Three-phase frequency converter with MC3PHAC controller

Ciprian Afanasov¹, Mihai Raţa¹

¹ Faculty of Electrical Engineering and Computer Science, Stefan cel Mare University of Suceava, Romania

Abstract - Alternating current (AC Motor) motor play a major role in the world today because of its ability that do heavy work, around the clock operation and can be use in all type of environment. In industrial sector, AC motors has been used for decades because it is reliable, low-cost, and highly efficient. AC motor also has long been use in home appliance such as washing machine and conventional fan. The most used solution to speed adjusts of induction motors in industry applications (i.e. fans, pumps and compressors) is variable-frequency drive. This paper presents a solution of low-cost variable-frequency drive using an intelligent motor controller (MC3PHAC) with computer interface. MC3PHAC have been selected as a circuit processor base on its advantages in cost, simplicity, robustness, and features. Some results of the proposed inverter are presented.

Keywords – variable-frequency drive, induction motors, power electronics, MC3PHAC controller, PWM

1. INTRODUCTION

This paper presents a system for three-phase motor speed control, so that a cheap solution is obtained for frequency converter, which uses an intelligent controller for speed control (MC3PHAC). The device is adaptable and configurable according to the needs, integrated with all active functions necessary for controlling a three-phase electric motor. Some of the unique aspects of this device are the following:

- Volt-per-Hertz speed control;
- 6-outputs PWM channels;
- 3-phase waveform generation;
- 4-channel analog-to-digital converter (used for speed control, acceleration adjust, PWM frequency select and DC bus voltage feedback);
- User configurable for standalone and hosted operation;
- Selectable PWM polarity (Logic low = ON, or Logic high = ON) and frequency (in 4 steps 5.291 kHz, 10.582 kHz, 15.873 kHz and 21.164 kHz);
- Selectable 50/60 Hz base frequency;
- Serial communication.

In MP3PHAC are included, also DC bus monitoring and a system fault input that will disable all 6 PWM outputs upon detection of a system fault.

The project was developed based on the use of an integrated circuit MC3PHAC, it has two operating modes. One of them is standalone way, where potentiometers and buttons are used for carrying out various commands. The second method consists in controlling microprocessor with the aid of a computer. In this case commands can be given software, the connection being made via the serial port.

The main functions that can be performed by the microcontroller are starting or stopping the motor, reversing the direction of rotation, speed control, throttle control, PWM frequency control, and error control function.

Developing the principle of PWM modulation, helped develop this type of processor. The processor is programmed and built to be integrated on AC machine market, offering multiple applications. The microprocessor is able to generate six individual PWM signals, which allows it to connect directly to the three-phase inverters[1]-[6].

2. MC3PHAC MOTOR CONTROLLER

MC3PHAC integrated circuit is an intelligent controller specifically designed to meet the requirements of low cost manufacturing, representing an alternative to control the speed of a three phase asynchronous motor. It is adaptable and configurable at will and contains active functions for an open-loop control of an electrical machine. One great advantage of it is that does not require intervention at the programming level. Constructed with high-speed CMOS technology, the MC3PHAC offers a high degree of performance and ruggedness in the hostile environments often found in motor control systems.

The serial communications interface is used in a mode, called PC master software mode, whereby control of the MC3PHAC is from a host or master personal computer executing PC master software commands.
Regarding the motor control, this includes the following main functions:
- Open loop volts/Hertz speed control;
- Forward or reverse rotation;
- Start/stop motion;
- System fault input;
- Low-speed voltage boost;
- Internal power-on reset.

The dc bus voltage is sensed by the MC3PHAC, and any deviations from a predetermined norm (3.5 V on the dc bus input pin) result in corrections to the PWM values to counteract the effect of the bus voltage changes on the motor current.

The main functions provided by the integrated circuit MC3PHAC:

**3-Phase Waveform Generation** — The MC3PHAC generates six PWM signals which have been modulated with variable voltage and variable frequency information in order to control a 3-phase ac motor. A third harmonic signal has been superimposed on top of the fundamental motor frequency to achieve full bus voltage utilization;

**DSP Filtering** — A 24-bit digital filter is used on the SPEED input signal in standalone mode, resulting in enhanced speed stability in noisy environments;

**Selectable Base Frequency** — Alternating current motors are designed to accept rated voltage at either 50 or 60 Hz, depending on what region of the world they were designed to be used;

**Selectable PWM Polarity** — The polarity of the PWM outputs may be specified such that a logic high on a PWM output can either be the asserted or negated state of the signal;

**Selectable PWM Dead Time** — Besides being able to specify the PWM frequency, the blanking time interval between the on states of the complementary PWM pairs can also be specified;

**Speed Control** — The synchronous motor frequency can be specified in real time to be any value from 1 Hz to 128 Hz by the voltage applied to the SPEED pin;

**Acceleration Control** — Motor acceleration can be specified in real time to be in the range from 0.5 Hz/second, ranging to 128 Hz/second, by the voltage applied to the ACCEL pin.

### 3. EXPERIMENTAL TEST BENCH

The main component of the control part is the microcontroller MC3PHAC. The main objective of using microcontroller is to produce 3-phase PWM waveform. We can configure this microcontroller in two modes: computer mode and standalone mode. In standalone mode MC3PHAC can be controlled with switches and can be configured with variable resistors.

The circuit diagram of control board in standalone mode is presented in Fig. 2. The speed and acceleration can be adjusted by two potentiometers using two analog inputs of the controller: SPEED and ACCEL. The Start/Stop and Forward/Reverse motor direction can be controlled by two switches. The PWM dead time, the PWM frequency, the voltage boost and the retry time are establish using fixed resistors.

In computer mode we can control MC3PHAC with software and can configure it with the software. Also in computer mode we can easily measure the various values like actual speed, frequency, modulation index, bus voltage etc. directly. The MC3PHAC is compatible with Freescale’s PC master host software serial interface protocol.

The circuit diagram of control board in computer mode is presented in Fig. 3.
When the MC3PHAC is placed in computer mode, inputs such as START, FWD, SPEED, ACCEL, MUX_IN, and PWMPOL_BASEFREQ have no controlling influence over operation of the system. Even though the SPEED, START, and FWD inputs are disabled while the system is in PC master software mode, through PC master software, it is possible to monitor the state of those inputs.

In figure 4 is illustrated the PCB of control board. PCB of control board can configure the microcontroller in computer mode and standalone mode through jumpers.

In figure 5 is presented the experimental model of variable frequency drive realized.

The controller can monitor the DC bus voltage. The DC_BUS pin is monitored at a 5.3 kHz frequency and when the voltage reaches a certain threshold, the RBRAKE pin is driven high. This signal can be used to control a resistive brake placed across the dc bus capacitor, such that mechanical energy from the motor will be dissipated as heat in the resistor versus being stored as voltage on the capacitor. In standalone mode, the DC_BUS threshold required to assert the RBRAKE signal is fixed at 3.85 volts (110 percent of nominal) where nominal is defined to be 3.5 volts. In PC master software mode, this threshold can be set to any value between 0 volts (0 percent of nominal) and greater than 5 volts (143 percent of nominal) and can be changed at any time.

PWM control signals are sent to the three drivers that provides the following functions:
- PWM signals are galvanically isolated;
- enables the establishment control mode for different configurations of transistors IGBT inverter;
- raise the drivers IGBT control signals from 5V to 15V;
- report optically presence of the control voltage;
- report optically the state of IGBT drivers;
- provides link with power sources of different circuits;
- provides start and stop of ATX type switching sources used in the power circuits.

Galvanic isolation between control and force was made with performance optocouplers that have the ability to work at a frequency of several hundred kHz.

Due to the facilities offered by the family of modules SEMIX and from the desire to realize a high power inverter we have used for its construction, three IGBT modules of the range SEMIX2s, IGBT modules with the name SEMIX302GB126HDs.

The characteristics of this family lead to the realization of a compact inverter with low inductance. Using the family modules SEMIX, entire design of the inverter is simplified significantly. To control the IGBT modules SEMIX302GB126HDs, we chose an IGBT driver offered by the company SEMIKRON. Driver's name is SKYPER 32 PRO R, an it is professional version and top of the range of the drivers for IGBT modules type chosen.
4. EXPERIMENTAL RESULTS

The following experimental results have been obtained by performing experimental tests with an induction motor for load. For controlling the proposed inverter, in computer mode, was used “PC master” software and application called “MC3PHAC Motor Control Demo”. Almost all the functions required to control a three-phase induction motor with: start/stop, reverse/forward run, acceleration (Hz/sec), selection of base frequency, PWM frequency, actual frequency, dead time, modulation index etc. are available in this version. Additionally, a built-in oscilloscope is available in this version.

Figure 9 illustrates PWM control signals generated by the microcontroller MC3PHAC.

In the figure below is presented, the startup sequence of a three-phase asynchronous motor at the frequency of 70 [Hz], and a minimum acceleration. It can be seen on the oscilloscope, how evolves the frequency and modulation index. Imposed frequency is represented in red, and the current frequency that evolving in real-time is represented in green.
5. CONCLUSIONS

The main objective of this project work is to design and construct a three phase PWM inverter controlled by microcontroller MC3PHAC and necessary control circuit to run a three phase induction motor. From the theoretical and practical results the following conclusions can be made:

✓ A good argument between the experimental setup and theoretical model suggested that the constructed inverter is accurate enough;
✓ Variation of frequency from 0 Hz to 127 Hz can be controlled smoothly;
✓ Motor acceleration or deceleration can be controlled from 0.5 Hz/Sec. to 128 Hz/Sec. and can change the direction of motor at any time;
✓ The constructed inverter is equally applicable for 50 Hz and 60 Hz base frequency;
✓ It is possible to change the modulation index and voltage boost both in online and off line therefore it is possible to control the output voltage;
✓ PWM frequency can be changed at four presentable values viz. 5.3 KHz, 10.6 KHz, 15.9 KHz and 21.1 KHz and can be changed at any time;
✓ It is possible to adjust PWM polarity and can adjust the dead time at any vale between 0 to 31875 ns;
✓ It is possible to monitor the DC bus voltage of the inverter;
✓ the frequency driver has dynamic brake which permits the extra energy from the load to be transformed into heat in the brake resistor.

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