

Real Time Development of MC Applications using the PC Master Software Visualization Tool

The PC Master Software Visualization Tool Simplifies the Development of Motor Control Applications in Real Time.

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1. Introduction

This Application Note describes the development of motor control applications using the PC master software visualization tool. It is a software tool for development and debugging of embedded applications in real time. It permits the reading, modification and visualization of arbitrary variables or parameters of a target application.

The application note discusses the common difficulties faced in the development of a motor control application. It presents the basic features of the PC master software tool. The examples illustrate the usage of the tool for the development of motor control applications.

2. Development of Motor Control Applications

The motor control application represents a real-time embedded application with a number of system variables and control parameters. It processes both analog and digital inputs and generates mostly digital control outputs that control a power stage of the drive. A number of application variables need to be observed and evaluated in real time in order to optimally develop, set up, and tune the control algorithm.

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Traditionally, developers use code debuggers and oscilloscopes for the development of motor control applications. Debuggers are used for visualization of the internal memory of the processor. Oscilloscopes are chosen for visualization of the input and output signals.

Such traditional development is quite arduous. **Debuggers** mostly do not allow visualization and change of the application variables at the run time of the target processor. Also, visualization of the selected variables as a time function is not possible. Often, debuggers require stopping the target processor to access the variables. Such an approach is not applicable in motor control applications - the developer cannot just stop the motor in order to access the memory of the processor, and then let the motor run again.

The input and output variables can be observed by an **oscilloscope**. The limiting factor of oscilloscope usage is that the real signals of the drive often differ from the signals measured by the processor. The measured signals are affected by the sensing circuitry used, by measurement noise and also by the offset and gain error of the analog-to-digital converter. Generated signals are modulated by Pulse Width Modulation (PWM), so they need to be filtered in order to obtain the real value. The filtering of the signals influences the precision of the measurement. The usage of oscilloscopes for visualization of internal variables is quite limited. The internal variables can be observed using a Digital-to-Analog Converter (DAC). Unfortunately such peripherals are not standard either at the motor control processor or at the motor control application board.

Another significant drawback of the traditional approach is the cost and availability of an oscilloscope and the necessary accessories (like current probes). Typically, two-channel oscilloscopes are available, which is not enough for the development of a multi-phase motor control system, especially when it is desired to observe several internal and input/output variables simultaneously.

In order to help the developers in the development of real-time embedded applications, Freescale has developed the PC master software tool. It enables access and visualization of the internal variables of the target processor and thus solves most of the difficulties the motor control developer faces.

3. The PC Master Software Visualization Tool

3.1 PC Master Software Introduction

PC master software was designed to make the development of motor control applications easier. It provides the debugging, diagnostic and demonstration tools needed for the development of real-time algorithms and applications. PC master software runs on a PC, connected to the target processor via an RS232 serial interface. A small program, resident on the target processor, communicates with the PC master software. It provides access to any memory location of the target processor in real-time. Once the data are loaded into PC master software, they can be visualized in a number of different ways. The PC master software, running on a PC, uses Microsoft Internet Explorer as the user interface. The detailed description can be found in the user's manual (see [6]) and in the dedicated application notes (see [2], [3], [4], [5]). A basic block diagram is illustrated in **Figure 3-1**.

PC master software is currently available for the 56F80x, 56F82x and 5685x families. The PC master software application is part of the Embedded Software Development Kit (SDK) [7] and may be selectively installed during the SDK installation. Support for other processors, including MC68HC08, MC68HCS12 and MPC500 families, will be released soon.

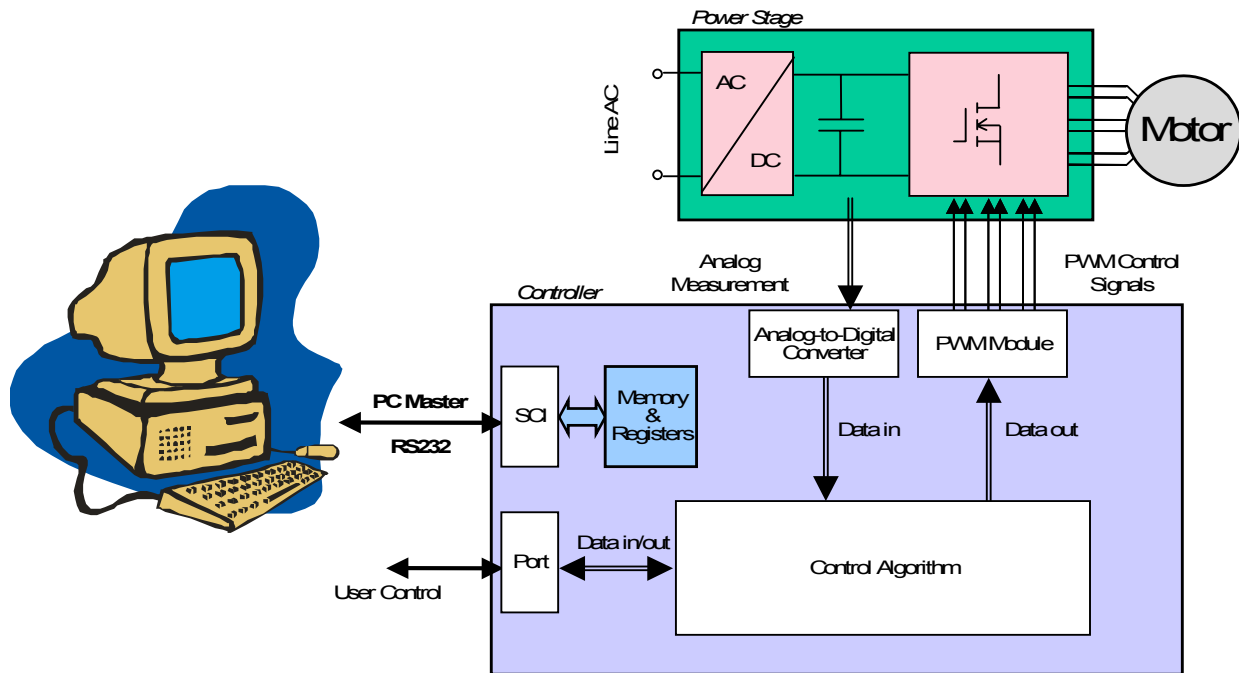


Figure 3-1. PC Master Software in Connection with Motor Drive

3.2 PC Master Software Features

PC master software provides access to the target processor memory via an SCI communication. The communication protocol on the base level reads/writes the application variable out/in the data memory of the target processor. The PC master software can:

- control the application
- read/change application variables
- scope slower variable courses
- record fast variable courses
- stimulate variables
- send application commands with parameters
- display help items, like block diagrams of the application, application characteristics, etc.
- control the application remotely through the Internet

Figure 3-2 illustrates the main PC master software window, together with the examples of the Control Page, the Variable window, the Scope, the Recorder and the help page from a real-life motor control application.

Main PC master software window

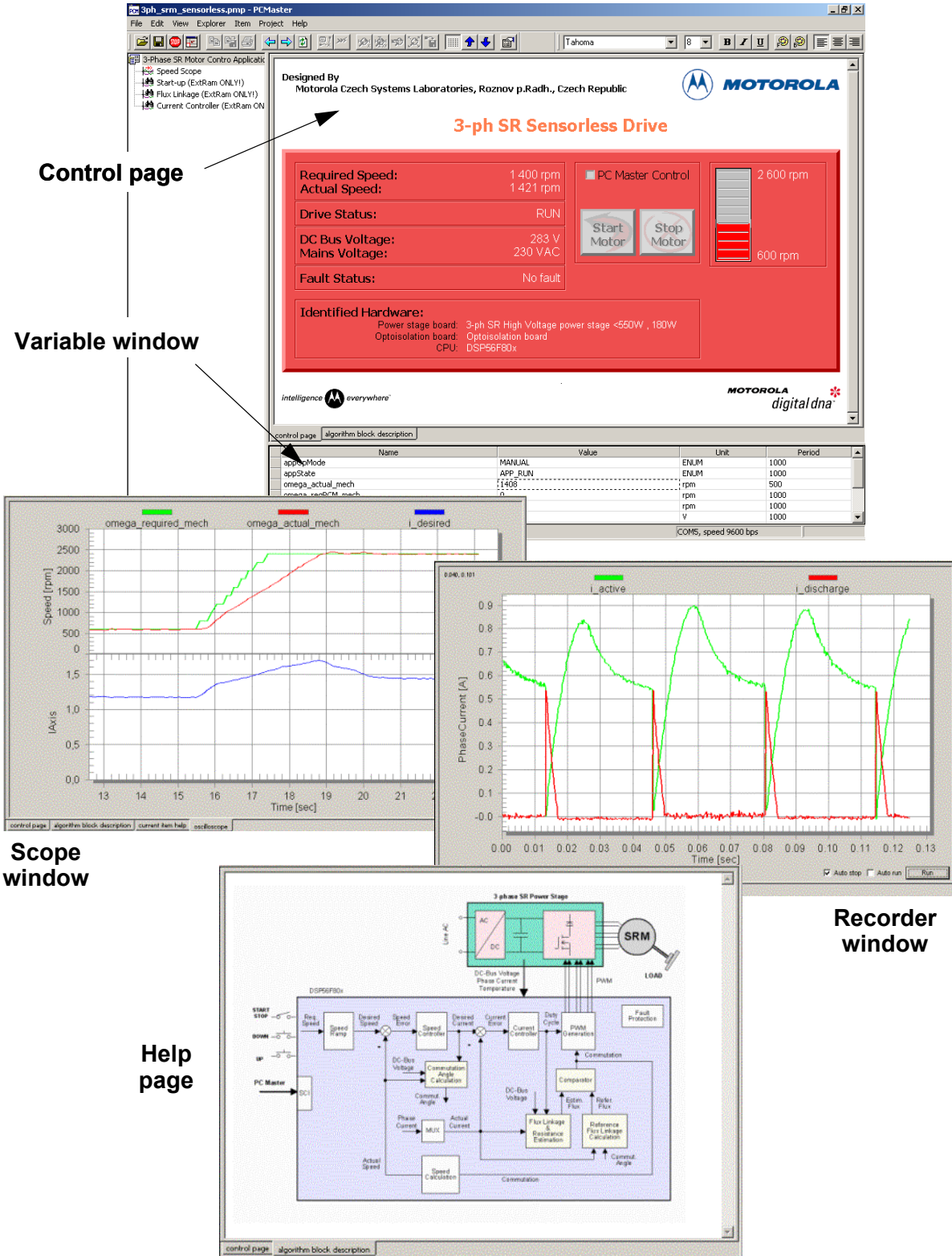


Figure 3-2. PC Master Software Window

The Control Page enables control of the application. It is created in *HTML*, so it is easy to create all the desired functionality. The individual components of the control page are linked to the appropriate variables of the target processor. The control page can also be used for creation of the application demo. Thanks to this unique approach, anybody who can create *HTML* web pages can create the Control pages for PC master software as well.

Typical examples are the push buttons that start or stop the motor, or the bar graph that sets/displays the motor speed. When the user clicks the push button on the control page screen, the appropriate variable is updated in the target processor enabling control of the application.

The Variable window displays the selected variables or the memory location of the target processor. The variable on the target processor can be directly set from the variable window. Users can select the variable address, variable type (signed/unsigned fixed point, floating point, signed/unsigned fractional, string), variable size, sampling period, etc. The important part of the setting is the real type transformation of the variables. It enables transformation of the variable available on the target processor into a format that is more understandable for users. The variables can be visualized in the variable window, as well as in the control page (see [Figure 3-2](#)).

A typical example is the transformation of the variable `omega_actual` that represents the motor speed. At the target processor, the variable is a signed fractional type, scaled as:

-1 = maximal motor speed in a negative direction

0 = zero motor speed

1 = maximal motor speed in a positive direction

The real type transformation transfers such signed fractional type into a real mechanical speed displayed in rotations per minute (RPM). Thus the speed can be easily set and observed in PC master software.

The Scope window enables visualization of the variables of the target processor in a way similar to the way classical oscilloscopes do. PC master software communicates with the target processor at predetermined intervals. Each time it reads the selected variable and displays it as a course. It enables the display of up to eight courses in a single Scope window. The communication speed between the PC and the target controller depends on a number of selected variables in both the Scope and Variables windows. Typically, the variable is updated each 10msec.

The oscilloscope is useful for tracking variables that change relatively slowly. The rate of their change should be comparable to the rate of variable updates in the Scope window. A typical example is the speed of the motor.

The Recorder window enables the visualization of fast changing variables. A small routine, that resides in user code, stores the selected variables in the on-board memory buffer. When the recording is finished, they are loaded into the PC and displayed as a course. The length of the buffer is limited by the accessible free on-board data RAM.

The Recorder is very useful for tracking variables which change so fast that they cannot be tracked by the Scope. A typical example is the motor current.

The Stimulator enables stimulation of the selected variables. PC master software updates the variable in the target processor according to a predetermined variable profile. Thus the response of the system can be observed and evaluated.

The stimulator is useful for both motor control and application development. A typical example is the speed profile of the washing machine application. The user can pre-set the profile of the motor speed and evaluate the behavior of the drive without touching the motor control software.

The Help Page enables the display of additional information the user might be interested in. For example, there can be a block diagram of the application, description of the control algorithm or application, description of the user interface of the application, etc. The help page is created in *HTML*.

A detailed description of PC master software, including the PC master software settings, detailed descriptions of the of the individual PC master software features, a description of the communication protocol, creation of PC master software control pages and remote control through the Internet, can be found in the Application Notes, listed in [Section 6](#).

4. Development of Motor Control Applications Using PC Master Software

Let's illustrate the advantages of PC master software for real-world motor control applications. They are described in examples of common issues the developer is facing during the design of the applications. The presented examples are based on the application "3-Phase SR Sensorless Motor Control Using 56F80x"[\[1\]](#). First, the visualization of the variables, measured by an Analog-to-Digital Converter (ADC), is shown. Then, the visualization of courses of calculated variables is illustrated. The setting of the controllers and tuning of the application with help of PC master software is presented. Finally, the on-line setting of the application parameters and variables is demonstrated.

4.1 Visualization of Measured Variables

Precise analog measurement is a key factor for the implementation of almost any motor control algorithms. Mainly, the phase and/or DC-Bus voltages and currents are measured and utilized for the control algorithms. Any inaccuracy in the measurement leads to control error and thus to the deterioration of drive performance.

PC master software enables the visualization of measured variables, as they are converted by the Analog-to-Digital Converter. The developer can evaluate the actual values and courses obtained from the analog-to-digital converter and can eliminate possible sources of inaccuracies. Both the Scope or the Recorder can be used for the evaluation.

A typical example of the visualization of the measured variables is the measurement of motor phase currents.

Phase currents are measured by current sensors. [Figure 4-1](#) illustrates a typical configuration of one phase of a switched reluctance (SR) motor power stage. It includes two power switches and two diodes per motor phase. The shunt resistor is inserted into the current path of the motor phase. The phase current is sensed as a voltage drop across the sense resistor. The control signals of the individual transistors, together with the actual current and the sensed voltage drop on the current sense resistor, are shown as well. As can be seen, the phase current is not visible at the current sense resistor continuously, and must be reconstructed by software.

For a reliable reconstruction of the shape of the phase current, the measurement needs to be sampled in the center of the PWM pulse. The zero current may be set to half of the ADC range, so both the positive and the negative voltage drops on the phase current shunt resistors can be measured. Proceeding like this, the current can be reconstructed with required accuracy and credibility.

It is apparent that usage of the oscilloscope for the visualization of the measured current at the ADC input is quite limited. We can see just PWM pulses on the oscilloscope screen. Also, it is important to evaluate what the actual value converted by the ADC is, what the influence of the noise is and how successfully the phase current is reconstructed. For a such purpose, the Recorder can be used to great advantage.

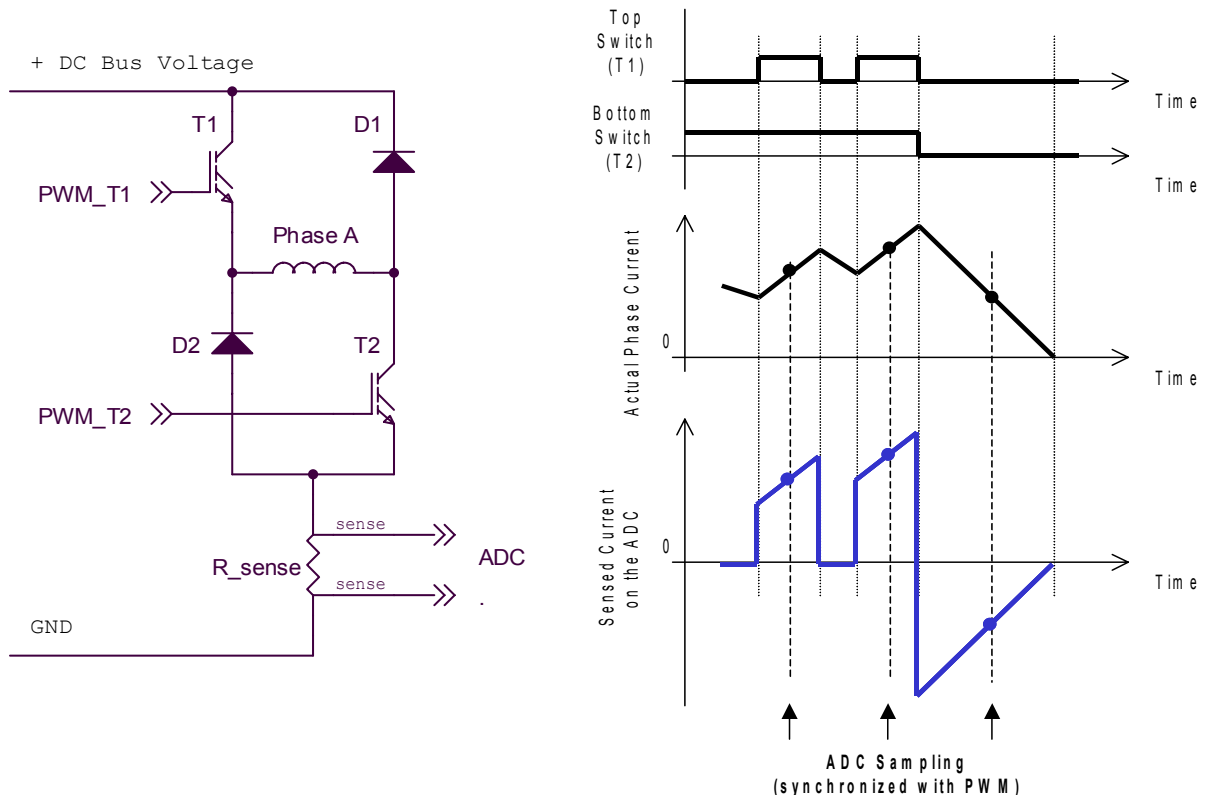


Figure 4-1. Shunt Resistors Current Sensors

The Recorder enables the observation and reconstruction of the phase current measured by the ADC. The Recorder “read” command is inserted into the ADC conversion completed interrupt routine, recording the result of the ADC measurement and phase current reconstruction. When the desired period is complete the measured profiles can be visualized on the Recorder window. [Figure 4-2](#) illustrates the visualized current profiles of a 3-Phase SR motor and the DC-Bus voltage on the Recorder.

Each Recorder window can display up to eight recorded profiles. This is extremely important when developing control algorithms for multi-phase motors. The start of the recording can also be triggered by a selected variable, so the desired interval can be recorded. It can be used, e.g., when investigating the profiles of measured variables during motor start-up or speed/load transition. Next, the recorded data can be loaded into a table processor, like MS Excel, for further evaluation.

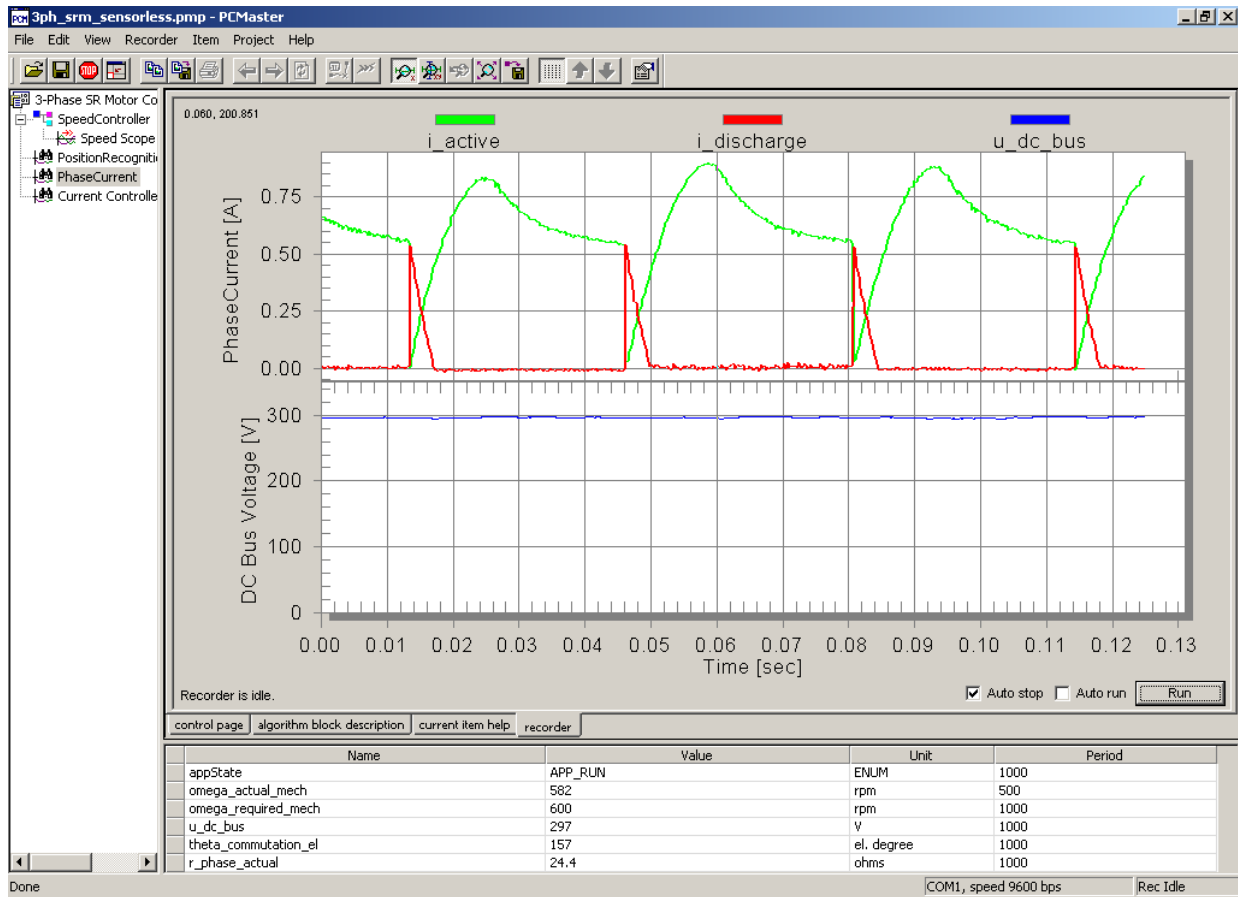


Figure 4-2. Visualization of Phase Currents and DC-Bus Voltage Using the Recorder

4.2 Visualization of Calculated Variables

During development of control algorithms it is necessary to visualize calculated variables, their courses, variations and mutual influences. It is especially valuable for development of algorithms, based on any kind of estimators. PC master software enables visualization of all variables using the Scope, Recorder or Variable windows.

Visualization of the calculated variables can be shown on the sensorless control algorithm of SR motors. The position estimation of the motor is based on the estimation of the phase flux linkage. The correctness of the flux linkage estimation is a key factor in the sensorless drive performance. During development of the algorithm, the encoder position sensor is used as a position reference for the evaluation of the sensorless determination of the motor position. The Recorder permits visualization of the calculated flux linkage together with the phase currents and with the reference position from the encoder (see Figure 4-3). The shape of the calculated flux linkage can be compared with the theoretical analysis. The individual parameters of the control algorithm can be easily modified to reach the desired behavior of the sensorless technique.

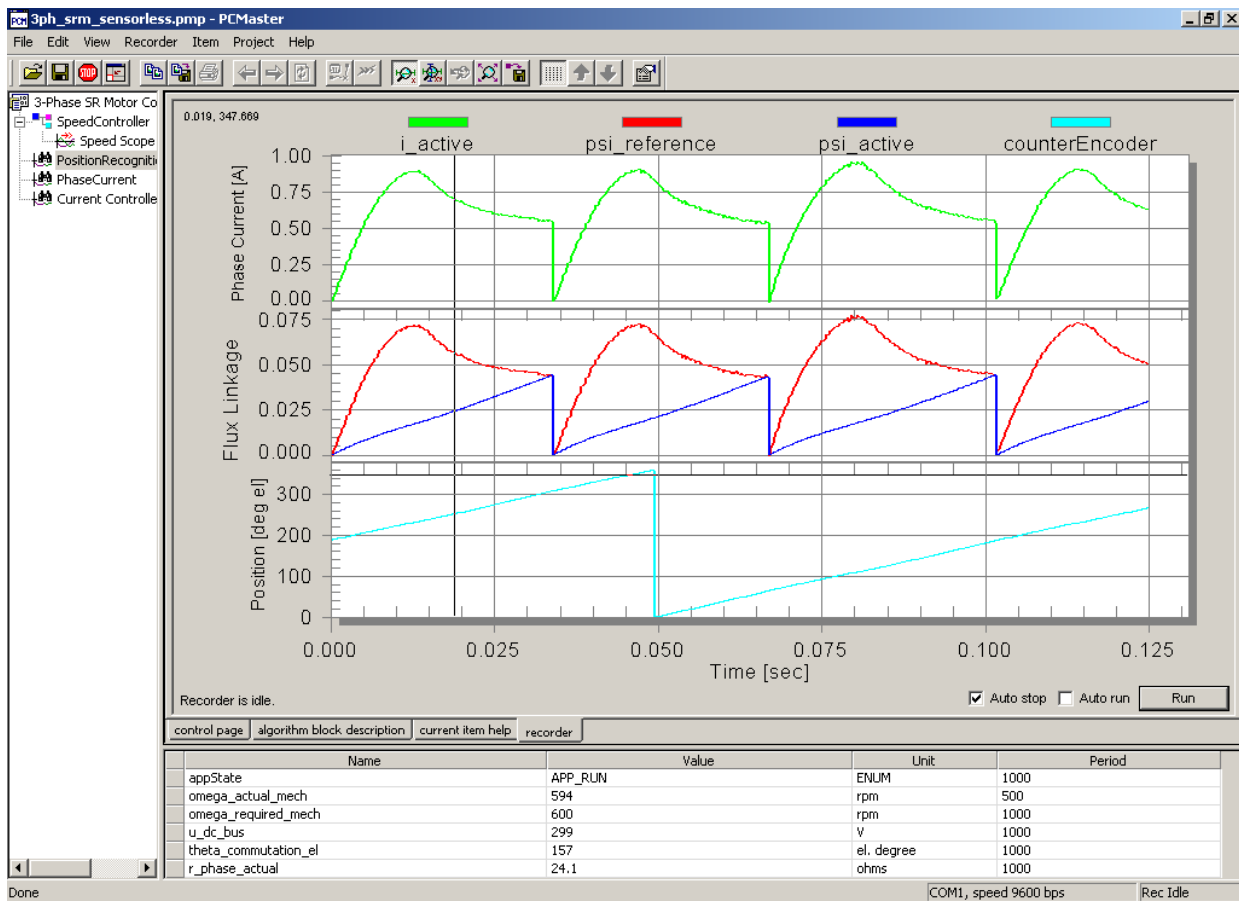


Figure 4-3. Visualization of Phase Current, Flux Linkage and Position Reference Using Scope

4.3 Setting Controllers, Tuning Applications

Almost any motor control application utilizes controllers. Controllers are used for control of variables of both the motor control algorithm and the control of the application algorithm itself. Motor speed, current, voltage, flux linkage or motor torque are the most typical motor control variables. Pressure, load, under-pressure, velocity, temperature, etc. are examples of typical application variables.

System controllers need to be set-up and tuned precisely to obtain optimal results for the control process. Although theoretical analysis gives the preliminary values of the control parameters, mostly they need to be tuned experimentally on a real system. During the tuning, both input and output variables of controllers need to be observed.

PC master software simplifies the tuning of the controllers in real-time. It enables visualization of the controlled variables, modification of the control parameters on-line and to immediately see the results. The inputs and the outputs can be observed using the Scope or the Recorder. On one hand, the **Scope** can be used for slowly changing variables, like for example, motor speed. On the other hand, the **Recorder** can be used for fast changing variables, like phase current.

Figure 4-4 and **Figure 4-5** show a simple example of tuning a speed controller with help of the PC master software Scope.

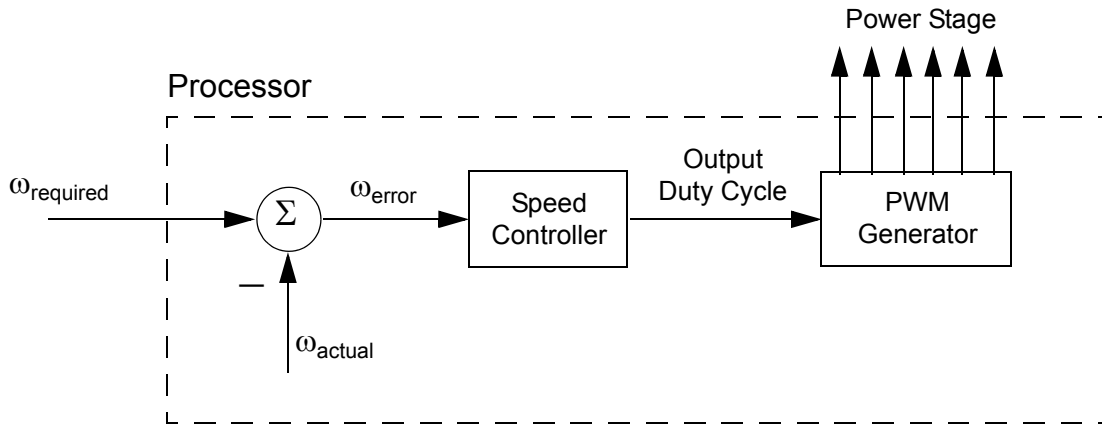


Figure 4-4. Block Diagram of the Speed Controller

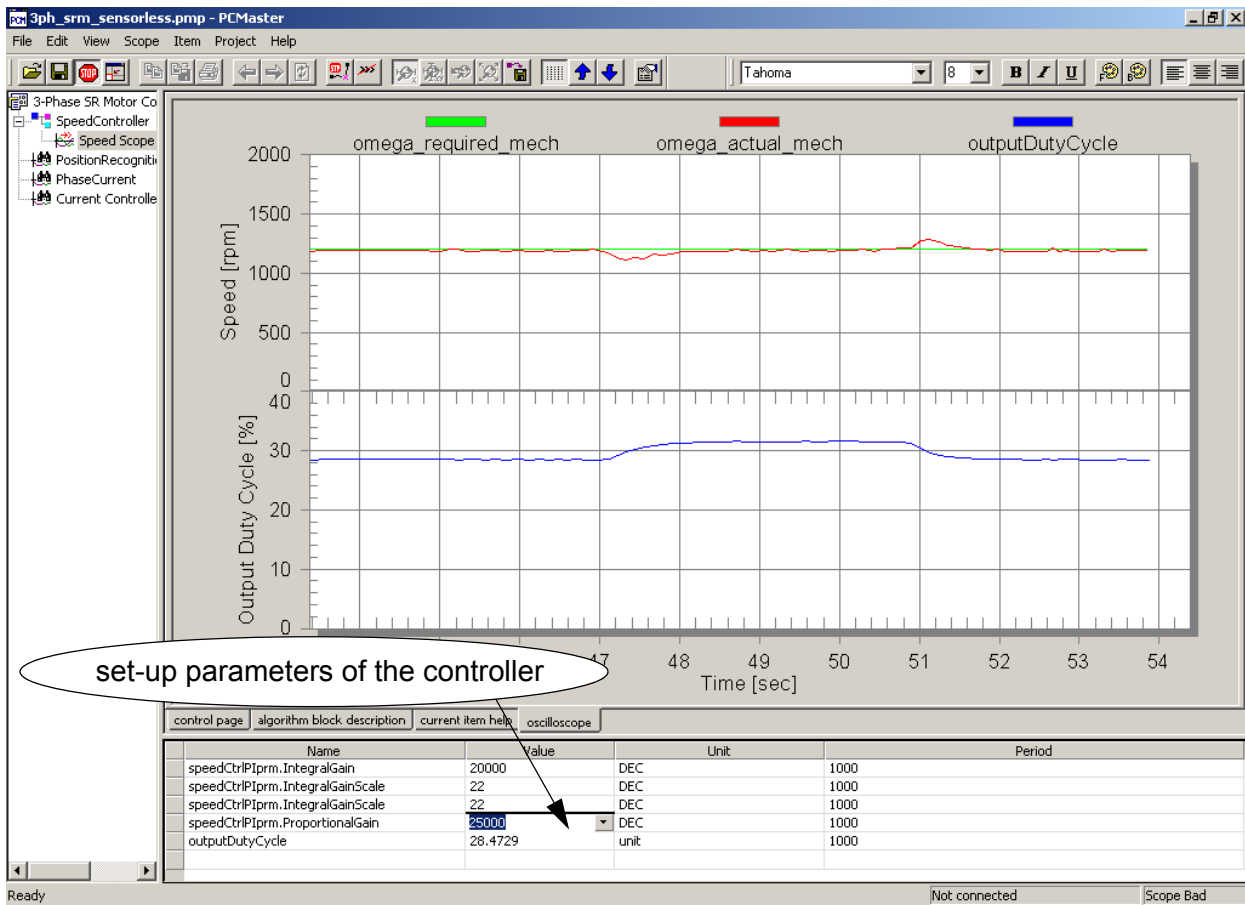


Figure 4-5. Tuning the Speed Controller Using PC Master Software

The speed controller is a Proportional-Integrational type (PI controller) that evaluates the required speed ($\omega_{required}$) and the actual speed (ω_{actual}). According to the speed error (ω_{error}), it generates the desired output duty cycle. The Scope window shows the required speed and the actual speed as the input variables, as well as output duty cycle as the output variable of the controller (see [Figure 4-5](#)). The response of the system to the change of the motor load is displayed. The Variables window enables on-line change of the individual parameters of the PI controller. The developer can easily evaluate the response of the system and tune the controller parameters to get the optimal system performance.

4.4 On-line Setting of Application Parameters and Variables

The development of an application often requires setting the application parameters and variables on-line and evaluating the application behavior.

Since PC master software allows the changing of any variable in the memory of the target processor, the task is pretty easy. The developer can read and modify any variable in processor memory. Since any memory variable can be changed, the developer is fully responsible for changing only the variables that do not cause the system damage. The response of the system can be observed either in the Variables window, or with the Scope or Recorder tool.

PC master software allows the simulation of a the selected variable in the time domain using Stimulator. The Stimulator updates the selected variable automatically according to the table. The stimulated variable is predefined in a simple table as a function of time (see [Figure 4-6](#)). [Figure 4-7](#) illustrates the stimulation of the desired speed and the drive response. The developer can easily evaluate the response of the system to the change of the variable according to a predefined profile.

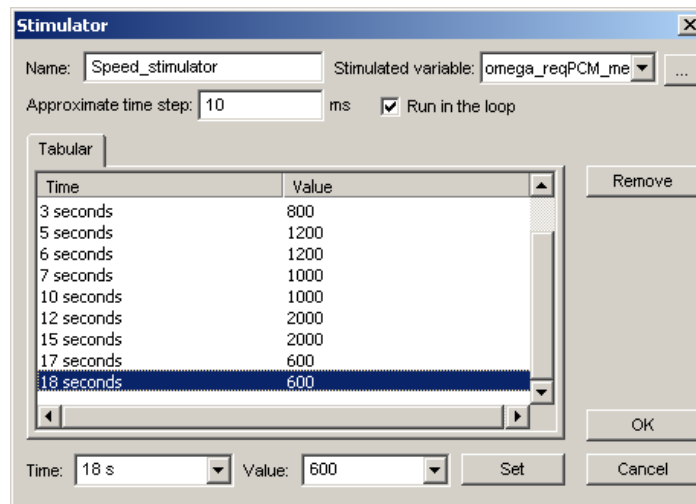


Figure 4-6. Setting of Speed Stimulator

As it was mentioned in the PC master software description, the variable can be transformed from the real-type into more meaningful physical variable. Thus a fractional number from the target processor can be easily transformed into RPM (speed variables), Volts, Amps, degrees, etc. PC master software also allows the enumeration of the variables. It is useful for displaying the status of the application or algorithm. For examples of the real type transformation and the enumeration, look at the variables listed in the Variable window in [Figure 4-7](#).

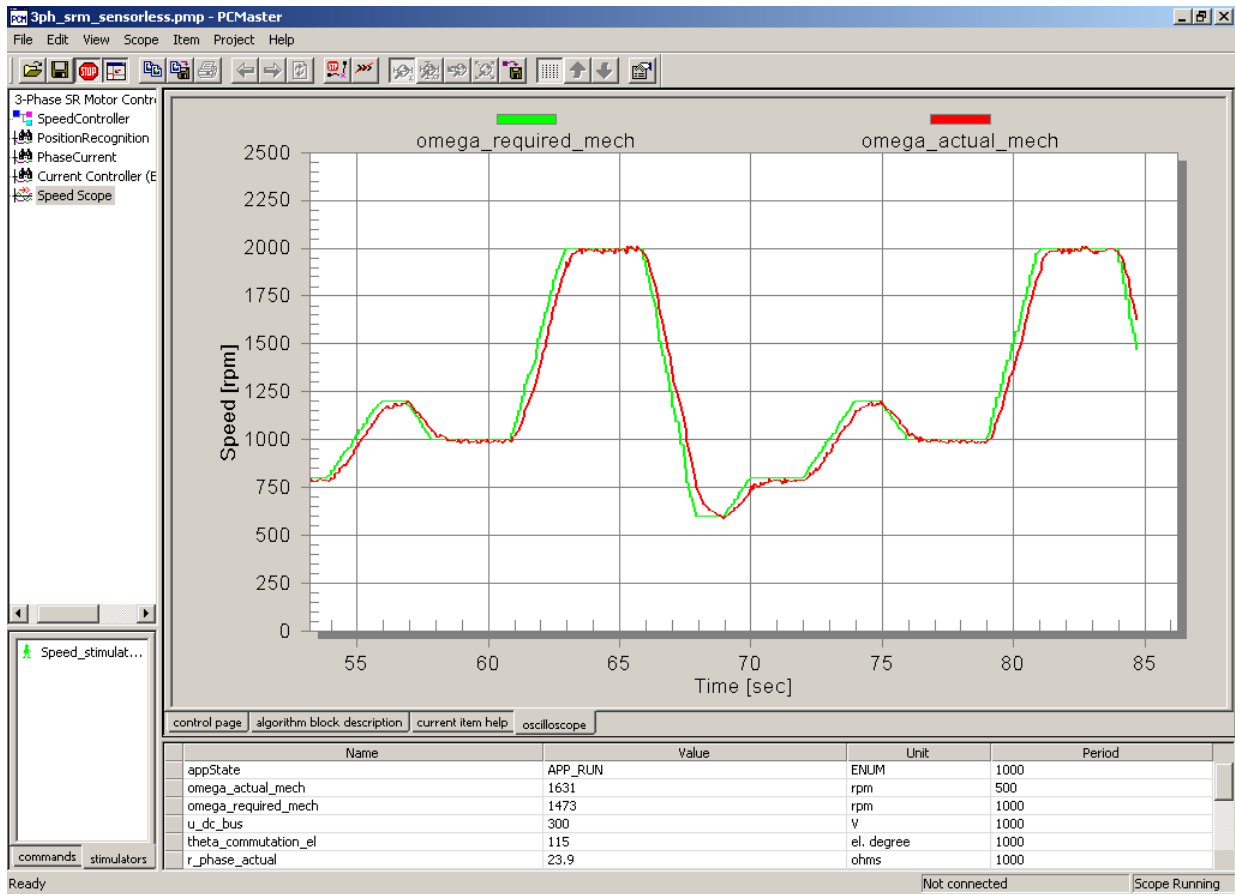


Figure 4-7. Stimulation of Desired Speed

5. Conclusion

PC master software puts into the developer’s hands a tool that enables development of user’s applications much faster and efficiently. It enables you “to see” into the target processor without stopping the application. This is extremely important for motor control applications where debugging and tuning needs to be done on-line during motor operation. It gives the possibility to visualize the course of the selected variables, so the developer can effectively develop the application. The tool enables creation of a demo to control the application, that can be demonstrated to customers. Overall, the PC master software saves the cost of extremely expensive equipment, like multichannel oscilloscopes and current probes. Also, it shortens development time significantly. Those who deal with customers remotely will appreciate having the ability to control the application remotely through the Internet.

6. References

The following materials were used to produce this paper:

- [1] 3-Phase SR Sensorless Motor Control Using 56F80x, AN1932, Freescale Semiconductor, Inc.
- [2] Connecting Motor Controllers to the Internet, Freescale Semiconductor, Inc.
- [3] PC Master Software Communication Protocol Specification, Freescale Semiconductor, Inc.
- [4] PC Master Software: Creation of Advanced Control Pages, Freescale Semiconductor, Inc.
- [5] PC Master Software Usage, Freescale Semiconductor, Inc.
- [6] PC Master Software User's Manual, included in the SDK documentation, Freescale Semiconductor, Inc.
- [7] Software Development Kit including PC master software is available at:
www.freescale.com

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