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FOUR PHASES DRIVER FOR STEPPER MOTOR CONTROL

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ABSTRACT

The paper presents two pulse distributors are remarkable for simplicity, high-reliability, multifunctional facilities and a unipolar bilevel R/L- driver circuit for four phases stepper motor.

Keywords: steppwer motor, unipolar control, R/L driver

1. Introduction

The progress of incremental motion control system has been enforced by the multiplicity of their utilization in numerically controlled machine-tool drives, peripheral computer equipments, communication through laser and satellites, nuclear techniques, industrial robots, aeronautical and military equipments.

A stepper motor can be considered as a digital electromechanical device where each electrical pulse input results in a movement of the rotor by a discrete angle called step-angle of the motor. In normal operation the number of the performed steps must correspond to input pulse number [1][2].

The advantages of the stepper motor use consist in the followings:

- linearity of the pulse-movement conversion function, which allows open-loop operation;
- wide band of the control frequency;
- high precision and resolution, hence leading simplifying the cinematic-link between motor and load;
- allows start, stop, and reverse without step losses;
- memorize the position;
- they are compatible with digital technique

To achieve a high speed operating the stepper motor requires complex drive circuits adapted with the motor type.

Without performances as: amortization, the maxim run frequency, the maxim dynamic torque, etc., as well as efficiency and power dissipation of the motor depends on the control and supply circuits.

This paper presents two pulse distributors and a unipolar drive circuit to force the current slope.

2. Pulse distributors

Pulse distributors are circuits which provide at the outputs pulse trains to control the motors corresponding with the input pulse frequency, direction and the chosen operating mode. To energize the motor phases this output pulses are passed through a drive circuit.

A first pulse distributor scheme (shown in figure 1) is based on a 8–Bit Directional Universal Shift Register (SN74198).

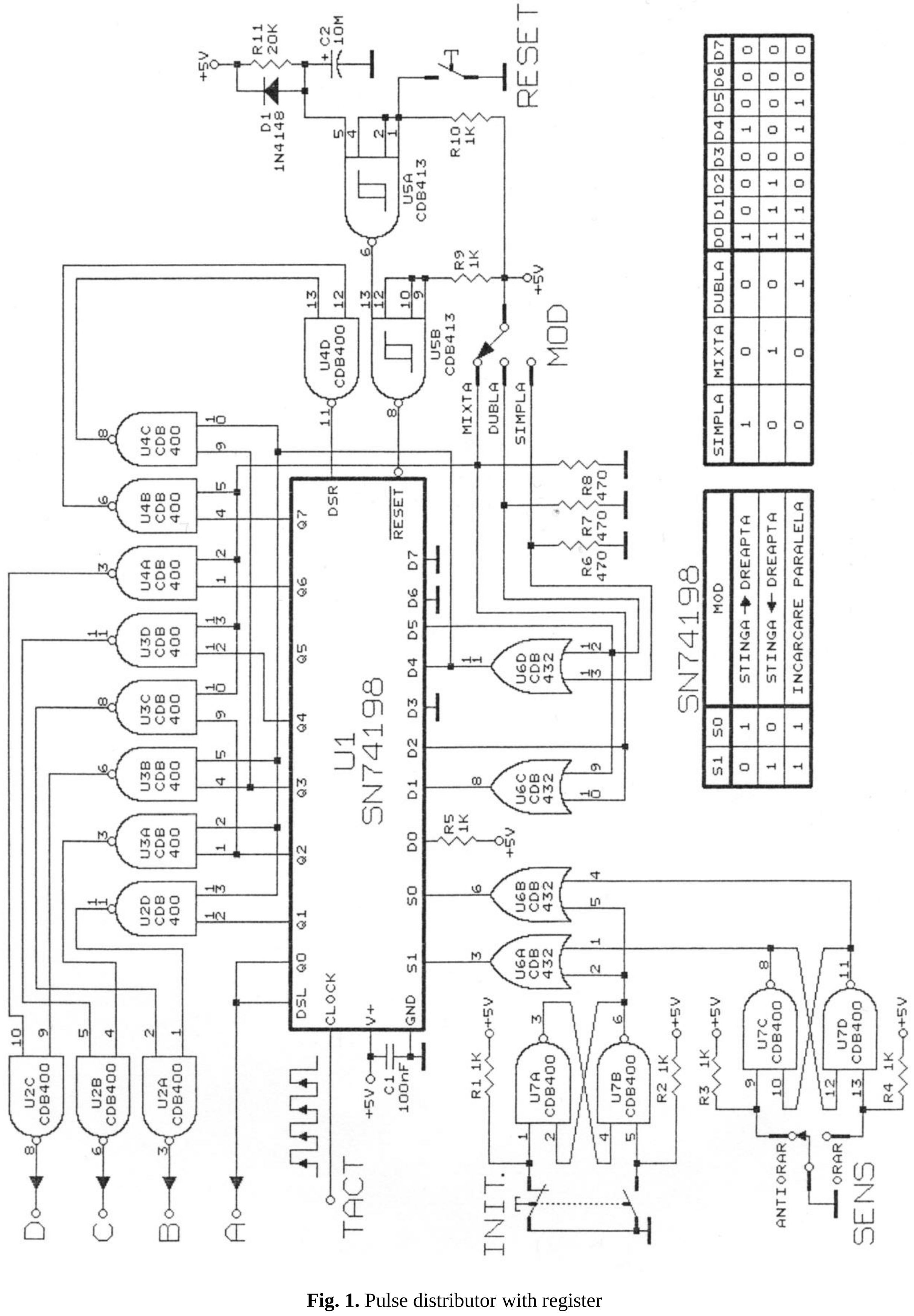
The possibilities of this multifunctional circuit such as parallel-parallel, serial-parallel shift left and shift right data transfer allow an easy implementation of a pulse distributors for a 4-phase stepper motor.

The motion direction for the stepper motor imposed by the SENS switch controls the mode selection inputs S0, S1.

The requested sequence (simple-S, double-D, mixed-M) may be chosen through the MOD switch. Thus, for each operating mode it is necessary a particular combination of parallel inputs D0-D7 which is transferred to the parallel outputs Q0-Q7 at start-up (INIT switch).

The output of the distributor: A, B, C, D are obtained by using a combinational circuit(CC).

The second pulse distributor, shown in figure 2 is based on a PROM (MH74188) controlled by a reversible binary counter MMC4029[2]. The motor-step control is achieved by the appropriate memory programming corresponding to the three operating mode (see Table1).



S1	S0	MOD
0	1	STINGA → DREAPTA
1	0	STINGA ← DREAPTA
1	1	INCARCARE PARALELA

SIMPLA	MIXTA	DUBLA	D0	D1	D2	D3	D4	D5	D6	D7
1	0	0	1	0	0	0	1	0	0	0
0	1	0	1	1	1	0	0	0	0	0
0	0	1	1	1	0	0	1	1	0	0

Fig. 1. Pulse distributor with register

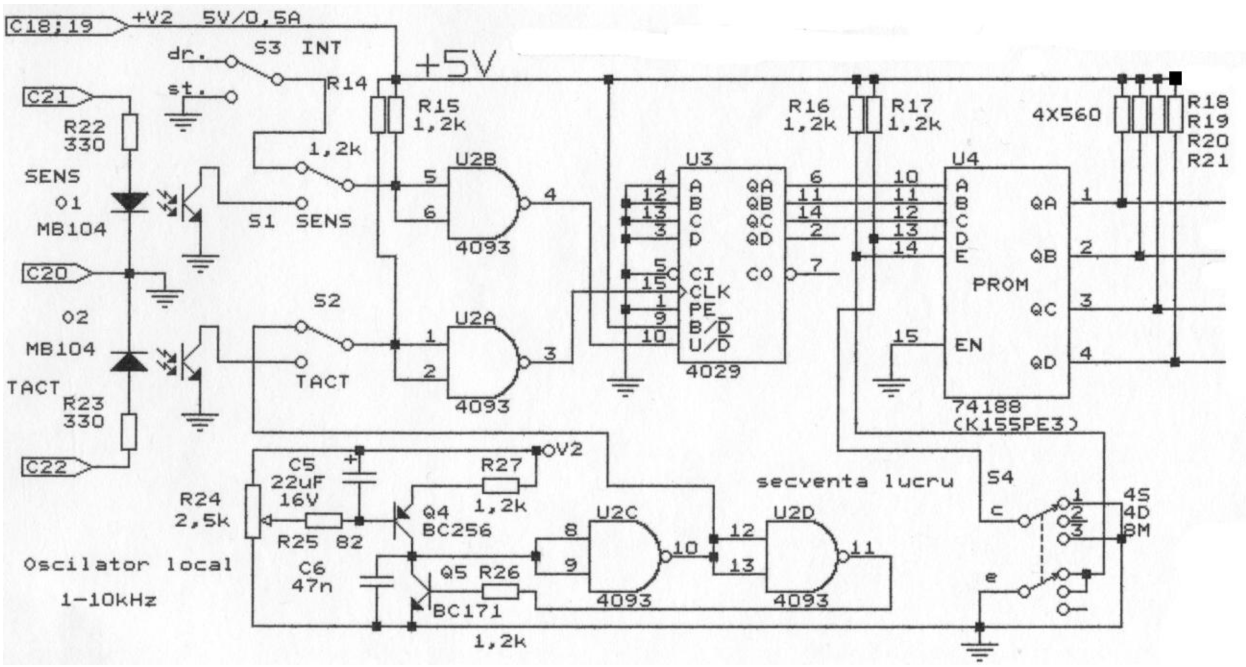


Fig. 2. Pulse distributor with PROM

3. Four phases stepper motor driver

Since motor phases are inductive loads which are periodically switched on and off, the power stage must be designed to protect switching elements against transitory inductive overvoltage.

The current through motor phase may be expressed [1]

$$i(t) = \frac{U}{R_m}\left(1 - e^{-\frac{t}{T_m}}\right) \qquad (1)$$

where $T_m = L_m/R_m$ is the phase electromechanical time constant, L_m, R_m, the own inductance respectively the phase resistance, and U d.c. supply voltage.

To achieve high frequency operation the time in which the phase current reaching the U/R_m value must be as short as possible. Therefore power stage must provide current slope forcing through motor phases.

This paper proposes a four step motor bilevel R/L-driver with improved performances.

The bilevel L/R drive provides a solution to the power waste using dropping resistors. In the beginning of the current build-up period, the winding is connected to a secondary high voltage supply.

After a short time, when the current has reached its nominal level, the second level supply is connected. Figure 3 explains further. The disadvantage of bilevel drive is the need of a second level power supply.

Table 1

Mode	Adress					Data				Phase sw.
	E	D	C	B	A	Y_1	Y_2	Y_3	Y_4	
4S	0	0	0	0	0	1	0	0	0	F1
	0	0	0	0	1	0	1	0	0	F2
	0	0	0	1	0	0	0	1	0	F3
	0	0	0	1	1	0	0	0	1	F4
	0	0	1	0	0	1	0	0	0	F1
	0	0	1	0	1	0	1	0	0	F2
	0	0	1	1	0	0	0	1	0	F3
	0	0	1	1	1	0	0	0	1	F4
4D	0	1	0	0	0	1	1	0	0	F1; F2
	0	1	0	0	1	0	1	1	0	F2; F3
	0	1	0	1	0	0	0	1	1	F3; F4
	0	1	0	1	1	1	0	0	1	F4; F1
	0	1	1	0	0	1	1	0	0	F1; F2
	0	1	1	0	1	0	1	1	0	F2; F3
	0	1	1	1	0	0	0	1	1	F3; F4
	0	1	1	1	1	1	0	0	1	F4; F1
4M	1	0	0	0	0	1	0	0	0	F1;
	1	0	0	0	1	1	1	0	0	F1; F2
	1	0	0	1	0	0	1	0	0	F2;
	1	0	0	1	1	0	1	1	0	F2; F3
	1	0	1	0	0	0	0	1	0	F3;
	1	0	1	0	1	0	0	1	1	F3; F4
	1	0	1	1	0	0	0	0	1	F4
	1	0	1	1	1	1	0	0	1	F1; F4

In some applications where 5 V and 12 V / 24 V are available, it may be a cost effective solution, but, if is possible to use voltage doubling techniques as well. An other very important consideration is current paths at turn-off and phase shift.

The inductive nature of the winding demands that a current path always exists. When using transistors as switches, diodes have to be added to enable current flow in both directions across the switch. The unipolar drivers is somewhat more complicated when it comes to current paths. The reason being the full coupling between the two halves of each phase winding, except for a small amount of leakage inductance.

The electric scheme is shown in figure 4 [2]. The pulse sequences provided by the pulse distributors (U3-MMC40193, U4-PROM 74188) are applied to the motor phases through four amplifiers (Darlington: Q1-2N2222, Q2-BD237, Q3-2N2222, Q4-BD237, Q5-2N2222, Q6-BD237, Q7-2N2222, Q8-BD237). The forcing of the current slope through motor phases is achieved by using a high voltage U2(+32V) during the current increasing and then switching to a low voltage U1(+7V) corresponding to the rating current. The high voltage is achieved through Darlington transistors Q9, Q10(BD682) which are controlled by the monostable multivibrators U5A, U5B(74LS123).The phase excitation begins with high voltage supplying on a length time achieved by the monostable RC groups.

The logic control of the two monostable multivibrators is achieved by PROM distributors. The transistor protection against inductive overvoltage is achieved by suppressor circuits with diodes (D5-D8).

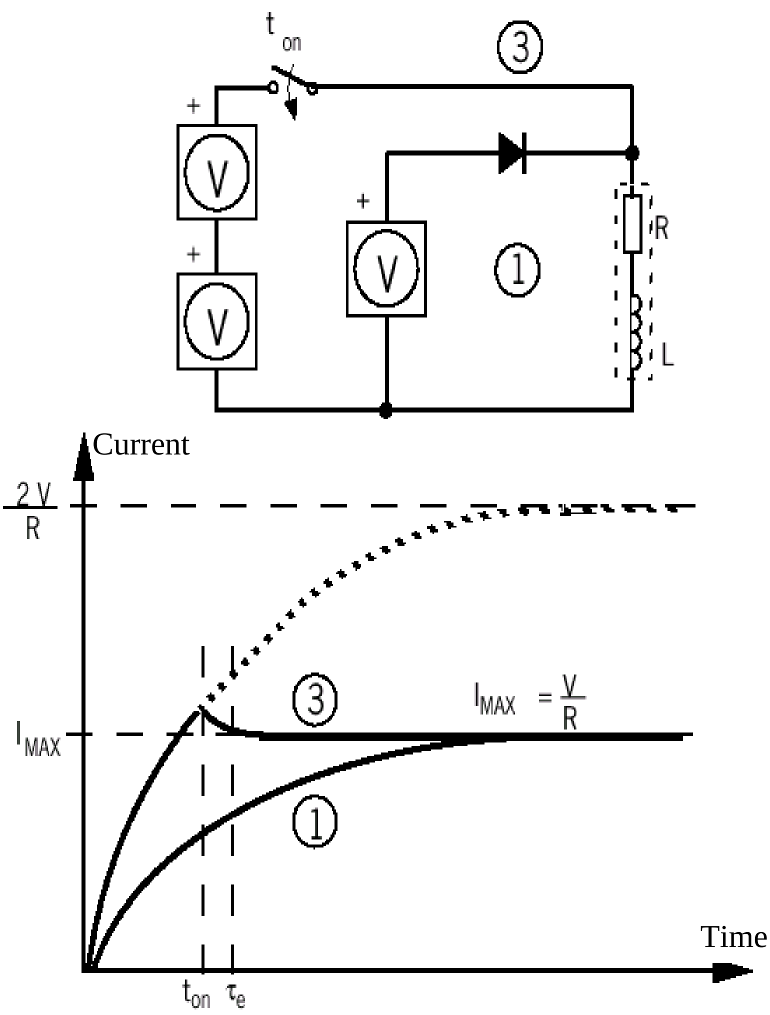


Fig. 3. The bilevel drive

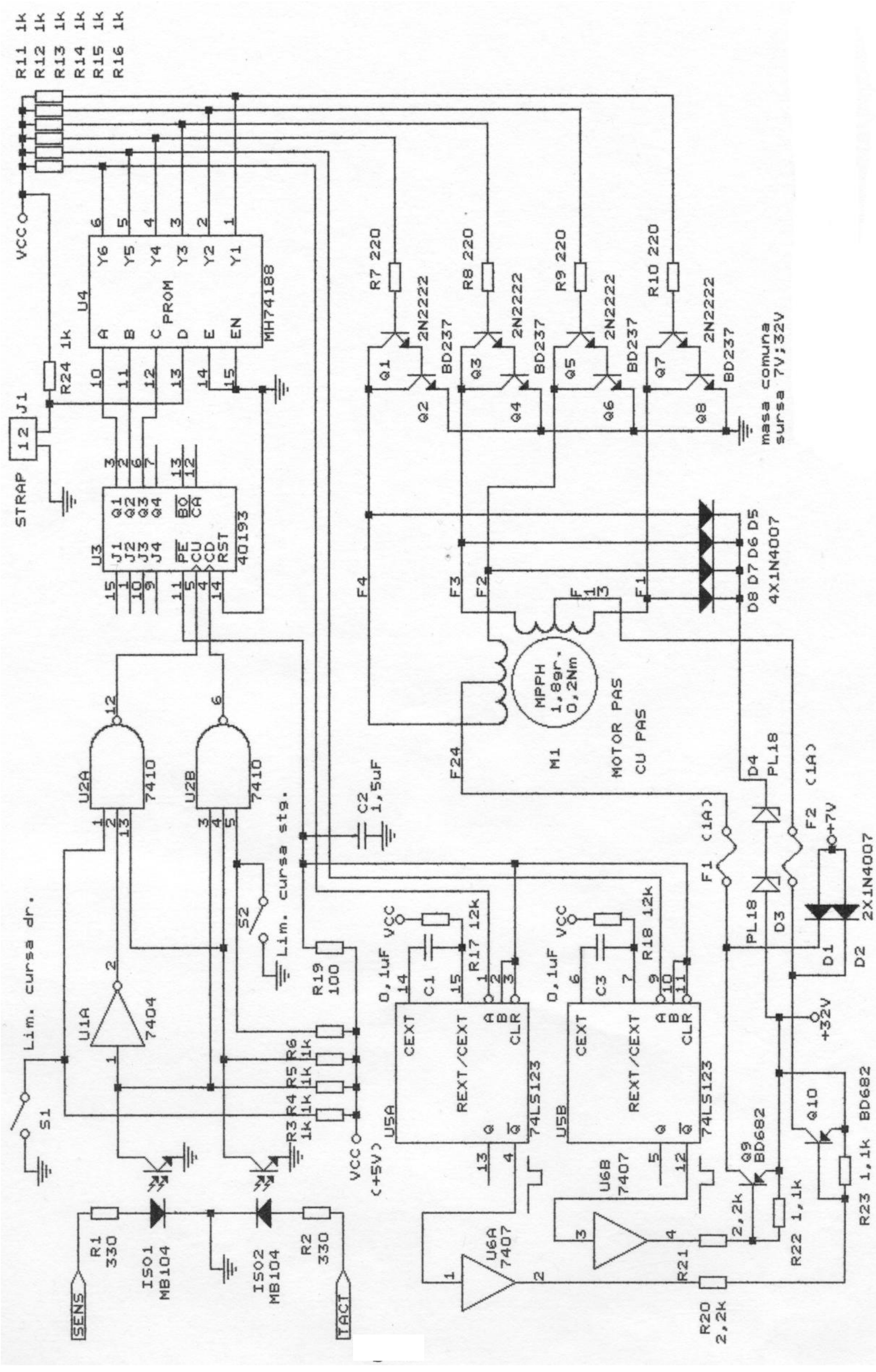


Fig. 4. The electric scheme of unipolar driver for 4 phases stepper motor

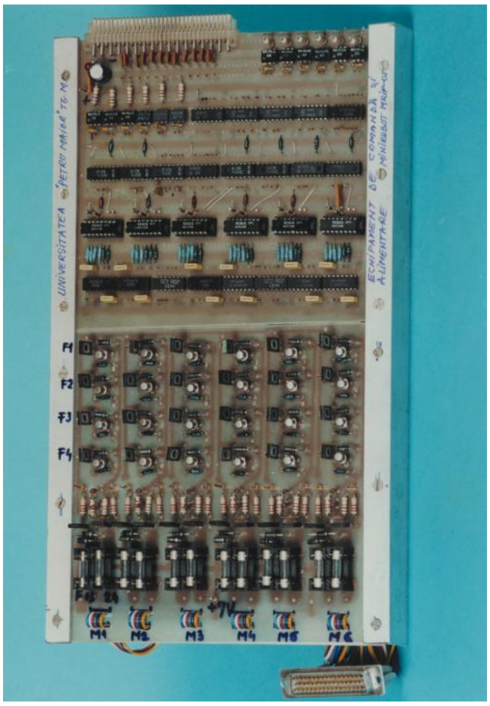


Fig. 5. The general view of driver card (for six stepper motor).

Fig. 6. The general view the Minimover Teachrobot MRIP-02

4. Experimental results and conclusion

It is known that static and dynamic performances of the stepper motor depend as much on the motor type as well on the control and supply scheme. The proposed pulse distributors and driver were designed and experimented (shown in figure 5) on the electric drives systems with stepper motor[2], existing in Electric Drives Laboratory, Engineering Faculty, “Petru Maior” University of Tg.-Mureş. A hybrid stepper motor with four phases ,type MPPH-$1{,}8^{o}$-0,2 (S.C.RELE+E S. A. Mediaş) , with drive of the six axes of the Minimover Teachrobot (MRIP-02, Automatica Buc., shown in figure 6), has been used. The pulse distributors are remarkable for simplicity, high-reliability and multifunctional facilities.

By association one of the pulse distributors with propose driver, a multifunctional compact module for six 4-phases stepper motor control may be obtained.

5. References

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