

Lead-Free Electronic System integrated in a Vapour Phase Soldering Equipment Prototype

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Abstract: The purpose of this paper is to present the applied research work, performed in POLITEHNICA University of Bucharest, Center for Technological Electronics and Interconnection Techniques (UPB-CETTI) in the frame of one European project and two diploma projects, oriented to the development of a VPS (Vapour Phase Soldering) equipment using ecological, lead-free, electronics and tailored to small and medium size electronics companies (SME) needs. The VPS technology seems to be today the most appropriate for many EMS companies, especially for SMEs. The lead-free electronic system developed in UPB-CETTI is in the stage of integration in a VPS equipment prototype, which is under construction in these months. The system can be embedded also in plotters, cutter plotters or milling/drilling equipment for PCB manufacturing.

1. INTRODUCTION

The VPS technology was introduced in the manufacturing of electronic products since the early 1970s but only in the last years, due to the RoHS Directive, became a real competitor for IR and convection reflow technologies, the reason being the following advantages: lower peak reflow processing, inert environment, improved solder wetting and flow, and reduction in profiling time.

For controlling a VPS technological equipment to execute specific commands, as fine movement on OZ direction of the table onto which the board with not soldered components was placed, it is necessary to develop and execute a specific program for following the thermal profile (figure 1), profile which is necessary for a good and reliable soldering of electronic components placed onto the board. From the hardware point of view, the commands can be transmitted to the external circuit that drives the VPS motor using the parallel port of the computer.

The main task of the authors was to realize a low cost computer numerical control electronic system using ecological, lead-free technologies and working as driver of the VPS equipment. To obtain good results for driving the technological equipment but also keeping the manufacturing costs at a low level, it

was necessary to choose a motor having the best compromise between price and quality.

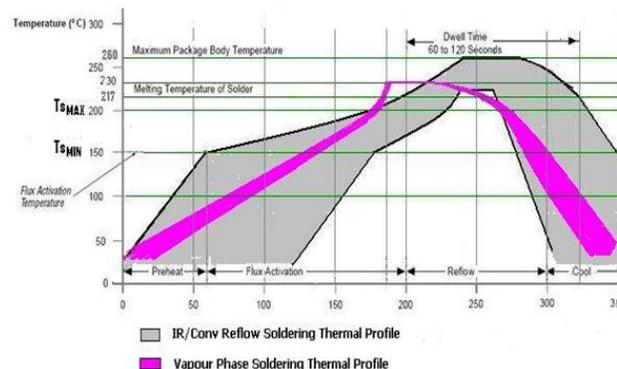


Fig. 1. IR/convection vs. VPS thermal profile.

The advantages and disadvantages of various types of motors that can be used are the following:

1. D.C. motors: **advantages:** easy to find, large diversity, powerful, easy to interface; **disadvantages:** too fast, they need a limiter, high power consumption, high prices, complex PWM control, short life unless they are brushless motors;
2. Servo motors: **advantages:** included limiters, large variety, good speed, good power for small and

medium size equipment, medium power consumption; **disadvantages:** low speed control;

3. Stepper motors: **advantages:** precise control, large variety, good speed, possibility of PWM command to obtain micro-steps (highly improving resolution), low cost, good possibility of cooling (the coils are on the stator not on the rotor); **disadvantages:** not very powerful, high power consumption.

2. CHOOSING THE HARDWARE SOLUTION

After investigations, the research team has decided to use a bipolar stepper motor. Because the precise control and the very good resolution of movement (high number of steps per rotation) are essential issues, more important than the working speed, the authors have designed a driving electronic circuit for the motor, the block diagram being presented in figure 2.

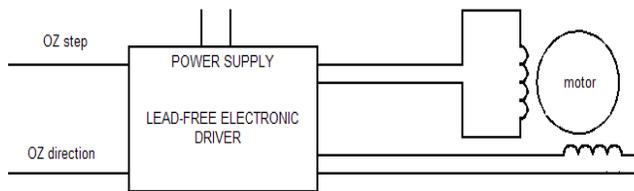


Fig. 2. Block diagram of the driver

As for the hardware, the commands can be transmitted to the external circuit that drives the motors using the parallel port of the computer. A very good functioning can be obtained if bipolar stepper motors are used and using a command system based on two signals (thus using only 2 pins for each motor). The signals are: 1. the direction signal: if the value is 0 the motor spins in one direction, if the value is 1, it spins in the other direction; 2. the step signal is a clock signal which, when passing from 0 to 1, will move the motor by a step. The movement speed is equal to the clock frequency.

Generally speaking, to obtain a higher resolution of the motor, a H bridge (controlled by pulses) must be used, composed on 4 MOS transistors. Moreover, there is needed a complex circuit to interpret the clock and drive the H bridge. This leads to complicating the electronic circuit and obtaining a large printed circuit. After market investigations, it was found an integrated circuit that contains in one package both the driving block and the H bridges. This circuit can be easily

controlled and needs very few external components for a correct functioning. This integrated circuit controls internally the H bridge and there can be externally selected the type of functioning: full step or 2/4/8 micro-steps by configuring two logical inputs, has a large range of powering voltage and presents an ED, 44-pin PLCC package, with internally fused pins.

The package has small dimensions, possibility of choosing the functioning mode, large range of the power supply voltage, does not require cooling, has the possibility of optimizing the output current for powering multiple types of motors, and is easily driven. As disadvantages, we can mention the low value of the maximum output current (2.5A max.) and the pinout configuration, leading to a more complex printed circuit board.

3. DEVELOPING OF THE ELECTRONIC SYSTEM

For developing the schematic diagram of the electronic system, the authors have used OrCAD 16.2 EDA environment.

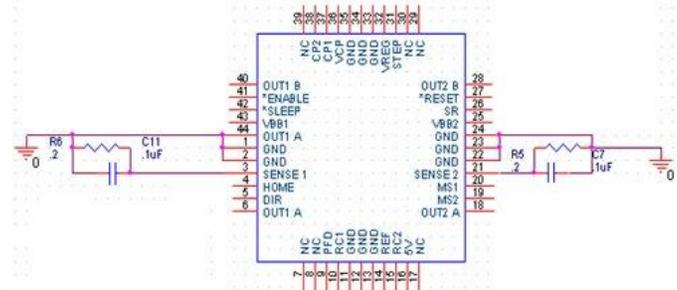


Fig. 3. Schematic diagram of the A3977 circuit

To test the schematic diagram, the intention was initially to perform a circuit simulation. Because no proper Spice model for A3977 was found and designing a model was difficult due to the internal high complexity, the authors preferred to use a simple proto-board. With this experimental model was tested the functioning of the IC, connecting a stepper motor at its output, for the input being used a rectangular signal generator with 1/2 fill factor and low frequency, and an adjustable power supply. The results of the tests were positive, problems being observed only when moving the wires of the proto-board, negative aspects which cannot appear when using a PCB.

Regarding the restrictions imposed by the A3977 circuit, the specifications of the manufacturer offer various rules regarding the design of the printed circuit board, requirements which underline the importance of the layout design in today's electronic modules and assemblies:

1. There cannot be used a socket for the integrated circuit, because on the surface beneath the copper must be left intact in order to act as a heat-sink. This also means that the area cannot contain other tracks;
2. The R_s resistance must be placed as close to the IC as possible to eliminate the resistance of the circuit and the parasitic signals. This restriction is very important because the voltage on the resistor gives the output current, so the parasitic signals and the change in resistance because of the length of the circuit could generate errors;
3. The filtering capacitor must be placed as close to the IC as possible;
4. The RC (C_t , R_t) net must be placed as close to the IC as possible, to be protected from other signals existing onto the board;

A very important requirement is to design the logic signal tracks far away from the output tracks, because the high speed of switching can highly affect them. In this case, the STEP signal is the most important, and if it is affected, it would lead to an erroneous driving of the circuit.

Regarding the PCB design, because the technical specification is to use a heavy ground plane, the authors have used a board with four layers, having the SMD components placed mostly on the bottom side and THD components on the top side of the board. In a few cases, SMD components were placed on the top side, too. For optimum electrical and thermal performance, A3977 was soldered directly onto the board. The load supply terminal, VBB, was decoupled with an electrolytic capacitor of 100 μF , placed extremely closed to the IC. To avoid problems due to capacitive coupling of the high dv/dt switching transients, the bridge-output traces were routed away from the sensitive logic-input traces.

According to these conditions, the authors have obtained the following circuit:

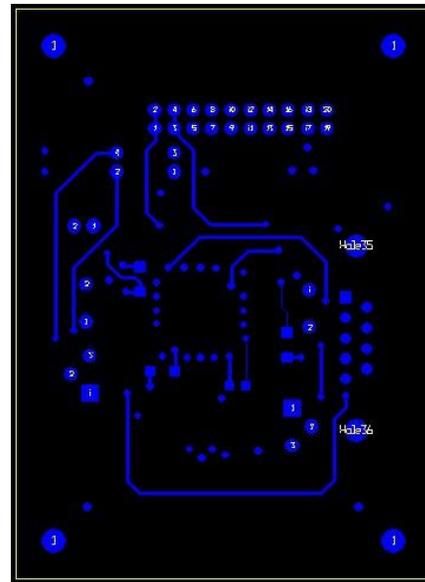


Fig. 4. TOP side of the driver board

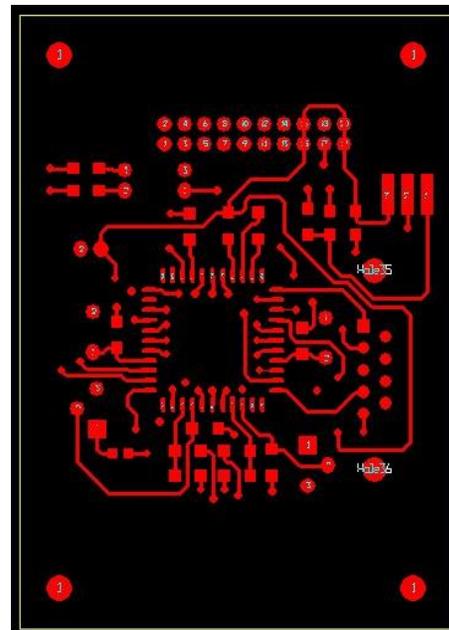


Fig. 5. BOTTOM side of the driver board

4. TESTING THE EXPERIMENTAL MODEL

For using the circuit correctly, authors were established the functioning mode of the experimental model (figure 6). First of all, the value of the micro-step was configured to be changed using two micro-switches. Other points to set the functioning mode are linked to values of voltages on VREG and PFD pins. The first one sets the value of the output current and

the other one the cutoff mode of the current. The two voltages can be modified using two variable resistors.

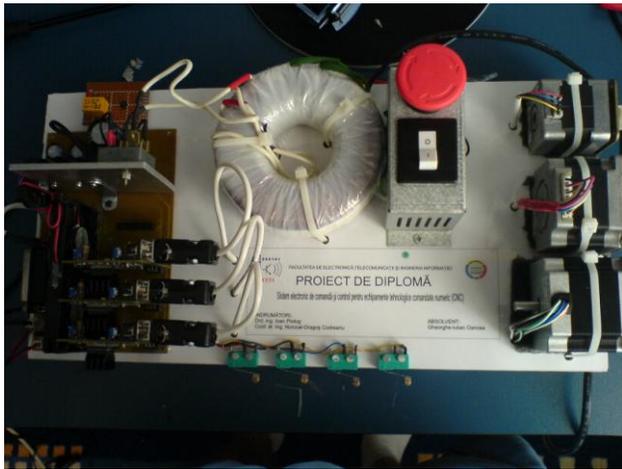


Fig. 6. The first experimental model, used for a laboratory CNC equipment

Testing the circuit power-up was done visually, by inspecting the LED placed in the circuit and using an oscilloscope. The LED lights when powering the circuit because it is connected to the HOME output of the IC. The motor will be blocked and it will not spin freely, because its coils are powered at $0.707I_{max}$, represented by the HOME state.

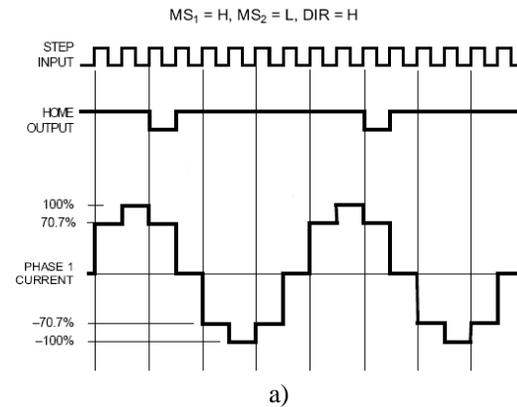
If it is not blocked, then there is a problem in the power circuit, and must be measured the voltages on pins 1, 2, 5 or 6 of the connector, on the filtering electrolytic capacitor, on the pins 25 and 43 of A3977 and on pin 1 of the LM317 voltage regulator. Next, it was tested the voltage generated by LM317.

The last test was performed on the output waveform. Because the load is inductive, two resistors were connected in series with the motor coils, being measured the voltage at their terminals. In figure 7 (a and b) one of the experimental results is presented, this being the case of two micro-step version, 7a) presenting the theoretical waveforms of the current and 7b) the measurement results.

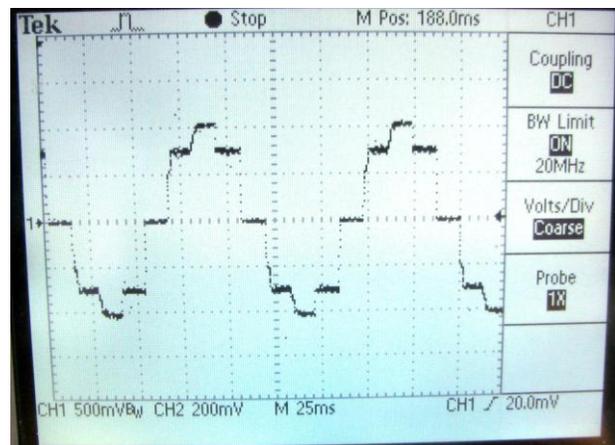
5. CONCLUSIONS

The development of the electronic system necessary to drive the stepper motor of the VPS equipment has opened the door to a large range of future technological prototypes, among which we mention: milling equipment, equipment for automatic placement of components, for automatic testing printed circuits, robotic arms, system having attached

a thermal infra-red camera which take automatically thermograms from a large electronics area under investigation.



a)



b)

Fig. 7. a) theoretical waveform of the current; b) experimental results with voltage of 500mV/div and time of 25ms/div

In this configuration, after finishing it, the prototype shall be used in the technology laboratories of UPB-CETTI for VP reflow soldering of lead-free electronic components. This model can be also improved and a first low series can be released in order to reach the requirements of some small companies. This implies adding a standardized connection interface, introducing the product into a industrial case etc.

The electronic system was developed in lead-free technology, being RoHS-compliant. In the last years the authors have observed a high need of such equipment and systems, also among small innovative

enterprises, which can become potential customers of this system developed in the university.

6. ACKNOWLEDGEMENT

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