# Developing a PC- and SMS-μC-based Stepper Motor Drive Set*

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*This paper describes a PC- and SMS-μC-based Stepper Motor Drive set developed at Marmara University for use in graduate and undergraduate studies. The drive set presents an environment utilizing GSM service, in which students implement stepper motor real-time driving applications, readily get familiar with short message service SMS AT commands with an interface program and learn driving fundamentals through an animation program. Additionally, they can develop and implement different driving algorithms for the stepper motors in this environment.*

**Keywords:** PC- and SMS-μC-based stepper motor drive; GSM; SMS AT commands

## INTRODUCTION

AFTER ESTABLISHMENT of the GSM standard in 1987, service providers having millions of subscribers have been increasingly providing inexpensive and quality service as the result of competitions between wireless telecommunication systems. GSM is the world's fastest growing communications technology of all time and the leading global mobile standard [1]. Since industrial needs have ignited demand of mobile technology usage, mobile technology usage in engineering education has also increased rapidly.

The GSM standard is an open, digital cellular technology used for transmitting mobile voice and data services such as SMS and GPRS. The standard uses a variation of time division multiple access technique and operates at either 900 MHz or 1800 MHz frequency band [2]. SMS is a globally used wireless service. SMS enables the transmission of alphanumeric messages between mobile subscribers and external systems such as electronic mail, paging and voice-mail systems [3]. Additionally, SMS is also used in automation. For example, nowadays, new remote control devices begin to receive/transmit data via SMS and they are used as a wireless I/O module for a part of PLCs or programmable relays [4].

Stepper motors are still widely used in the industries like CNC and robotics technologies because of their low-costs and easily controllable structures. The Stepper motor is an electromechanical device that converts electrical pulses into discrete mechanical rotations. Shaft rotation occurs in constant discrete step increments when control pulses are applied in a correct sequence. The speed of shaft rotation is directly proportional to the applied pulse intervals. The sequence of the applied pulses determines the direction of shaft rotation and the number of pulses is directly proportional to the movement length [5].

Most common drive modes for stepper motors are wave drives, full-step drives and half-step drives. A wave drive energizes only one phase at any discrete time. A full-step drive energizes two phases at any discrete time. A half-step drive combines the above two modes. The Microstepping drive has also been a common drive, which continuously varies the motor current breaking up one full step into many smaller discrete steps.

In the literature similar studies mostly use an internet environment for remote laboratory implementations [6, 7, 8, 9]. Although cellular-based remote laboratory implementations are not reported in the literature, in the market there are a few educational or industrial development kits for remote stepper motor drives [10]. The author believes that as new generations for cellular phone devices come into the market, the applications in this area will spread. In the literature, only a single similar application is found. This is not an educational study and is related to remote control of an ultrasonic motor through a standard GSM mobile phone [11]. In the study, the GSM controlled drive system was successfully tested for different speed, position and direction conditions to achieve remote control of the ultrasonic motor. This is rather a technical report for control applications through a GSM mobile phone. For educational purposes, on the other hand, there appears to be no related paper in the literature.

The present paper starts by describing the developed Stepper Motor Drive set. The study continues with discussing the PC- and SMS-μC-based drives and their driving strategies. Then, theoretical and experimental studies for some drive parameters are introduced and their results given. Then, an SMS Test Interface program is

Fig. 1. Photos of the drive set (the drive set side and parameter sending side).

introduced. Next, the other interface program for the tutorial and animations is introduced that provides a basic knowledge for engineering students. Finally, some concluding remarks are given.

## DESCRIPTION OF THE STEPPER MOTOR DRIVE SET

The Stepper Motor Drive set consists of one 1.5 GHz centrino notebook (PC), two GSM/GPRS modems, a stepper motor drive board, a stepper motor belonging to Stepper Motor System (SMS2), a product of TecQuipment [12], a smaller PM stepper motor driven from 5.25 inch diskette drive and a development software, written in Microsoft Visual Basic. The drive set is shown in Fig. 1.

The drive set provides a complete PC- and SMS-based drive control for the drive modes. The designed stepper motor drive board contains an efficient microcontroller, PIC18F452, [13] with 16-bit wide instructions and an 8-bit wide data path, with a 32-kilobyte Flash-EPROM as program memory. Hi-Tech C18 compiler [13] is used in compiling the program codes, written in ANSI C. GSM 07.05 SMS standard AT commands [14] are used for data transfer between the GSM modem and the microcontroller through the serial port.

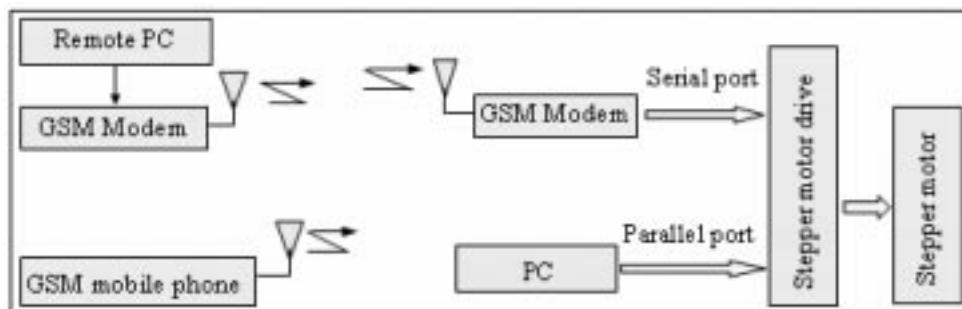The drive set block diagram is given in Fig. 2.

The drive set provides PC- or SMS-μC-based drives for the stepper motor as shown in the figure. In the SMS-μC-based drive the Stepper motor drive parameters can be sent via a remote PC or a cellular phone. The microcontroller generates the drive pulses providing the drive parameters for the stepper motor. In the PC-based drive the drive pulses are transmitted through the parallel port. The schematic of the drive board is shown in Fig. 3.

The drive board consists of the microcontroller 18F452, two identical full H-bridge MOSFETs drivers, isolating, sensing and mode selection circuitry, a voltage regulator, parallel and serial ports used for the PC- and SMS-μC-based drives, a connector for the stepper motor coils, an LCD and a connector ICD2 [13] for programming the μC. The two full H-bridge drives are actually designed for a bipolar drive, in which the stepper windings are connected between the output terminals A and B as shown in Fig. 3. Unipolar and wave drives are also accomplished by firing only the upper part of the MOSFETs. Heat sinks mounted on the MOSFETs are required for dissipation of MOSFET conduction and switching losses. Since the inertia of the Stepper motor of SMS2 is large and driven by 80 V a shock bobbin may be optionally connected in series between the drive supply inlet and motor windings to protect the stepper motor and to avoid heating problems in the H-bridges.

The number of coil ends being connected to the


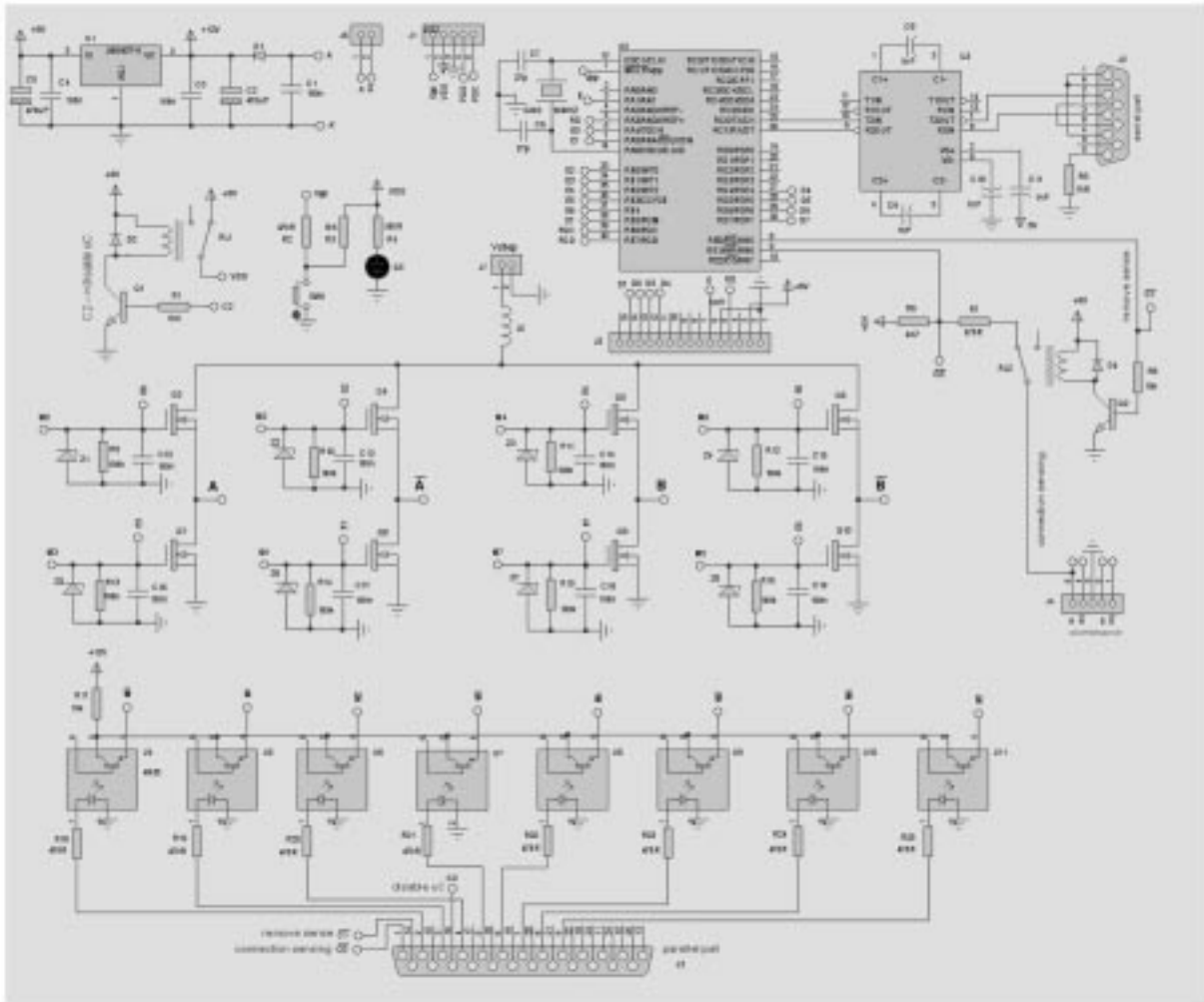
Fig. 2. The Stepper Motor drive set block diagram.

Fig. 3. The schematic of the stepper motor drive.

drive set gives a sensing knowledge for a decision whether bipolar or unipolar driving will be initiated. This approach makes the drive set more compact and multi-functional.

The PC- and SMS-μC-based Stepper Motor Drive set allows students to implement the applications such as bipolar and unipolar winding drives, acceleration and deceleration, half-/full-step drives, continuous/counted run, changing pulse sequence and its frequency.

### THE DEVELOPMENT SOFTWARE FOR THE STEPPER MOTOR DRIVE SET

The development software designed for the drive set is shown in Fig. 4. The software environment consists of three interface programs, which are Stepper Motor Drive, SMS Test Environment and the Tutorial and Animations.

The Stepper Motor Drive interface program is activated by clicking on one of the buttons, PC Drive or SMS-μC. The values for drive parameters are chosen by clicking on and rotating the related parameter knobs. The displays above the knobs

show the chosen values of the drive parameters, which are pulse frequency, fall time, rise time and stepping number. The other drive parameters are chosen by clicking on the buttons below the knobs. Each button has double functions and its function changes when clicking on it. The buttons, as default, represent the parameters as CCW, Continuous Run, Stop and Half Step. When clicking on the buttons they change as CW, Counted Run, Start and Full Step. The Drive Type label, located at the left lower part of the window automatically shows the drive type during the stepper motor run. It can be either Unipolar or Bipolar according to the sensing signal.

### PC-BASED STEPPER MOTOR DRIVE

The students enter the stepper motor drive parameters using the related knobs and buttons as shown in Fig 4. The parallel port is used in driving the stepper motor through the PC. The used parallel port pins for data and control signals are shown in Fig. 5. When the PC-based drive is

Fig. 4. The development software for the drive set.

activated, firstly SMS-µC-based drive is disabled by the relay RL1 in the drive board through the control signal C2. Meanwhile, the control signal C0 senses, by one end of a stator winding, whether the common ends of the stator windings are grounded. This is accomplished by enabling the control signal C1 that energizes the relay RL2. After the sensing, the coil end is disconnected from the parallel port and from the input port of the µC by disabling the control signal C1.

The drive parameter sending procedure is initiated when the PC-based button is clicked as shown in Fig. 4. Next, the drive menu is opened and then a call number and the drive parameters are entered. The procedure is completed by clicking on the OK button.

Since the drive parameter data structure for the PC-based drive is the same with SMS-µC-based drive, this part is discussed in the next section.

## SMS-µC-BASED STEPPER MOTOR DRIVE

Stepper Motor Drive parameters for SMS-µC can be sent via alternative ways such as the Stepper Motor Drive interface program, Windows XP Hyper Terminal and any mobile GSM phone. However, the data structure of drive parameters

to be sent via SMS must be in the same byte format shown in Fig. 6.

As shown in Fig. 6, after entering the stepper motor parameters 5-byte data are sent by clicking on the SMS-µC Drive button. The data are sent from the PC by using AT commands [9], which are received by an MC35i modem from the serial port. The first byte consists of five one bit-control data, which are Start/Stop, CW/CCW, Continuous/ Counted Step and Half/Full Step. The start bit initiates the step movement and the stop bit terminates the stepping. The Continuous/Counted Step bit determines whether the stepping will be continuous or counted. The second byte determines the pulse frequency for the stepper motor. The third byte shows the step number. The last two bytes hold the rise and fall time durations for acceleration and deceleration. For acceleration and deceleration of the stepper motor, linear ramp functions are used. The rise and the fall time durations can be entered as 0 to 10 seconds.

## STEPPER MOTOR DRIVE STRATEGY

Since the drive strategy is the same for both PC- and SMS-µC-based drives, only the flowchart related with SMS-µC-based drive is shown in



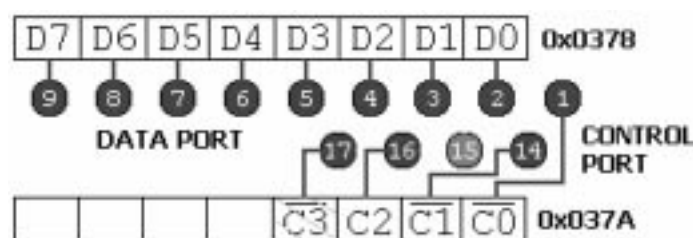Fig. 5. The used parallel port pins for data and control signals.

| Fall Time | Rise Time | Number of Steps | Pulse Frequency | - | - | - | - | Half / Full Step | Continuous / Counted Step | CW/ CCW | Start/ Stop |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 byte | 1 byte | 1 byte | 1 byte | | | | | | 1 byte | | |

Fig. 6. The drive data structure for the stepper motor control parameters.

Fig. 7. The stepper motor drive parameters sent through the GSM modem on the PC side are received by the other GSM modem on the drive board side. When the SMS is received by the modem, a signal is generated through its serial port for a short time. This signal is noticed by the μC through its received interrupt mechanism, which is enabled at the initialization stage of the μC run.

When an interrupt occurs, the μC requests the current calls through an AT command to check there is an authorized call for driving the stepper motor. Then, the embedded program sends an AT command to the modem for rejecting the waiting call. If the rejected call is an unauthorized one, the μC goes back to the receive interrupt mode again and continues writing the drive parameters on the LCD. If the waiting call is an authorized one the SMS message is read and the stepper motor driving parameters are queued to a defined buffer variable byte to byte. After the receiving data is completed, the stepper motor drive parameters are assigned to the related variables.

In the flowchart the subprograms, unipolar main drive and bipolar main drive are not demonstrated in detail because of the lack of volume.
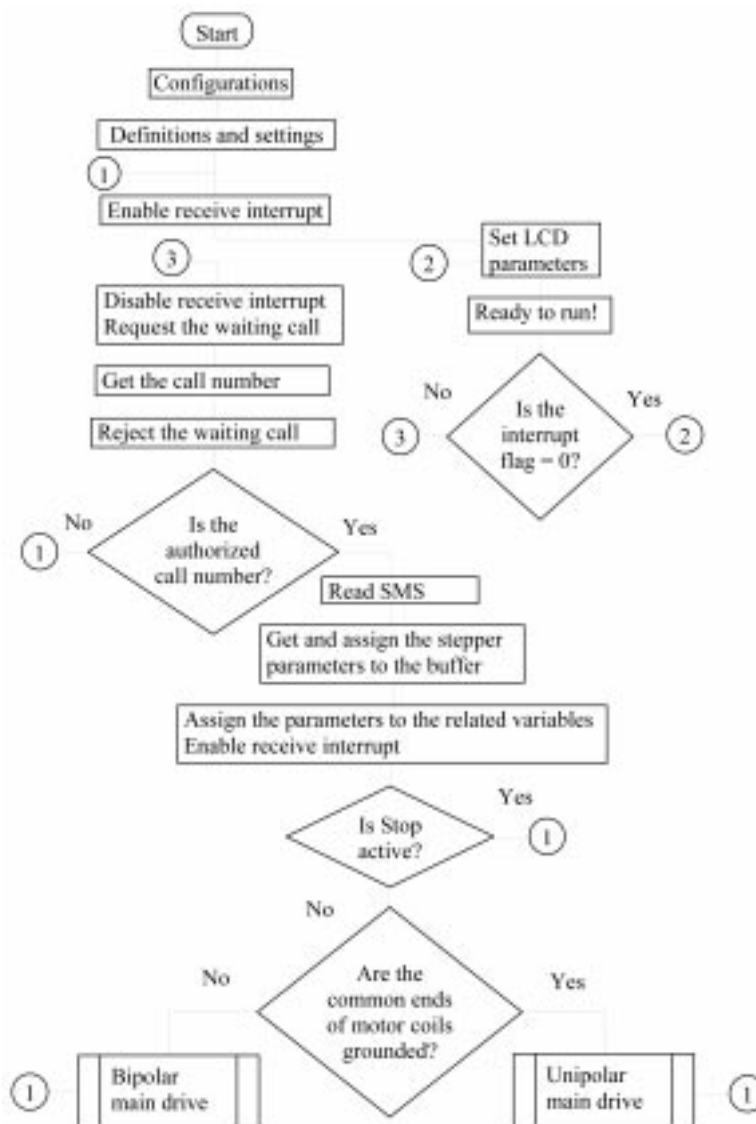


Fig. 7. The flowchart for the Stepper Motor Drive set.

Their code structures are similar and they show a few differences at supporting the drive modes. They implement the drive modes in relation to the drive parameters and they also govern the LCD.

## EXPERIMENTAL STUDIES

The acceleration and deceleration linear ramp functions governing the motor at rising and falling times for the stepper motor are extracted and graphically shown in Fig. 8 using Matlab.

The deceleration ramp function can be given as in Equation (1) in time domain. The equation determines new pulse interval values increasing during the fall time:

$$t_{pulse\_fall} = \left[ k \frac{t - t_c}{t_c + t_{fall} - t_c} + 1 \right] t_{pulse} \qquad (1)$$

where the parameter k changes the slope of the ramp function, which changes the pulse interval. $t_c$ represents the beginning of deceleration or acceleration, $t_{pulse}$ represents the current pulse interval. $t_{fall}$ depicts the fall time and finally $t_{pulse\_fall}$ shows the new pulse interval value.

The acceleration ramp function can be given as in Equation (2) in time domain. The equation determines new pulse interval values decreasing during the rise time:

$$t_{pulse\_rise} = \frac{t_c + t_{rise} - t}{t_c + t_{rise} - t_c} t_{pulse} \qquad (2)$$

where $t_{rise}$ represents the rise time and $t_{pulse\_rise}$ shows the new pulse interval value.

The program does not allow $t$ reaching the value $t_{rise}$. Because, in this case the time interval value goes to zero, this causes the instability for the μC. Therefore, $t$ value cannot be less than a certain value, called $t_{min}$. In the drive set $t_{min}$ is found as 0.05 s.
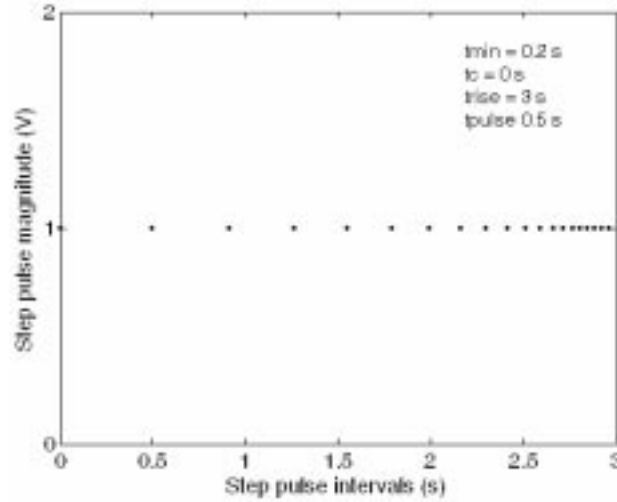


(a)
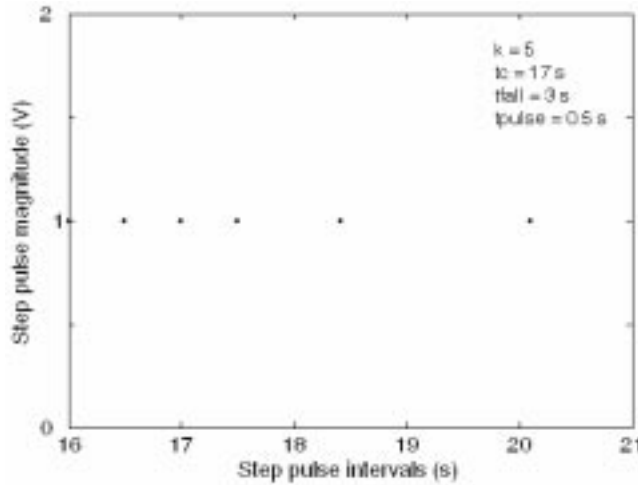


(b)

Fig. 8. Changing pulse intervals for (a) acceleration and (b) deceleration.

In the MathWorks environment, students can graphically test the validity of the above equations comparing them with the experimental results and can easily comprehend the parameters and coefficients for the acceleration and deceleration ramp functions.

*Some AT commands used in the stepper motor control*

Some basic SMS-related AT commands used in driving codes are explained below. An example for an AT command usage is also given in the following sample code:

```
void inquiry(void) //call for inquiry
{
  far char *s = ''at+clcc''; // to list
current calls
int i;

TXIE = 1;
  for (i = 0; i != '\0'; ++i) {
    TXREG = s[i];
    while(!TXIF)        continue
    while(!TRMT)        continue;
  }
}
```

When the above code part is executed the response acquired is in the form of:

```
+CLCC: 1,0,0,0,0,''03038639839'',
129,''Test''
```

coming from a GSM servicing company. Hence, the call number in the response is extracted for inquiry. The development software and its source codes can be downloaded from the website: www.tef.marmara.edu.tr/~monat

## THE INTERFACE PROGRAM FOR THE SMS TEST ENVIRONMENT

In this environment AT commands can be easily learned and tested by the modem MC35i when it is connected to a PC. Students can list all incoming calls by pressing the button 'MESSAGE ANALYSIS' as shown in Fig. 9. The student can clear the message screen by pressing the button 'CLEAR'. AT commands can be executed writing to the 'OUTGOING COMMAND' box and then clicking on the button 'SEND'. The student can expect to see the modem response, which is shown in the box 'RESPONSE'. The program can be exited by clicking on the button 'EXIT'.

## THE INTERFACE PROGRAM FOR THE TUTORIAL AND ANIMATIONS

The tutorial and animation interface program, shown in Fig. 10, is developed for presenting basic knowledge about conventional and mobile drives for the stepper motors. This environment serves to reduce periods of learning and implementation and making the laboratory studies more attractive.

In the program, the Stepper motor driving animations are designed in three parts: the drive circuit, the connection type of stator windings (CL1, CL2, CL3 and CL4) and the structural model of a Stepper motor. In the animation program the connection type of stator windings changes according to the chosen drive type.

Students can learn the energizing sequence of coils and magnetizations between rotor magnets and stator windings by using various drive methods such as half-step and full-step by clicking on the wave, unipolar or bipolar drive button. The pulses sent in sequences from a PC or via SMS to



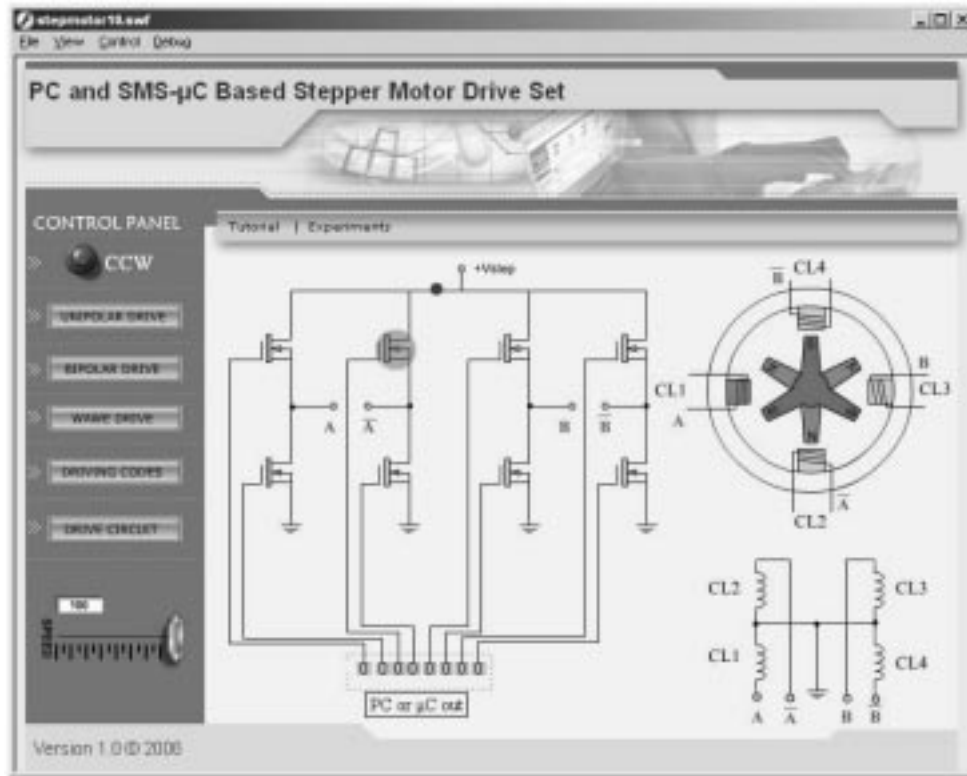Fig. 9. SMS test environment interface program.

Fig. 10. The animation program for the Stepper Motor Drive.

fire the power MOSFETs in the drive set are demonstrated by a moving red ball. The power signal arising from the supply is depicted by a moving blue ball. In unipolar drive one red and one blue ball are used, whereas in bipolar drive two red and two blue balls are used. When the red ball arrives at any MOSFET gate, the gate color turns into brown. In addition, the related coil is highlighted in the structural model. The speed of the ball (pulse frequency) is changed by the sliding button in the lower left side in the figure.

The direction of the motor shaft rotation is modified by CW/CCW button. A password window opens when clicking on the button 'DRIVING CODES'. This part is normally closed to the students. The instructor enters this part to present the real-time driving strategy and to demonstrate the drive codes in class. In this part all the codes for PC- and SMS-μC-based drives are classified by using text box buttons, which are named according to the code groups. For example, when clicking on the subbutton 'HALF STEP', the codes written for half-step in the stepper motor drive interface program are displayed with an explanatory text. In the same way, when pressing on the button 'DRIVE CIRCUIT', the drive circuit is displayed. The circuit is divided into the subcircuit areas according to their functions. When clicking a subcircuit area, that part is enlarged and an explanatory text window is displayed on the screen, which describes the operation of the chosen subcircuit.

## CONCLUSIONS

At Marmara University, Institute for Graduate Studies in Pure and Applied Sciences, this approach has been introduced in the Wireless Data Transmission and Control course in the Spring 2005 semester. It is observed that this kind of 'hands on' approach increases the student's interest in the wireless control world. On the other hand, the Department of Computer and Control Education is a member of MVET (Modernization of Vocational Education & Training in Turkey) project, which is supported by the EU. In this project, a modular education program is being adapted to the curriculum. This course is planned to be included in the curriculum as a elective course.

The study offers many practical possibilities. The educational drive set can be driven from a PC- or GSM-equipped hardware, which can determine the driving type automatically. The classical drive modes such as half step, full step, rotating in limited number and, rotation in CW and CCW directions are all supported for the stepper motor. Additionally, acceleration and deceleration ramp functions are also introduced to the driver set. The stepper motor drive parameters can be changed on-line during the run time. Interface programs for teaching SMS AT commands and animations for stepper motor drives reinforced and accelerated the learning.

The author intends encouraging the students to implement similar mobile-based case studies. The

students are also able to develop their own algorithms and codes for other mobile technologies such as GPS and Bluetooth after getting familiar with the driving strategy and its codes.

As a result, an instructive case study through a stepper motor drive set equipped with the mobile technology has been developed for control education. The work can also be readily adapted to a web server-based case study by using GPRS AT commands.

## REFERENCES

1. www.wirelessintelligence.com, 23 February 2006.
2. W. Stallings, *Wireless Communications and Networks*, Prentice Hall, New Jersey, (2002), p. 312.
3. www.panasonic-wireless.com/cellterms.asp, 14 May 2006.
4. Idec Electronics, *The Engineering Talk*, 11 November 2005.
5. Texas Instrument, *MSP430 Stepper Motor Controller, App. Report: SLAA223*, (2004).
6. H. Ewald and G. Page, Performing experiments by remote control using the Internet, *Global Journal of Engineering Education*, **4**(3), 2000, pp. 287–292.
7. H. Shen, Z. Xu, B. Dalager, V. Kristiansen, O. Strom, M. S. Shur, T. A. Fjeldly, J. Q. Lu and T. Ytterdal, Conducting laboratory experiments over the Internet, *IEEE Transactions on Education*, **42**(3), 1999, pp. 180–185.
8. Gonzalez-Costano *et al.*, Internet access to real equipment at computer laboratories using the Java/ COBRA paradigm, *Computers and Education*, **36**, 2001, pp. 151–170.
9. B. Atkan, C. Bohus, L. Crowl and M. Shor, Distance learning applied to control engineering laboratories, *IEEE Transactions on Education*, **39**(3), 1996, pp. 320–326.
10. Saia-Burgess Dresden GmbH, http://www.saia-burgess.com, accessed 16 May 2006.
11. E. Bekiroglu and N. Daldal, Remote control of an ultrasonic motor by using a GSM mobile phone, *Sensors and Actuators A: Physical*, Elsevier, **120**, 2005, pp. 536–542.
12. TecQuipment, *Stepper Motor System Manual*, (1995).
13. *Microchip 18F452 Data Sheet*, www.microchip.com., accessed 13 February 2006.
14. *MC35i AT Command Set*, Siemens AG, (2003).

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## GLOSSARY

| | |
|---|---|
| PC | Personal computer |
| SMS | Short message service |
| µC | Microcontroller |
| GSM | Global system for mobile communication |
| GPRS | General Package Radio Service |
| AT | ATtention: command line prefix |
| ICD | In circuit debugger |
| EU | European Union |
| Hi-Tech C18 | Hi-Tech C compiler |
| GSM 07.05 | One of the GSM standard protocols |
| CW/CCW | Clockwise/Counter clockwise |