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Temperature Control System for Accelerated Aging Tests on Printed Circuit Boards

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Abstract – **In this paper is presented an automated system that is dedicated for testing the electronic assemblies from the point of view of resistance to temperature variations. The system consists of a sealed thermal enclosure with a volume of one cubic decimeter and an accurate, digital control module that can perform preprogrammed temperature cycling tests on various equipped and unequipped printed circuit boards. The control architecture of the proposed design is based on the versatile PIC16F877 microcontroller. The cooling and heating of the thermal enclosure is actually realized using Peltier elements and resistors with the power of approximately 50W. The system can operate standalone or connected to a PC through a standard serial interface. When the external connection is used, the control module sends the locally displayed parameters and the measured data also to the PC. In addition, the bidirectional communication with PC allows the remote control and a closer integration of the proposed system into an extended testing network that can perform highly complex and customized climatic tests on electronic boards.**

Keywords - temperature control; accelerated aging tests; microcontroller; thermal enclosure.

I. INTRODUCTION

The reliability of electronic assemblies has become of tremendous practical importance for any type of application been a key feature that must be carefully considered in the design, implementation and exploitation phases of any equipment.

Accelerated aging test has imposed as an efficient method that allows a good estimation of lifetime and reliability of various products. In the electronics industry the advantage of this method is given by the possibility to increase the speed of normal aging process allowing the evaluation, in a reasonable period of time, of the resistance of electronic modules to the unwanted influences of specific climatic conditions like heat, vibrations, radiations, humidity etc. This technique is very useful especially in the prototyping phase when the new developed equipment has not been yet operated a sufficient period of time for undergoing a natural failure as would appear at the end of its lifetime.

From the multitude of external factors that affects an electronic printed circuit board, the temperature is most critical, inducing correlated, subsequent stresses that can be remarked also at the mechanical level.

In this context this paper presents an improved design for a versatile temperature control system that is intended to be used for accelerated aging tests on printed circuit boards [1].

II. THE STRUCTURE OF THE SYSTEM

The block diagram of the temperature control system with attached thermal enclosure for accelerated aging tests on electronic assemblies is presented in Fig. 1. The main component of the control board is the PIC16F877 microcontroller. This important component was choose considering the fact that it offers a versatile architecture and has sufficient hardware and software resources for the implementation of the proposed system [2].

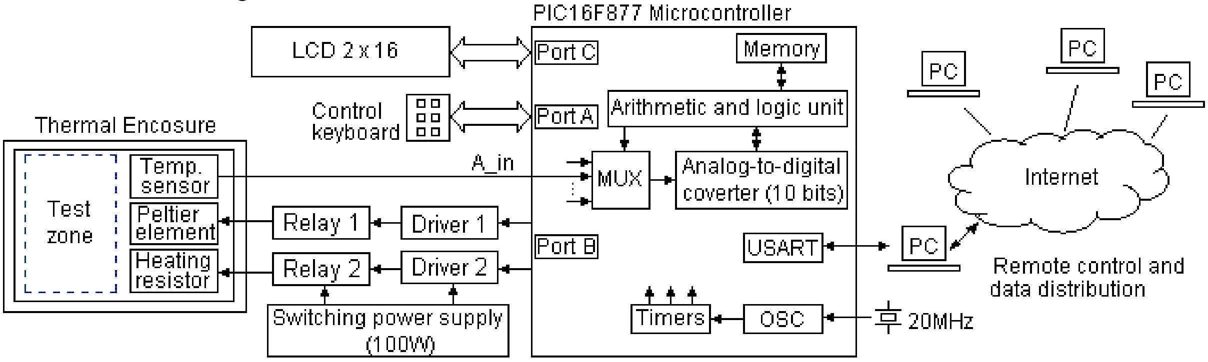

Figure 1. The simplified structure of the temperature control system used for accelerated aging tests on printed circuit boards

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On the A and C ports of the microcontroller are attached standard peripherals that allows local configuration of the software application used for controlling the system. The keyboard is composed of five pushbuttons for the proper navigation and command selection in the menu of the microcontroller's application. The monitoring of the temperature in the thermal enclosure is ensured by a mesh of four LM35 electronic sensors that are connected on the analog inputs of the microcontroller.

The heating and cooling of the thermal enclosure is realized in an efficient manner by using Peltier modules and printed resistors. The big advantage of using Peltier elements is represented by the possibility to cool the thermal enclosure at temperatures below ambient values. Also, this type of cooling system is very reliable compared with other classical implementation solutions. For an even distribution of the temperature gradient inside the enclosure, but also for a rapid response of the test system, in the presented design were used pairs of Peltier elements and printed high power resistors assisted permanently by a cooler with controlled speed.

The hardware interface between the microcontroller's port B and the heating and cooling modules is ensured by reliable relays and drivers based on MOS transistors. O this way it was resulted a minimal impact on the microcontroller's ports regarding the power consumption but obtaining the required level of currents of around 100mA for the proper control of the relays. The data integration from the temperature sensors is realized by a special software routine. By using this temperature sensing method the accuracy of the system is greatly improved and is alleviated the unwanted influence of the sensors positioning on the measurement results. This comes with the penalty of an increased need for more software processing of signals from the sensors, which inevitable lead to larger delays in the system's response.

Due to the efficient realization of the software application for the microcontroller, in this project these delays have low values, of hundreds of milliseconds. As a consequence, in this case the overall processing delays do not have a significant influence on the operation of the system. Also, because the temperature is a slow varying parameter, even more we can consider that these delays have not an important impact on the performances of the implementation presented in this paper.

The external control of the tests performed with the thermal enclosure is realized through a serial link based on RS232 serial protocol. This communication between the main control module of the system and an external PC is essential for the integration of the proposed system into a larger, more complex testing network, which would allow remote monitoring of the performed tests. In this case the data publishing on the Internet reveal the possibility of realizing enhanced analyses of the results of the performed tests using various software tools. This could lead to a better prediction of reliability and lifetime of the tested printed circuit boards [3], [4].

III. The Software Application for Microcontroller

The dedicated software application for the PIC16F877 microcontroller was written using embedded C language. A simplified state diagram of the main routine of the software application for PIC16F777 microcontroller is presented in Fig. 2. The software tool used for write and compile the program for microcontroller was PIC C which offers a friendly and versatile environment for such kind of applications. For loading the assembler code into the flash memory of the microcontroller was used PICFLSH software and a hardware programming kit connected to the computer through the serial interface. In the design process of the software application for microcontroller an important step was represented by the simulations that were done using the Proteus software. The simulation of the software application was carried out by loading in the Proteus schematic the same assembler file obtained through compilation. This allowed a better debugging of the initial programming errors and also helped to improve the operation of the application by elaborated analyses that were realized before hardware implementation.

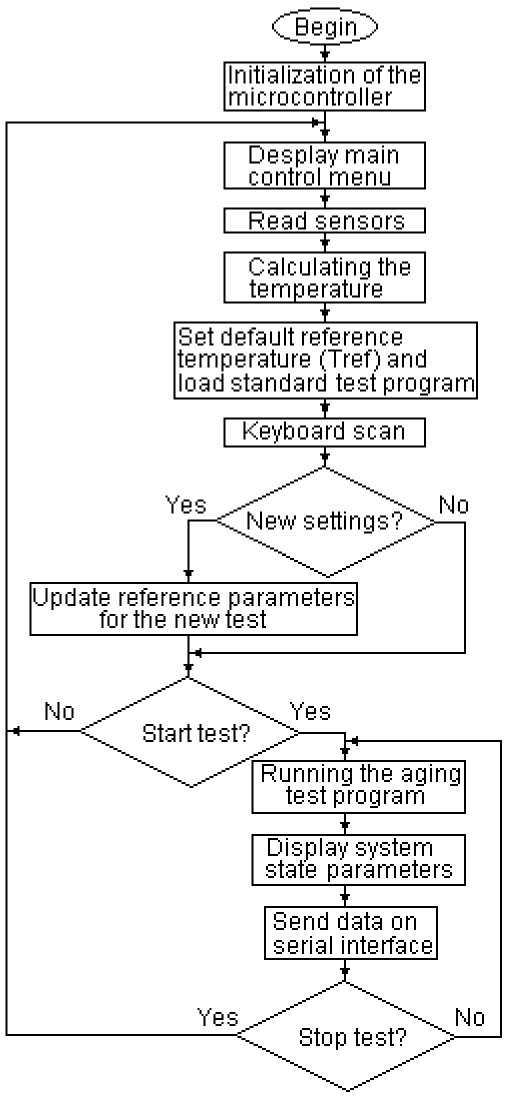

Figure 2. The state diagram of the main routine of the software application written for PIC16F777 microcontroller

From the state diagram presented in Fig. 2 we can observe that after the initialization of the microcontroller's internal variables, ports, analog-to-digital converter and other hardware blocks, on the local display is presented the main menu used for controlling and configuring the system.

The initial reading of the signals generated by the temperature sensors and the calculus of the mean value of the temperature represents the subsequent steps that follow in the state diagram. Actually, these two steps are performed continuously as log as the aging test program is running.

In the initial state, just after is started, the control system is configured to load the standard aging test program for normal printed circuit boards. If is necessary, the user can modify the basic parameters of this test program defining new time periods and different reference temperatures. In this mode is ensured an increased level of customization, for better cope with various types of standards and different technologies that can b encountered in practice.

The configuration of the test programs can be realized not only locally, through the attached keyboard, but also through the serial interface of the system. In this case, using a PC connected to the Internet allows the integration of the proposed system into a larger testing network and publishing of the measured parameters to a site where further, more elaborated analyses can be done [5], [6].

In this context, in the initial tests was realized a proprietary LabVIEW application that receive data from the proposed module using the serial interface and permits the remote control of the system. The LabVIEW application that is resident on a local PC allows also data publishing on an Internet page of the state parameters of the test system.

IV. IMPLEMENTATION AND RESULTS

As was briefly mentioned before, the temperature control system that was proposed for realizing accelerated aging tests on printed circuit boards is implemented around the PIC16F877 microcontroller. This programmable circuit allows a good programming flexibility and is characterized by a reduced instruction set allowing a rapid implementation of relatively complex applications. The used microcontroller is sufficiently rapid because it operates at clock frequencies up to 20 MHz and has a built in multi-channel analog-to-digital converter with 10 bit resolution that is very useful for interconnecting the system with analog sensors and actuators. Also, another important advantage of the PIC16F877 is represented by its serial communication interface which allows the connection of the proposed control module to an external PC.

The temperature monitoring inside the thermal enclosure that is used for testing PCBs is realized with a set of LM 35 sensors. These integrated devices were chosen because are calibrated directly in Celsius degrees and offers a good linearity and a sensitivity of 10mV/ºC. The accuracy of the LM 35 sensor which, in fact, directly influence the overall accuracy of the proposed system, is of 0,5 ºC. Also, this sensor has a negligible self-heating of 0,08 ºC and can operate in a extended domain of temperatures, ranging between the -55 ºC and 150 ºC. Regarding the Peltier elements that are used for cooling the thermal enclosure, can be said that it represent a compact and efficient solution for this application. A set of two Peltier modules were employed, each with a maximum power of 32W and a current consumption of 6A at a forward polarization of around 8,9V. Also, could be mentioned that the modules supports a maximum temperature difference between the cold and warm side of 69 ºC.

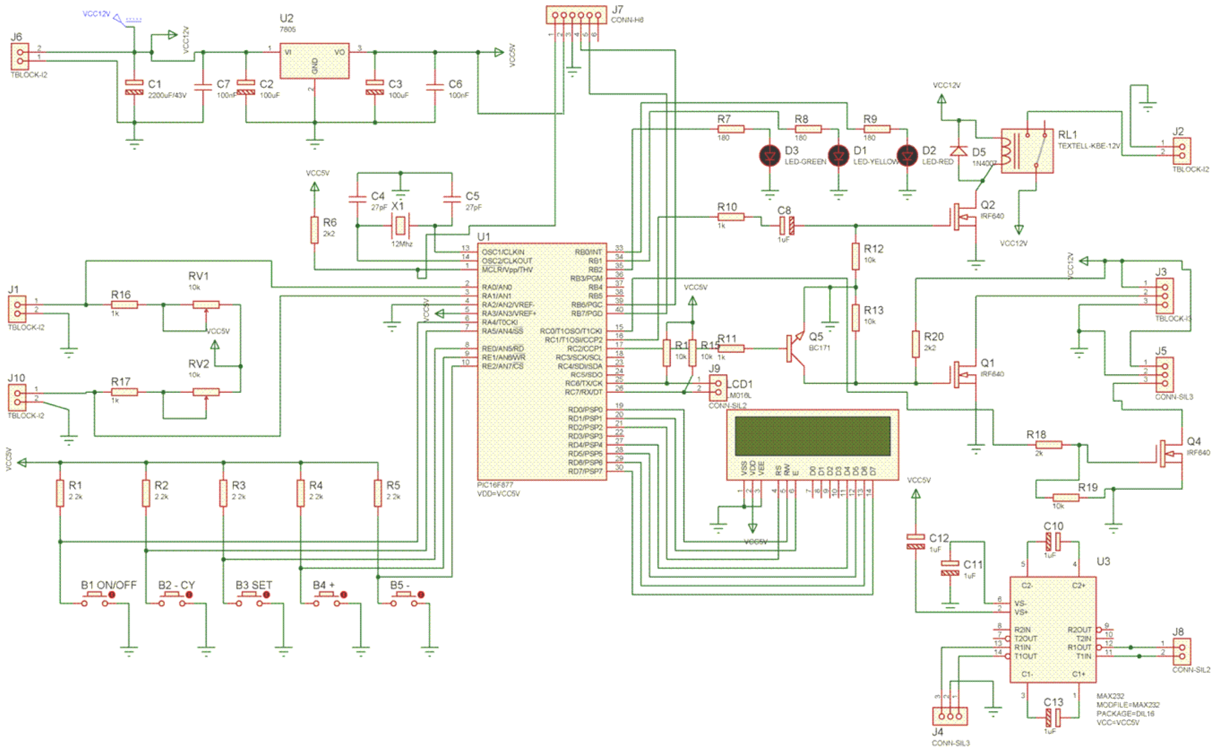

Figure 3. The schematic of the main module of the temperature control system used for accelerated aging tests on printed circuit boards

The local LCD with a resolution of two rows and 16 columns is used for implementing a minimal user interface. The display is controlled by the PIC 16F877 microcontroller through the port C, using only four bidirectional data lines and three control pins. This mode of operation was preferred for minimizing the number of pins that are used from the corresponding port of the microcontroller.

In Fig. 4 can be observed some images that are taken when the system operate in three different modes. In the first image the system is in the cooling state. The Peltier elements are activated and perform the temperature decreasing in the thermal enclosure. When the desired level is reached, the system enters in the stand-by mode. Finally, the last image is presenting the display of the system when the heating mode is activated. The system has two control methods that are configurable by the user. First method is based on nonlinear control and operates with a hysteresis characteristic. The second method is more accurate is based on software implemented proportional-integral-derivative (PID) algorithm. The parameters that are specific to this mode can be manually introduced into through the local keyboard, but more often and preferable can be more quickly configured through the serial interface [5].

Figure 4. Few screenshots illustrating the operation of the system: a) the cooling state; b) the stand-by state; c) the heating state

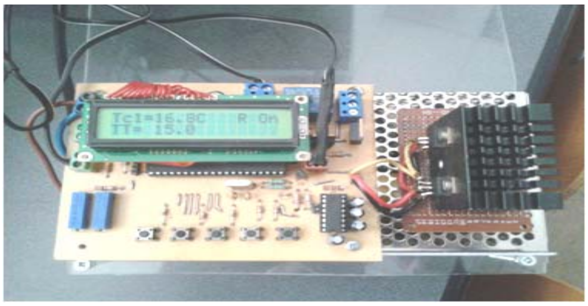

Figure 5. The implementation of the temperature control module, with high power MOS transistors mounted on the heat sink

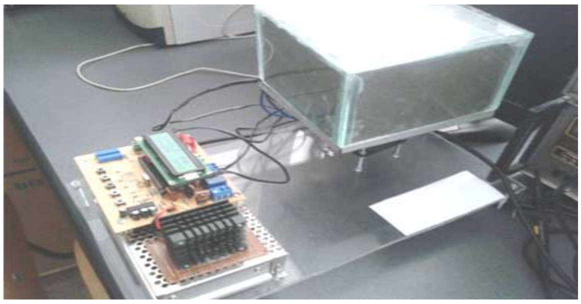

Figure 6. The aspect of the complete system used for accelerated aging tests on printed circuit boards

V. CONCLUSIONS

Compared with other methods, the accelerated aging based on thermal cycling represent a very usefully technique for evaluating the long term reliability of electronic assemblies.

The accuracy of the predictions obtained with the proposed system can be further improved by using more diverse tests, based on additional influences like humidity, vibrations, radiations etc.

The bidirectional communication with a PC connected to the Internet make possible the remote control of the system. In this way is possible the integration of proposed equipment into an extended testing network that can perform highly complex and customized climatic evaluations together with accurate lifetime predictions for various electronic boards.

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