000C9153480075017100 08AA1A00720065006C00E4002000E40072002 000F6007000700065006E"+"\x1a"	→, +CMGS: 72 ,OK
Set incoming call indication	AT+CLCC	OK
Hang up the call	ATH	OK
Dial	ATD0400571017	BUSY /NO CARRIER