A Data Acquisition Unit for Real-Time Control of a Three Phase Inverter

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Abstract: In this study, the design and implementation of a data acquisition system to control the currents, voltages on a 3-phases inverter and the rotor speed of an asynchronous machine are presented. Different solutions are investigated based on trade-off between hardware, software and price. A solution based on PC interface is investigated in depth. The purpose of this study is in fact to solve some problems up raised by researcher and industrial engineers, their main problems are how to get information such as currents and voltages within the inverter on charge. Designing a proper interface board will make it flexible and allow us to use any type of programming language to control the process. Moreover, a design of a data acquisition unit can be used for education purpose.

Key words: Data acquisition system, DSP, microcontroller, PC interfaces, inverter

INTRODUCTION

The improvement of speed control for asynchronous machines is based on the development of new robust, fast and power type of semi-conductor and also on using powerful pulse modulation techniques, however these techniques are limited by the electronic command used to control the inverter (Michel and Krim, 1995, 1997; Lee et al., 1996; Filippetti et al., 2000) .

The electronic used to control the process of old machines is based on analogue and discrete logic devices which are a collection of transistors, operational amplifiers and TTL or MOS circuits mounted as comparators, amplifier, filters counters, registers and buffers. So, to improve the evolution in the control of the machine, it is necessary to change the command circuits (Patil, 1984).

There are different solutions that can be implemented to command the inverter and control the speed, voltages, currents and temperature of the motor. Three solutions for this type of problem have been studied. The solutions are the use of a microcontroller, the use of an Industrial Programmable Automata (IPA) and finally the use of a general purpose Personal Computer (PC) (PIC, 2001; TIAN, 2004; Artur, 1985; Fezari and Debache, 1998; Lilen, 1986). In each solution, the advantages and inconvenient are mentioned, then the best fit solution depending on type of inverter and signals to be processed is chosen.

The PC solution is proved to be better in many cases because of the following points: Its flexibility, the choice of interface, the ease of program development and possible hardware or software evolution (Von et al., 2002; Michel and Mohand, 1998; Holtz and Quam, 2002; Michael, 1994).

The design of a Data Acquisition Unit (DAU) for parallel port has been tested using MATLAB graphic user interface and results are discussed within this study.

MICROCONTROLLER AND DSP SOLUTION

MOS technology reduces the cost of hardware in computer systems by reducing the size of the packages and increasing components density. Advances in MOS technology allow a whole Arithmetic Logic Unit (ALU), program memory, timers and other components to be placed on a single chip (Filippett et al., 2002). This has opened the door to complex an important applications in various fields. It plays a vital role in a more economical development of intelligent systems namely sensors or actuators.

Nowadays, microcontrollers solved many problems in developing electronics cards.
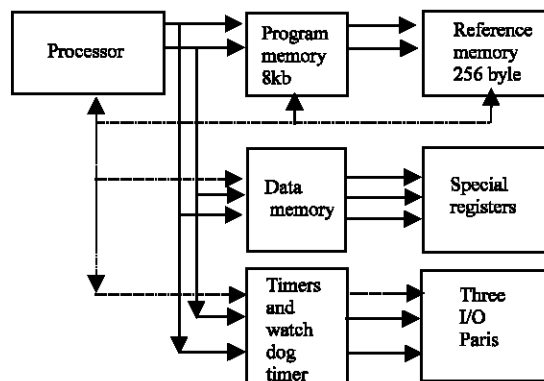

Fig. 1: PIC16F877 internal architecture

A microcontroller like the PIC16F877 from Microchip, as shown in Fig. 1, contains the necessary components to design a complete command and control circuit for an Inverter.

These main components are : an 8 bit microprocessor, a program memory , a data memory, a referenced data flash memory, 5 ports with 33 Input/Output lines, three timers, eight channel of a 10-bits A/D Converter, two pulse width modulation generators and serial interfaces (USART, I2C and SPI). Moreover, this microcontroller can execute 20 MIPS (Million of Instruction Per Second). However, the program memory of a microcontroller is limited and therefore the process algorithm can control a limited number of sensors or actuators (PIC, 2001; TIAN, 2004).

INDUSTRIAL PROGRAMABLE AUTOMATA (IPA) SOLUTION

The architecture of the IPA is similar to that of a PC, since within an IPA there are the following components: The CPU card, the program memory card, an interface to the CRT and a rack for input and output cards. The input/output cards depends on the power circuits needed, they can be based on relay or electronic switch 'TRIAC'.

The main hardware differences between IPA and PC are:

In hardware, the IPA is developed for automation of industrial machines, it has some adapted DI (Digital Inputs), DO (Digital Outputs), AI (Analogue Inputs) and AO (Analogue Outputs) to control industrial sensors or actuators. While the PC is dedicated to general purpose applications and thus it has some interfaces to communicate with external peripherals.

In software, the IPA has its special language easy to learn based on industrial schemes called "GRAFCET" or "STEP-7".The PC may be programmed with different languages.

The IPA controller is desirable. However, it is expensive as a solution since the system is sold all together "the CPU and I/O cards".

PERSONAL COMPUTER (PC) SOLUTION

The PC gives a flexible solution in both hardware and software, the architecture provides the following items:

- Powerful microprocessor in speed and computation.
- Flash ROMBIOS (Read Only Memory Basic Input Output System).
- Extension bus, to add optional cards, such as PCI (Peripheral Interface Controller) bus and ISA (Industrial standard Architecture) bus.

- External communication interfaces such as parallel port, serial port and USB (Universal Serial Bus) port.

The Windows operating system accepts high level language and graphics to develop a friendly user interface program as in (Fezari *et al.*, 2005; Bahi *et al.*, 2005).

Solutions based on PC interfaces: An interface card consists of a circuitry needed to condition the signals that originate in an experiment to meet the input requirements of the microcomputer (PC). It also treats microcomputer-originated signals to provide what is needed by experiments.

Most important point in PC solution is the maximum flexibility for interfacing to a large variety of devices (Michael, 1994). The basic principals of design are similar for most applications but some devices need a specially designed interface. A few general-purpose interfaces exist and can be supplied by manufacturers.

For standard interfaces, off-the-shelf boards are available. However, if a proprietary interface is required or if some unavailable function is needed, hardware must be designed anyway.

Real-time applications in industrial machines control need different interfacing to a large variety of peripheral devices, example: Input cards, output cards, analogue input signal device (data acquisition cards), analogue output signal device and external sequences counter.

Various techniques for interfacing peripheral devices to a PC are described in the following sub-paragraphs.

Parallel port as interface: This port was designed to communicate with a printer, the architecture is based on three interface registers which are:

- Data register, programmed as 8 bits output, used to send ASCII code to the printer, its address is 378 in hex-code (hex).
- Status register, programmed as 5 bits input, used to read the status of the printer, its address is 379 in hex.
- And the control register, programmed as 4 bits output, user to command the printer motors, its address is 37A in hex.

By adding some decoders, three states latches and three states 4 bit buffers , the data acquisition system to control the inverter is designed as shown in Fig. 2.

Serial port as interface: This port was designed to transmit files to a serial printer, modems, or terminals. It has two lines for bidirectional communication, a the Transmission line (TX) to send data or commands to the
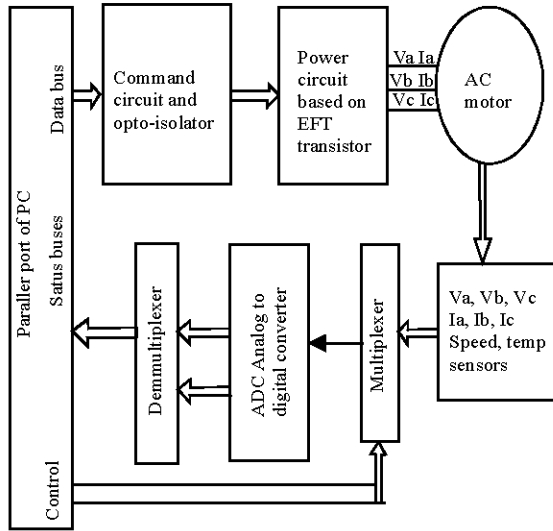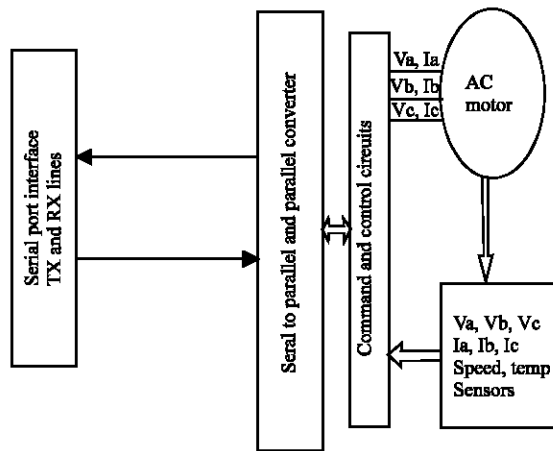
Fig. 2: Experimental design

Fig. 3: Serial port interface

machine and the Reception line (RX) to receive information from sensors, the addresses for COM1 are from 3F8 to 3FE in hex (Patil, 1984). However, in this case at the end of the communication line, a serial to parallel conversion and parallel to serial conversion is needed, which needs a microcontroller as an interface Fig. 3. This type of interface is useful in the case of industrial machine remote control, since the RS232 protocol permit a transfer of data at distance less than 500 m.

ISA and PCI bus interface: There is a free I/O address space within PC for adding extension cards or prototype cards. The I/O address space 300 to 31F in hex and the address 1B0 to 1Bf in hex are left by the designer for prototype cards. That means, up to 32 /OI
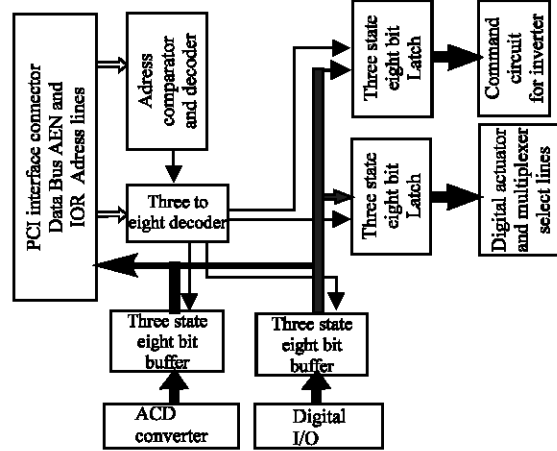

Fig. 4: PCI Interface

cards o f 16 bits each (PIC, 2001) can be added to the system without any address conflict.

The interface card to this bus is based on an address comparator, as example the TTL circuit 74HCT688, some 8 bits three states latches such as 74HCT573 and some 8 bits three states buffers such as 74HCT245. This type of interface is fast in transferring data, able to transfer 16 bits in parallel, nevertheless it is suitable for relatively small distance and the interface is presented in Fig. 4.

DATA COMMAND AND CONTROL SYSTEM

The main parts of a data command of an inverter and control of an AC motor are the following as shown in Fig. 2:

- The interface to the PC.
- The command circuit.
- The Data Acquisition Unit (DAU) which is based on D/A Converters , A/D Converters and multiplexer.
- And sensors and actuators.

In this design, the parallel port interface is based on an eight bit buffer to send command, a two four bit three-state buffer to read data from converter and three to eight bit decoder to select multiplexer and buffers. A study was done to choose a better rate efficiency- price for the converters choice.

Thus, in the experimental implementation a simple eight bit A/D Converter of type successive approximation such as ADC-804 with 100 micro-second time of conversion were used as can be seen in Fig. 5.

Useful signals in three phase inverter control: The asynchronous motor Is modelled by the following
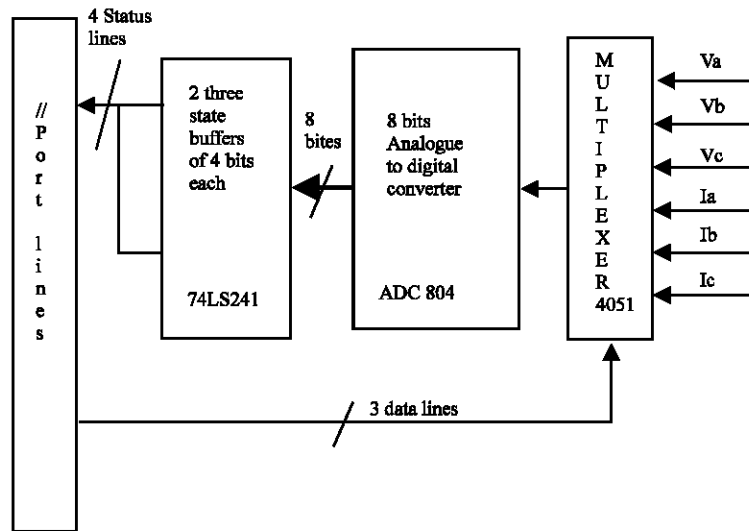
Fig. 5: Interface electronic design

electrical equations with all parameters Va, Vb,Vc, Ia, Ib and Ic are taken from stator (Holtz and Quan, 2002; Michael, 1994; Lahyani *et al.*, 2001; Cranor and Parulkar, 1995; Davie, 1993; Dittia *et al.*, 1995):

$$
\begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix} = \begin{bmatrix} Rs00 \\ 0Rs0 \\ 00Rs \end{bmatrix} \begin{bmatrix} Ia \\ Ib \\ Ic \end{bmatrix} + \begin{bmatrix} d\phi/dt \\ d\phi/dt \\ d\phi/dt \end{bmatrix} \tag{1}
$$

And mechanical equation:

$$
j\frac{d}{dt}\Omega_r + f\Omega_r \text{ With } \omega_r = p*\Omega_r \tag{2}
$$

it is obvious that from (1) and (2) the voltages, currents and speed of the asynchronous motor are signals rich of information. The digital processing of these signals would give better control and also in advance detection of default within an asynchronous motor such as: Broken torque, broken bear, cell switch damage detection and faulty transistor location.

DAU principal functions: The main program drives the DAU card, the PWM signals are generated then sent to the command circuit, a dead time is taken in consideration, the sensors provide to the multiplexer (Mux-4051) eight analogue signals from the system : the three voltages (Va, Vb, Vc), the three currents (Ia, Ib, Ic), speed of the rotor and the temperature on the engine. They are selected one by one and presented to the ADC, the result of conversion, 8 bits, is read in two steps by de-multiplexing the higher and lower four bits,

the data is stored in a file to be processed and plotted on the screen (Fezari *et al.*, 2005; Bahi *et al.*, 2005).

RESULTS AND DISCUSSION

The output signal generated by the command system is a set of three PWM signals based on some computation discussed in (Bahi *et al.*, 2005). The PWM signal generation is done and the command is sent to the power circuits.

In test and simulation phase, a function generator was used to emulate three types of signals: triangle, square and sinus. The acquisition unit display the signal on the screen in real-time and save the samples in a file in order to be processed in details off-line.

A non negligible distortion is seen in signal acquisition, this is due probably to the 8-bits resolution of the A/D Converter witch introduces a quantification error and also to the multiplexing of more than two signals on parallel port.

CONCLUSION

Using a PC solution is very benefit, since this type of controller is less expensive comparatively with some electronics components or API solutions. The Fig. 5, shows the designed interface card. This PC solution, to command a three phase inverter and control an asynchronous machine system may significantly improve the reliability and the efficiency of the control and security of an industrial machine.

However, the parallel port interface has a limit speed in getting simples to show on the graph for more than two

signals, the enhancements can be done by developing a PCI interface card with a flash A/D Converter as it is mentioned before.

The improvement in the process control can be reached by:

- Adding some sensors and actuators.
- Development and amelioration of the graphics user interface by adding some key requirements such as: a simple-to-use operator interface.
- Some software features can be improved such as: Saving data in files for off-line processing and default diagnostics are easy to reach.

Finally we can say that modern controls and instruments bring aging industrial machines and engine a new standard of reliability. Beside that, the designed system is a good tutorial product and some laboratory work can be accomplished around it.

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