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AT COMMANDS IN PROJECT BASED LEARNING

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Abstract: *AT commands are strings of data that can be sent to a communication module for the purpose of programming it. The paper presents several applications of programming different types of modem, all of them using AT commands. The types of modems considered in the paper are: dial-up modem, GPRS modem, Bluetooth modem and WLAN modem. The paper shows how some of the modules used in Project Based Learning experiment were programmed using AT commands. The paper also presents the results of a test that queries the opinion of the students engaged in this centractivity, showing the effectiveness of PBL and outlining the difficulties arisen during the project realization.*

Key words: *AT Commands, dial-up, GPRS, Bluetooth, WLAN.*

1. Introduction

The paper presents several applications of AT commands supporting learning, some implemented and others just designed theoretical. The most important educational role of these commands is that they eases the programming work, providing a quick success of the interfacing with wireless data modules, which is very stimulating for students engaged in a project. Getting a quick success and attractiveness of the theme, as the wireless applications are, is important in PBL [1]. It is said [4] that PBL is an educational system with better results than the classic, providing a greater involvement and empowerment of students. In most applications chosen by the students, the structure contains a microcontroller that measures a certain parameter and sends data to a data alization unit. Almost all microcontrollers have UART (RS232) and SPI interfaces integrated, which are quite primitive, while wireless modules have evolved to higher level interfaces, e.g. USB. In order to use common microcontrollers and ease the hardware connection, wireless modules with RS232 interface were purchased. To facilitate software connection, modules that can be programmed with AT commands were selected.

AT commands are strings of data that begin with the prefix AT and can be sent to a communication module for the purpose of programming it. AT commands are related to asynchronous serial interface and can be sent using a program such as Hyper-Terminal in Windows, if the module is connected to a PC over RS232 interface or directly from the microcontroller, also over the RS232 interface. AT commands were introduced in 1977 by Hayes Communications Company for dialup modems. GSM/3G Communications took over the principle of AT commands and

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standardized them in ETSI GSM 07.07 standard [7]. Unfortunately there is no uniform standard for AT commands and the manufacturers of new circuits define their own AT commands.

Connecting a communication module to a PC is useful in the initial phase of fixing the software part of the application. After the program has been developed, the microcontroller is programmed to communicate with wireless module also over RS232 serial interface using the same AT commands.

2. Data Transmission via Dial-Up Modem

The first application in which AT commands have been used was formed by a microcontroller-based data acquisition system, transmitting data over a dialup modem. Modems support various types and categories of AT commands that are firmware dependent. The current application used a modem based on an AMBIENT chipset CL-MD56XX. Part of the AT commands are basic commands and they are implemented in almost all types of modems. AT command set can be divided into five categories: fax, data, V.42/MNP, voice and VoiceView. All commands to the modem must be preceded by the string 'AT' (means Attention), and end with a carriage return <CR>. A command line may contain several AT commands that may or may not be separated by a space. AT commands may use upper or lower case, provided that only one type of character is used in a command. Modem can be configured to send back all the characters to the DTE (Data Terminal Equipment), (only in command state). The last command can be repeated by using the command A/without using character <CR>. Each command line may contain maximum 80 characters.

DCE (Data Communication Equipment) being in online status, communicates with the remote modem. Any data sent from DTE to DCE is transmitted to the remote modem. Similarly, any data received by the DCE device is transmitted to the DTE. The modem recognizes AT commands transmitted at any valid speed from 300 to 115.200 bps. Each command can have one or more associated parameters. If a numerical parameter is not sent, then it is considered to be equal to 0.

When initiating a modem connection manually, one modem should be the initiator and the other the listener. The connection is done by sending the command ATD to the initiator modem, and the ATA command to the receiver modem. In automatic mode the initiator sends the command ATD + phone number. The answer is done automatically by setting a nonzero value of the register S0. S1 register counts how many rings have passed. If S0 is equal to S1, the modem tries to connect.

After the connection with the remote modem is done, the DTE can send link interruption commands (called escape sequences). A modem connection ends when the modem is disconnected or when the carrier transmission of the remote modem is idle for a period longer than that specified in register S10. Connection and transaction algorithm consists of the following phases:

Modems must be initialized the first time. This is done by sending the following AT commands:

ATZ - reset modem
ATE1 - echo activation for verification
ATL2 - volum=2
ATM2 - active speaker (for audio control)
ATW1 - to report speed after CONNECT
AT&D0 - ignore DTE
AT&K0 - no handshake
ATS0=5 - 5 calls are expected in automatic mode
ATS6=4 - wait 4 seconds before dial

3. Data Transmission via GPRS

GPRS transmission system is provided by mobile operators and acquired data are sent to a user's server. Maximum transfer rate can be achieved by GPRS is 171.2 Kbps, which is 21.4kBps. Data transfer can be performed using UDP (User Datagram Protocol) or TCP/IP. Each module must have a GPRS SIM card provided by the mobile operator with a subscription or pre-paid system for data transfer. The applications were done using two types of GPRS modules, Telit products [8], GM862-GPRS model and EZ10 model. Both models are equipped with RS232 interfaces.

Telit EZ10 module is a GPRS/GPS built like a whole separate board that connects to the microcontroller via a serial RS232 connection. The module is based on GM862 device, additionally having the GPS function. EZ10 manages internally the TCP-IP stack and facilitates the implementation of such application. The module is powered from an external power supply.

The connection between the Telit module and the microcontroller is performed via RS232 serial interface, communication is based on AT commands.

When activating the GPRS connection, one must specify the network parameters and the dialed phone number to establish a connection between the modem and a data server (can not establish a connection between two GPRS modems). Connection with an application located on a server is done as follows:

An AT command sets the properties to enable the GPRS modem to activate the GPRS connection whenever a data transfer is needed;

An AT command sets authentication parameters, username and password that will be used to validate the connection;

An AT commands defines the port connection to the server and UDP or TCP-IP protocol;

The connection starts with a dialing command.

Some of the commands used to connect are:

AT-Empty command empty, will always return the answer "OK", used in the AT format

AT # USERID [= <user>] - Send names for network authentication used as AT # USERID = "net.vo

AT # PASSW = <pwd> - Send password to login, use as AT # PASSW

AT + CPIN [= <pin> [, <newpin>]] - Send your PIN, use the form AT + CPIN = 2649 (PIN)

AT + CREG =? - After you insert the SIM card PIN the system is waiting until the connection is made. The command was used in the form: AT + CREG?

AT + CGDCONT = 1 -

The IP connection through GGSN server name "net.vodafone.ro" without data compression or packet header.

The command used was: AT + CGDCONT = 1, "ip", "net.vodafone.ro", "0.0.0.0", 0.0

AT # GPRS [= [<mode>]] - GPRS activation with 1, deactivation with 0, transmission has been activated with AT # GPRS = 1. AT # GPRS? interrogates the modem status

at#sktd=0 -

Socket type used is the TCP, listening port number is 2222, server's IP address is "86.125.93.184", and the connection closes when the server closes the connection port. The command used was: AT # SKTD = 0.2222, "86.125.93.184", 0

Transmitting data follows after this sequence. Practically everything is received by the module over the serial interface will be sent to the server; after closing the connection, the module will be passed to off state. A complete list of AT commands can be found in the Telit documentation [9].

GPRS applications are easier to implement than it seems at first glance, this due

primarily GPRS modem programmability with AT commands (Easy GPRS). It is not necessary to know the route of the user data to the server, the only condition for the server is to have assigned a fixed IP.

GPRS transmission is suitable for applications where no receiver exists near the point of data collection, but there is mobile coverage.

GPRS transmission system was implemented to measure the radon concentration in the air at several points and in real time. The project was done by a team of teachers and students that took part in PBL (Project Base Learning) interfacing lessons and continued the same theme in their diploma works [3].

4. Data Transmission via Bluetooth

Bluetooth is used for short-distance data transfers between a computer and various peripherals, such as headsets, mobile phones, music players, printers, cameras, GPS etc.

The allocated spectrum is in the 2.4 GHz frequency band between 2.402 GHz and 2.480 GHz. Transmission distance is usually 1 m, the speed is 1Mbps, but there are some higher power devices that provide emission distances up to 100m. Connecting a Bluetooth device to a host computer is accomplished through a software breakthrough.

Bluetooth interface from Rayson BTM222 contains a BlueCore4 nucleus with SPI, UART, USB connection interfaces and a PCM (Pulse Code Modulation) for connecting an audio module.

From the core, data are issued by a power antenna amplifier; the received data are amplified by an LNA. Power supply and the core supply are different. The interface provides Bluetooth transfer version 2 with EDR (Enhanced Data Rate) up to 3 Mbps. Power saving modes are provided.

This type of Bluetooth module accepts AT commands.

Some AT commands that are supported by the circuit:

ATAn - establishing connection with the devices n = 1-8

ATB? - displays addresses of slave devices connected

ATD=xxxxxxxxxxxx - defines a 12-digit address for a device connected

ATEX - set echo for the USART transmission, X = 0 without echo, with echo X =1, X =? queries the current state

ATF? - 60s looking for devices and displays their names

ATHX - Set the permission of discovery, X = 0 can not be found, X = 1 can be found, X =? queries the current state

ATI? - query software version

ATKX - determine the number of stop bits to the serial transmission

ATLX - determines serial transmission transfer speed

ATMX - establish parity control

ATN=xxx…. - set a device name, maximum 16 characters

ATO - automatic connection command

ATP=xxxx - send PIN

ATQX - Set sending a command execution confirmation

ATRX - master or slave mode set

ATU= password - password to access the firmware upgrade

ATZ - restores the original settings

A simple programming sequence for a module to enter slave mode:

ATN=Slave; slave name is established

ATP=3527; PIN code is sent

ATR1; slave mode is set

ATH1; discoverable mode is set

A simple programming sequence for a module in master mode is:

ATN=Master; master mode is set

ATP=3527; PIN code is sent

ATR0; master mode is set

ATO1; automatic connection is disabled

ATF?; devices looking for 60 sec

ATA1; device 1 is connected

Another Bluetooth module that can be used in embedded applications is LM058 serial adapter [10].

This adapter complies with the specification v2.0 + EDR, and provides a transmission distance of 100 m, speed is 115.2 kbps but also 230.4 kbps with clock sent. Power can be achieved with a 5 V power supply through USB hook or from an unused serial signal. The module can be programmed using AT commands. Some AT commands are:

AT - verification

AT+ENQ - displays all settings for Bluetooth and RS232

AT+ACON - validate the automatic connection

AT+CONN =xxxxxxxxxxxx- establishes a connection to the device whose address is xxxxxxxxxxxx

AT+FIND - earch for a Bluetooth device for a minute

AT+NAME - set a Bluetooth device name

AT+PIN - send PIN code

AT+RESET - initialize device

AT+BAUD - sets RS232 communication speed

The complete list of AT commands is given in data sheet.

5. WLAN Transmission

HW86050 module Hoft & Wessel from [11] is designed to provide wireless connectivity with a microcontroller-based module over the serial interface RS232. The module operates in IEEE 802.11b and provides a maximum transfer rate of 11 Mbps at a distance of 300 m outside and 60 m inside. The module contains an interface RS232, SPI and a parallel interface for data, an ADC, PWM channels and GPIO pins.

The advantage of the module consists not having to implement the communication protocol, as it is software implemented and accessible with simple commands on the serial line. The commands for this module do not start with AT, so you could say that they arenot AT commands, but they respect the philosophy of AT commands. Thus, commands that begin with S (set) are commands that set some parameters, namely those that start with G (get) read the current parameters. For example, the command AT that returns OK for the other modules becomes Gok (Get OK) and returns OK.

6. Deployment of PBL Activity

PBL activity takes place without changing the structure of classical learning, and is optional. Students who perform this activity may receive a maximum of two bonus points at the examination, and it is optional.

The proposed theme for interfacing subject is a microcontroller-based data acquisition system using wireless transmission of the acquired data. The process in which data is acquired, the type of measurement and wireless transmission mode is the student's choice. Students can work individually or in groups, maximum group size is 3 students. The results are communicated using PowerPoint presentations, in front of all colleagues, including those who have not participated in the PBL. Grading of projects is done also by the students, considering the Gauss distribution curve.

Conception and design must be complemented by theoretical simulations. Practical implementation is not mandatory but is recommended for students, especially to those who want to continue the theme in their diploma work.

This approach was implemented with students specializations Telecommunications, Applied Electronics and Computer Science, final year in the first semester.

During the project presentation session, after the realization of projects of wireless systems with AT command interface, together with the students, several conclusions were identified:

1. Concept, design and realization of a wireless communication is easier than it looks, because of the specialized interface circuits. Using specialized circuits reduces production time of an application - Time to market;
2. The concept of an electronic communication system begins with a study regarding the existence of specialized circuits (accessing circuit-builders pages ATMEL, TI, Microchip etc.) and continues with identifying the commercial availability (accessing pages of Romania suppliers - Vitacom, Ecas, Adelaide, Farnell etc.). Check if the available circuits on the market are using AT commands.
3. Interfacing a microcontroller with a dedicated circuit is reduced mostly to connect the microcontroller through a standard serial or parallel interface to the circuit, therefore detailed study of these interfaces is important, which is the justification for carrying out the classical part of the course for this part.

The power point presentation session to discuss the projects carried out include discussions about recommended bibliography [2] which provide useful details for understanding AT commands, serial RS232 protocol description, compatibility to 16 550 etc.

If several types of wireless interfaces are used, a comparative table is added at the end, as for example Table 1:

Wireless interfaces comparison Table 1

	GPRS	**802.11**	**Bluetooth**
Application	International voice and data networks	Internet	Connectivity between devices
Battery life	Days	Days	Weeks
Speed	2 Mbps	54 Mbps	720 kbps
Coverage	km	100 m	100 m
Advantages	High coverage	Speed	Convenience
Network	Internet access	Possible	Possible

By analyzing this table, the optimal radio transmission options for each application can be derived.

7. Educational Outcomes

A poll was conducted which included three groups of students, a group from the specialization of Computer, one from Telecommunications and one from Applied Electronics, each one of the final year. The test was completed by 61 students from the 3 groups. A total of 12 students from those three groups have opted for PBL, which is only 19.6%. Project presentation was made in the presence of all students in the three groups.

When asked if they heard about AT commands, 0% answered they have not heard, 31% had heard only once and 69% have heard several times. It can be said that the project presentations in front of all students had the desired effect.

The distribution of the answers to the question to what extent they understand AT commands is given in Figure 1.

Only three students believe that they fully understood AT commands, which is quite a bit. 17 students have very well or fully understood AT commands (category 4 and 5), which means an even higher number than the students who have completed a project.

A total of 30 students said they did not use AT commands and a total of 31 students say they wrote programs that contain AT commands.

It is interesting to note in the last two questions that some students have even written but did not understand AT commands.

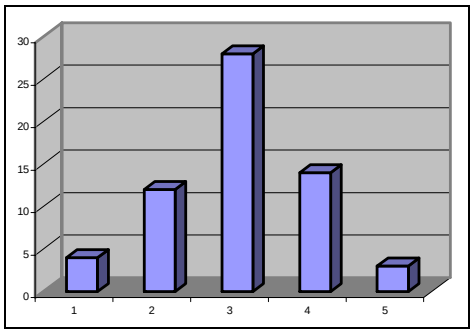

Fig. 1. *Answers to the question to what extent they understand AT commands: 1 - not at all; 5 - complete*

The distribution of answers to the question how important is the simplification brought by AT commands is given in Figure 2.

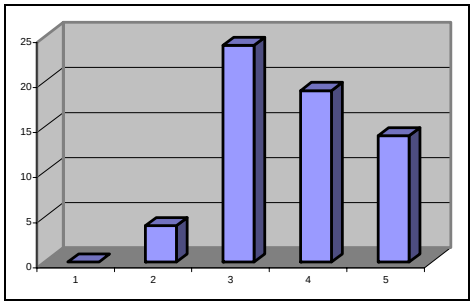

Fig. 2. *Answers to how important is the simplification brought by AT commands: 1 - not at all; 5 - very important*

More than half of the students are not enlightened to the simplification brought by AT commands, only 14 considered it very important.

The distribution of the answers to questions when you first heard of AT commands is given in Figure 3.

A majority of 34 students have heard of AT commands through this project, even if only 12 students have done project.

When asked if they will choose AT commands in the design of their future applications, a total of 13 students have said they will use in all the applications, five students will not use AT commands and the remaining 43 students answered correctly that they will use AT commands depending on the specific application.

Unfortunately, being not a compulsory activity, less students chose to do this project. Thus, for the first graduates to which this system was first proposed, in the three groups of the Telecommunication specialization (2007-2008), out of 57 students only five chose not to do this project, i.e. 8.7%. In 2010-2011 80.4% of students chose not to make this project.

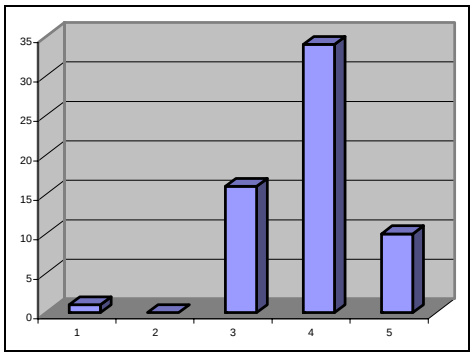

Fig. 3. *Answers to the question when they first heard of AT commands: 1 - first year; 2 - second year; 3 - third year; 4 - forth year at the project; 5 - forth year at another activity*

There are several possible explanations for this phenomenon. One of them is that an increasing number of students have a job during the faculty. The test of opinion included a question which showed that 34.4% (21 students) of the students who responded have a job in parallel with the faculty.

8. Conclusions

The case studies presented in this paper were conducted in the context of granting the students wider action freedom and increased responsibilities, in accordance with the CDIO concept (Conceive, Design, Implement, Operate), which is similar to the one presented in [5].

According to the competence criteria required for engineering undergraduates established by ABET (Accreditation Board for Engineering and Technology) [12], it can be concluded that PBL is a more effective system compared to traditional education systems.

Acknowledgment

The Faculty of Electrical Engineering and Computer Science in *Transilvania* University of Braşov, implemented in 2007 a Project Based Learning initiative.

A combination of classic and PBL was applied to Electromagnetic Compatibility and Interfacing disciplines studied by the students in Applied Electronics and Telecommunication. Some of the projects were continued in the University Degree Projects with the first two series of Bologna graduates. The results in environmental applications have been published in [6].

References

1. Firebaugh, S., Piepmeier, J.: *The RoboCup Nanogram League: An Opportunity for Problem-Based Undergraduate Education in Microsystems.* In: IEEE Transaction on Education **51** (2008), p. 394-399.
2. Gerigan, C., Ogruțan, P.: *Tehnici de interfațare* (*Interfacing Techniques*). Braşov. Editura Transilvania Braşov, 2000.
3. Kertész, C., Ogruțan, P., Szekely, I.: *Embedded System with ATMEGA16 for Measuring Radon Concentration.* In: Bulletin of the *Transilvania* University of Braşov (2007) Vol. 14 (49), Series I, p. 243-248.
4. Mantri, A., Dutt, S., Gupta, J.P., Chitkara, M.: *Design and Evaluation of a PBL-Based Course in Analog Electronics*. In: IEEE Transaction on Education **51** (2008), p. 432-438.
5. Max, L., Thiringer, T., Undeland, T., Karlsson, R.: *Power Electronics Design Laboratory Exercise for Final-Year M. Sc. Students.* In: IEEE Transaction on Education **52** (2009), p. 524- 531.
6. Ogruțan, P., Aciu, L., Gerigan, C., Romanca, M.: *Environmental Education in Electrical Engineering, Environmental*. In: Engineering and Management Journal **9** (2010) No. 9, p. 1187-1194.
7. http://www.3gpp.org/ftp/specs/html-info/0707. Accessed: 15-09-2009.
8. http://www.telit.com/en/. Accessed: 20-10-2009.
9. www.semiconductorstore.com/pdf/newsite/Telit/GM862-GPS/GM862-GPS_Software_User_Guide_r4.pdf. Accessed: 15-01-2010.
10. http://www.lm-technologies.com/business/product_item.php?item_id=15. Accessed: 01-.12-2010.
11. http://www.hoeft-wessel.com/en/HW86050.pdf. Accessed: 10-10-2010.
12. http://www.abet.org.: *Engineering Criteria,* (*2000*)*, Accreditation Board for Engineering and Technology, On line*. Accessed: 07-01-2011.