DC MOTOR SPEED AND POSITION CONTROL SYSTEM CONNECTS DIRECTLY TO MICROCOMPUTER CHIPS

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ABSTRACT

The papers presents a high performance speed and position control system for separately-excited D.C. motor, which was designed and performed with a dedicated integrated circuits (L290, L291, L292), made by SGS-THOMSON Microelectronics Company. The L290, L291 and L292 together form a complete microprocessor-controlled (microcomputer chips) DC motor servo positioning system that is both fast and accurate with an adequate software . The papers presents a description of the system, detailed function descriptions of each device and application information.

Keywords: D C motor, PWM, encoder, taho converter.

1. Introduction

The L290, L291 and L292 are primarily intended for use with a DC motor and optical encoder in the configuration shown schematically in figure 1. This system is controlled by a microprocessor, micro controller, or microcomputer chips which determines the optimum speed profile for each movement and passes appropriate commands to the L291, which contains the system's D/A converter and error amplifiers. The L291 generates a voltage control signal to drive the L292 switchmode driver, which powers the motor. An optical encoder on the motor shaft provides signals, which are processed by the L290 tachometer converter to produce tacho voltage feedback and position feedback signals for the L291 plus distance/direction feedback signals for the control micro.

The system operates in two modes to achieve high speed and accuracy: closed loop speed control and closed loop position control. The combination of these two modes allows the system to travel rapidly towards the target position then stop precisely without ringing.

Initially the system operates in speed control mode. A movement begins when the microcomputer applies a speed demand word to the L291, typically calling for maximum speed. At this instant the motor speed is zero so there is no tacho feedback and the system operates effectively in open loop mode (see figure 2). In this condition a high current peak – up to 2A – accelerates the motor rapidly to ensure a fast start. As the motor accelerates the tacho voltage rises and the system operates in closed loop speed mode, moving rapidly towards the target position. The microcomputer, which is monitoring the optical encoder signals (squared by the L290), reduces the speed demand word gradually when the target position is close. Each time the speed demand word is reduced the motor is braked by the speed control loop.

Finally, when the speed code is zero and the target position extremely close, the micro commands the system to switch to position mode. The motor then stops rapidly at the desired position and is held in an electronic detent.

2. Optical encoder

The optical encoder used in this system consists of a rotating slotted disk and a fixed partial disk, also slotted. Light sources and sensors are mounted so that the encoder generates two quasi-sinusoidal signals with a phase difference of ±90°. These signals are referred to as FTA and FTB. The frequency of these signals indicates the speed of rotation and the relative phase difference indicates the direction of rotation. An example of this type is the TIRO 1000 (Made in ROMANIA), which has 1000 tracks. Similar types are available from a number of manufacturers including Sharp and Eleprint. This encoder generates a third signal, FTF, which consists of one pulse per rotation. FTF is used to find the absolute position at initialization.

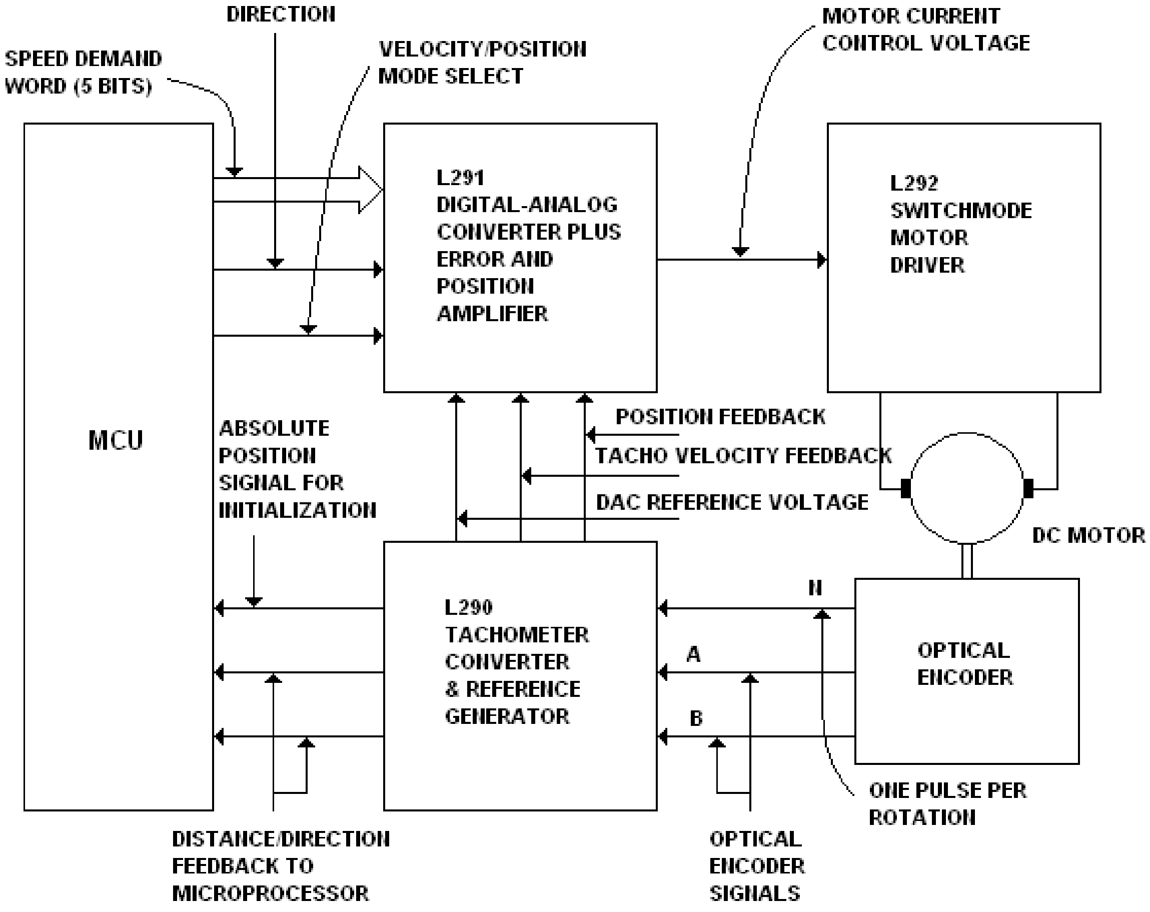

Fig. 1. The L290, L291 and L292 form a complete DC motor servopositioning system that connects directly to microcomputer chips

3. The L290 tachometer converter

The L290 tachometer converter processes three optical encoder signals FTA, FTB, FTF to generate a tachometer voltage, a position signal and feedback signals for the microprocessor. It also generates a reference voltage for the system's D/A converter.

Analytically, the tacho generation function can be expressed as:

$$TACHO = \frac{dV_{AB}}{dt}\cdot\frac{FTA}{|FTA|} - \frac{dV_{AA}}{dt}\cdot\frac{FTB}{|FTB|} \qquad (1)$$

In the L290 (block diagram figure 3) this function is implemented by amplifying FTA and FTB in A1 and A2 to produce V_{AA} and V_{AB}. V_{AA} and V_{AB} are differentiated by external RC networks to give the signals V_{MB} and $V_{MB,}$ which are phase shifted and proportional in amplitude to the speed of rotation. V_{MA} and V_{MB} are passed to multipliers, the second inputs of which are the sign of the other signal before differentiation. The sign ($\frac{FTA}{|FTA|}$ or $\frac{FTB}{|FTB|}$) is provided by the comparators CS1 and CS2. Finally, the multiplier outputs are summed by A3 to give the tacho signal.

This seemingly complex approach has three important advantages. First, since the peaks and nulls of CSA and CSB tend to cancel out, the ripple is very small. Secondly, the ripple frequency is the fourth harmonic of the fundamental so it can be filtered easily without limiting the bandwidth of the speed loop. Finally, it is possible to acquire tacho information much more rapidly, giving a good response time and transient response.

Feedback signals for the microprocessor STA, STB and STF are generated by squaring FTA, FTB and FTF. STA and STB are used by the micro to keep track of the position and STF is used at initialization to find the absolute position. Position feedback for the L291 is obtained simply from output of A1.

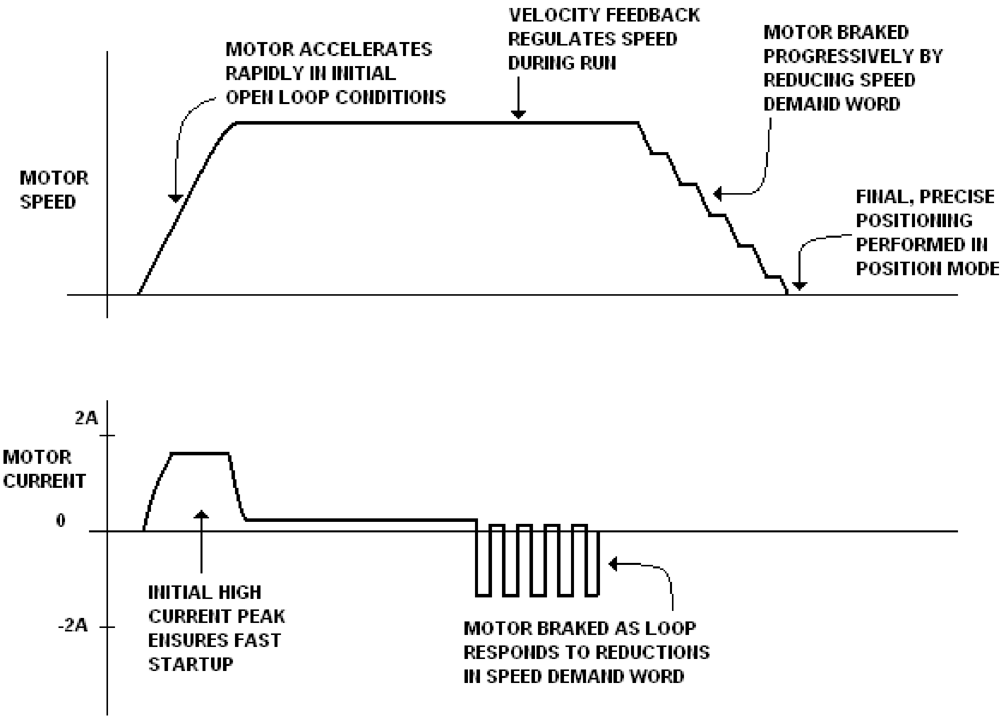

Fig. 2. The system operates in two modes to achieve high speed and accuracy. Tachometer feedback regulates the speed during a run and brakes the motor towards the end. Position feedback allows a precise final positioning.

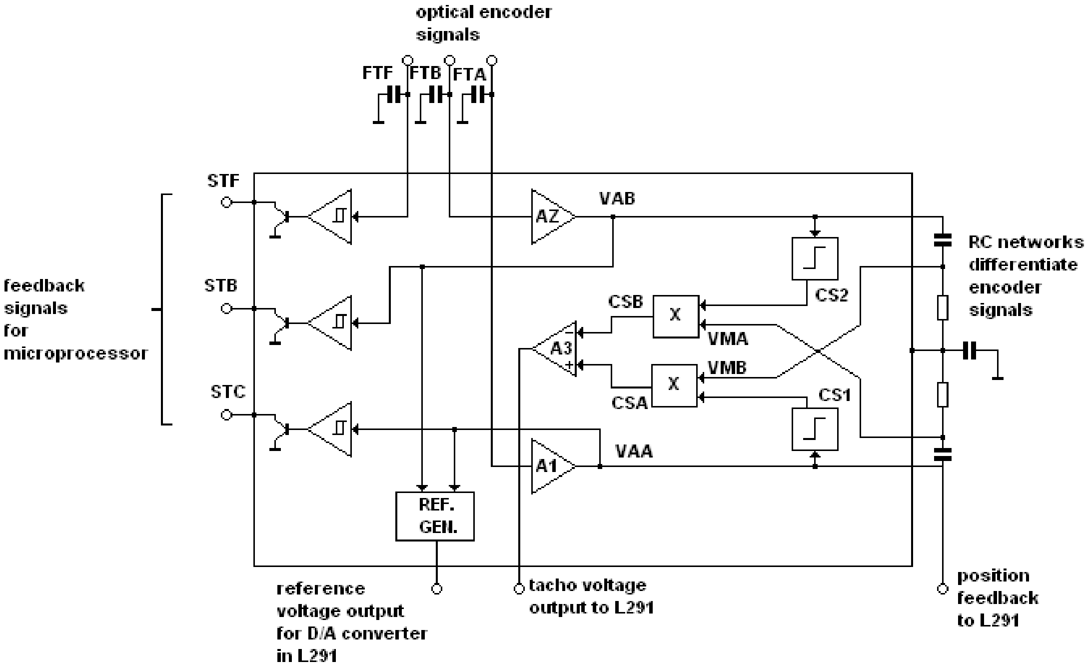

Fig. 3. The L290 processes the encoder signals, generating a tacho voltage and position signal for the L291 plus feedback signals for the microprocessor. Additionally, it generates a reference voltage for the L291’s D/A converter.

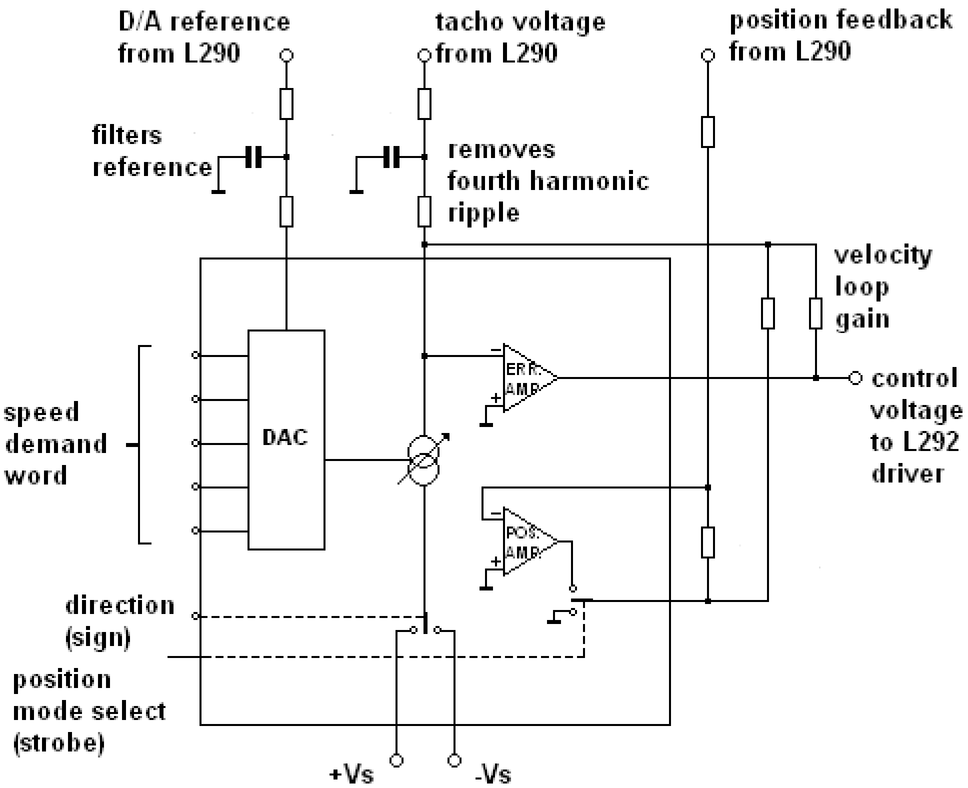

Fig. 4. The L291 links the system to the microprocessor. It contains the system DA converter, main error amplifier and position amplifier.

The L290 also generates reference voltage for the L291's D/A converter. This reference is derived from V_{AA} and V_{AB} with the function:

$$V_{ref} \equiv |V_{AA}| + |V_{AB}| \qquad (2)$$

Since the tacho voltage is also derived from V_{AA} and V_{AB} it follows that the system is self-compensating and can tolerate variations in input levels, temperature changes and component ageing with no deterioration of performance.

4. The L291 D/A converter and amplifiers

The L291, shown in figure 4, links the system to the micro and contains the system's main error amplifier plus a position amplifier, which allows independent adjustment of the characteristics of the position loop.

It contains a five bit D/A converter with switchable polarity that takes its reference from L290. The polarity, which controls the motor direction, is controlled by the micro using the SIGN input. The main error amplifier sums the D/A converter output and the tacho signal to produce the motor drive signal ERRV. The position amplifier is provided to allow independent adjustment of the position loop gain characteristics and is switched in/out of circuit to select the mode. The final position mode is actually "speed plus position " but since the tacho voltage is almost zero when position mode is selected the effect of the speed loop is negligible.

5. The L292 switch mode motor driver

The L292 can be considered as a power transconductance amplifier – it delivers a motor current proportional to the control voltage (ERRV) from the L291. It drives the motor efficiently in switchmode and incorporates an internal current feedback loop to ensure that the motor current is always proportional to the input control signal. The input control signal (see block diagram from figure 5) is first shifted to produce a unipolar signal (the L292 has a single supply) and passed to the error amplifier where it is summed with the current feedback signal. The resulting error signal is used to modulate the switching pulses that drive the output stage. External sense resistors monitor the load current, feeding back the motor current information to the error amplifier via the current sensing amplifier. The L292 incorporates it's own voltage reference and all the function required for closed loop current control of the motor. Further, it features two enable inputs, one of which is useful to implement a power inhibition function. The L292's output stage is a bridge configuration capable if handling up to 2A at 36V.

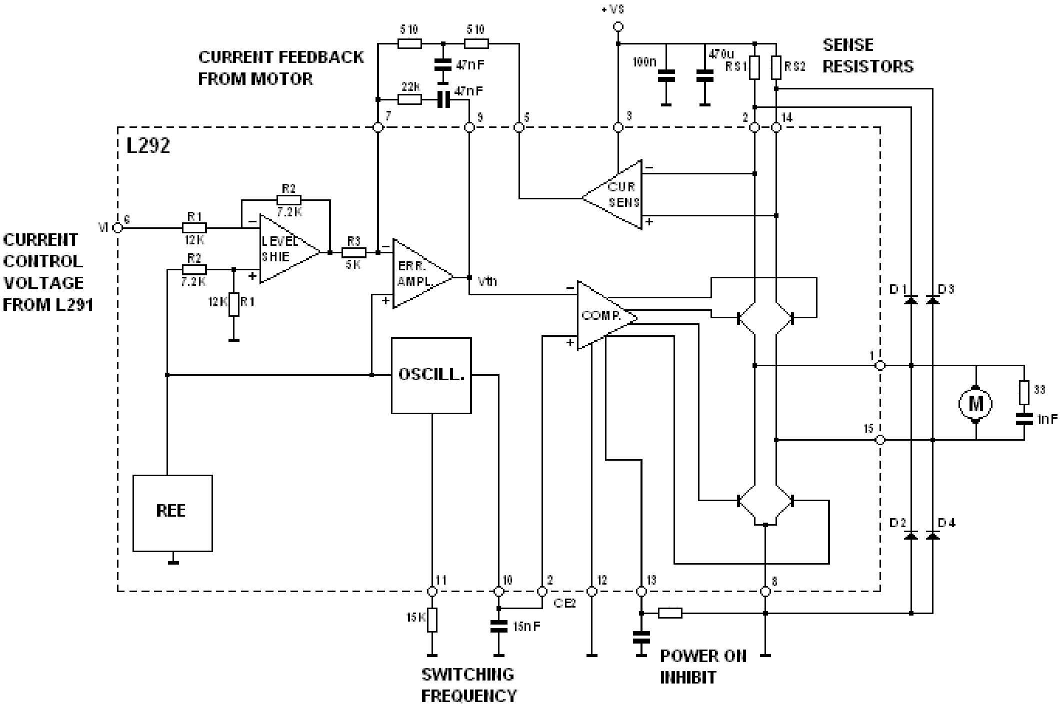

Fig. 5. The L292 switchmode driver receives a control voltage from the L291 and delivers a switchmode regulated current to the motor.

6. Interfacing to the micro and conclusion

In a typical system the L290/1/2 system is connected to the control microcomputer through ten I/O lines: seven outputs and three inputs.

The outputs are all connected to the L291 D/A converter and consists of five bit speed demand word, SIGN (which sets the direction) and the speed/position mode select line. Position feedback for the micro comes from the L290 tacho converter and consists of the signals STA, STAB (the squared encoder outputs) plus the one-pulse-per rotation signal, STF.

To follow the motor position the micro counts the STA pulses to measure the distance traveled and compares the phase of STA and STB to sense the direction. The most convenient way to do this is to connect the STA line to an interrupt input. An interrupt service routine will then sample STB and increment or decrement the position count depending on the relative phase difference: +90° if STB is high; -90° if STB is low.

It could be argued that the micro doesn’t need to sense the direction of the rotation because it controls the direction. In practice, however, it is better to sense the direction to allow for the possibility that the motor may be moved by externally applied forces.

For each movement the micro calculates the distance to be traveled and determines the correct direction. It then sets the L291 to velocity feedback mode, sets the director appropriately and sets the speed demand word for maximum speed (possibly less if the move is very short).

By means of the STA interrupt service routine it follows the changing position, reducing the speed demand word to brake the motor when the target position is very close. Finally, the micro orders the L291 to switch to position loop control for the final precise positioning.

When the system is powered up the mechanical subsystem may be in any position so the first step is to initialize it. In applications where the optical encoder never rotates more than one revolution – the daisy wheel of a typewriter, for example – this is simply done by rotating the motor slowly until the STF signal (one pulse per rotation) is detected. Where the optical encoder rotates more than once the “one pulse per rotation” signal is not sufficient. An example of this is the carriage positioning servo of a computer printer. In this case the simplest solution is to fit a microswitch on one of the endstops.

First the motor is run backwards slowly until the carriage hits the endstop. Then it moves forward until the STF signal is detected. The beauty of this solution is that the endstop microswitch does not need to be positioned accurately.

The experimental research was performed has been made in the Electrical Drives Laboratory of the Electrical Engineering Faculty, “Petru Maior” University of Targu-Mures, the tests were done using a single-linear axis CNC machine (Controlled by one D.C. motor + optical encoder TIRO 1000).

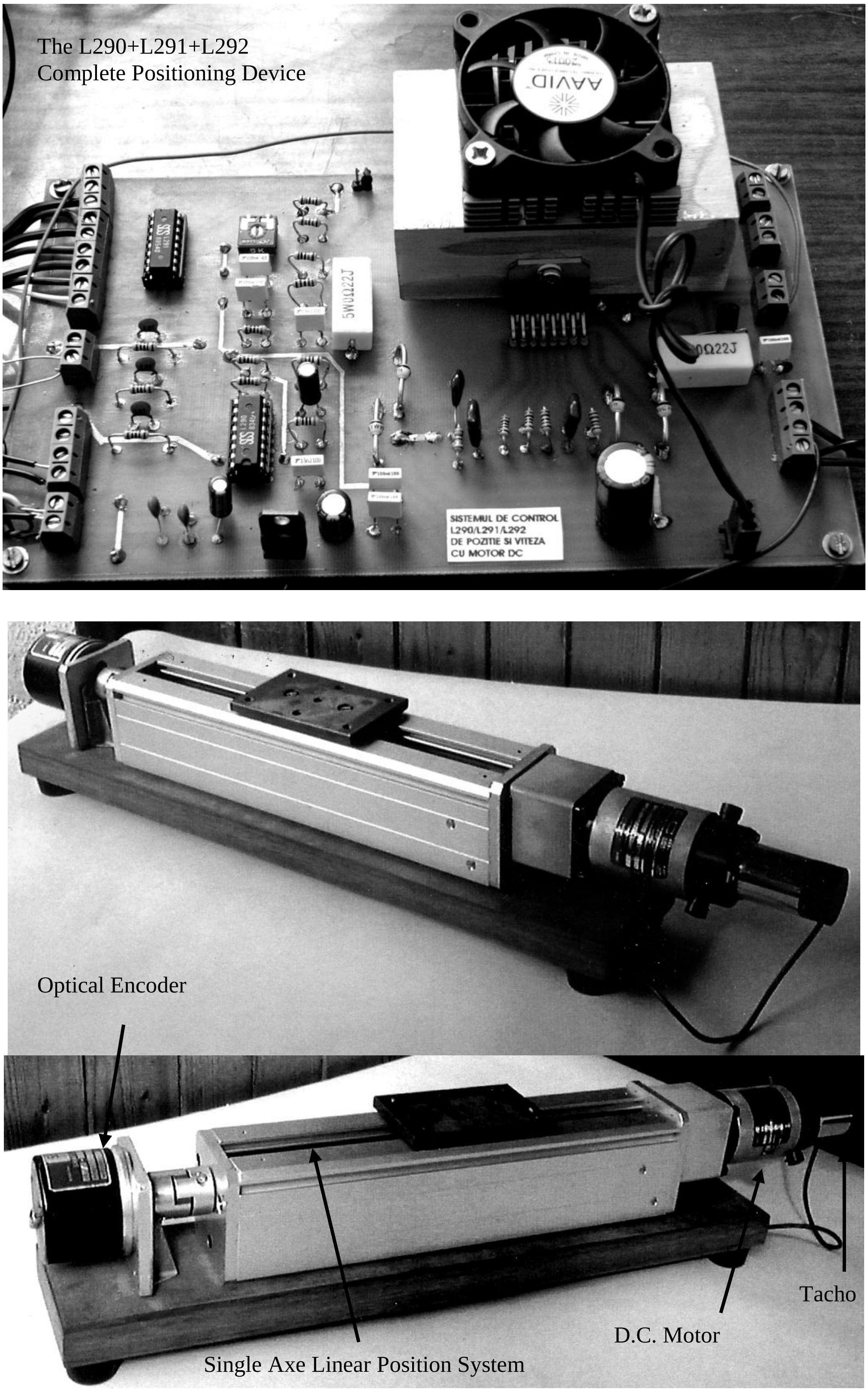

Fig. 6. General view of the realized experimental precision positioning linear axis system

The CNC prototyping linear axis includes application which is ideal for educational uses as well as an industrial application. Figure 6 shows the general view of the realized experimental precision positioning linear axis system.

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