Door Automation System for Smart Home Implementation

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***Abstract*— In this paper is presented the design and the prototype implementation of a pneumatic door automation system intended to be used for access control in smart homes. The structure of the developed application is realized around the PIC 16F877A microcontroller which operates together with a pneumatic actuator based on a double acting cylinder controlled through an air distributor with solenoid valve. In the basic mode, the door opening and closing actions can be initiated manually by the user, through password authentification. The main parameters of the system can be configured locally, but an in-depth diagnoses and reconfiguration can be performed only through the serial interface which ensure the communication between the main module of the system and an external PC. Compared with other similar systems, the proposed implementation solution allows a high operation speed and very good reliability due to the pneumatic actuation. In addition, the door automation module can be integrated in a centralized access control system dedicated to the smart homes that has all the appliances and other electricity based equipments connected into a local network.**

Keywords*— door automation, smart home, microcontroller, pneumatic control.

I. INTRODUCTION

The smart home concept based on the newest achievements in the field of artificial intelligence and network communications offers a very broad spectrum of applications which are expected to improve significantly the quality of life in the future. For example, the daily management of an increasing number of appliances including heating, ventilation, and air conditioning equipments (HVAC) that are often present in a modern house could represent a stressing but unavoidable task for ensuring the required level of safety and the certitude that all systems are in the proper state.

The smart home systems allow a continuous and real-time data exchange between the installed equipments and the user for obtaining highly advanced features for the buildings. Also, in recent times the concerns regarding the energy efficiency and human environmental impact represent other important driving factors that generate new developments in the field of automation systems for smart homes. In this context this paper describes a versatile door automation system dedicated for operation in smart homes access control equipments [1].

II. THE MODEL OF SMART HOME SYSTEMS

The smart home concept refers to a building that contains a particular type of automation system that is specifically implemented and dedicated for controlling the operation of the appliances, equipments and installations existent in that a residential environment (Fig. 1). The main functionalities and services ensured by a smart home consists in an enhanced security based on advanced access control and surveillance facilities, an efficient management of the energy consumption for an increased comfort but with a sustainable energetic performances and an extended and integrated support for the lifestyle and entertainment of the inhabitants. These kinds of systems integrate a variety of sensors and devices and usually use a communication network for internal and external information exchange. In practice can be distinguished two types of approaches for implementation of the home automation systems, based either on local or remote control. Both these implementation solutions have their specific advantages and drawbacks [2].

Designs based on local and centralized control are inherently more secure but suffers a certain lack of accessibility because of the missing features for remote connectivity. In contrast, home automation systems with open architectures that are based on various communication networks achieve an improved remote access. This important advantage came with the penalty of an increased vulnerability regarding the unauthorized access to the control functions of the system, but using appropriate encryption algorithms and other measures for security improvement this issue can be significantly alleviated.

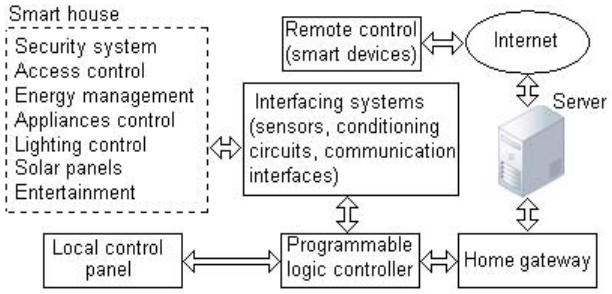

Fig. 1. The simplified model for the smart home concept implementation.

III. The Structure of the Door Automation System

The control module is implemented with PIC 16F877A general purpose microcontroller which realizes all the tasks required for the correct operation of the system. As can be observed in the Fig. 2 the pressurized air generated by the compressor is stored and directed to the proper port of the pneumatic actuator by the air distributor implemented with a dedicated solenoid valve. The position and implicitly the opening degree of the door are continuously monitored through a resistive potentiometer acting as angular displacement sensor. For increased safety of operation and reliability, the control module is galvanic insulated, through optical coupler, from the solenoid valve of the pneumatic actuator [3]. The block diagram containing the most important elements that compose the hardware architecture of the proposed door automation system is depicted in Fig. 2.

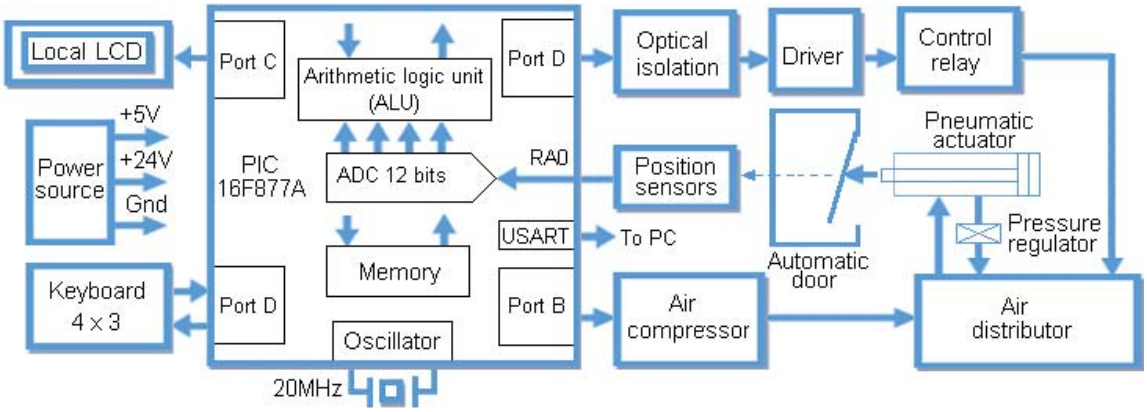

Fig. 2. The block diagram of the door automation system used for access control in smart homes.

IV. The Software Application

The general view of the state diagram for the software application that controls the operation of the PIC 16F877A microcontroller is presented in Fig. 3. The program was written, verified and compiled in assembler format using MikroC PRO development environment. The transfer of the assembler programming file into the flash memory of the microcontroller was realized using the MPLAB software tool which was choose because it represents a easy to use but versatile solution that allows the development of embedded applications for common types of microcontrollers, especially PIC devices. As can be seen from the state diagram presented in Fig. 3 the software application begins with an initialization sequence followed by two successive readings of the values at the outputs of the position sensors and also the values from the all microcontroller's ports. In addition is activated the serial port (RS232) for establishing the communication with an external PC acting as server for an integrated smart home system. In this case it was used a proprietary LabVIEW application for managing the operation of the proposed door automation system. In normal conditions the system is in the idle mode waiting for a command from the user. In this state, on the local display of the control module is maintained visible the program interface and few representative parameters regarding the current situation of the system. The program interface contains a simplified menu that basically allows to the user to choose between two possibilities: configuration of the system or direct control of the position of the door. The access to the control menu is conditioned by the introduction of a valid password consisting in a string of four alphanumeric characters. The software application contains control procedures which continuously verify if the values introduced by the user are in the proper range and also if the required tasks are realized successfully.

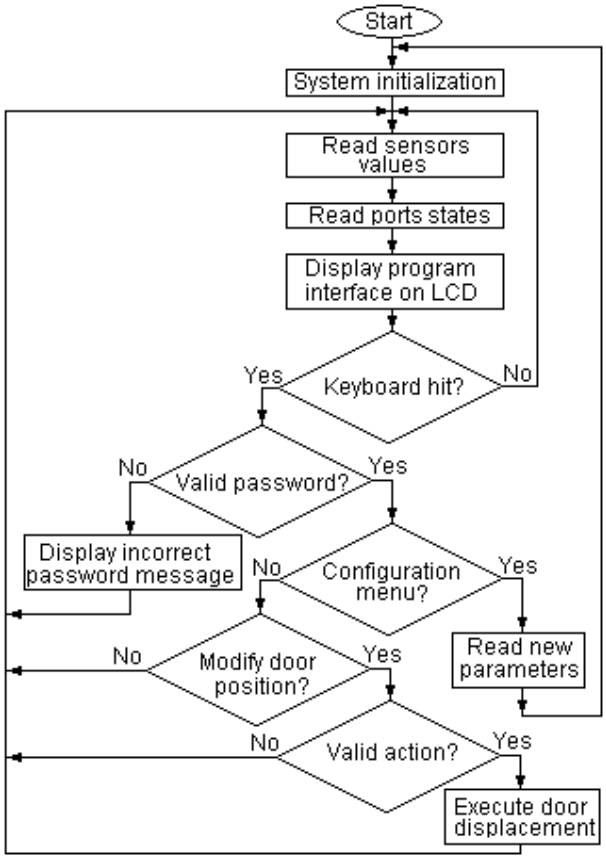

Fig. 3. The state diagram for the software application that controls the operation of the door automation system.

V. IMPLEMENTATION AND RESULTS

The correct operation of the proposed design intended to be used for implementing an advanced access control for smart homes was verified using an experimental model that was practically realized and tested. The electrical diagram containing the main hardware components that compose the door automation system is shown in Fig. 4.

Extensive simulations of the electronic schematic using Proteus software environment were realized in the development phase of the project. This software was choose because it allows the simulation of the schematic including the PIC 16F877A microcontroller with the assembler program loaded in its flash memory, which lead to more realistic results and a credible verification of the proper operation of the proposed design. Regarding the hardware structure of the door automation system, it can be remarked that the structure has as main component the 16F877A microcontroller. The local display is connected to the microcontroller through a simplified data bus containing of six wires. The remaining pins of the LCD are wired to the contrast adjusting potentiometer and to the supply source or are left unconnected [4].

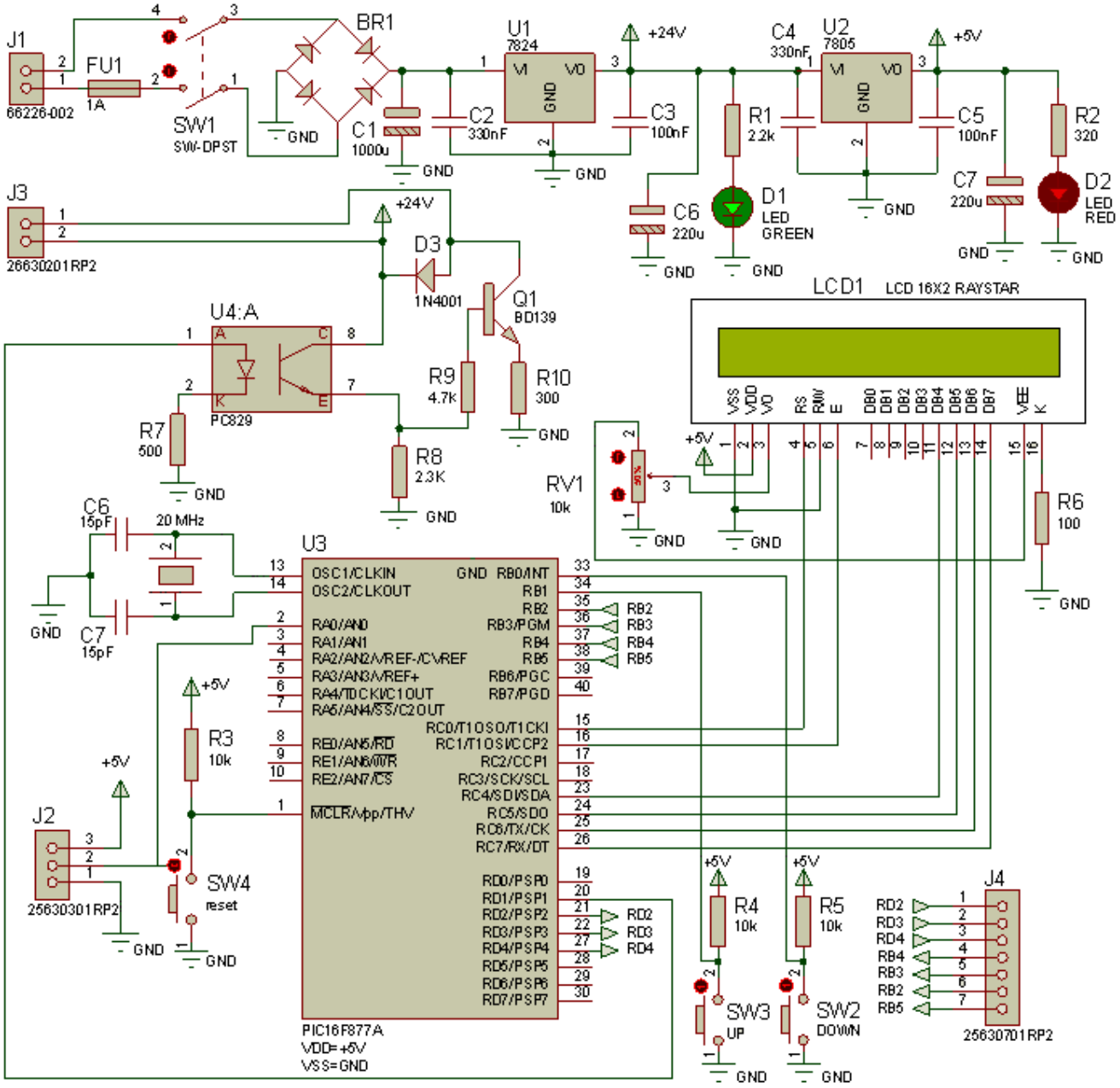

Fig. 4. The electrical diagram of the hardware part of the experimental model used for testing the principle of operation for the proposed door automation system

In the Fig. 5 is presented the main control module connected to a small model of the automated door. The displayed data and the control sequences for the LCD are generated on the C port of the microcontroller. Also, on the port D of the same PIC 16F877A microcontroller is connected a control keyboard that allows the user to define and subsequently to introduce the password for authentification. In addition, the introduction of the valid password conditions any modification of the parameters and controls that are further used in the operation of the door automation system. The serial interface based on the internal USART block of the microcontroller allows the integration of the proposed system into the complex network of an advanced smart home implementation. For safety considerations, the extreme positions of the automated door are detected with additional switches for limiting the possibility of erroneous operation of the system. The extreme position sensors also have the role to validate the state of the door indicated by the proportional sensor. As air distributor was used E-MC V5211-06 reliable solenoid valve, powered from 24V source. The driver for the solenoid valve has a simple structure and satisfies the speed requirements of the proposed design, been realized with BD 138 bipolar transistor and a 10A relay.The pneumatic actuator is based on a double acting cylinder characterized by a maximal axial force of 6000N with a stroke of 750mm and a maximum displacement speed of 19m/min when is considered a drive torque of 5.7Nm. The hardware structure of the microcontroller based automation circuit together with the proprietary software application that controls the operation of the entire system proves to operate as was predicted.

However, the above mentioned mechanical characteristics were sufficient only for small door automation and were used in the implementation of the initial testing model. But, with minimal changes in the electronic control module and by choosing more powerful actuation elements, the proposed automation system can be adapted to operate with larger and heavier doors, been suitable in almost any type of access control application required for implementation of the smart home concept [5].

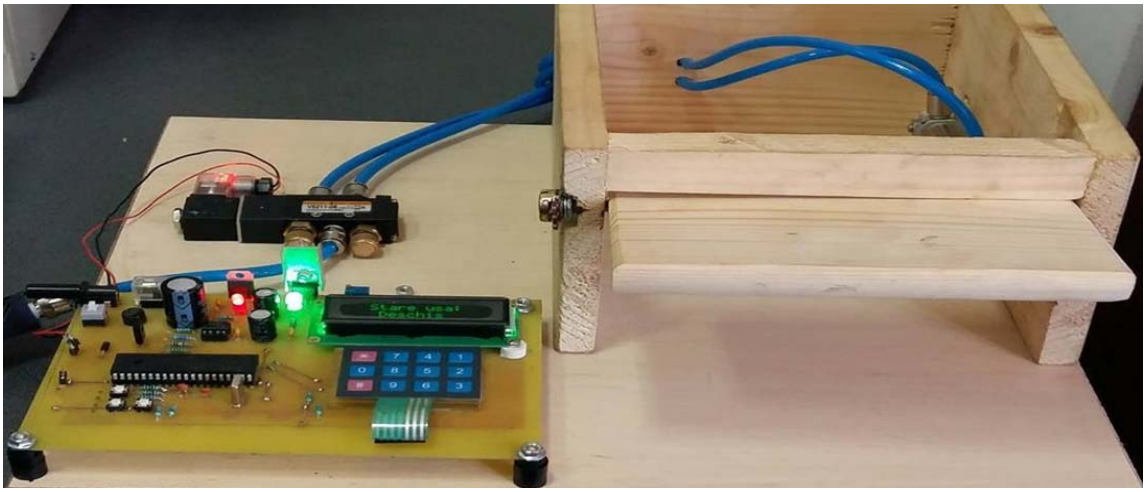

Fig. 5. The experimental model used for testing the operation of the proposed door automation system.

VI. Conclusions

The tremendous evolution of the microcontrollers and communications technologies combined with the interest for developing new and advanced facilities for increasing the comfort and the efficiency of the buildings made possible to arise the concept of smart home.

The proposed implementation solution allows a high operation speed and very good reliability due to the pneumatic actuation. The door automation module presented in this paper can be integrated in any centralized access control system dedicated to the smart homes.

Acknowledgement

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