Laboratory setup for variable speed control of a three phase AC Induction Motor using a DSP Controller

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Abstract:

This paper presents the hardware and software aspects of a Digital Signal Processor (DSP) based controller for AC Induction motors. The hardware part of the setup consists of a DSP module, a three-phase inverter module and an interface module. The system implementation involves the use of different software modules to achieve the desired variable speed operation in open loop or closed loop. This setup can be effectively utilized to demonstrate to students the various motor control functions for variable speed operation and how it can be controlled in software by a DSP controller. DSP based systems have become an indispensable part of many modern equipment and industrial processes. Laboratory experience from the setup presented in this paper will familiarize the students to state of the art variable speed motor control methods that are being used in the industries. The setup can also be used as a research platform to test different motor control algorithms.

Introduction:

Electric motors have wide application in industry, such as in the control of fans, pumps and compressors. There are many special applications, such as variable speed air-conditioners, heat pumps and furnaces, where a range of motor powers would be preferred. This has led to the development of electric motors with variable-speed drives. A full range of variable-speed drives are currently available and are being used in industries, with motor sizes ranging from fractions to thousands of horsepower. The capability of varying the speed of an electric motor to match the load required by their end-use system will optimize its performance and minimize energy use. Tests with pump, fan and compressor applications have indicated typical energy savings of 20-50% using motors with variable speed drives.

Electric motors are taught very justifiably in almost all Universities along with some basic motor control methods. However, in order to keep pace with the industrial changes, present day Electrical Engineering or Technology students need to know the state of the art variable speed motor control methods that are being used in the context of exciting new applications. In view of this, this paper presents the hardware and software aspects of a Digital Signal Processor (DSP) based controller for ac induction motors. This setup can be effectively utilized to demonstrate to students the various motor control functions for variable speed operation. This can be included as a laboratory experiment in any motor or motor control course. Many programs offer specific courses on motor drives where a laboratory experiment based on the proposed setup can be effectively incorporated. This setup can also be used in control courses to illustrate open loop and closed loop operation and how it can be controlled in software. Moreover, DSP based systems have become an indispensable part of many modern equipment and industrial processes. The proposed DSP based laboratory setup would provide the students the opportunity to get acquainted with DSP based control.

DSP Controllers for motor drives

Implementation of advanced motor drive systems requires the following features from a typical motor controller -

- Capability of generating multiple high frequency, high-resolution PWM waveforms.
- Fast processing to implement advanced algorithms to minimize torque ripple, on line parameter adaptation, precise speed control etc.
- Implementing multiple features using the same controller (motor control, power factor correction, communication, etc.)
- Making the complete implementation as simple as possible (reduced component count, simple board layout and manufacturing etc.)
- Implementing a flexible solution so that future modification can be realized by changing software instead of redesigning a separate hardware platform.

A new class of DSP controllers has addressed these issues effectively [1,2]. These controllers provide the computational capability of a DSP core and integrate useful peripherals on chip to reduce the total chip count.

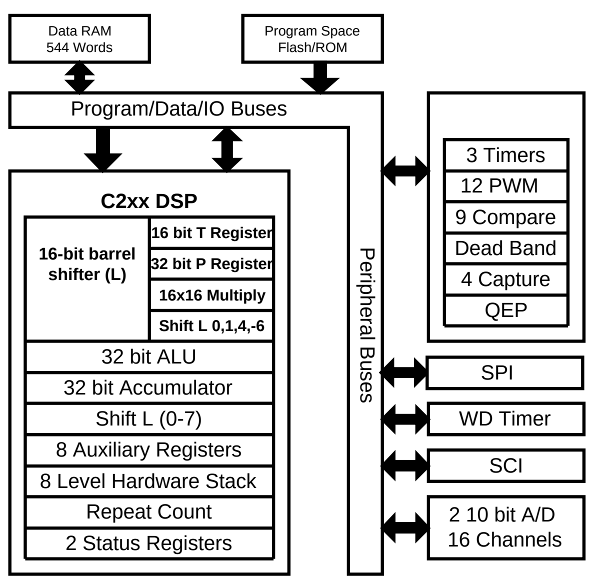

Figure 1 Block diagram of DSP controller.

The DSP controller TMS320F24xx [3] from Texas Instruments is utilized to implement a three phase AC induction motor drive. Figure 1 shows the overall block diagram of TMS320F24xx. TMS320F240 has a 20MIPs 16 bit fixed point DSP core. It also integrates the following power electronics peripherals – 12 PWM (Pulse Width Modulation) channels (out of which 9 are independent), three 16 bit multimode general purpose timers, 16 channel 10 bit ADC with simultaneous conversion capability, four capture pins, encoder interface capability, SCI, SPI, Watch Dog etc.

Six PWM channels (PWM1 through PWM6) control the three phase voltage source inverter. These six PWM channels are grouped in three pairs (PWM 1&2, PWM 3&4, PWM 5&6). Three compare registers, called Full Compare, are associated with each PWM channel pair. The compare register values are updated to obtain the proper PWM output. The on-chip software programmable, dead band module provides sufficient dead time to avoid shoot through fault. There are three more PWM channels left to implement other functions like power factor correction.

System Description

Figure 2 shows the complete system diagram for a three phase AC Induction motor drive. A three phase voltage source inverter is utilized to operate a three phase AC Induction motor. Six PWM channels from the DSP controller regulate the motor phase voltages by controlling the six power devices of the three phase inverter. This provides the flexibility to vary the motor speed by software means. Space Vector Pulse Width Modulation (SVPWM) is utilized to implement Volts/Hertz (V/Hz) algorithm for the motor drive at different speeds. Both open and closed loop control of the speed of an AC induction motor can be implemented based on the constant V/Hz principle. The SVPWM refers to a special switching sequence of the upper three power devices of a three phase voltage source inverters used in AC motor drives. This special switching scheme for the power devices results in 3 pseudo-sinusoidal currents in the stator phases. One capture input is utilized to measure the motor speed. A detailed description of the system hardware components including software description is given in the subsequent sections.

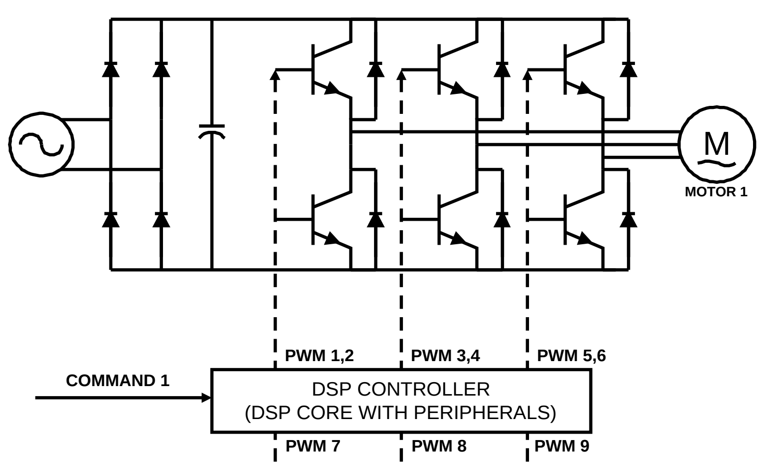

Figure-2 Three Phase AC Induction Motor Drive

Hardware Configuration

The experimental system consists of the following hardware components:

- Texas Instruments TMS320F243 EVM platform – The DSP controller is utilized to generate the required PWM outputs based on the V/Hz principle at different speeds.
- Spectrum Digital DMC1500 Drive platform – This provides the power stage of the drive system. It consists of a bridge rectifier, DC bus capacitor, a three phase inverter with the associated driver circuitry for the inverter switching power devices (MOSFETs). PWM control signals from DSP Controller are input to the inverter module and output of this module is connected to the motor terminals.
- Spectrum Digital DMC to EVM Interface board
- Three phase AC Induction (ACI) motor.
- IBM compatible development environment including an IBM compatible PC with Code Composer 4.1 or higher installed and XDS510pp emulator.

The complete hardware setup is shown in Figure 3.

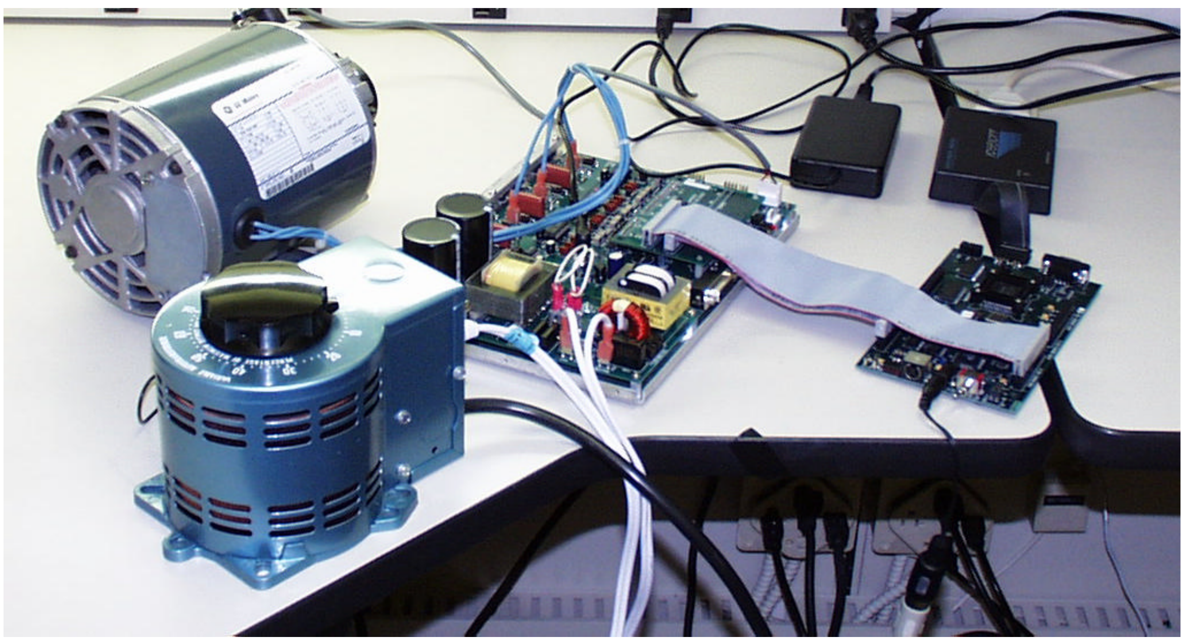

Figure 3 Hardware setup for a DSP controlled three phase AC induction motor drive.

Software Description

The drive system utilizes various software modules for motor control. Figure 4 shows the software block diagram with the various software modules such as RAMP_CNTL, V_HZ_PROFILE, SVGEN_MF and FC_PWM_DRV. Modifying the variable “speed_setpt” can vary the motor speed. The RAMP_CNTL module implements a ramp up and ramp down function. The V_HZ_PROFILE module generates an output command voltage for a specific

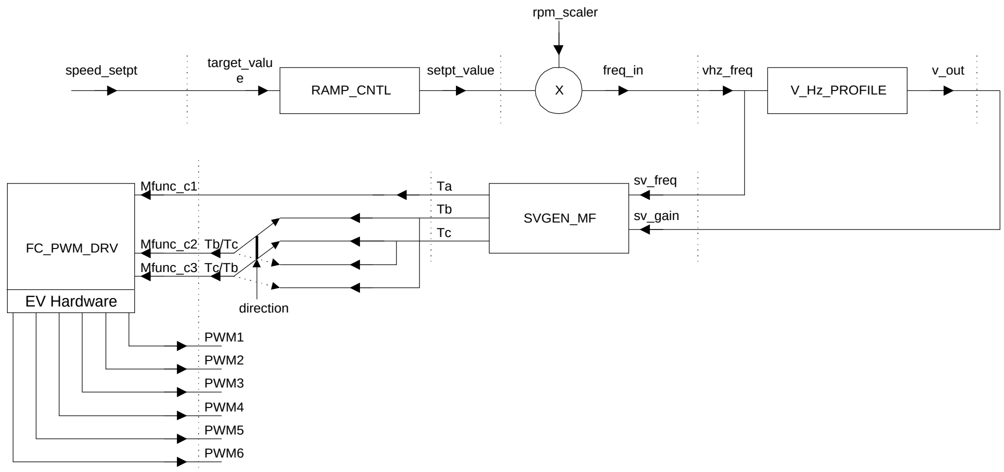

Figure 4 Complete software block diagram to implement one of the operating modes.

input command frequency according to the specified volts/hertz profile. This is used for variable speed implementation of A

C induction motor drives. The SVGEN_MF module calculates the appropriate duty ratios needed to generate a given stator reference voltage using space vector PWM technique. The stator reference voltage is described by its magnitude(sv_gain) and frequency(sv_freq). The FC_PWM_DRV module uses the duty ratio information and calculates the compare values for generating PWM outputs. It also provides the required dead band to avoid shoot through faults. The entire application software is driven by an Interrupt service routine (ISR). The main code (i.e. background loop) consists simply of TMS320C243 peripheral initialization (e.g. PLL, Watchdog, Interrupt control & Event manager). The remainder of the code is taken up entirely by PWM_ISR. This ISR is invoked every 50uS (20KHz) by the Period event flag on Timer 1 of the Event manager.

Experimental Results

The ACI motor drive system described above was used to operate a three phase AC Induction motor with open loop speed control in variable speed mode. The operating frequency

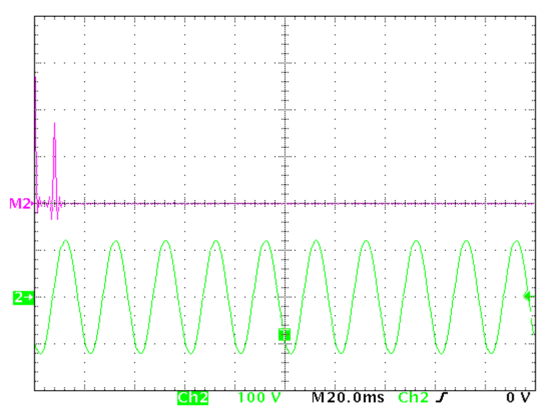

Figure 5 Motor phase current and its frequency spectrum

was varied between 0 to 60 Hz and the PWM switching frequency was 20 kHz. Figure 5 shows the motor phase current and the corresponding frequency spectrum. From the frequency spectrum of the phase current it can be seen that the motor current consists of the fundamental frequency component and higher order switching frequency harmonics. The 20 kHz SVPWM results in a distortion free phase currents that is used to drive the motor.

Conclusion

The DSP based ACI Motor drive system presented in this paper can be used as a laboratory platform to perform experiments involving various motor control functions along with variable speed operation. It can also serve as an equally effective research platform to test and evaluate new and innovative motor control algorithms. Software modules can be added or removed from the system software loop to achieve the desired operation.

Reference

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