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INTELLIGENT MICROSTEPPING SYSTEM FOR BIPOLAR STEPPER MOTOR CONTROL WITH STEP AND DIRECTION INTERFACE

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ABSTRACT

The paper presents a intelligent system for stepper motor control in a microstepping mode, which was designed and performed with a specialized integrated circuit (L292), made by SGS-THOMSON Microelectronics Company. With an interface and an adequate software, L292 circuit can be used as a chopper in 2 or 4 quadrant. The microstepping control system improves the positioning accuracy and eliminates low speed ripple and resonance effects in a stepper motor electric drive. The same microstepping system is ideal for robotics, printers, plotters, X-Y-Z tables and can facilitate the construction of very sophisticated positioning control systems while significantly reducing component cost, board space, design time and systems cost.

Keywords: stepper motor control, microstep, positioning

1. Introduction

The most remarkable effect of the integrated circuits increasing complexity and functions number is represents by, as it is widely accepted, its "intelligence". There is almost no applications domain in which the microelectronic devices "intelligence" shouldn't have played a major role, one of the fields enjoying its advantages being the low power electric drives [1]. By introducing the "intelligence" in the drives command, this one will take over some complex functions usually accomplished by the human factor. In the automatic regulation systems, the electric stepper motors are utilized as execution elements. Stepper motor is the most utilized motor in low power adjustable electrical drives due to relatively simple methods of speed control. The stepper motors are used in many applications because of their advantages. Thus, they move in quantified increments (steps) which lands them easy to digital control motion systems in open-loop mode. In addition, their drive signals are square waves which are easily generated by the digital circuits with relatively high efficiency. But stepper motors are not free of problems. The most typical application for these drives is represented by the precision positioning systems. These ones must satisfy relatively exacting dynamic conditions, generally difficult to be fulfilled, sometimes even contradictory, fact that partially explains why is necessary that the command devices must be "intelligent". Taking into consideration the above mentioned aspects, the author presents in this paper the command in microstepping mode of stepping motor with two L292 specialized integrated circuit.

2. Microstepping mode

One way to avoid the problems associated with stepper motors while still retaining their open loop advantages is to use them in the microstepping mode. In this mode each of the steps is subdivided into smaller steps or "microstep". Applying currents to both phases of the motor creates a torque phasor which is proportional to the vector sum of both currents. When the phasor completes one "turn" (360 electrical degrees), the motor moves exactly four full steps or one torque cycle. Similarly, when that phasor moves 22.5 electrical degrees the motor will move (22.5/90)•100=25% of a full step. Thus the position of the motor is determined by the angle of the torque phasor. When used with an appropriate motor a positioning accuracy of 2% of a full step can be achieved, equaling 0.036 degrees for a 200 full steps per revolution motor. In this manner the motor can be positioned to any arbitrary angle. A common way to control the angle of the torque phasor is by applying to the motor's phases two periodic waveforms shifted by 90 electrical degrees. Let the phase current equations be:

$$i_A = I_o \bullet \cos\theta e \quad (1)$$

$$i_B = I_o \bullet \sin\theta e \quad (2)$$

Note that θe is the electrical position.

The resulting torque generated by the corresponding phases would then be:

$$T_A = K_o \bullet i_A = K_o \bullet I_o \bullet \cos\theta e \quad (3)$$
$$T_B = K_o \bullet i_B = K_o \bullet I_o \bullet \sin\theta e \quad (4)$$

where K_o is the torque constant of the motor. Substituting equations (1), (2) into (3), (4) and doing vector summation the resulting total generated torque measured on the motor shaft is given by:

$$T_g = K_o \bullet I_o \quad (5)$$

Note that in this case we have zero torque ripple. Using this technique one can theoretically achieve infinite resolution with any stepper motor. Since the drive current waveforms are sinusoidal instead of square, the step to step oscillations are eliminated and the associated velocity ripple. This greatly improves performance at low rotational speeds and helps avoid resonance problems. In an actual application, the extent to which these things are true depends on how the two sinusoidal reference waveforms are generated. Seemingly we have lost the quantized motion feature of a stepper when used in this mode. This can be regained by defining the term microsteps per step. Each full step is subdivided into microsteps by applying to the motor's phases those intermediate current levels for which their vector sum tracks the circle of figure 2 and divides the full step (90 electrical degrees) into the require number of microsteps. An example of the required phase currents for full step and four microstep per step operation are shown in figure 1 and figure 2 respectively.

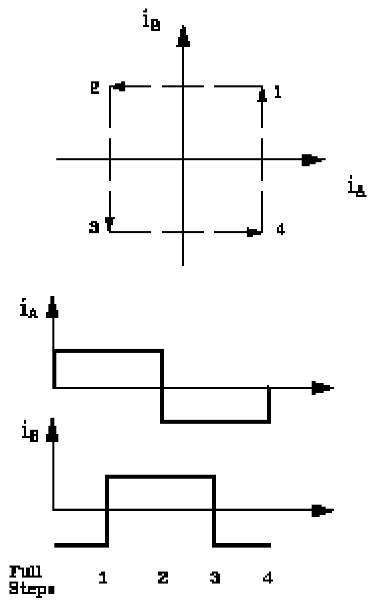

Fig. 1. Full StepDrive Waveforms

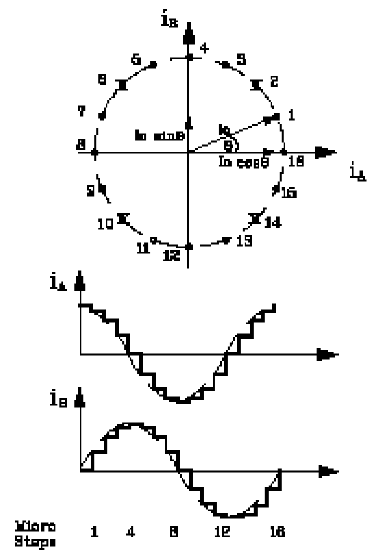

Fig. 2. Four Microstepper StepDrive Waveforms

3. Microstepping system description

The block diagram of microstepping control system is shown in figure 3. In this diagram the two L292 switch mode driver commands a two phases stepper motor in microstepping mode. To obtain this mode the current has to be as much sinusoidal as is possible in the two phases of the motor. A correct command is obtained when the two sinusoidal current's waves corresponding to the phases are 90 electrical degrees shifted. For this goal it has to be applied to the L292 driver's inputs (V_{INA} , V_{INB}) two reference signals (SINE, COSINE) obtained using the two reprogrammable memories (EPROM) and the two D/A converters (DAC1,DAC2). A up/down counter is used to generate the most appropriate address location in EPROM's. Pulses from a programmable divider (8254.) are used to increase or decrease the counter. The pulses frequency (CLK1) and direction (SENSE1) can be modified by specialized dedicated intelligent stepper motor control interface to computer based command (IBM-PC 586+ ISA interface)[3], programming to vary the motor's speed, finally.

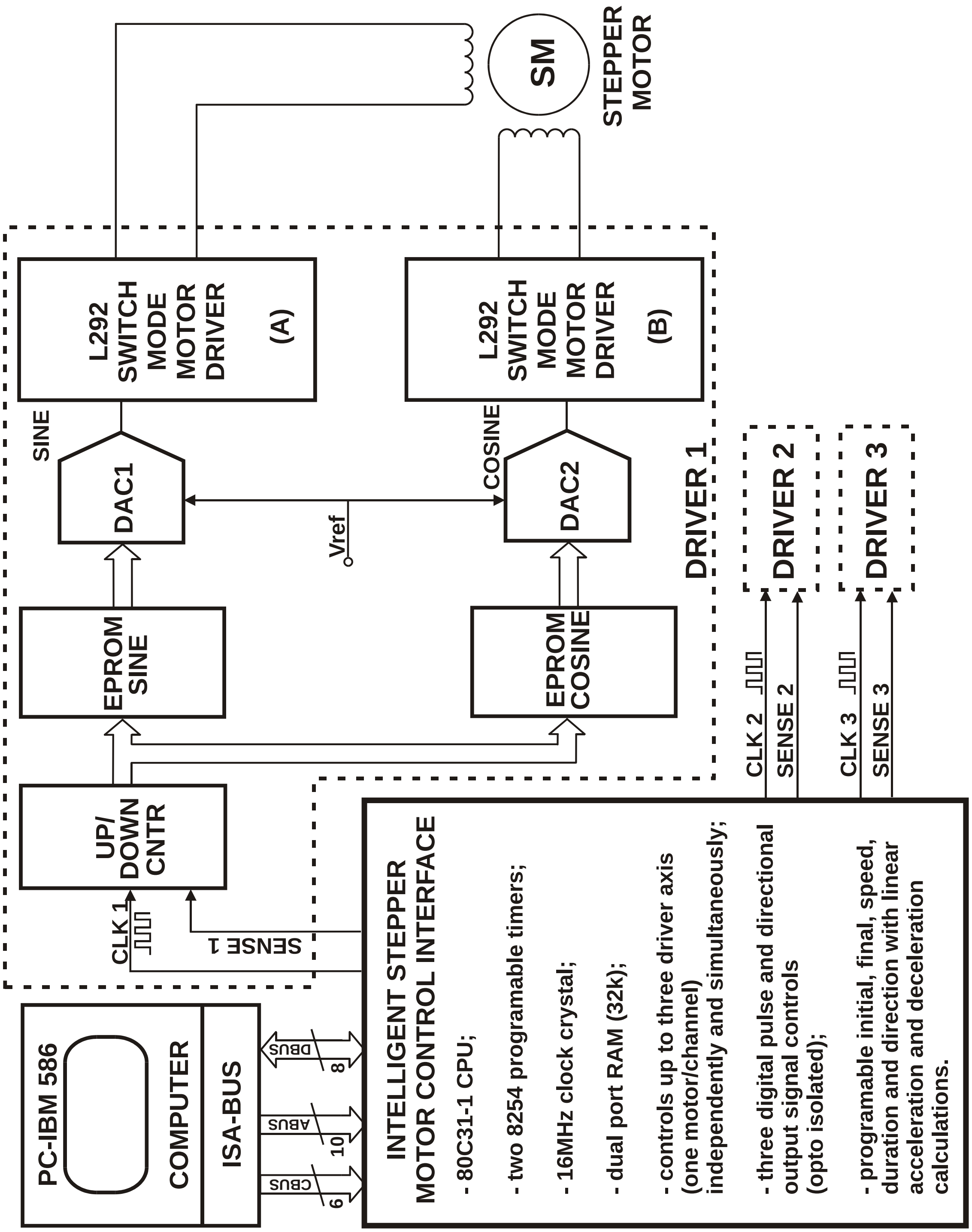

Fig. 3. The block diagram of microstepping control system

3.1. Input waveform generation (sine, cosine)

As it has been said before, has to apply two 90^{o} el. shifted sinusoidal reference signals to command a sinusoidal current to the stepper motor's phases as a microstepping mode at L292 command circuit's inputs. The command input range is ± 9,1 V full scale. To obtain this two reference signals has more possibilities[5]. As seen in figure 4 this may be accomplished by using two look-up tables stored in EPROM's (2732) and two DAC's (TLC 7524) respectively. An up/down 8 bits counter (IC4, IC5) is used to generate the appropriate address locations for EPROM's and the data outputs used to control DAC's. To be able to get a certain variant, the used 4 Kbytes memory of EPROM's (IC6, IC7) is divided in 16 x 256 bytes zones, selected by SW1. Another more precise way to change the motor's rotation sense is using SENSE1(PC – INTERFACE) selection signal produce up or down counting of the reversible counter. The 256 memory locations which are scanned by reversible counter contain binary values (8 bits) representing every sample magnitude of those 256 in which every phase reference sinusoids were divided. Then, binary values of these samples are converted in corresponding voltages levels ($V_{out\ sine1,}$ $V_{out\ sine2}$) by those two DAC's (TLC 7524) and amplifiers (TL 074-IC10). Thus, the reference sinusoidal signals frequency is

$\mathbf{f} = \mathbf{f}_{CLOCK}/256$. The clock signal frequency and so the reference signals frequency can be modified by I8254 programmable divider which has a dividing factor settable by the dedicated computer interface (PC - INTERFACE).

The reference voltage necessary for the two DAC TLC 7524 converters (IC8, IC9) is generated by the TL 431 stabilizing circuit (IC3).

3.2. The power stage

In figure 5 is shown the electrical schematic of power stage with two switch mode driver L292 [6] integrated circuits. A the input (V_{sine1} , $V_{cosine1}$) there is the levels adapter, whose aim is to transform the symmetric error signal (issued by the speed controller) in a positive signal necessary for the following blocks command. The transformation is imposed by the fact that the L292 circuit do not have symmetric supply. Afterwards, through the error amplifier, in PI structure, the command positive signal is applied at the comparator input while at its other input there is a triangular voltage, generated by a local oscillator. From the two voltages, at the comparator's output it is realized a PWM signal with variable duty cycle, necessary for the bridge command with the transistors T1÷T4. Depending on the duty cycle, in the bridge is established a current either positive, either negative, which flows through the measuring amplifier resistance's $R_{s1}=R_{s2}=R_s$ as well. Thus it formed reaction signal, which, through the filter R5-C1-R7 is applied at the error amplifier input. The L292 integrated circuit is a switch-mode driver, driving capability: 2A(I_{MAX}=2.5A), 36V, 30kHz, two logic chip enable, external loop gain adjustment, single power supply (18V to 36V), input signal symmetric to ground, thermal protection.

4. Experimental results

The experimental research was performed in the Electrical Drives Laboratory of the Electrical Engineering Faculty, "Petru Maior" University of Târgu-Mureş, where it has been realized an high performance microstepping system for stepper motor control[3] [4].

Figure 6 shows the general view of realized microstepping board. Figure 7shows the general view of the intelligent interface (ISA PC BUS). In Figure 8 is shows the general view of the realized experimental precision positioning system

In order to measure the phase currents, two hall sensors (LEM modules – LA25NP) were used, and a data acquisition numerical system dedicated to the electric drives as in [3] [4].

As experimental results, the phase currents of a two-phase bipolar stepper motor (2, 4, 8,16, 20 microstep/step) are shown in Figure 9.

5. Conclusions

The last progress both in control in motor drive domain impose on the researchers a continuous reorientation in order to solve the design problems with the newest technical means. In this sense the author have developed an original microstepping system for the open-loop control 1 to 3 stepper motors for precision positioning systems. Among the facilities offered by this system we mention:

- resonance's are significantly reduced
- noise generation is considerably reduced
- very high step resolution
- bipolar switching operation
- 3 independent channels
- precise X-Y-Z position control
- precise rotation control
- robotics and assembly equipment
- other stepping motor application

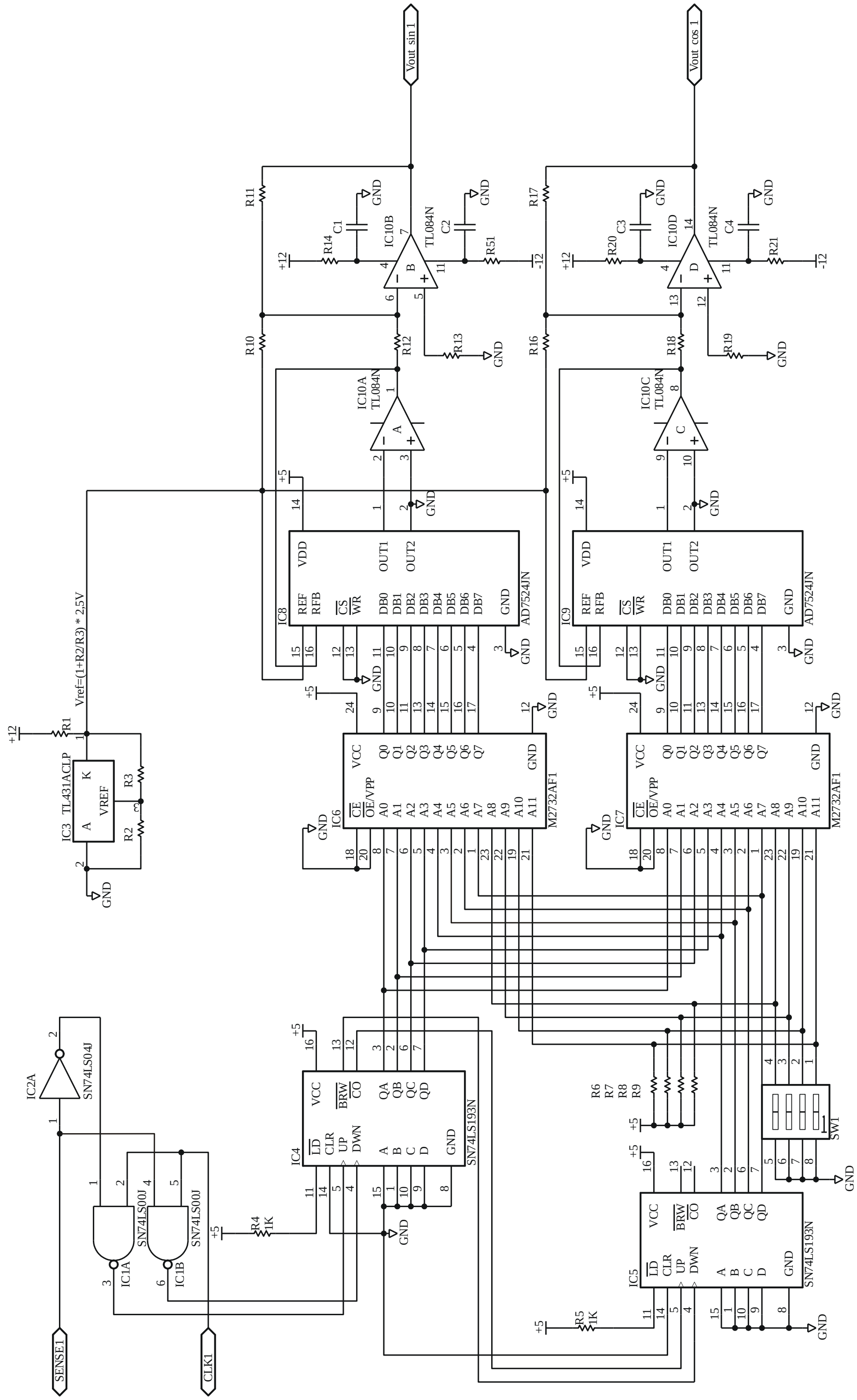

Fig. 4. Reference signals generating stage

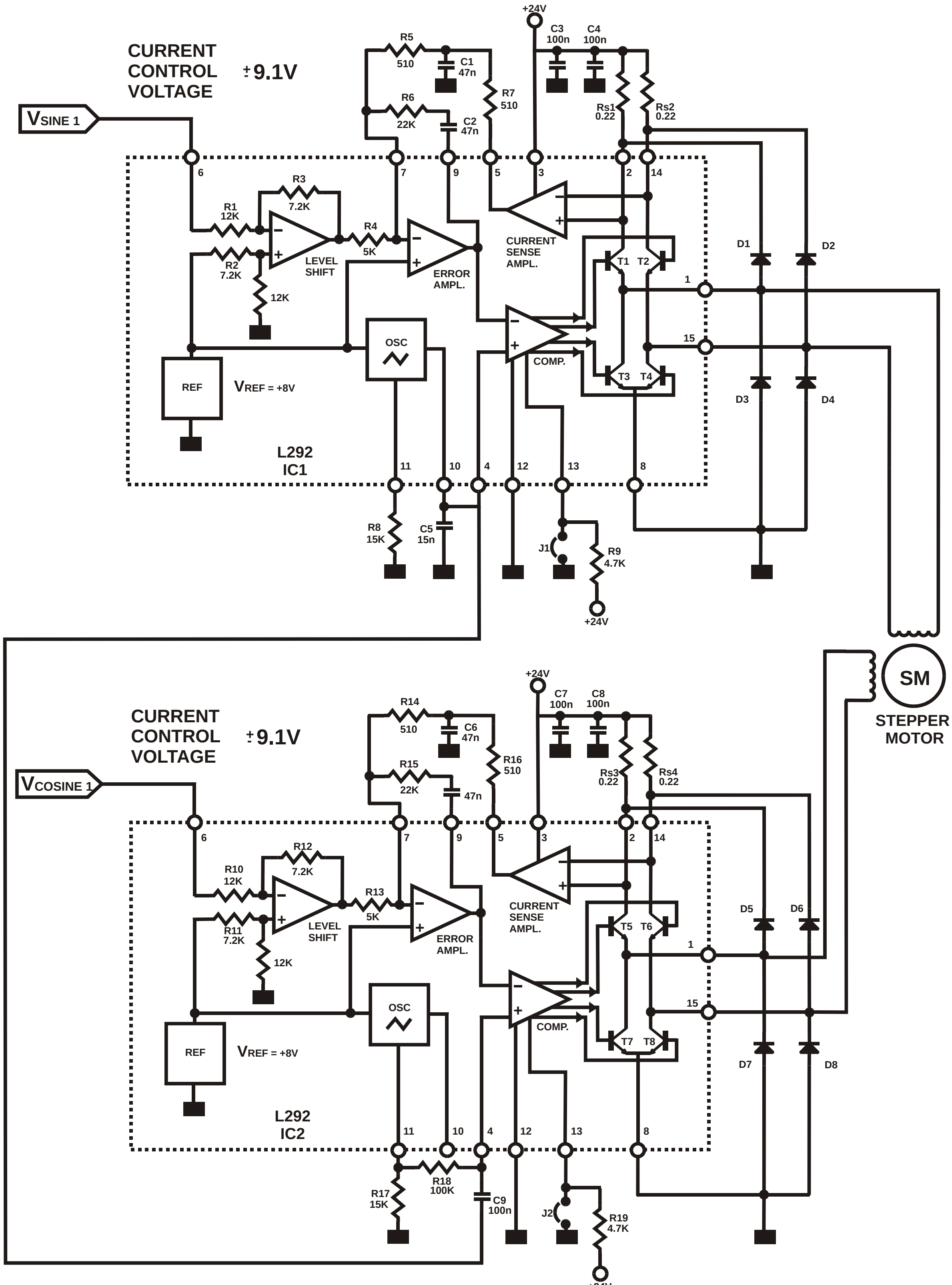

Fig. 5. The electrical schematic of the power stage

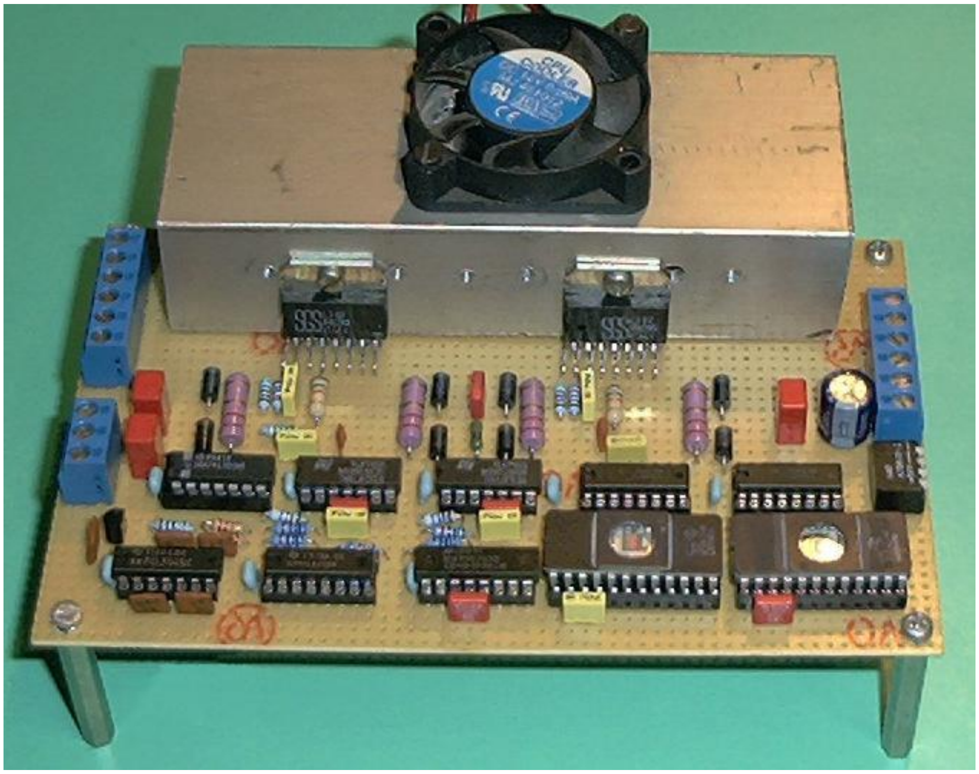

Fig. 6. General view of the realized microstepping board

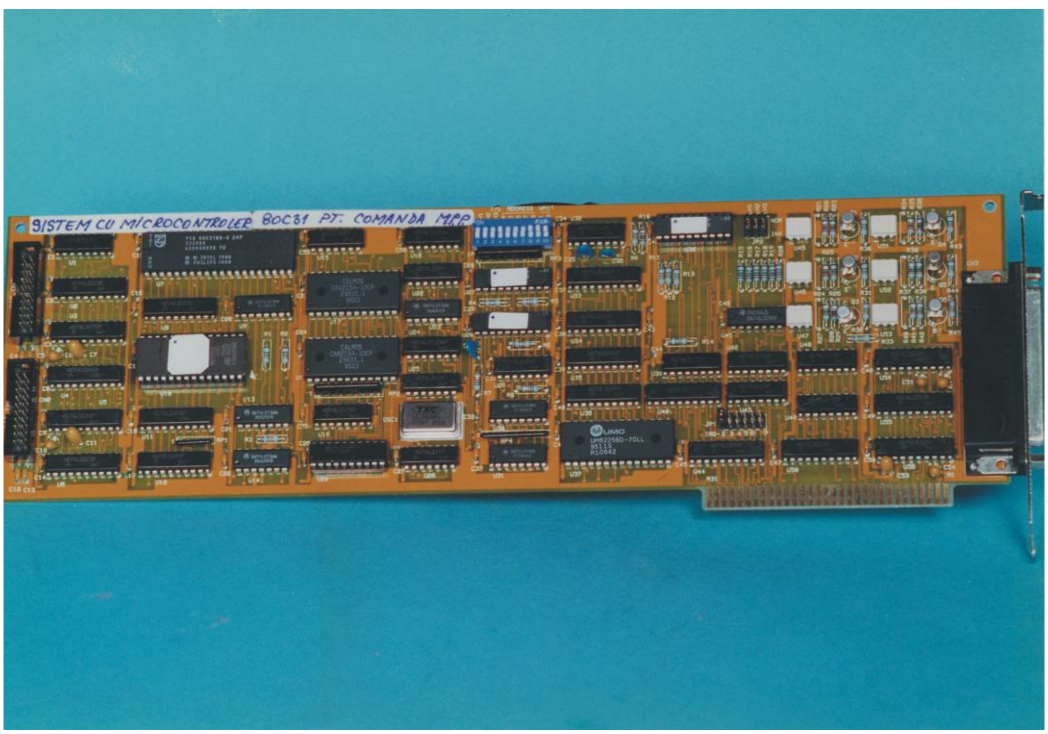

Fig. 7. General view of the intelligent interface (ISA PC BUS)

Fig. 8. General view of the realized experimental precision positioning system

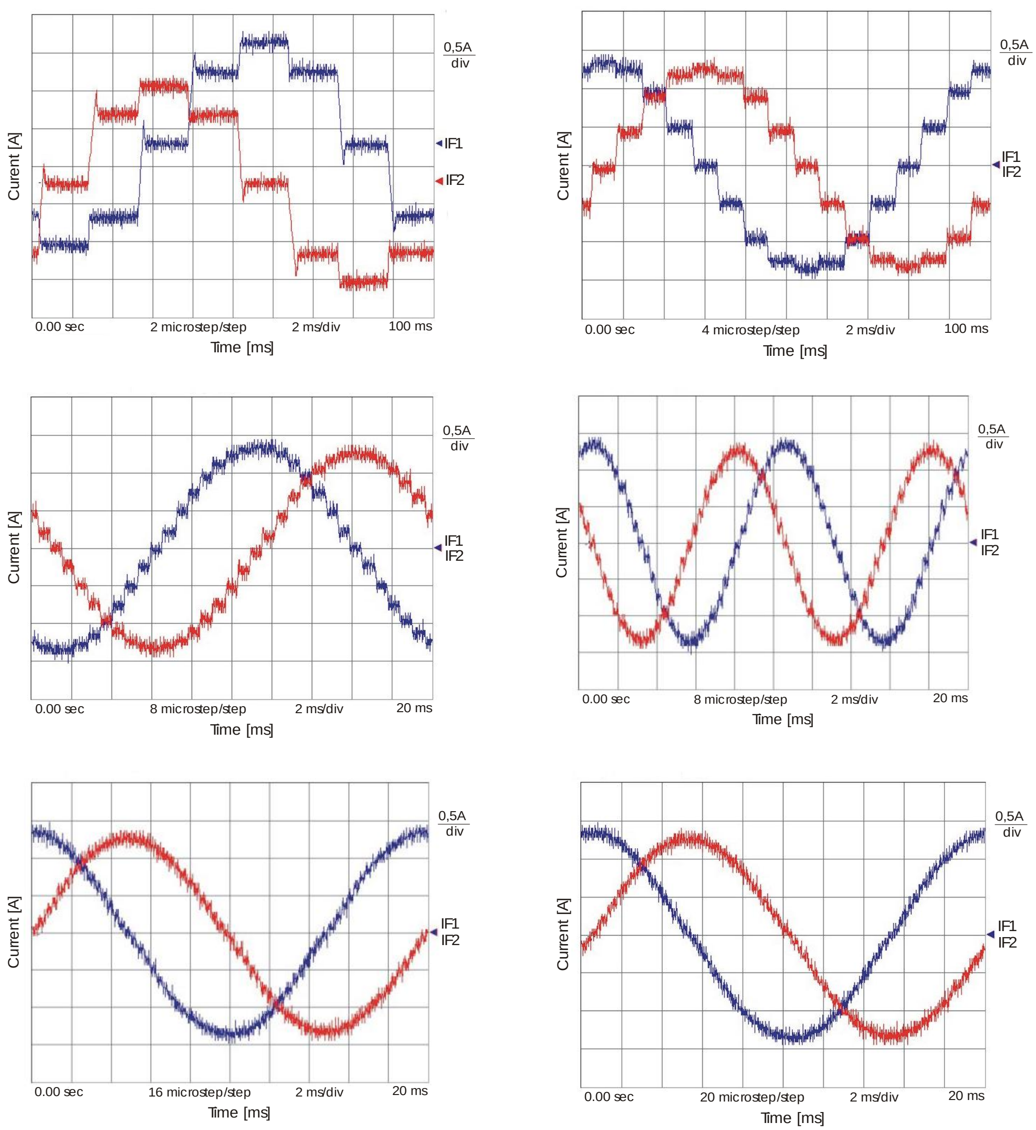

Fig. 9. Experimental results, the phase currents of a two phase bipolar stepper motor

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