7th International Conference on DEVELOPMENT AND APPLICATION SYSTEMS
S u c e a v a, R o m a n i a, M a y 27 – 29, 2 0 0 4

USING AD2S100 VECTOR PROCESSOR IN ADVANCED MOTION CONTROL

Mihai RAȚĂ [1], Gabriela RAȚĂ [2], Crenguța Elena BOBRIC [3]
"Sefan cel Mare" University of Suceava
str.Universitatii nr.13, RO-720229 Suceava
[1] *mihair@eed.usv.ro,* [2] *gabrielar@eed.usv.ro,* [3] *crengutab@eed.usv.ro*

Abstract. *Field Oriented Control solves the limiting of bandwidth for P-I controllers by controlling the current space vector directly in d-q reference frame of the rotor. This means the measured motor currents must be mathematically transformed from the three-phase static reference frame of the stator windings to the two-axis rotating d-g reference frame, prior to processing by the PI controllers. The simplifying of Field Oriented Control is realized with the help of coprocessors for transformations.*
Keywords: *field oriented, coprocessors, Clarke and Park transformations.*

Introduction

If used field oriented control of AC induction machine in a rotor flux frame, the coprocessors permits the DSP or µP computing core to execute the motor control in what is normally termed the rotor reference frame. This paper present two coprocessors, by Analog Device, AD2S100 and ADMC401.

AD2S100 Vector Processor

The AD2S100 performs the vector rotation of three phase 120 degree or two-phase 90 degree sine and cosine signals by transferring these inputs into a new reference frame which is controlled by the digital input angle ϕ. Two transforms are included in the AD2S100. The first is the Clarke transform, which compute the sine and cosine orthogonal components of three-phase input. These signal represent real and imaginary components, which then form the input to the Park transform. The Park transform relates the angle of the inputs signals to a reference frame controlled by the digital port. The digital port input is a 12-bit parallel binary representation.

If Vds and Vqs represent the input current signals, respectively, where V_{ds} and V_{qs} are the real and imaginary components, then the transformation can be described as follows:

$$\begin{cases} V_{ds}' = V_{ds}\cos\phi - V_{qs}\sin\phi \\ V_{qs}' = V_{ds}\sin\phi + V_{qs}\cos\phi \end{cases} \quad (1)$$

Where V_{ds}' and V_{qs}' are the output of the Park transform and $sin\phi$ and $cos\phi$ are the values internally derived by the AD2S100 from the binary digital data. The input section of the device can by configured to accept either three-phase inputs, two-phase inputs of a three-phase system, or two 90 degree inputs signals. The homopolar output detects the imbalance of three-phase input only. Under normal conditions, this output will be zero.

The digital input section will accept a resolution of up to 12 bits (AD2S100). An input data strobe signal is required to synchronize the position data and load this information into the device counters. A busy output is provided to identify the conversion status of the AD2S100. The busy period represents the conversion time of the vector rotation.

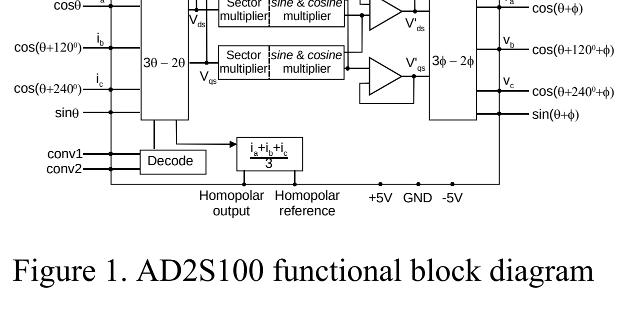


Figure 1. AD2S100 functional block diagram

This circuit has the following highlights:

Hardware peripheral for standard microcontrollers and DSP systems. The AD2S100 removes the time consuming cartesian transformation from digital processors and benchmarks a speed improvement of 30:1 on standard 20 MHz processors. AD2S100 transformation time = 20 μs (typ).

Field oriented control of ac and dc brushless motors. The AD2S100 accommodates all the necessary functions to provide a hardware solution for ac vector control of induction motors and dc brushless motors.

Three-phase imbalance detection. The AD2S100 can be used to sense overcurrent situations or imbalances in three-phase system via the homopolar output.

Resolver to digital converter interface.

The AD2S100 provides general purpose interface for position sensors used in the application of dc brushless and ac induction motor control. [1], [2]

Field orientated control theory and practice has offered the same level of control enjoyed by traditional dc machines. Practical implementation of these algorithms involves the use of DSP and microprocessors based architectures. The AD2S100 removes the needs for software implementation of the rotor-to-stator and stator-to-rotor transformations in the DSP or microprocessor. Figure 2 shows the block diagram of advanced motion control motor using the AD2S100, configured for both forward and reverse transformation

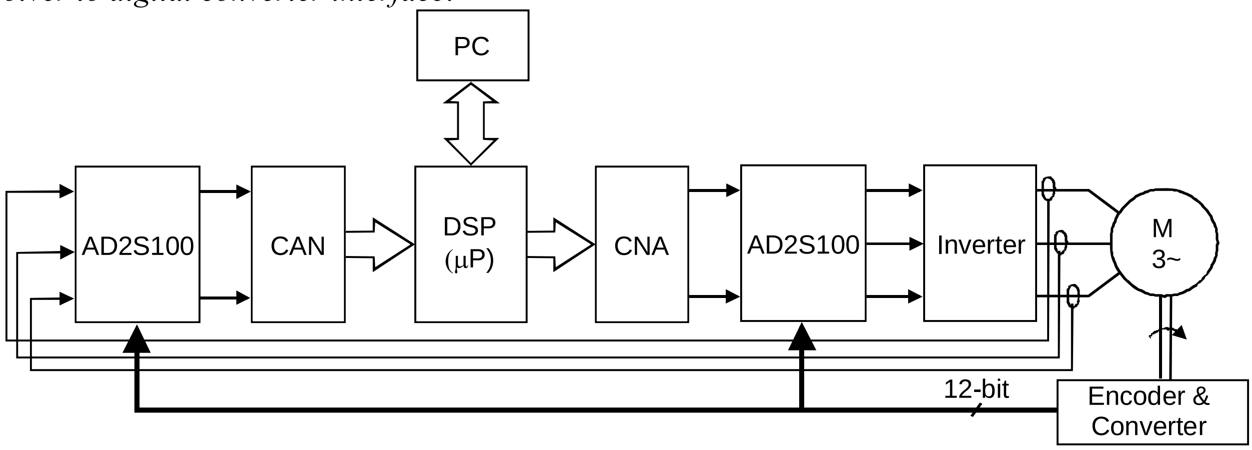


Figure 2. Advanced motion control motor

ADMC201 Motion Coprocessor

The ADMC201 is a motion coprocessor that can be used with either microcontrollers or DSP.

The functional blocks in this single 68-pin package, as shows in figure 3, include:

- Analog input block
- 12-bit PWM timer block
- Vector transformation block
- Programmable digital I/O port
- DSP & microcontroller interface

Analog input block includes four S/H performing simultaneous sampling of up to four different signal inputs (0 to 5 volt input range, with a 2.5 V offset as defined by REFIN), which allows three-phase motor currents to be sampled simultaneously, reducing errors from phase coherency. Sample and hold acquisition time is 1.6 μs per channel (using a 12.5 MHz system clock). The input stage to the A/D converter is a four channel SHA that allows the four channels (U, V, W and AUX) to be held simultaneously and then sequentially digitized. The auxiliary input (AUX) is fed by a four channel multiplexer that allows the channels AUX0, AUX1, AUX2 and AUX3 to be individually converted along with the primary channels U, V and W. The auxiliary inputs are ideal for reading slower changing variables such as bus voltage and temperature.

The subsequent 11-bit successive approximation A/D converter is multiplexed and requires 3.2 μs for each channel. A/D Conversions are initiated via the CONVST pin. A synchronizing pulse (PWMSYNC) is provided at the beginning of each PWM cycle. This pulse can be used to synchronize the A/D conversion process to the PWM switching frequency.

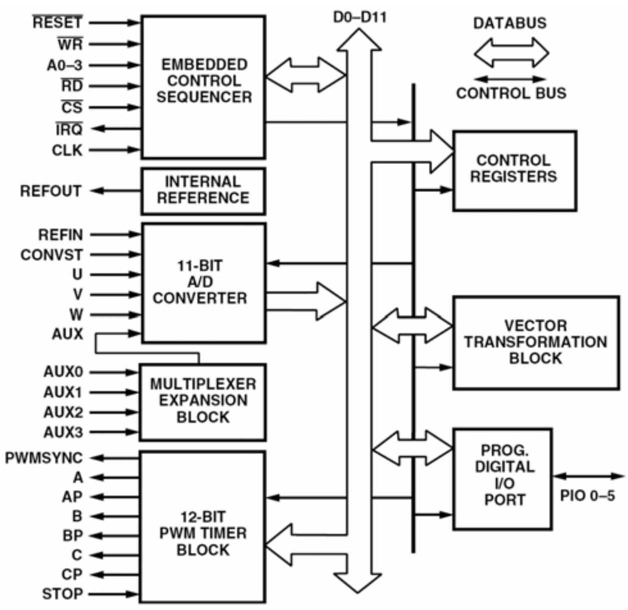
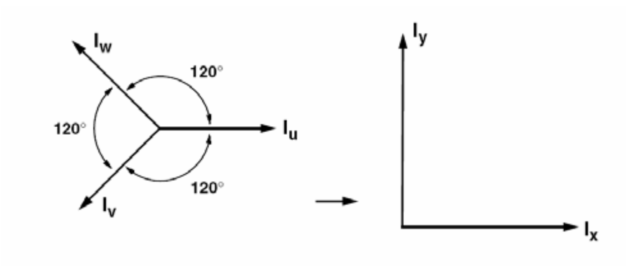


Figure 3. ADMC201 functional block diagram

The PWM timer block generates three center-based signals A, B and C based upon user-supplied duty cycles values. The three signals are then complemented and adjusted for programmable deadtime to produce the six outputs (active LO). The ADMC201 PWM master switching frequency can range from 2.5 kHz to 20 kHz, when using a 10 MHz system clock. The ADMC201 programmable deadtime value is loaded into the 7-bit PWMDT register, in which the LSB is set to zero internally, which means the deadtime value is always divisible by two. With a 10 MHz system clock, the 0–126 range of values in PWMDT yield a range of deadtime values from 0 µs to 12.6 µs in 200 ns steps. The switching time is set by the PWMTM register which should be loaded with a value equal to the system clock frequency divided by the desired master switching frequency.

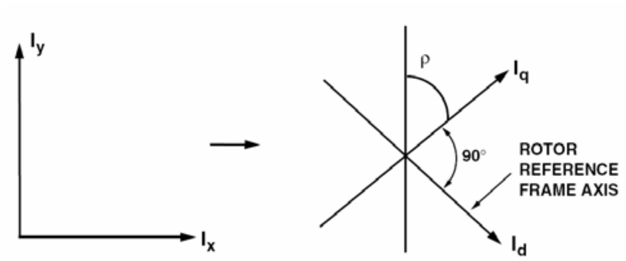
There is an external input pin (STOP) to the PWM timers that will disable all six outputs when it goes HIGH.

The *Vector Transformation Block* performs both Park and Clarke coordinate transformations (reverse and forward) to control a three-phase motor via independent control of the decoupled rotor torque and flux currents. The figures below illustrate two of these transformations.



3-phase stator currents Equivalent 2-phase currents

Figure 4. Reverse Clarke transformation



Rotating reference frame Stationary reference frame

Figure 5. Reverse Park transformation

Reverse Transformation is defined by the following operations: (a) Clarke: 3-phase current signals to 2-phase current signals followed by (b) Park: 2-phase current signals cross multiplied by *sin ρ*, *cos ρ* which effectively measures the current components with respect to the rotor (stationary) where *ρ* is the electrical angle of the rotor field with respect to the stator windings.

Forward transformation is defined by the following operations: (a) Park: 2-phase voltage signals cross-multiplied by *sin ρ*, *cos ρ* followed by (b) Clarke: 2-phase to 3-phase voltage signal conversion. In order to provide maximum flexibility in the target system, the ADMC201 operates in an asynchronous manner. This means that the functional blocks (analog input, reverse transformation, forward transformation and PWM timers) operate independently of each other. The reverse and forward vector transformation operations cannot occur simultaneously.

Programmable digital I/O port has a six bit. Each bit is individually configurable as input or output. All bits configured as inputs have the ability to operate as interrupt sources. Each pin is independently capable of generating an interrupt should its input level change.[3],[4],[5]

Experimental results

In the follows we present the experimental results with AD2S100 development board. This board includes two AD2S100 configured for both forward and reverse transformations, and encoder converter. The used is 1024-line encoder, which provides 12-bit of resolution.

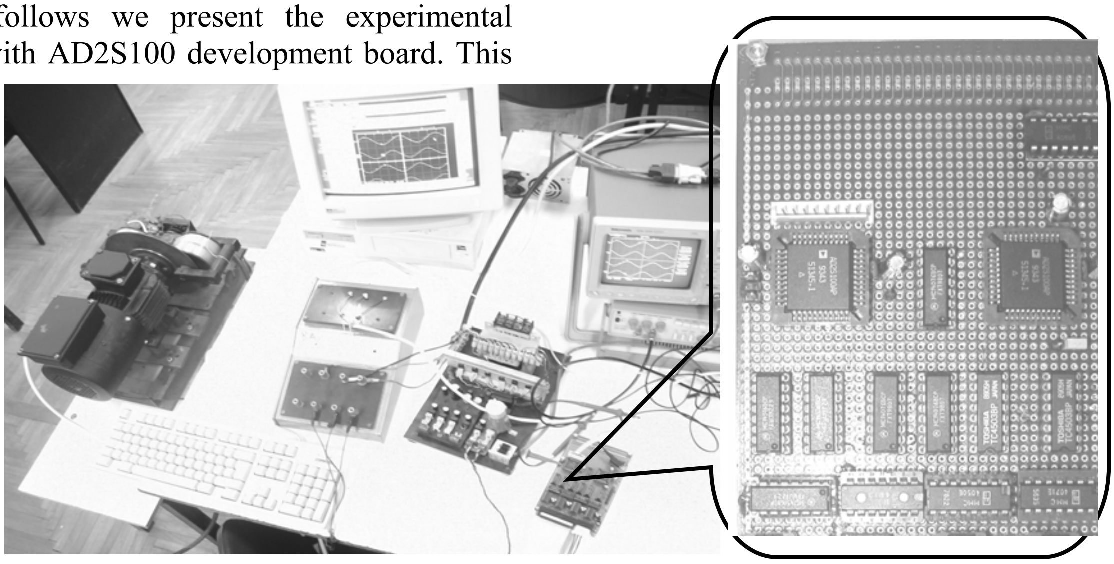


Figure 6. The arrangement with AD2S100

The width of positive STROBE pulse should be at least 100 ns, in order to successfully start conversion.

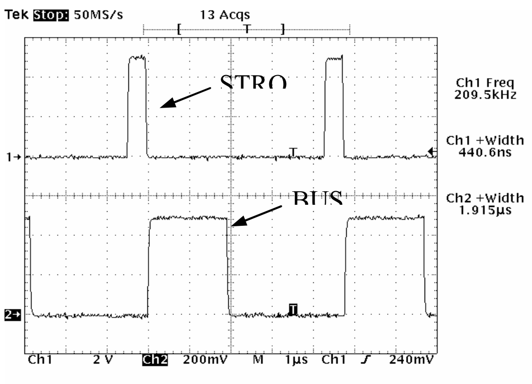


Figure 7. AD2S100 timing diagram

The state of converter is indicated by the state of the BUSY output (Pin 44). The BUSY output will go HI at the negative edge of the STROBE input, as seen from figure 7. This is used to synchronize digital input data and load the digital angular rotation information into device counter. The time of conversion is 2 µs.

Figure 8 shows the output reverse Clarke transformation that computes the *sine* and *cosine* orthogonal components of a three-phase input.

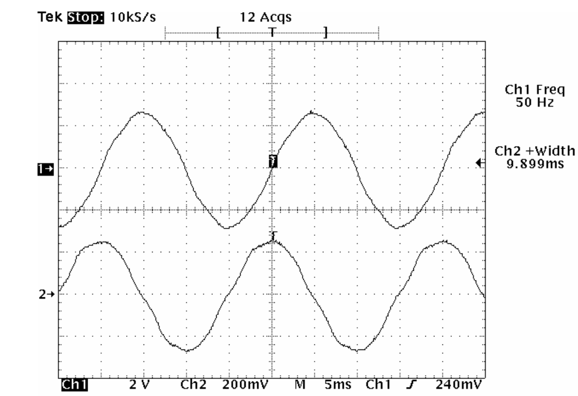


Figure 8. Outputs reverse Clarke transformation

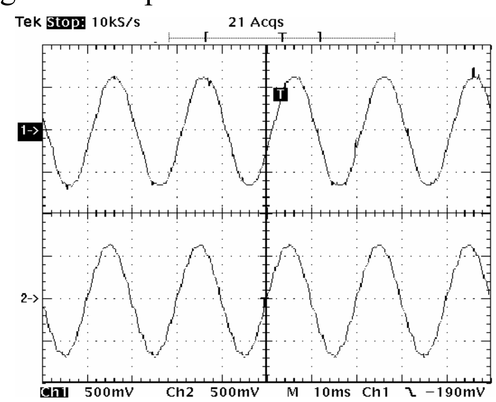


Figure 9. Outputs reverse Park Transformations (case 1)

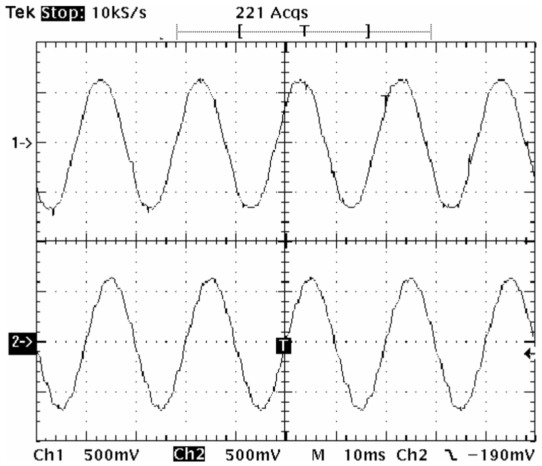


Figure 10. Outputs reverse Park transformations (cas 2)

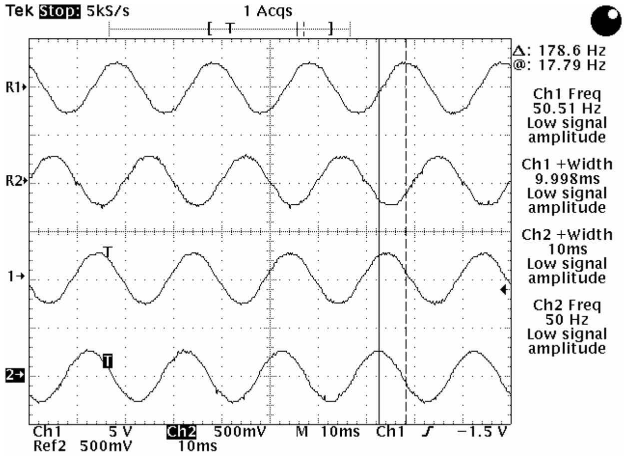


Figure 11. Outputs forward Park transformations

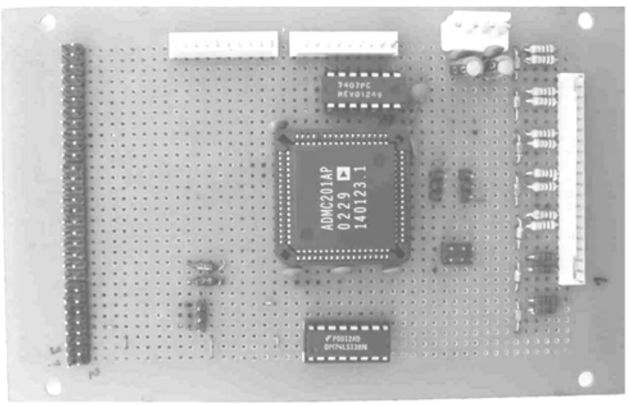


Figure 12. Experimental board with ADMC201

Figures 9 and 10 display the output reverse Park transformations (*cos*θ and *cos*($\theta+\phi$) in two cases at different digital angular ϕ.

The forward transformations use *sine* and *cosine* orthogonal components. These are obtained with an orthogonal signals generator realized with operational amplifiers. Figure 11 illustrates the forward Park transformations.

Figure 12 shows the experimental board with ADMC201. This can be connected with DSP or microcontrollers board. Both boards (ADMC201 +DSP or ADMC201+ microcontrollers) provide all the functionality required to implement a digital control system for AC drive system.

Conclusions

The AD2S100 removes the need for software implementation of the rotor-to-stator transformation in the DSP or µP. the reduction in throughput times from typically 100 µs (µP) and 40 µs (DSP) to 2 µs increases system bandwidths while also allowing additional features to be added the CPU The combination of fixed point DSP and AD2S100, enables bandwidth previously attainably only through the use of floating point devices (figure 2)

The ADMC 201 has more advantages than AD2S100. In a typical application, the DSP performs the control algorithms (position, speed, torque, and flux loops) and the ADMC201 provides the necessary motor control functions: analog current data acquisition, vector transformation, digital I/O, and PWM drive signals.

References

[1] Analog Device, *AD2S100-Data Sheet*, www.analog.com;

[2] Graur A., Filote C., *AD2S100,* (1998) *Single Chip Processor Simplified the Vector Control Strategy on Induction Motor*, Acta Electrotehnica Napocencis, Volume 39.

[3] Analog Device, *ADMC201-Data Sheet*, www.analog.com;

[4] Analog Device, AN-408 *AC Motor Control Using the ADMC200 Motion Coprocessor*, www.analog.com

[5] Analog Device, AN-409 *Advanced Motor Control Techniques Using the ADMC200 Motion Coprocessor*, www.analog.com