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Some Aspects Regarding the Use of Digital Signal Controllers in Electrical Drivers for Stepper Motors

In the first part of this paper are presented and compared two practical implementation of unipolar stepper drives for didactical destination, one with 8 bit microcontroller and one with 16 bits digital signal controller. In the second part, a practical implementation of micro stepping drive for bipolar motor with a 16 bits digital signal controller designed for switching mode power supply. A physical prototype was realized and some experimental measurements are presented.

Keywords: micro-stepping, peak current limiting, MOSFET H-Bridge

1. Introduction

A microcontroller offers more flexibility and reduces the space used for printed circuit board.

A stepper motor can be considered a digital electromechanical system; therefore a microcontroller is the simplest way to command drives for motor, and especially when the motor is in unipolar configuration.

Development of microcontrollers and implementation of hardware multiplier in the core permits to have possibility to design digital control of a lot of industrial processes, including the motor control.

2. Unipolar stepper motor drivers

For unipolar motor configuration, the hardware implementation of drive is very simple: four output pins of a port assure the four commands for motor's phases. Usually microcontrollers are biasing from 5V or 3.3V power supply. For small stepper motors, a bipolar transistor for each phase is a good choice, and the transistor's base is connected to the output of microcontroller by a resistor for obtaining the necessary base current. A lot of integrated circuits are on the market.

For big stepper motors, power MOS transistors are the best solution especially for low voltage, because they present a low "ON" resistance actually around 1 mΩ.

For achieve the lowest "ON" resistance NMOS-transistor needs a voltage between 10 and 15 volts (usually 12V). A driver stage is necessary to translate the voltage level and to assure the rapidly charge and discharge the input capacitor of NMOS-transistor for reducing switching loses.

A prototype for didactical destination was realized using small surface mounted devices (SMD). The block diagram is showed in figure 1, and a photo of practical realization in figure 2. The motor is type is 103H6701-1142, and it has the coil resistance: 3.3Ω, inductance: 4.5 mH, nominal current: 1.2 A. Hence the necessary voltage is U=I*R=4V, and time constant of motor coil: L/R=4.5mH/3.3Ω=1.36 ms.

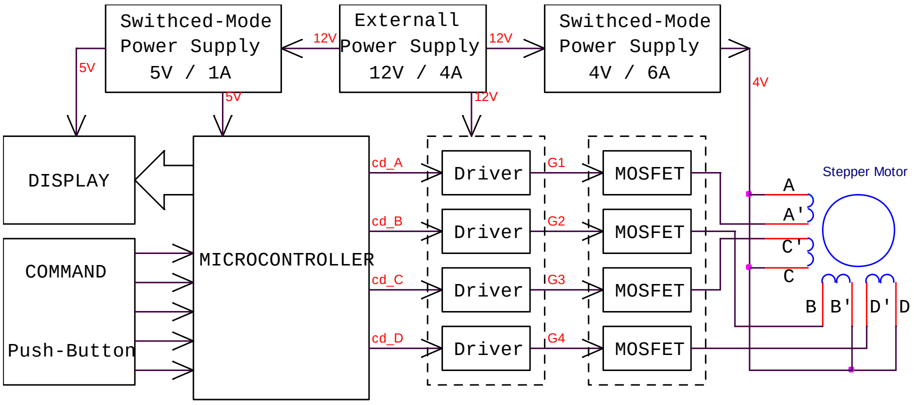

Figure 1. Block diagram of motor drive SMD prototype

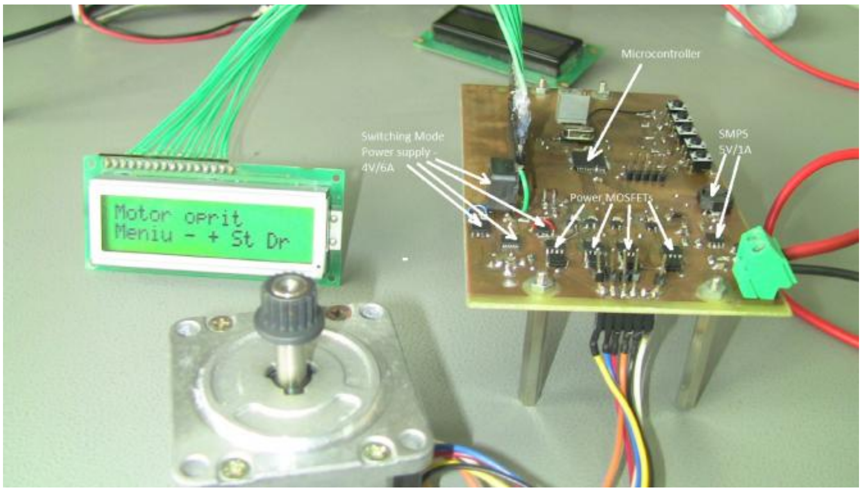

Figure 2. Motor drive SMD prototype, physical realized

The software program was developed in MPLAB 8.80, an Integrated Development Environmental (IDE) from Microchip for their microcontrollers. The source code program was realized in C language using HT-PICC Compiler. The used microcontroller is PIC16F877A in SMD package. The step duration is determined by one of the microcontroller's timer, TMR1, using interrupts technique. Because this type of microcontroller generates a single hardware interruption, the interrupts subroutine becomes complicated if we desire to test push-buttons state as an interruption request and program stays too much time inside the interrupts subroutine. In the realized program the push-buttons states are tested in the infinite loop.

Another prototype was realized for didactical destination, with 16 bits digital signal microcontroller dsPIC16F4012, as you see in figure 6. The source code program was realized in C language using MPLAB C30 Compiler v3.31. For this microcontroller we have possibility to assign 8 level of interrupts priority for our interrupts request. Therefore the commands (push button) are treated as the interrupts requests. The timers for this family of microcontrollers count in down direction, which simplifies the software for imposed step duration.

In figure 3 is presented the chronograms obtained for full step - full drive command, a step duration is 0.5 seconds, the current flow through the two coil simultaneously.

In figure 4 is presented the chronograms obtained for full step - half drive command, a step duration is 0.5 seconds, the current flow through a single coil during a step duration. In figure 5, are the chronograms for full step - half drive command and 5 milliseconds for step duration. A typical oscillation for unloaded motor can be observed on the current diagram [1].

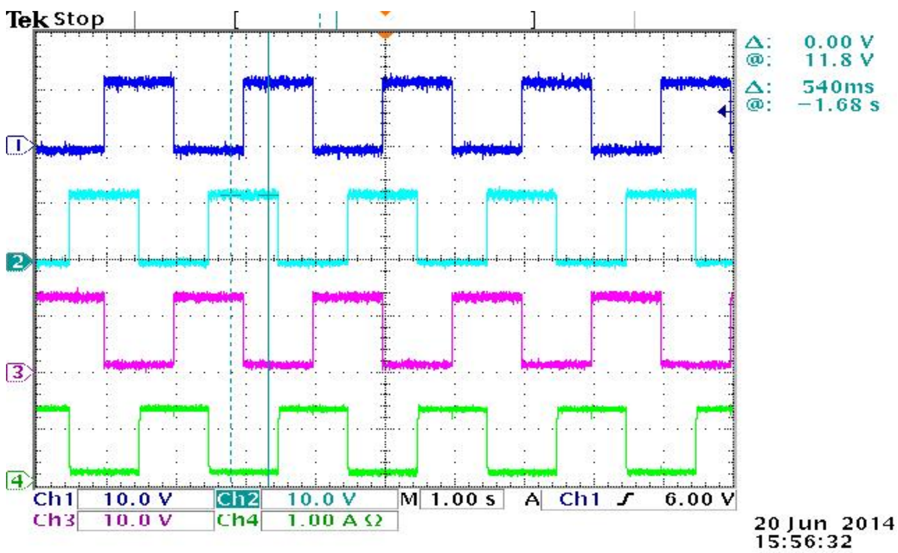

Figure 3. Chronograms for Full Step Full Drive (double command mode)

The oscilloscope channels one two and three, show the voltage for MOSFET gate command, corresponded to phases A, B, and C. The channel 4 chronogram show the current trough phase D.

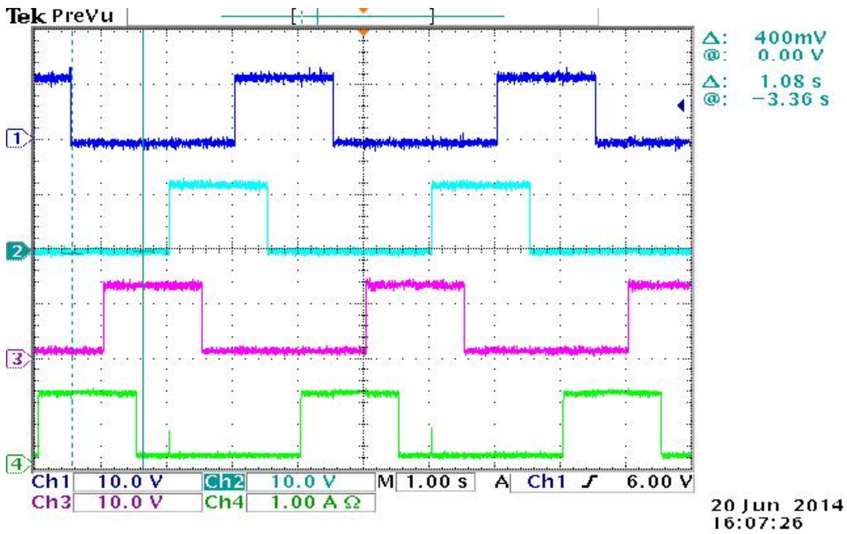

Figure 4. Chronograms for Full Step Half Drive (simple command mode)

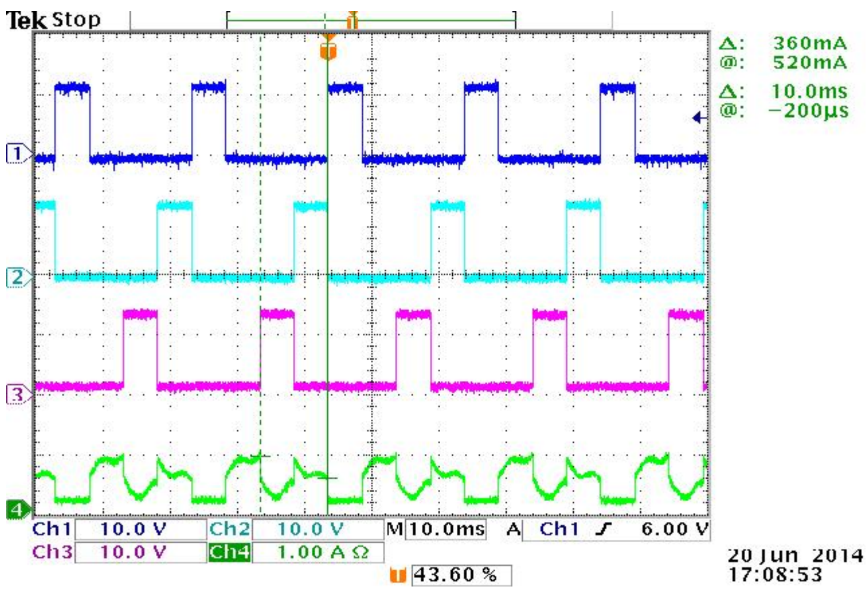

Figure 5. Chronograms for Full Step Half Drive, 5 ms step duration

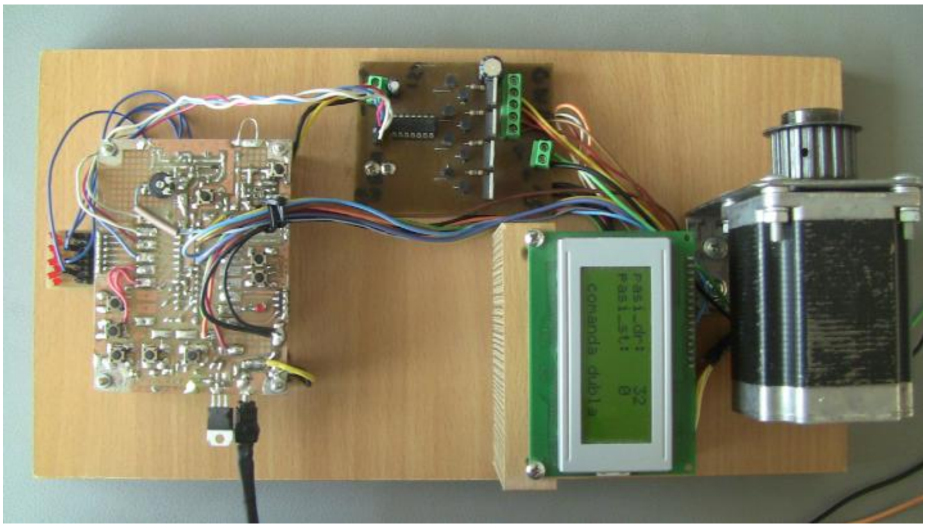

Figure 6. Unipolar motor drive prototype realized with digital signal controller dsPIC30F4012.

Rise time of current trough the motor's coil can be reduced by using a high voltage power supply for motor. Like is showed in figure 8, for the beginning, the high voltage is applied on the coil of motor. The current increases rapidly. When the value of current becomes the nominal value, a Pulse Width Modulation (PWM) technique with adequate duty cycle make average voltage on the motor coil at nominal value, that means current is limited to the nominal value, the series inductance having the roll of filtering the current.

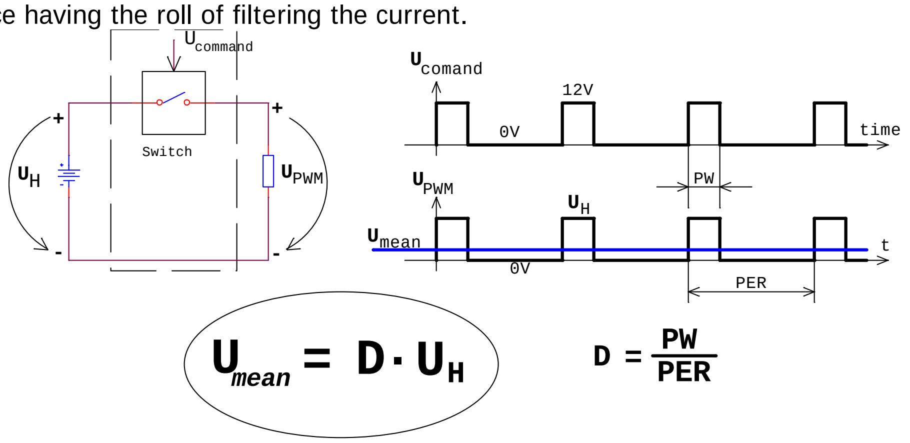

Figure 7.The Principle of reducing the mean value of output voltage using Pulse Width Modulation technique.

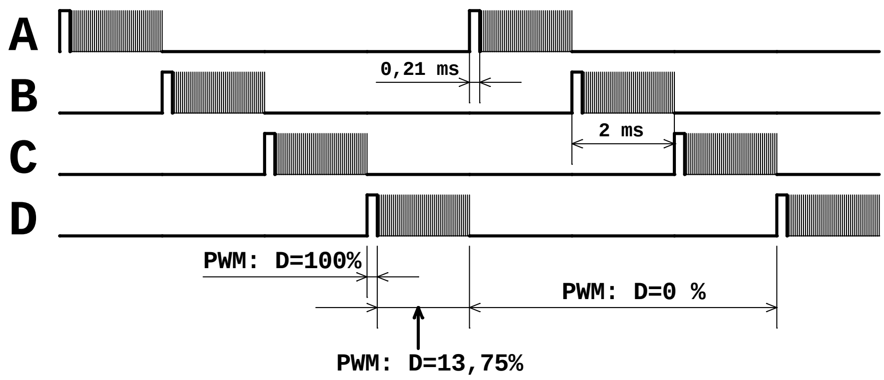

Figure 8. Current limiting technique based on average voltage command.

For unipolar motor the falling slope of current trough the motor coil can be making fast by connecting the freewheeling diodes at another high voltage connected in series with power supply. This is complicated; this voltage source is not in generator regime. For bipolar connection, using H-Bridges, the rise time is equal with the fall time. But an error on the program can do to high value of current trough the motor coil.

3. Bipolar stepper motor drivers with microcontroller.

The principle of current control using a microcontroller with analogue comparator inside is presented in figure 9. Of course, the analog comparator can be externally; microcontroller it must to have fault event function and associated pin.

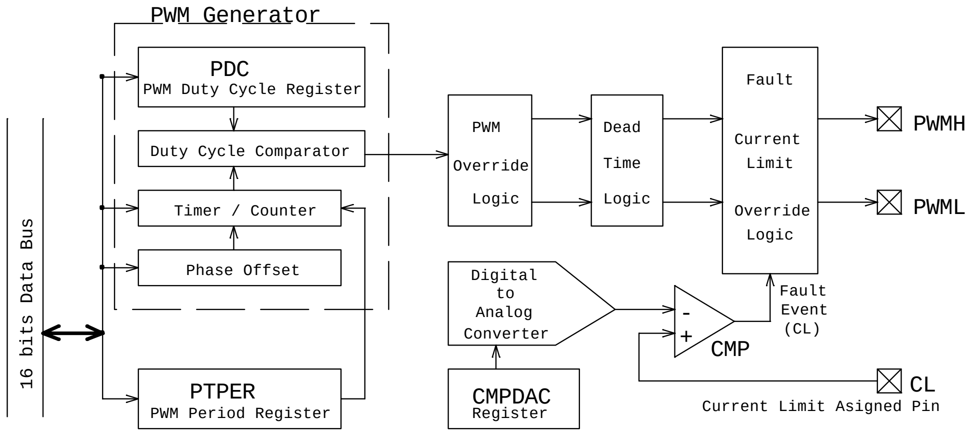

Figure 9. The current limiting principle, using a digital signal controller with analogue comparator inside - hardware block diagram.

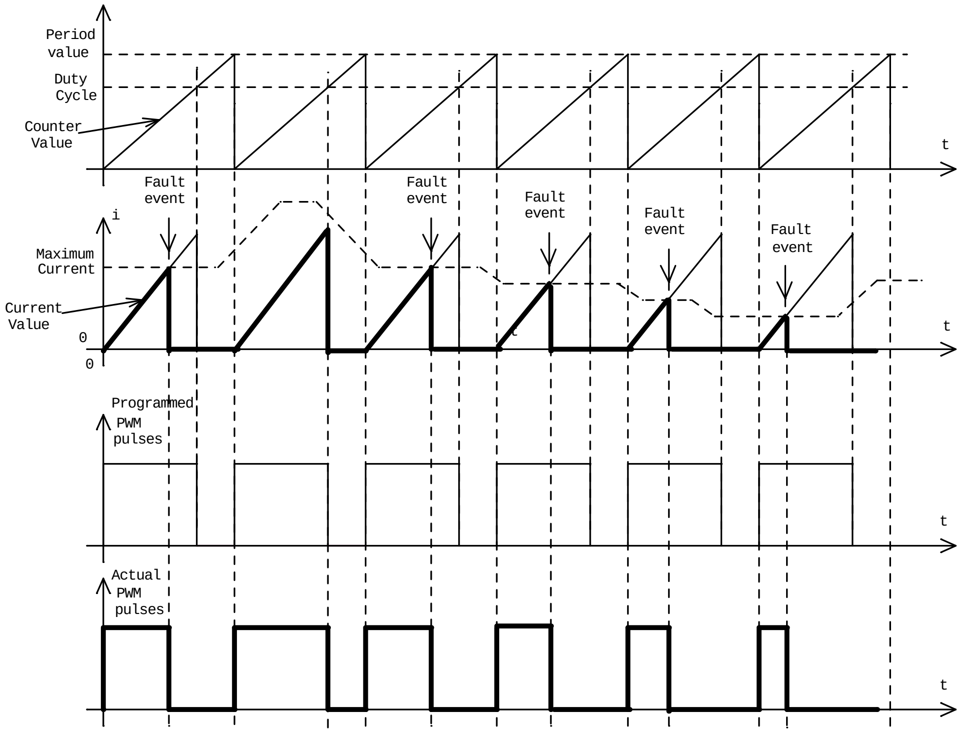

Figure 10. The current limiting principle, using a digital signal controller with analogue comparator inside

The electronic module for stepper motor command was realized around a 16-bits Microchip digital signal controller: dsPIC30F2020. This microcontroller has four PWM module, each module has own fast Analogue Comparator with own 10-bit Digital to Analogue Converter to provide Reference Voltage and Current Limit Assigned Pin. The value of CMPDAC Register (in conjunction with current sensor transfer rate) determines the instantaneous value of limiting current.

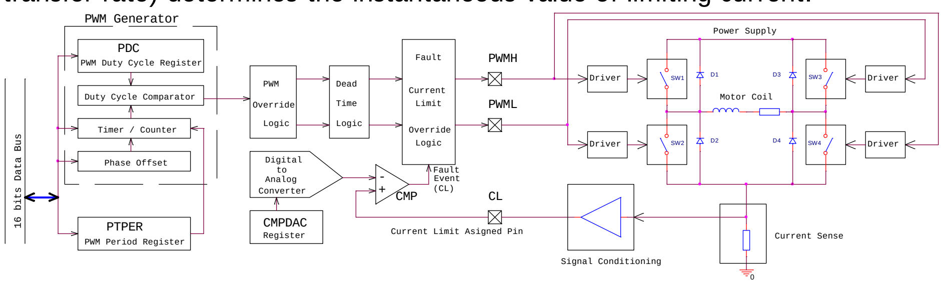

Figure 11. Block diagram of drive with DSC peak current limiting technique

The source code program was realized in C language using MPLAB C30 Compiler v3.31. The high performance PWM modules have a high frequency PLL oscillator and can be programmed to assure switching frequency for PWM signal above 100 KHz. In the experimental prototype an 80 KHz PWM switching frequency was used. Bootstrap technique integrated drivers, HIP4082, was used for H-Bridge command, and like is showed in figure 12. The high noisy CRT1 and CRT2 signal do to the false blocking the PWM pulse during the sinusoidal current trough the motor coil passes by zero. The Leading Edge Blank technique was used, but the problem still remain. A very careful PCB design is recommended for minimize the noise.

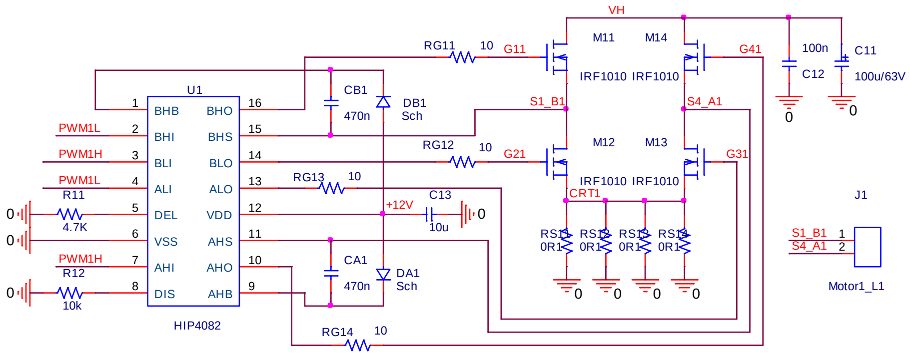

Figure 12. Detailed schema for H-bridge and bootstrap integrated driver

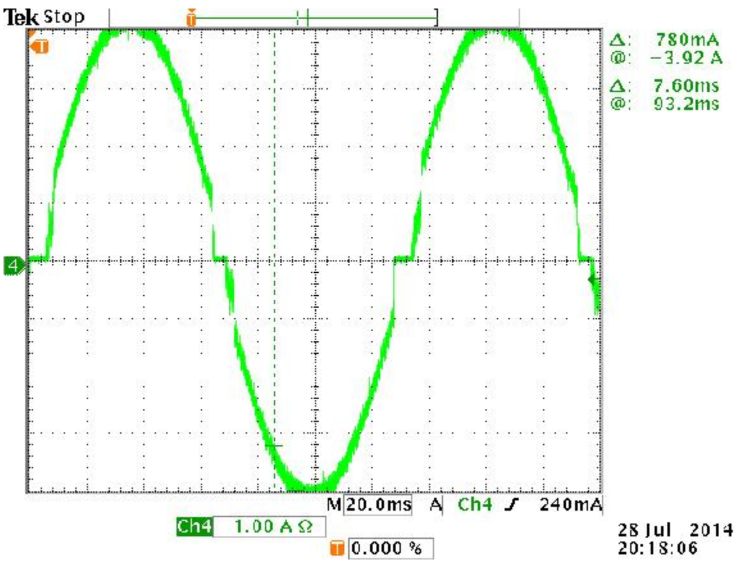

Figure 13. The chronograms for motor's coil current, 64 micro steps.

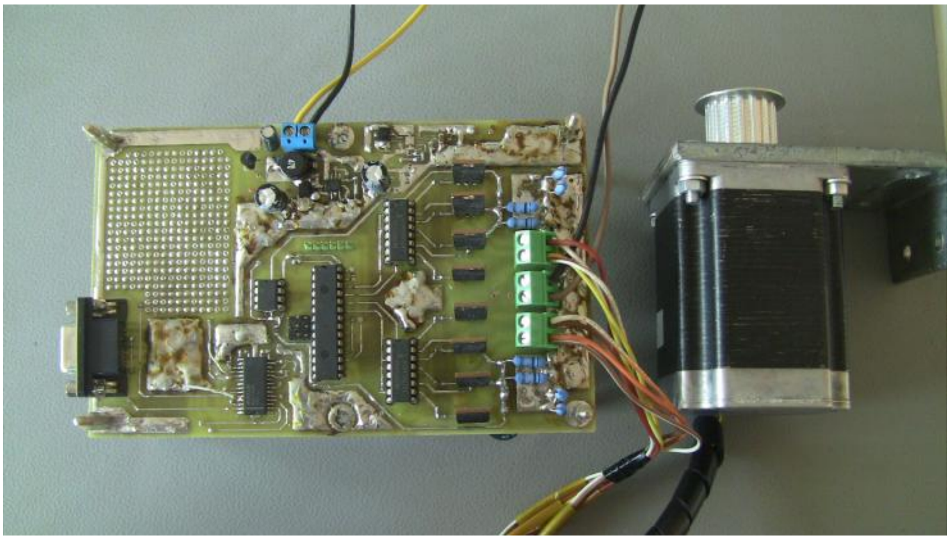

Figure 14. The Realized Prototype of Bipolar Stepper Motor Drive with Digital Signal Controller dsPIC30F2020.

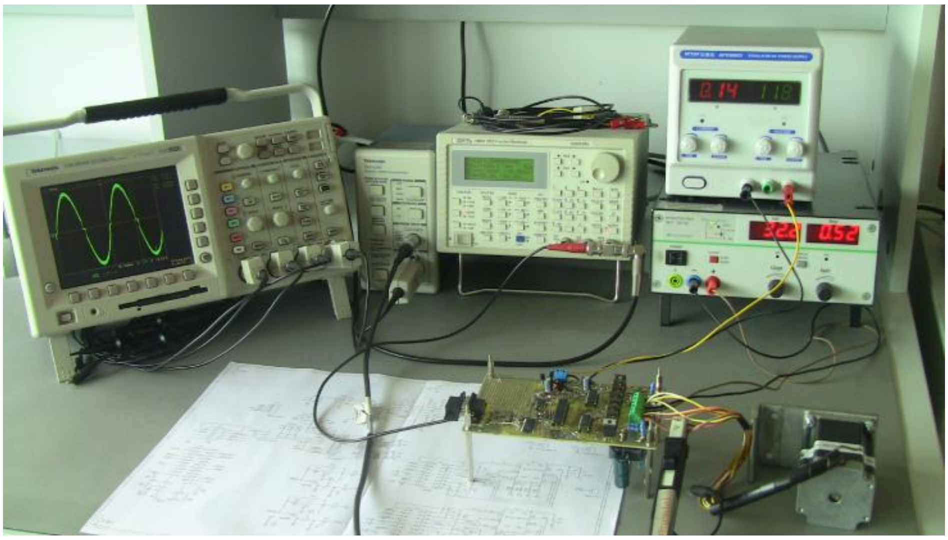

Figure 15. Experimental set up.

The experimental current and voltage waves are visualized on the screen of Tektronix TDS3034B Oscilloscope. A 50amperes current probe TCP305 in conjunction with TCPA300 amplifier is also used for motor coil current measurement and visualization.

For reducing the noisy current feedback signal we can design another feedback topology, using current sensor in series with the motor coil. A sensor based on the Hall Effect can be a good solution but the maximum frequency is unfortunately around 100 KHz. A good choice for our application is the integrated circuit AD8210, which have the superior frequency around 500KHz.

Another way to realize micro stepping drive for bipolar stepper motor is to use a microcontroller and two digital to analogue converters to deliver reference voltage for a driver with peak current limiting analog technique, like is showed in figure 16.

An example with microcontroller, two DACs and two integrated circuits drivers is presented in literature [3].

Another way to realize a performing micro stepping driver and motor control is to use FPGA or CPLD circuits in conjunction with microcontrollers [2], [6], [7], [8].

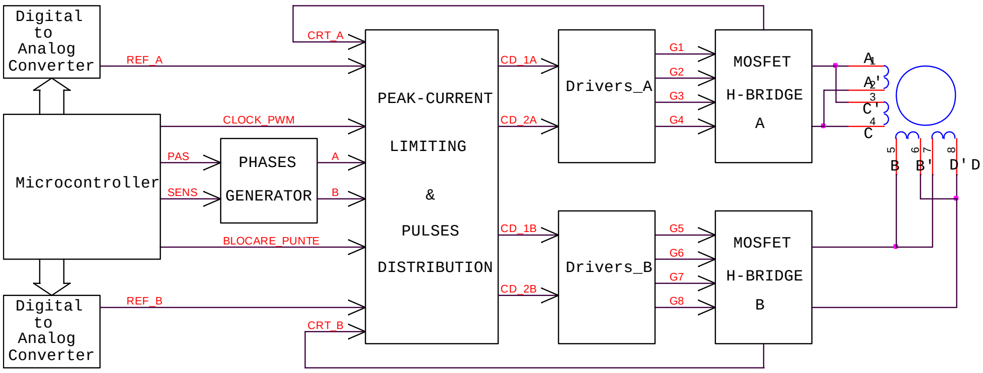

Figure 16. Block diagram of micro stepping motor drive controlled by a usual microcontroller and digital to analog converters.

4. Conclusions

Microcontrollers use for stepper motor drives offers more flexibility and reduces the space used for printed circuit board. A newest power SMD circuits permits the drive realization for several amperes current trough the motor coil.

The digital signal controller offers more facilities in industrial application use and the software can be simplified comparative with the eight bits middle class microcontroller.

The digital signal controllers designed for switched mode power supply offer advanced possibility to realize micro stepping current control.

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