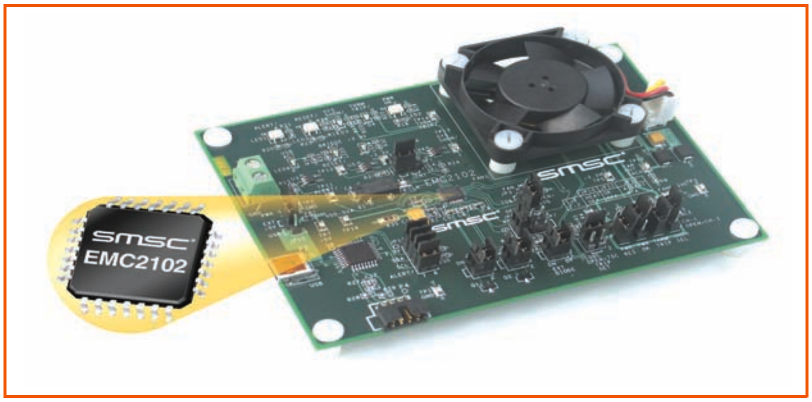
Fan Speed Control with the EMC2102 Device



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1 Overview

SMSC has introduced a series of Environmental Monitoring and Control (EMC) devices with integrated fan control. This fan controller family devices feature the advanced closed-loop fan control technology developed by SMSC's engineering team.

This user manual provides detailed information about fan control features supported by one of those EMC devices -- EMC2102, with detailed hand-on experiments for configuring the devices in real applications.

2 Audience

This user manual assumes that the reader is familiar with the functionality of the EMC2102 device and its evaluation board. The goal of the user manual is to help users to evaluate the new EMC device using Chip Manager (ChipMan) software provided by SMSC. This user manual also can be used as a reference material for other EMC devices which have fan control features.

3 References

The following documents should be referenced when using this user manual:

- EMC2102 Device Datasheet
- EVB-EMC2102 Evaluation Board User Manual
- EVB-EMC2102 Evaluation Board Schematics
- ChipMan Software User Manual

4 The Evaluation System

The evaluation system used for this user manual has two major parts, as shown in Figure 4.1, "EMC2102 Fan Control Evaluation System":

- An EMC2102 evaluation board (EVB-EMC2102) with on-board 5V DC fan (Figure 4.2)
- A PC with SMSC ChipMan software installed (requiring XML file for EMC2102 device)

This user manual contains several groups of user experiments which cover most of the fan control features of the EMC2102 fan controller device. All examples are based on the 2102 device evaluation board (EVB-EMC2102) and its software, but the methods and the results will apply to other EMC2102 applications.

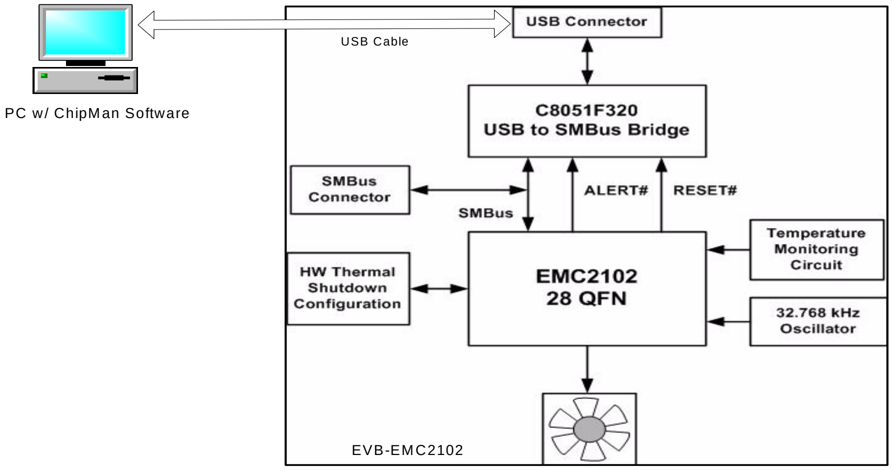


Figure 4.1 EMC2102 Fan Control Evaluation System

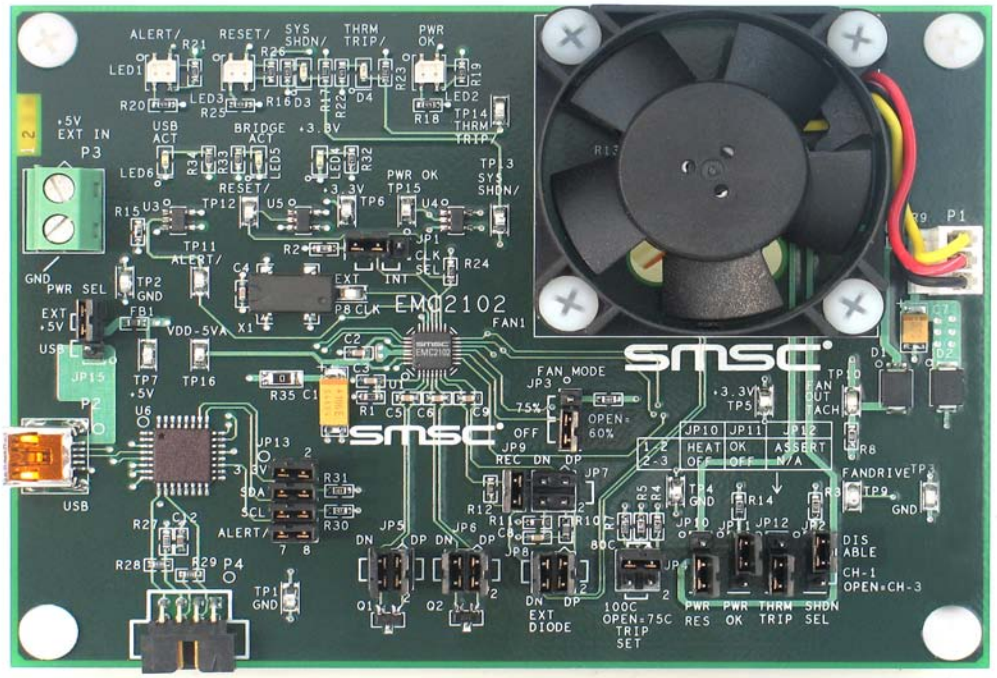


Figure 4.2 EVB-EMC2102 Board

5 Basic Operation Experiments

In this chapter basic operation experiments will be provided to help users to get familiar with the system.

5.1 Experiment 1 - Manual Fan Control

This experiment is designed to gain familiarity with both the EMC2102 device, and the application software, ChipMan.

The ChipMan application can be used to configure the EMC2102 device and to monitor the status of the device. It includes tools to capture and plot data at rates up to 10Hz. Additionally, ChipMan can be used to review previously saved data.

5.1.1 ChipMan Installation

Install the ChipMan application and device driver on a PC by running Setup.exe from the EMC2102 Evaluation System Software CD provided by SMSC. A revision history and install/uninstall notes may be found in the readme.txt file on the disk.

ChipMan uses definition files and data files to identify the devices it supports, to load specific values into registers, and monitor, plot, or record the values of any register set in the device. ChipMan definition files are XML files conforming to XML Version="1.0" and Encoding="utf-8". The data files for downloading values to the device are CMF files, specific to the ChipMan application.

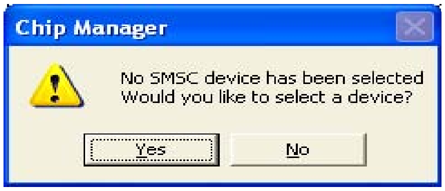
The CMF files may be located anywhere on the hard drive, but the XML files MUST reside in the ChipMan directory, typically located at: C:\Program Files\SMSC\ChipMan\Chips. An XML file usually names with the device name that supports (EMC2102.xml, EMC2103-2.xml, etc.)

During the installation of the ChipMan application, it is possible to specify a non-default installation directory. If this was done, substitute the path provided at that installation for "C:\Program Files" to store the XML files in the proper location.

Connect the USB cable to an available USB port on the PC, (The other end, “mini-B” end, of the USB cable should be connected to an EMC Evaluation Board). The “Find New Hardware” wizard will pop up on the PC’s screen for USB driver installation. Follow the instructions on the screen to complete the installation process.

5.1.2 Setting Up the ChipMan

Once the ChipMan has been installed, start the software by selecting Start -> Programs -> SMSC -> Chip Manager. If this is the first operation, the application will guide you to select a device, as shown in Figure 5.1 below.



No SMSC device has been selected
Would you like to select a device?

Figure 5.1 ChipMan Message for First Operation

Answer "Yes", then the device selection menu as shown in Figure 5.2, "ChipMan Device Selection Window" will appear.

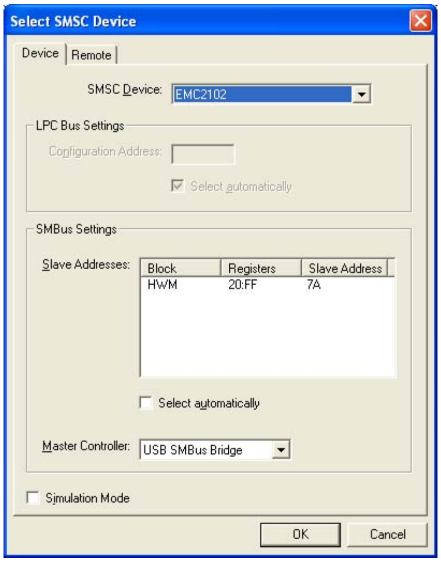
Click on the Pull-Down menu at the top, select EMC2102 as shown in Figure 5.3, "Selecting the Device and Master Controller Type", and click OK. The ChipMan operation window will then appear, as shown in Figure 5.4, "ChipMan Operation Window". Click on the HWM icon to show the different windows available.

The EMC2102 WatchDog will have timed out at this point, and the on-board DC fan will be running at 100%.

Note: Starting the ChipMan application without the USB cable/EVB connected to the PC, an error message "Supported company ID on device not found" will pop-up. Plug in the USB cable and click on “Abort”, another pop-up window will ask if you want to select an SMSC device. Click on “Yes” and then select the device as shown in Figure 5.3.

In the same device selection window the user also has the options to chose the SMBus Slave Address (Default is 7A for EVB-EMC2102, use “Select automatically” is recommended), the Master Controller type (Default is USB SMBus Bridge, see note 1 below) and if the ChipMan needs to be configured to run in simulation mode. In the simulation mode, users can practice the software functions without connecting a USB cable/EVB to the PC.

For more help with ChipMan, select Help -> Contents for an html based help document.



Select SMSC Device

Device | Remote

SMSC Device: EMC2102

LPC Bus Settings

Configuration Address:

☑ Select automatically

SMBus Settings

Slave Addresses:

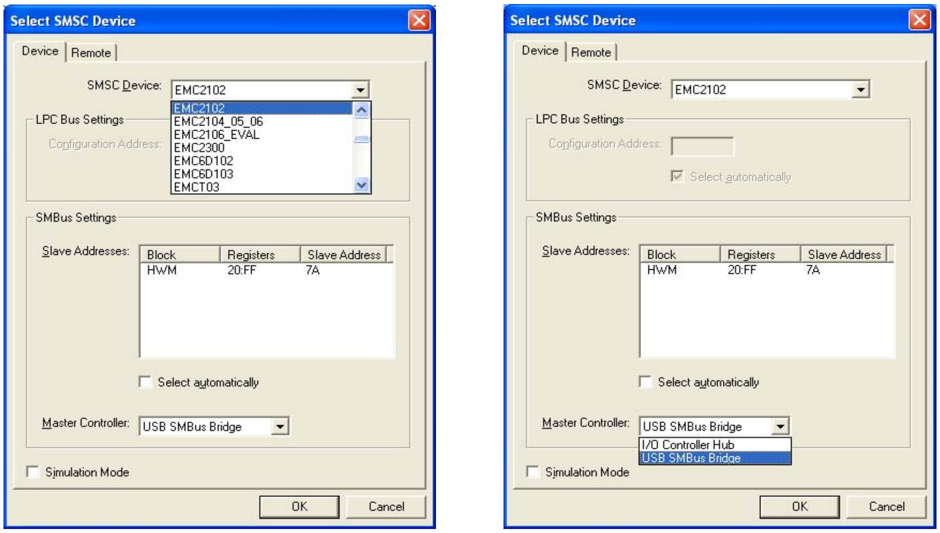
Block	Registers	Slave Address
HWM	20:FF	7A

□ Select automatically

Master Controller: USB SMBus Bridge

□ Simulation Mode

Figure 5.2 ChipMan Device Selection Window



SMSC Device: EMC2102

Slave Addresses:

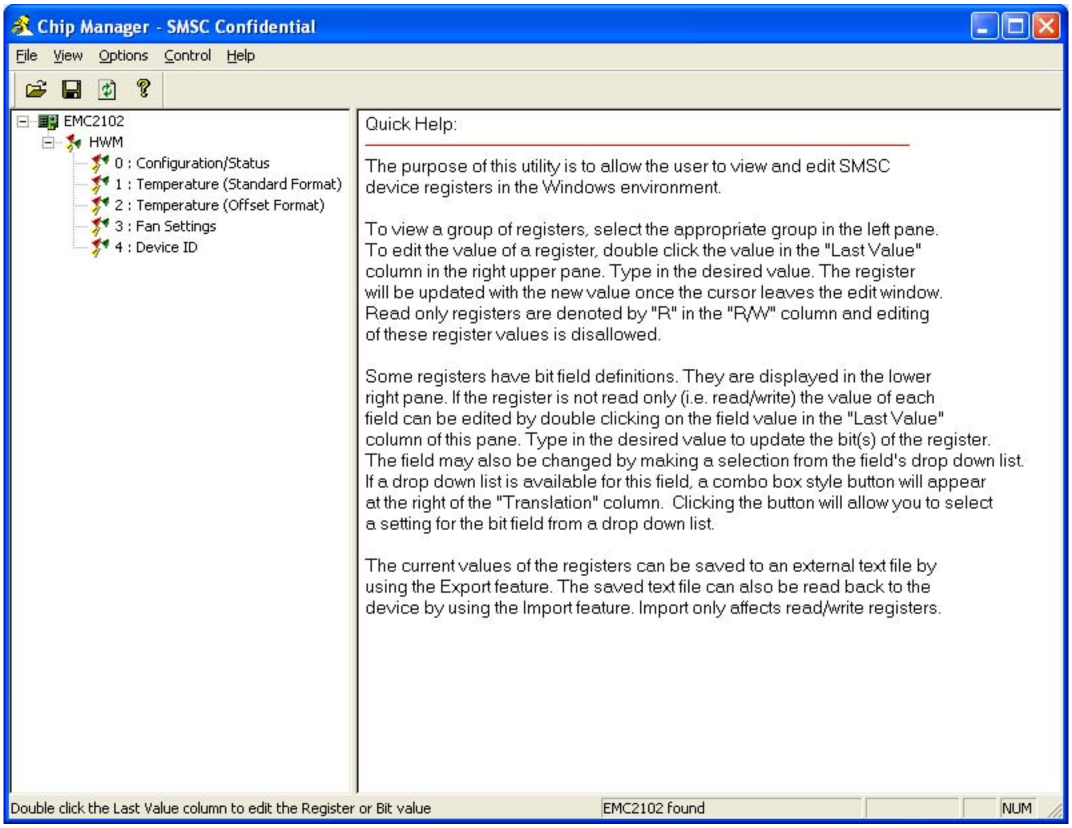
Block	Registers	Slave Address
HWM	20:FF	7A

☐ Select automatically

Master Controller: USB SMBus Bridge

☐ Simulation Mode

Figure 5.3 Selecting the Device and Master Controller Type


Chip Manager - SMSC Confidential
File
View
Options
Control
Help
EMC2102
HWM
0 : Configuration/Status
1 : Temperature (Standard Format)
2 : Temperature (Offset Format)
3 : Fan Settings
4 : Device ID
NUM

Quick Help:

The purpose of this utility is to allow the user to view and edit SMSC device registers in the Windows environment.

To view a group of registers, select the appropriate group in the left pane. To edit the value of a register, double click the value in the "Last Value" column in the right upper pane. Type in the desired value. The register will be updated with the new value once the cursor leaves the edit window. Read only registers are denoted by "R" in the "R/W" column and editing of these register values is disallowed.

Some registers have bit field definitions. They are displayed in the lower right pane. If the register is not read only (i.e. read/write) the value of each field can be edited by double clicking on the field value in the "Last Value" column of this pane. Type in the desired value to update the bit(s) of the register. The field may also be changed by making a selection from the field's drop down list. If a drop down list is available for this field, a combo box style button will appear at the right of the "Translation" column. Clicking the button will allow you to select a setting for the bit field from a drop down list.

The current values of the registers can be saved to an external text file by using the Export feature. The saved text file can also be read back to the device by using the Import feature. Import only affects read/write registers.

Double click the Last Value column to edit the Register or Bit value

EMC2102 found

Figure 5.4 ChipMan Operation Window

Notes:

1. The EVB-EMC2102 needs to be configured using the USB SMBus Bridge to work properly. If in the device selection window the Master Controller type is set to I/O Controller Hub then the "Supported company ID on device not found" message will pop-up again.
2. Disconnecting the USB cable and reconnecting it without restarting the ChipMan may cause register reading errors (all zeros). This problem can be cleared by re-selecting the EMC2102 device through the device selection window (Options -> Select Device).
3. The SMBus Slave Address could vary depending on the device. If a correct XML file is installed, the ChipMan should be able to select the correct slave address automatically. Refer to the device datasheet for more details about the SMBus protocol and its configurations.
4. The SMSC ChipMan application allows viewing and changing register values for a variety of devices. The ChipMan software only needs to be installed once to support all of these devices. The list of supported devices may be found in the pulldown menu under Options -> Select Device.

The next step will be to load the CMF file. Simply select File at the top of the window, and "Import" from the pull-down menu. A pop-up window will let the user to locate the right CMF.

Select the appropriate file and click "open". The CMF file will then load up the values into the EMC2102 device.

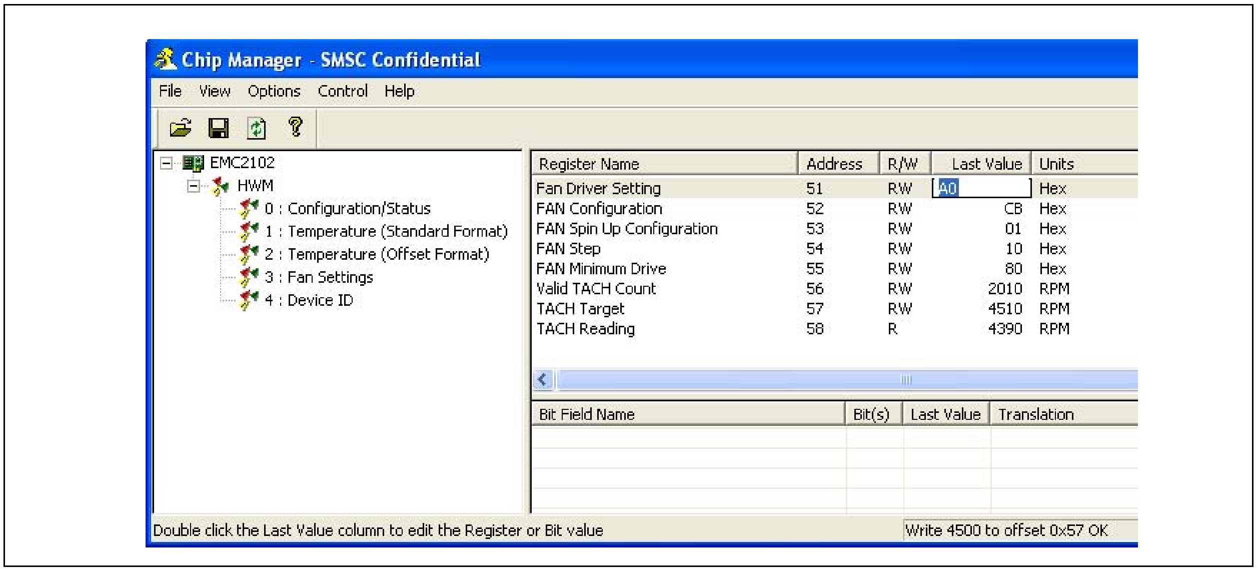
SMSC provides all CMF files for the operation experiments introduced in this user manual to help customers to evaluate the EMC2102 device. Customers can also export their own configurations to CMF files through the pull-down menu File -> Export/Export As.

The CMF file used for the Experiment 1 is EMC2102_manual.cmf.

To ensure the ChipMan application and the EMC2102 are communicating, select File -> Import and then select the file emc2102_manual.cmf. This will import a configuration file to disable EMC2102’s RPM control function and then set a valid fan control output value. The on-board DC fan’s speed will be reduced to about 5000 rpm at this time.

Select "3: Fan Settings" in the ChipMan window by double-clicking. The window as shown in Figure 5.5, "Changing Fan Speed" will open. Double-click the "last value" of Fan Driver Setting register (51h) and enter a new drive value (should be greater than 9Ah for the on-board DC fan). The fan should respond, and the TACH Reading register (58h) should indicate an RPM reading.

It is recommended to set Autorefresh Registers option in ChipMan for all experiments in this user manual. Select Options -> Autorefresh registers.


Chip Manager - SMSC Confidential
File View Options Control Help
EMC2102
HWM
0 : Configuration/Status
1 : Temperature (Standard Format)
2 : Temperature (Offset Format)
3 : Fan Settings
4 : Device ID

Register Name	Address	R/W	Last Value	Units
Fan Driver Setting	51	RW	A0	Hex
FAN Configuration	52	RW	CB	Hex
FAN Spin Up Configuration	53	RW	01	Hex
FAN Step	54	RW	10	Hex
FAN Minimum Drive	55	RW	80	Hex
Valid TACH Count	56	RW	2010	RPM
TACH Target	57	RW	4510	RPM
TACH Reading	58	R	4390	RPM

Bit Field Name	Bit(s)	Last Value	Translation

Double click the Last Value column to edit the Register or Bit value

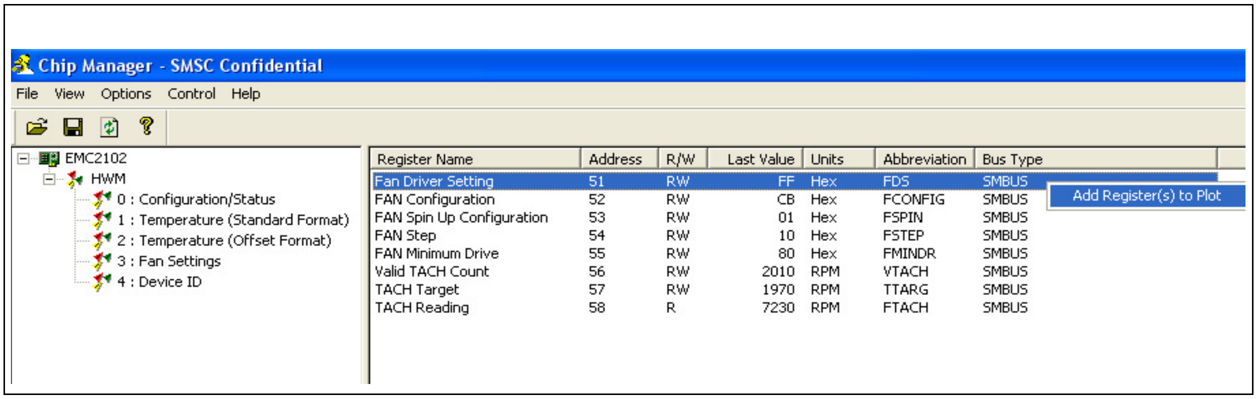
Write 4500 to offset 0x57 OK

Figure 5.5 Changing Fan Speed

5.1.3 Plotting From ChipMan

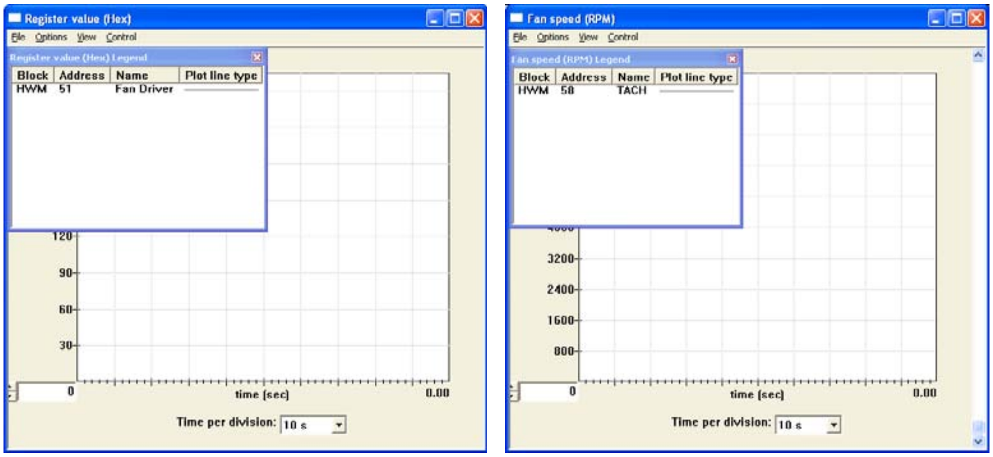
The ChipMan software has the ability to plot register values in real-time, up to 10Hz continuous rate. To select a register to plot, highlight its name or value, and right-click. A menu with a single entry "Add register to Plot" will appear (Figure 5.6, "Plotting from the ChipMan"). Click the entry then a plot window should appear, with a legend on top. When additional registers with the same data type are selected, they are added to the existing plot window. In the experiment shown in Figure 5.7, "Plot Windows", Drive Setting, TACH Target, and TACH Reading were selected. Note both the Tach registers are being plotted on the same graph.

The last step is to start the plots. All plots can be started simultaneously by selecting the "Control" pulldown from the main application window and then "Plot -> start all plots". Individual plots may be paused at any time without loss of captured data on the other plot windows.


Chip Manager - SMSC Confidential
File View Options Control Help
EMC2102
HWM
0 : Configuration/Status
1 : Temperature (Standard Format)
2 : Temperature (Offset Format)
3 : Fan Settings
4 : Device ID
Add Register(s) to Plot

Register Name	Address	R/W	Last Value	Units	Abbreviation	Bus Type
Fan Driver Setting	51	RW	FF	Hex	FDS	SMBUS
FAN Configuration	52	RW	CB	Hex	FCONFIG	SMBUS
FAN Spin Up Configuration	53	RW	01	Hex	FSPIN	SMBUS
FAN Step	54	RW	10	Hex	FSTEP	SMBUS
FAN Minimum Drive	55	RW	80	Hex	FMINDR	SMBUS
Valid TACH Count	56	RW	2010	RPM	VTACH	SMBUS
TACH Target	57	RW	1970	RPM	TTARG	SMBUS
TACH Reading	58	R	7230	RPM	FTACH	SMBUS

Figure 5.6 Plotting from the ChipMan



Block	Address	Name	Plot line type
HWM	51	Fan Driver	

Block	Address	Name	Plot line type
HWM	58	TACH	

Time per division: 10 s

Time per division: 10 s

Figure 5.7 Plot Windows

The two plots shown in Figure 5.8, "Plot Examples" are in sync. If the scaled data is desired for analysis or archival, the data may be stored in a semi-colon separated text file from each of the plot windows. Simply select File Export, and enter a filename in the Save window.

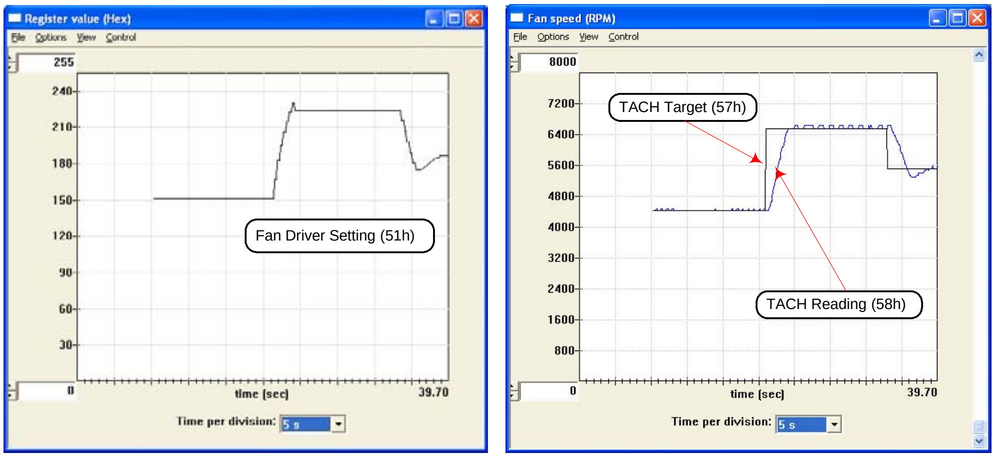


Figure 5.8 Plot Examples

5.2 Experiment 2 - RPM Based Closed-Loop Fan Control

The experiment 2 is designed to gain familiarity with the closed-loop RPM controller implemented in the EMC2102. This experiment will discuss the effects of gain, spin-up, and minimum settings on the closed-loop performance.

The cmf file for this experiment is EMC2102_RPM.cmf.

5.2.1 Getting Started

For all these tests, the Fan Drive Setting register (51h), the TACH Target register (57h) and the TACH Reading registers (58h) are selected to plot. As bits are switched in each of the tests, the register name and address will be provided.

5.2.2 Basic RPM Based Fan Control

The EMC2102 defaults will enable closed-loop operation. Prior to other options, examine the various parameters on ChipMan window page 3: Fan Settings. The registers of most interest are the FAN Minimum Drive (55h), and Valid Tach Count (56h). The closed-loop controller will not drive below the minimum drive value, and will not respond to a TACH Target RPM speed less than the speed defined by the Valid Tach Count register.

Note: The TACH reading is a reciprocal function of the fan speed, i.e. a higher TACH reading value means a slower fan rpm speed. Refer to 6 "Appendix" for more details.

Same as Experiment 1, select Fan Drive Setting (51h), TACH Target (57h), and TACH Reading (58h) for plotting. Start the plot windows in order to see the response, and command a series of Tach Targets, starting at 4500 RPM, and going up in 500 RPM steps. The plots in Figure 5.9, "Plots for Proper Control Settings" will be representative of the response generated.

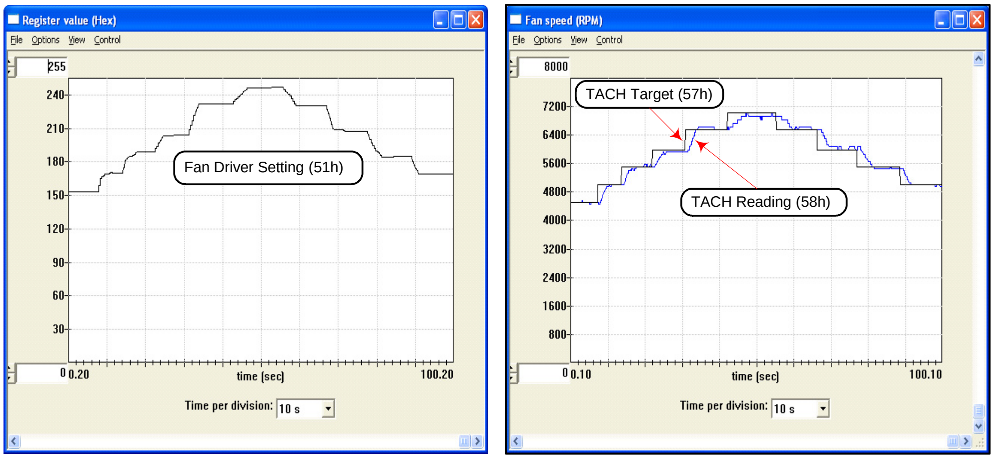
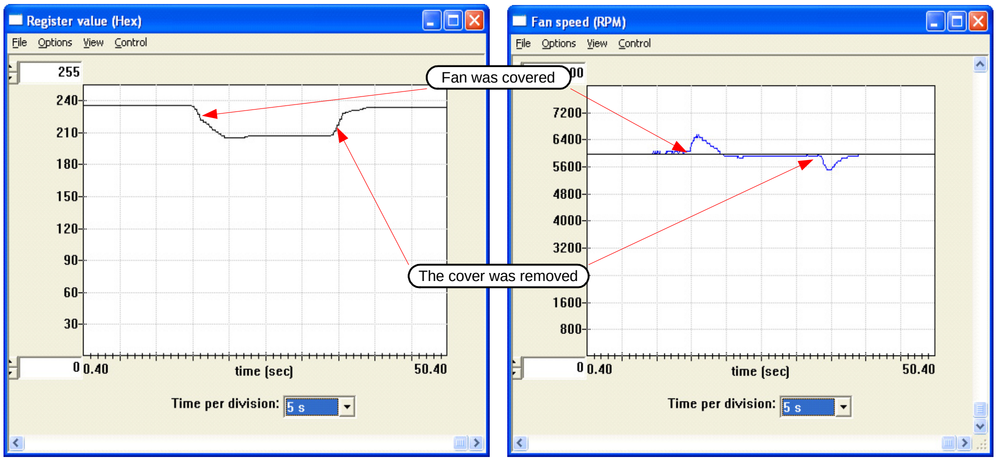


Figure 5.9 Plots for Proper Control Settings

Using this basic setup, it is possible to explore how well the fan is controlled using default values.

5.2.3 Effects of Loading

The EMC2102 has the ability to overcome changes in fan current requirements for a given RPM setting due to aging, a blocked vent, dust, etc. This is because the controller does not rely on absolute drive settings, but rather on driving the PID loop error to "0" (i.e., driving the TACH reading to equal to the TACH target). To illustrate this feature, simply command an RPM setting (6000 RPM for this experiment), and then use a piece of paper to cover the window of the fan. This will reduce the air flow through the fan and decrease the wind resistance. With the same Fan Drive Setting value (~240d in register 51h, set by devices’ RPM controller), less wind resistance will make the fan running faster. Once the PID controller inside the EMC2102 detects the difference between the TACH reading and the TACH target (6000 RPM), it will adjust the output values (down to ~210d in this experiment) to bring the fan speed back to the target, as shown in Figure 5.10, "Effects of Loading".



Time per division: 5 s

Time per division: 5 s

Figure 5.10 Effects of Loading

5.2.4 Register Change Summary

Table 5.1, "Register Change Summary for Experiment 2" lists all register value changes from the default cmf load to accomplish the tests.

Table 5.1 Register Change Summary for Experiment 2

REGISTER NAME	ADDRESS	DEFAULT VALUE	NEW VALUE	COMMENT
Fan Configuration	52h	4Bh (0100 1011b)	CBh (1100 1011b)	Enables the RPM based closed-loop fan control Algorithm

5.3 Experiment 3 - Spin-up Configuration Options

This experiment is designed to gain familiarity with the various spin-up options available in the EMC2102 devices.

This experiment will discuss the effects of Spin-Up Time and Spin-Up Levels. These parameters are important to ensure a valid start, while minimizing the turn-on overshoot for initial low RPM settings. (More examples regarding these two parameters can be found in Section 5.7.1, "Repetitious Spin-up Routine Caused by Incorrect Settings").

The CMF file for this experiment is the same as for Experiment 1, EMC2102_default.cmf.

5.3.1 Fan Control Parameters

The spin-up routine is a special algorithm that the EMC2102 uses to boot up the fan. In manual control (open loop) mode, it is only invoked when starting from a ‘0’ value in the FAN Drive Setting register 51h.

In the RPM control (closed-loop) mode, the spin-up routine is invoked when the device is driving a stalled fan to a valid target speed, i.e., the raw data value in register 57h (TACH Target) is smaller than the one in register 56h (Valid TACH Count). During the normal operation while the fan is running, the spin-up routine could also be invoked if the fan speed fell to below the valid fan speed, i.e, the raw data value in register 58h (TACH Reading) is greater than the one in register 56h (Valid TACH Count), since the fan will be considered as stalled by the controller.

There are several parameters that control the fan’s behavior during and after the spin-up routine, as shown in Figure 5.11, "Fan Control Parameters".

When the spin-up routine is operating, the fan driver is set to full scale for one quarter of the total user defined spin up time. For the remaining spin up time, the fan driver output is set a user defined level (60% or 75% of full drive). After the spin-up routine has finished, the RPM algorithm controls the fan speed to the TACH targets. At this point if the EMC2102 cannot detect a valid fan speed (the hexadecimal value in the TACH Reading register is higher than the Valid TACH Count register setting, which means the fan speed is below the valid speed), it will try to restart the fan.

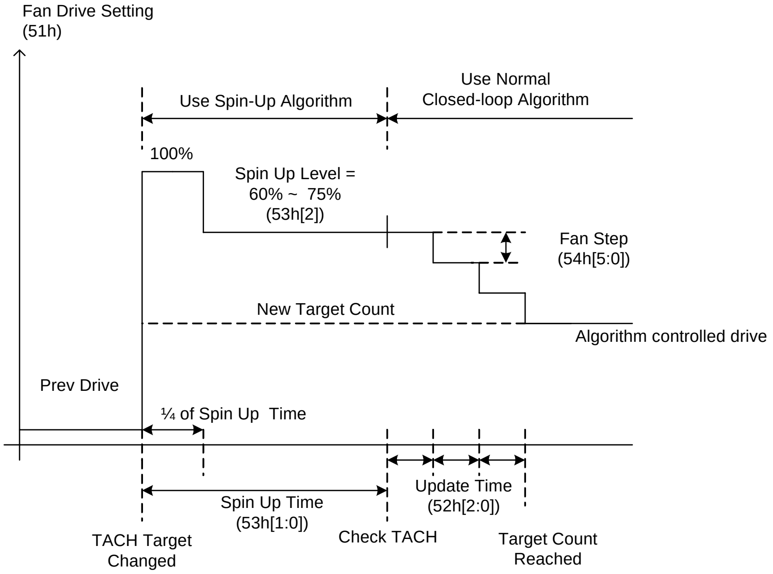


Figure 5.11 Fan Control Parameters

The spin-up LEVEL (60% or 75%, defined by 53h[2]) has corresponding Fan Driver Setting hexadecimal values (register 51h) which cab be calculated using FFh as 100% and 00h as 0%. For the 60% drive the register 51h value is 153d or 99h, and for 75% it is 191d or BFh. Those two drive settings will run a DC fan at two different speeds and we will call them rpm60 and rpm75. Depending on the fan, the speed for the same drive setting will vary.

All data and plot examples in this document were taken using an EVB-EMC2102 board with the on-board DC fan. This fan has an rpm60 of 4500 rpm, and an rpm75 of 5650 rpm.

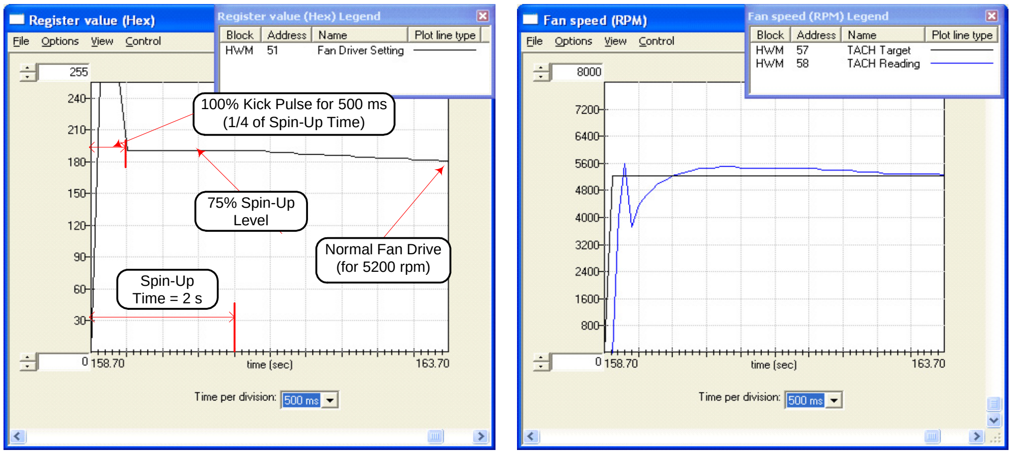
5.3.2 Getting Started

For all these tests, the Fan Drive Setting register (51h), the TACH Target register (57h) and the TACH Reading registers (58h) are selected to plot. As bits are switched in each of the tests, the register name and address will be provided.

5.3.3 Forced Kick Function

The EMC2102 has a forced 100% kick at turn-on. This feature drives the fan at maximum voltage for ¼ of the time set by the SPINUP_TIME[1:0] bits in register 53h. The plots in Figure 5.12, "Forced Kick Function" illustrate this function with a spin-up time of 2.0 sec while the TACH Target register (57h) is changed from 0 rpm to 5200 rpm.

Selecting a different "Time per Division" value in the pull-down menu in the center bottom of the plotting window, to make the 100% kick pulse can be viewed. This scale change affects both playback, and real-time mode. The rate at which data is recorded is unaffected by changing this parameter.



Register value (Hex) Legend

Block	Address	Name	Plot line type
HWM	51	Fan Driver Setting	———

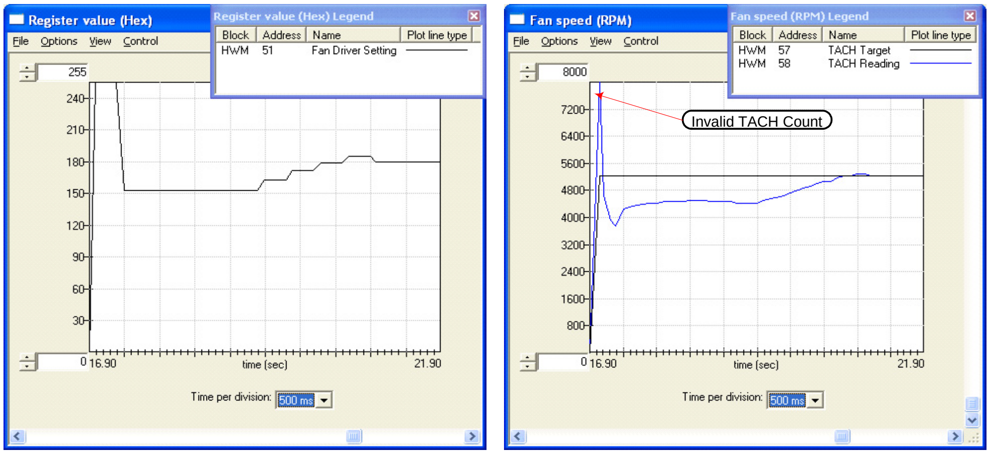
Fan speed (RPM) Legend

Block	Address	Name	Plot line type
HWM	57	TACH Target	———
HWM	58	TACH Reading	———

Figure 5.12 Forced Kick Function

5.3.4 Spin-Up Level

Depending on the application, the value of LEVEL (spin-up level, bit[1] in register 53h) may need to be adjusted to achieve the best fan control result. The plots in Figure 5.13, "60% Spin Level Setting" show the same experiment as Section 5.3.3, "Forced Kick Function" with a 60% spin-up level. Note the a smaller overshoot at the lower LEVEL setting.



Register value (Hex) Legend

Block	Address	Name	Plot line type
HWM	51	Fan Driver Setting	———

Time per division: 500 ms

Fan speed (RPM) Legend

Block	Address	Name	Plot line type
HWM	57	TACH Target	———
HWM	58	TACH Reading	———

Time per division: 500 ms

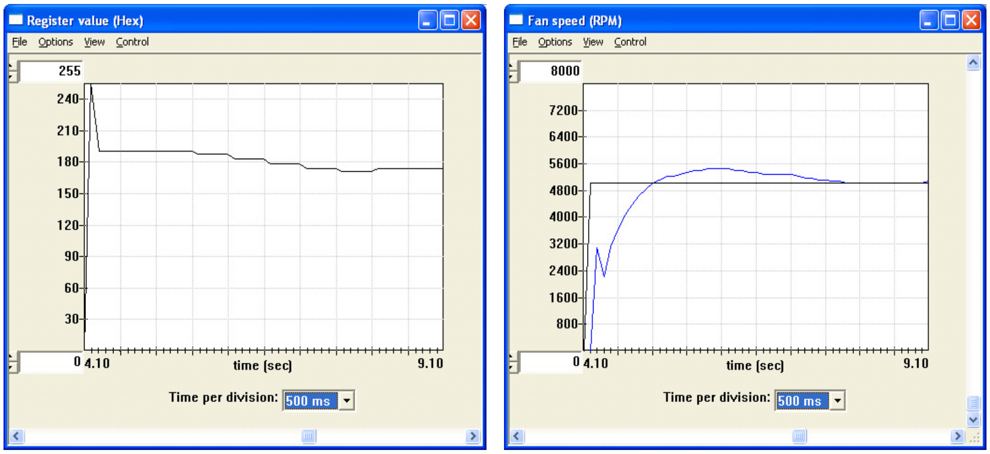
Figure 5.13 60% Spin Level Setting

Note: When a fan starts, the first TACH count captured by the EMC2102 may not reflect the fan's speed correctly, since the counting clock (32.768 kHz) could only partially fill the counting window, which will cause a higher speed reading. Also for some fans, the tachometer may not work immediately after the fan starts therefore some invalid TACH signals (very short, noisy pulses) could be sent out at the beginning. In either case, the invalid TACH counts could be displayed on the ChipMan plots (Figure 5.13), but will never be used to control the fan because the EMC2102 will not look at the TACH reading until the end of spin-up routine.

5.3.5 Spin-Up Time

The EMC2102 FAN Spin Up Configuration register (53h) contains 2 bits to set the overall spin-up time. This parameter allows for tailoring of rapid and slow response fans. Repeat the experiment in Section 5.3.3 with 500 ms SPINUP_TIME. This will provide a quicker response with smaller overshoot, as shown in Figure 5.14, "Reduced Spin-up Time".

In general, spin-up time should be tailored for the fan type being used or the effect may be undesirable.



Time per division: 500 ms

Time per division: 500 ms

Figure 5.14 Reduced Spin-up Time

5.3.6 Register Change Summary

Table 5.2, "Register Change Summary for Experiment 3" lists all register value changes from the default cmf load to accomplish the tests.

Table 5.2 Register Change Summary for Experiment 3

REGISTER NAME	ADDRESS	DEFAULT VALUE	NEW VALUE	COMMENT
FAN Spin Up Configuration	53h	01h (00000001b)	03h	SPINUP_TIME of 2.0 sec
			05h	Change the LEVEL from 60% to 75%

5.4 Experiment 4 - RPM Drive Mode Rate Controls

This experiment is designed to gain familiarity with the rate control options available in the EMC2102 devices.

This experiment will discuss the effects of Maximum Fan Step and Update rate that can be used to control the ramp rate of a fan. The two parameters ensure the fan reaches the desired drive in a reasonable time with no oscillations.

The CMF file for this experiment is the same as for Experiment 1, EMC1202_default.cmf.

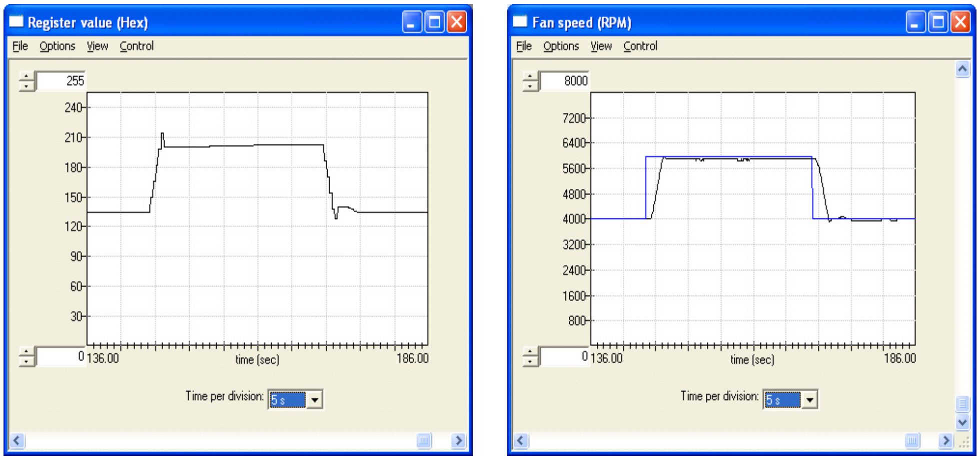
5.4.1 General Setup

For all these tests, the Fan Drive Setting register (51h) and the TACH Reading registers (58h) are selected to plot. As bits are switched in each of the tests, the register name and address will be provided.

5.4.2 Controlling the Ramp Rate

Controlling the ramp rate can improve the performance of the fan control loop by limiting the slew rate of the fan drive. The EMC2102 uses the UPDATE bits in the FAN Configuration register (52h, bits [2:0]) to determine the time interval between two updates of the controller output, and uses the FAN Step register (54h) to determine the maximum allowed hexadecimal count (STEP) of the output (Refer to Figure 5.11 "Fan Control Parameters" for more details). These two parameters can only work in the RPM control mode. When the RPM control function is disabled (52h[7]= 0), any change in the Fan Drive Setting register (51h) will immediately change the output.

The plots in Figure 5.15, "Default Ramp Rate" illustrate the drive and response with the default UPDATE (400ms) and default STEP SIZE (Max. 16 drive settings per update), while changing the fan target speed from 4000 rpm to 6000rpm.



Time per division: 5 s

Time per division: 5 s

Figure 5.15 Default Ramp Rate

The ramping rate in this mode can be accelerated or slowed down, depending on application and the values of register 52h (UPDATE) and 54h (STEP SIZE). In the next experiment (Figure 5.16, "Default Step Size with Different UPDATE Settings"), the default STEP SIZE with different UPDATE (400 ms and 100 ms) were used, The 100 ms setting has the effect of speeding the loop up by a factor of 4, as that is the ratio between minimum (100ms) and default (400ms) UPDATE settings.

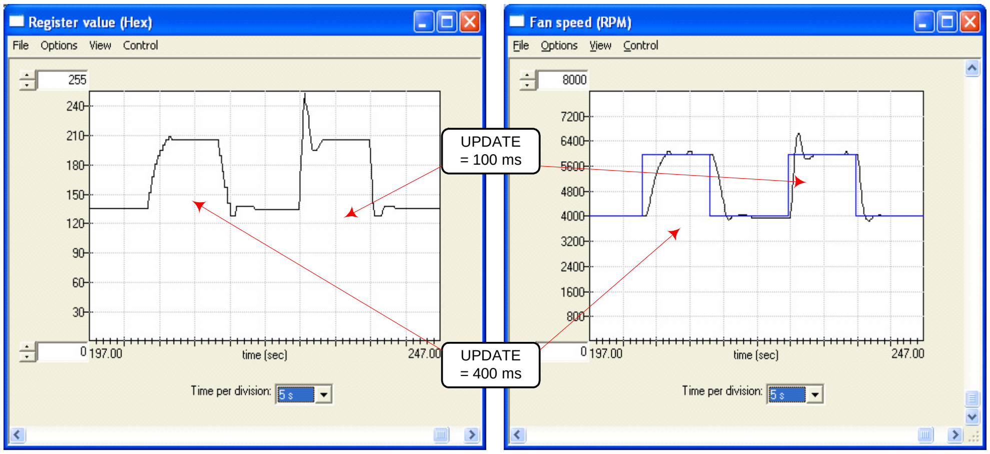


Figure 5.16 Default Step Size with Different UPDATE Settings

In the next experiment (Figure 5.17, "Default UPDATE with Different Step Size Settings"), two different maximum step sizes, 16 and 63, were used. with the 63 STEP SIZE setting, the output takes less steps (updates) from 4000 rpm to 7500 rpm because it gives the fan more power to follow the desired rpm settings.

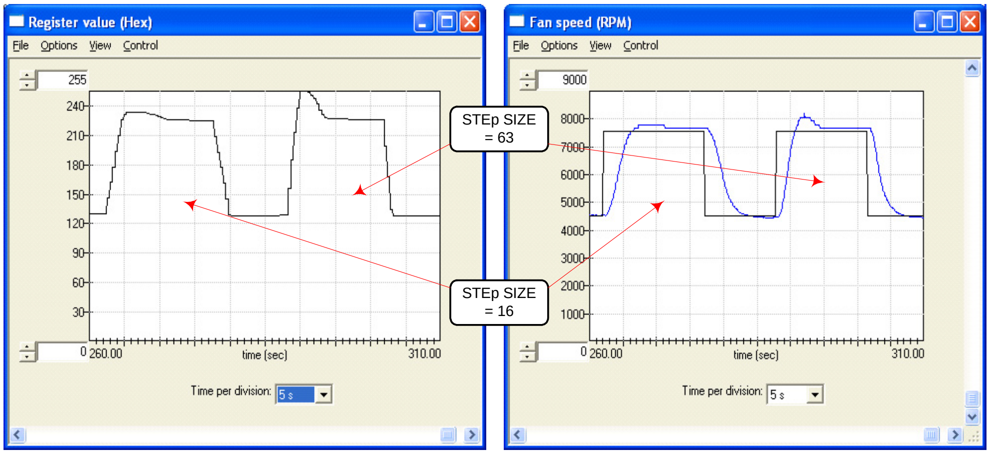


Figure 5.17 Default UPDATE with Different Step Size Settings

In the last experiment, an extremely slow ramp rate is demonstrated. The UPDATE was set to maximum (1600 ms), and the STEP SIZE was changed to 01h (Figure 5.18, "Exceptionally Slow Rate"). Note the large scale of the “Time per division” in the figure.

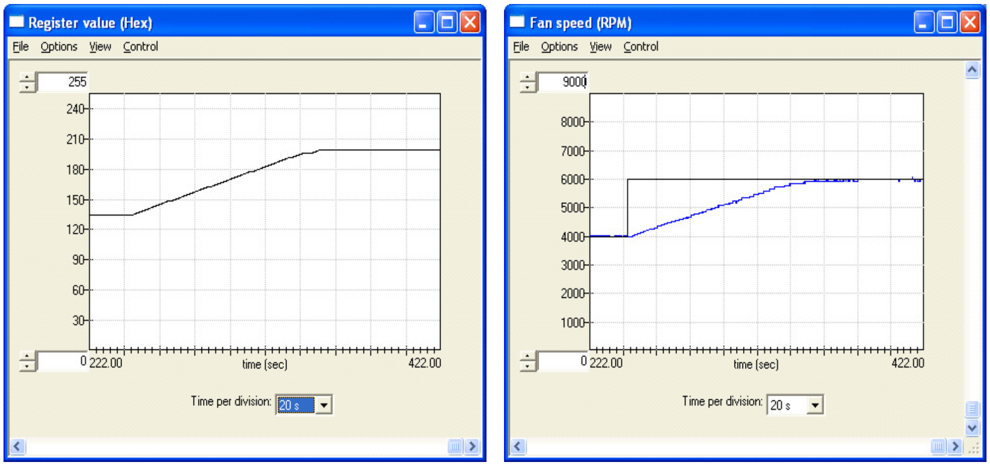


Figure 5.18 Exceptionally Slow Rate

5.4.3 Register Change Summary

Table 5.3, "Register Change Summary for Experiment 4" lists all register value changes from the default cmf load to accomplish the tests.

Table 5.3 Register Change Summary for Experiment 4

REGISTER NAME	ADDRESS	DEFAULT VALUE	NEW VALUE	COMMENT
FAN Step	54h	10h	01h	Demonstrate RRC long duration
Fan Configuration	52h	CBh	C8h, CFh	Demonstrate min (C8h) and max (CFh) UPDATE rates applied to RRC

5.5 Experiment 5 - Optimizing RPM Control Response

This experiment is designed to gain familiarity with the parameters that affect the closed-loop controller implemented in the EMC2102. All these registers are located on the Fan Setting page in ChipMan. This experiment will go through each register, examining the effects of parametric changes on the closed-loop controller in RPM mode.

5.5.1 General Setup

For all these tests, the Fan Drive Setting register (51h), the TACH Target register (57h) and the TACH Reading registers (58h) are selected to plot. As bits are switched in each of the tests, the register name and address will be provided.

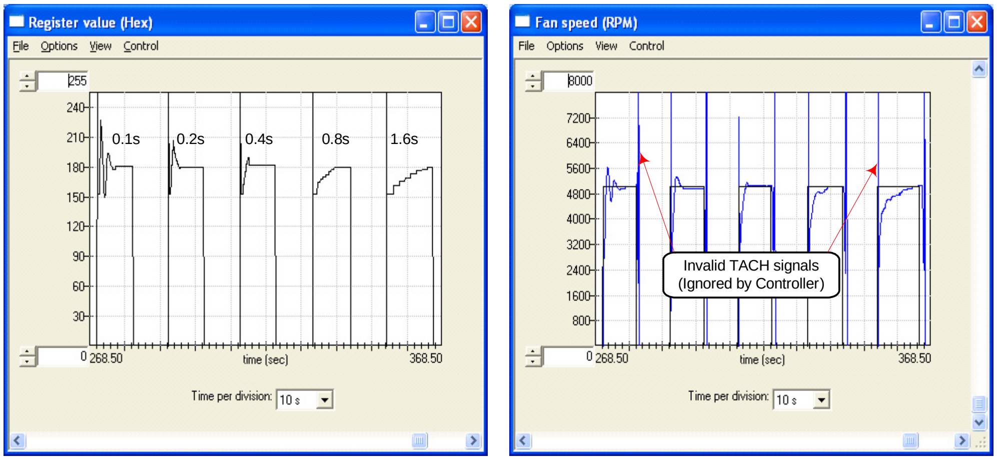
5.5.2 Fan Configuration Register (52h)

The Fan Configuration Register stores the basic operation parameters of the closed-loop controller. The EN bit turns on the RPM controller, and locks out manual updates to the Fan Drive Setting register (51h).

The next two parameters, LIMIT2K and EDGES[1:0] (both in register 52h) describe the fan itself. The EDGES[1:0] tell the controller how many tach edges to examine to determine the fan speed. The LIMIT2K parameter tells the RPM controller how to interpret the TACH Target register (57h). The value of this parameter provides an operating range for the fan by specifying the minimum rpm: the 500 rpm setting is for low speed fans and the 2000 rpm setting is typical for notebook and desktop fans (high speed fans). (Please refer to Section 6.1, "DC Fan Basics - Poles, Tach Meter Pulses and Edges" for more details about the TACH edges and ranges.)

For all experiments in this suite, the default values have been used. This keeps the scaling of those values fixed, allowing the ChipMan application to appropriately scale the counts to RPM values.

The UPDATE[2:0] parameter controls the speed at which the RPM controller updates the output drive, as already been discussed in Section 5.4, "Experiment 4 - RPM Drive Mode Rate Controls". This parameter is independent of the TACH Reading updates, which are controlled by the EDGES[1:0] parameter. The plots in Figure 5.19, "Update Time Modifications" show the effect of UPDATE on the closed-loop performance when starting the on-board fan. The numbers (in unit of second) in the left plot indicate the UPDATE value used for that sequence. By experimenting with the different update times you can determine the most stable setting for the fan to be controlled.

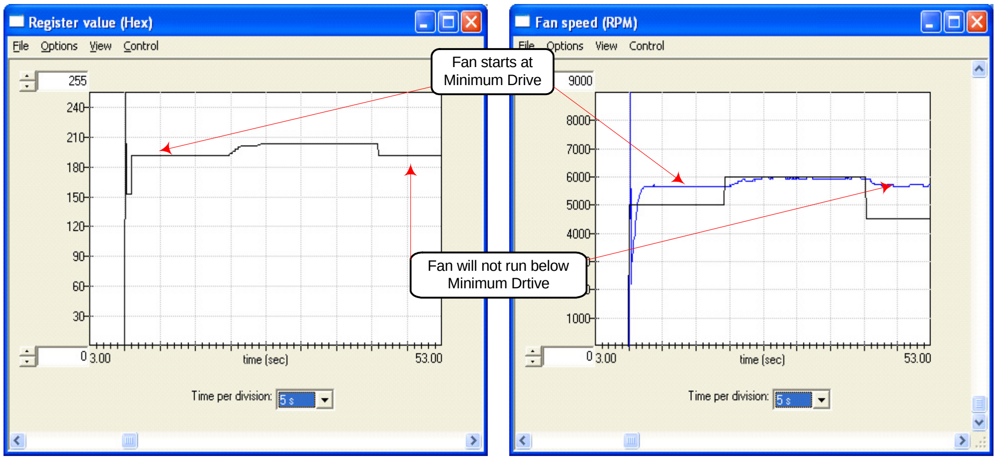


Invalid TACH signals
(Ignored by Controller)

Figure 5.19 Update Time Modifications

5.5.3 FAN Minimum Drive Register (55h) and Valid TACH Count (56h)

These two registers assist the user in defining the operational environment for a given fan. The Minimum Drive register is an absolute minimum value the RPM controller may drive to in an attempt to achieve low RPM settings. The Valid Tach Count register is used to compare against the Tach Target register. No value less than the Valid Tach Count will be accepted by the controller. To examine this feature, set the minimum drive to C0h, and command an RPM setting of less than 5500 RPM. The fan will start at about 5600 rpm (51h = C0h). Set the target to 6000 rpm, and the fan speed follows. Drop the fan target speed from 6000 rpm to 4500 rpm, the real fan speed will only drop to about 5560 rpm, as shown in Figure 5.20, "Minimum Drive Setting".



Fan starts at Minimum Drive

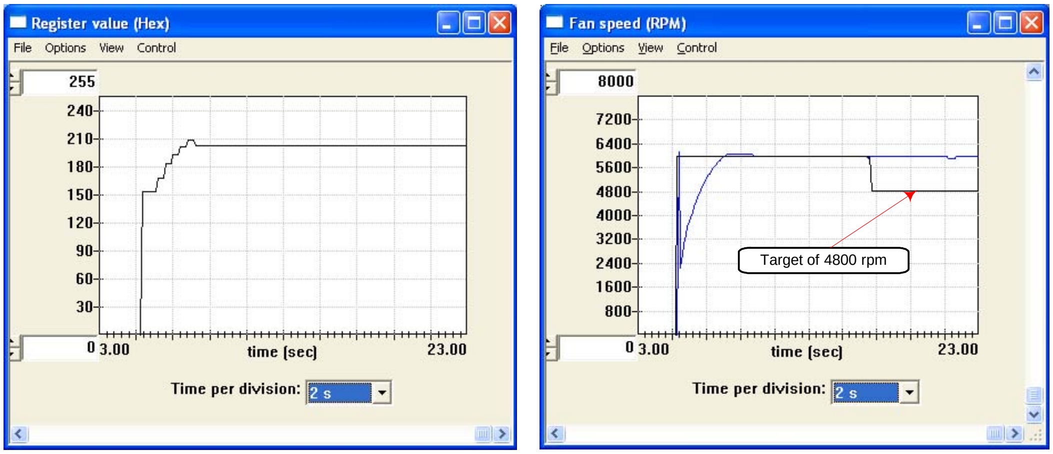
Fan will not run below Minimum Drtive

Time per division: 5 s

Time per division: 5 s

Figure 5.20 Minimum Drive Setting

Likewise, the Valid TACH Count register operation is simple to show. Start the fan at 6000 RPM with all default setting, and then set the Valid TACH register to 5000 RPM. Enter a command of 4800 RPM, and the fan will not respond as shown in Figure 5.21, "Valid Tach Count Setting".



Target of 4800 rpm

Time per division: 2 s

Time per division: 2 s

Figure 5.21 Valid Tach Count Setting

5.5.4 Register Change Summary

Table 5.4, "Register Change Summary for Experiment 7" lists all register value changes from the default cmf load to accomplish the tests.

Table 5.4 Register Change Summary for Experiment 7

REGISTER NAME	ADDRESS	DEFAULT VALUE	NEW VALUE	COMMENT
Fan Configuration	52Bh	CBh	4Bh	Disable RPM based fan control algorithm
		ABh	C8h - CFh	Demonstrate UPDATE effect
Valid Tach Count	56H	2010d	5000d	Changed from 2010 RPM to 5000 RPM to show the effect in closed-loop

5.6 Experiment 6 - Limits and Alerts

This experiment is designed to gain familiarity with the control registers for generating fan related alarms and alerts associated with the EMC2102.

The CMF file for this experiment is EMC2102_default.cmf.

5.6.1 General Setup

For all these tests, the Fan Drive Setting register (51h), the TACH Target register (57h) and the TACH Reading registers (58h) are selected to plot. As bits are switched in each of the tests, the register name and address will be provided.

5.6.2 Fan Spin and Stall Interrupts

The Configuration/Status page in the ChipMan application contains all the Interrupt configuration and status registers for the fan. In this experiment, the Fan Stall and Fan Spin status bits will be checked. In order to see the status bits change, the Interrupt Status 2 register (23h) is plotted along with other registers listed above. The Interrupt Mask register (24h) should be set to 10h (default) for this set of experiments.

Start the plotting function within ChipMan, and force the fan to stop spinning. This will induce a Fan Stall condition. The plot of the Status Register will show a peak of 1 count for the stall condition, followed by peaks of 2 counts for each time the spin-up routine is invoked, as shown in Figure 5.22, "Fan Spin and Stall". In order to see the spikes mentioned above, the max scale on the register 27h plot needs to be modified. To do this, simply double click the 255 at the top of the "Y" axis, type a different maximum value (10) and enter. And then double click the 0 at the bottom of the "Y" axis, type a minimum value and enter. The scale will be changed.

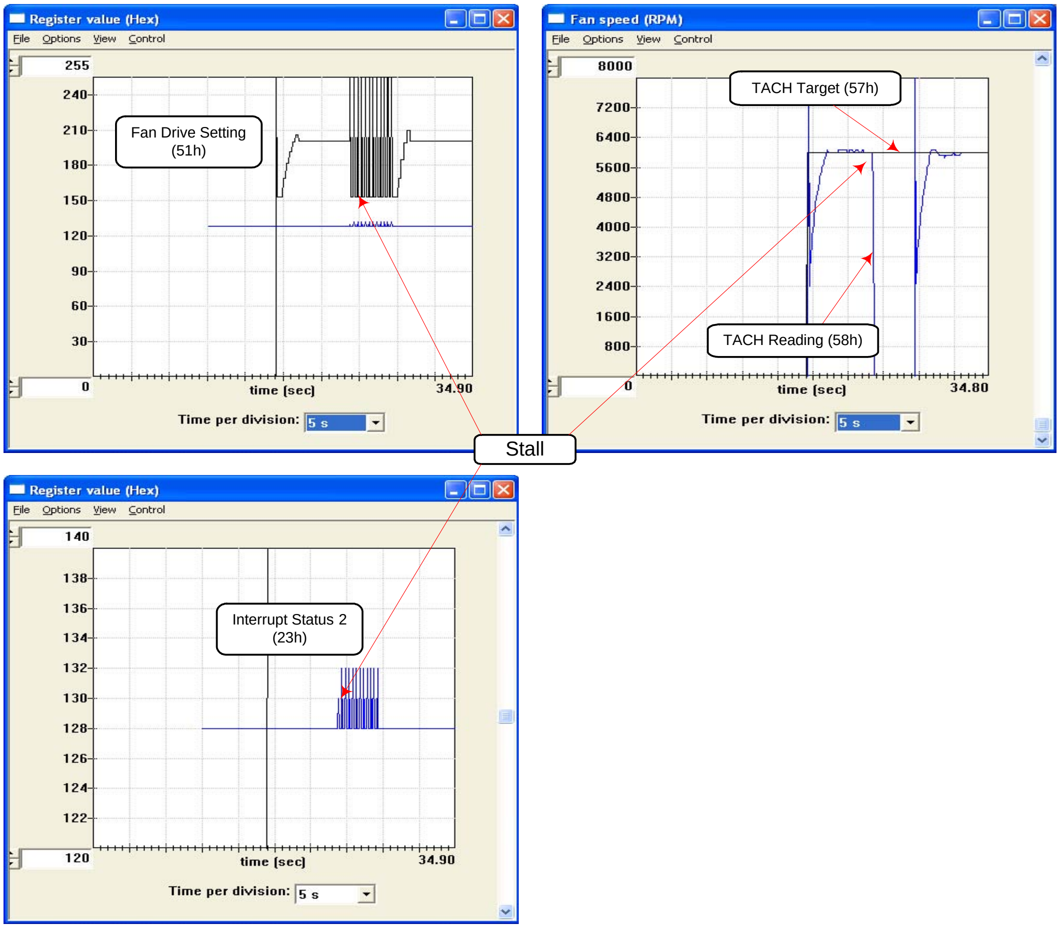


Figure 5.22 Fan Spin and Stall

5.6.3 Register Change Summary

All register values are default for the tests in this section.

5.7 Experiment 7 - Troubleshooting

5.7.1 Repetitious Spin-up Routine Caused by Incorrect Settings

At the end of spin-up routine (see Section 5.3.1, "Fan Control Parameters"), the EMC2102 checks the TACH Reading register (58h). If the value in this register is greater than the Valid TACH Count (56h), which means the fan is running at a speed slower than the minimum valid speed, the spin-up routine will be restarted (Figure 5.23, "Fan Spin-up Routine Restarted Repeatedly").

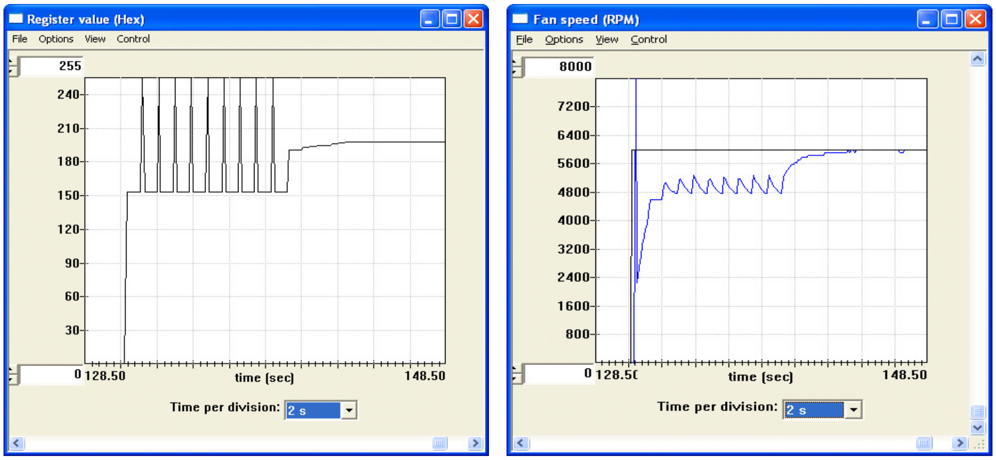


Figure 5.23 Fan Spin-up Routine Restarted Repeatedly

Depending on the fan characters and EMC2102 settings, there are several situations at the end of spin-up routine which will be discussed.

Notes: For ease of understanding, all TACH values will be converted to RPM values in the following examples.

5.7.1.1 Case 1 - Spin-up Lvel RPM < Valid RPM < Target RPM

In this case, the spin-up level rpm (rpm60 or rpm75) is smaller than both valid rpm (function of 56h) and target rpm (function of 57h). The theoretical plot of this situation is shown in Figure 5.24, "Theoretical Plot of Case 1".

Since the fan speed at the end of spin-up routine is always below the minimum valid speed (a function of 56h), the EMC2102 will think the fan is not running, and will try to restart the fan with spin-up routine over and over.

Using the EVB-EMC2102 to test this situation with rpm60 (~4500 rpm), simply set the Valid TACH register (56h) with 4800 rpm and start the fan with TACH Target (57h) = 5000 rpm. The repeating spin-up routines can be observed (Figure 5.25, "Spin-up Case 1 Fix 1").

For rpm75 (~5650 rpm), set 56h = 6000 rpm and 57h = 6500 rpm, as shown in Figure 5.26, "Spin-up Case 1 Fix 2".

There are mainly two ways to fix this problem. If the spin-up LEVEL in 53h is 60%, then change it to 75%, as shown in Figure 5.25.

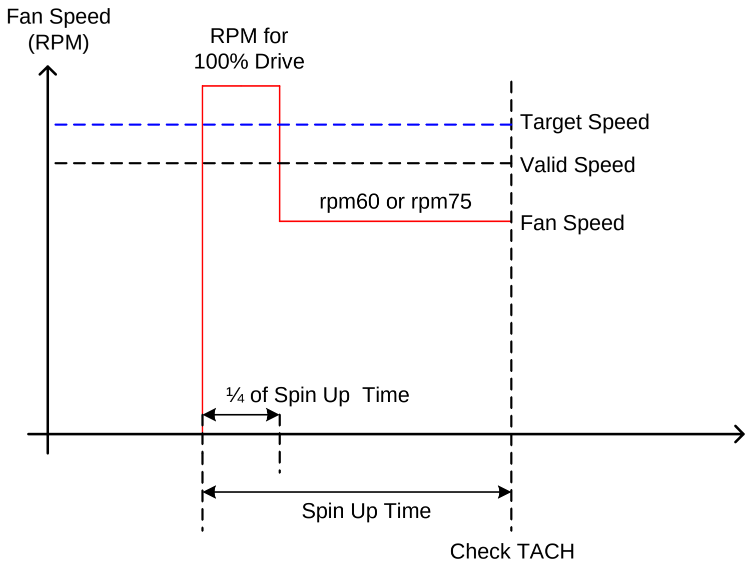
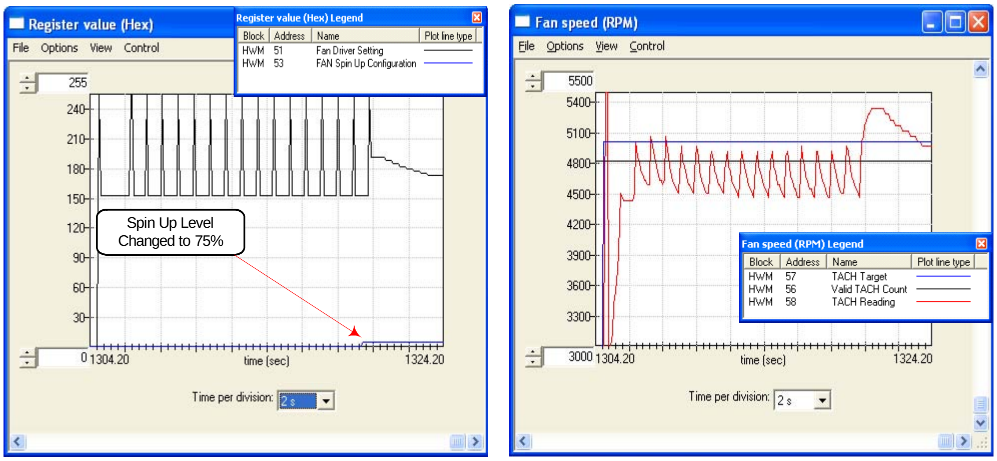


Figure 5.24 Theoretical Plot of Case 1



Register value (Hex) Legend

Block	Address	Name	Plot line type
HWM	51	Fan Driver Setting	—
HWM	53	FAN Spin Up Configuration	—

Time per division: 2 s

Fan speed (RPM) Legend

Block	Address	Name	Plot line type
HWM	57	TACH Target	—
HWM	56	Valid TACH Count	—
HWM	58	TACH Reading	—

Time per division: 2 s

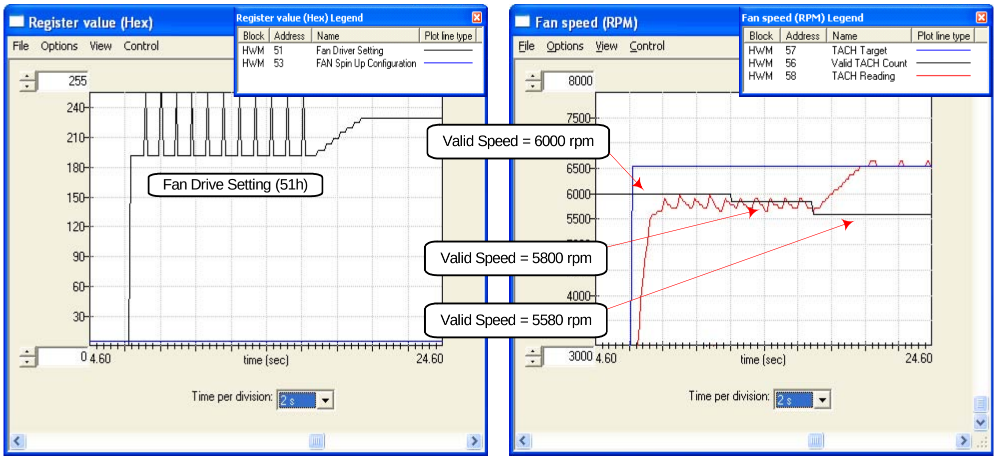
Figure 5.25 Spin-up Case 1 Fix 1

If the fan is already set to 75% level, we will need to lower the valid speed (function of 56h, Valid TACH) to a value below the rpm75, to fix the problem.

To test this situation, set spin-up level to 75% (53h[2] = 1), set the Valid TACH Count (56h) = 6000 rpm and then start the fan (57h) with 6500 rpm. The spin-up routine will run repeatedly.

Change the Valid TACH Count (56h) to 5800 rpm, the problem cannot be fixed since the valid speed is still higher than the fan speed (rpm75 = 5650 rpm).

Set 56h = 5580 rpm which is below 5650 rpm (the rpm75), the system gets out of the spin-up routine (Figure 5.26).



Register value (Hex) Legend

Block	Address	Name	Plot line type
HWM	51	Fan Driver Setting	―
HWM	53	FAN Spin Up Configuration	―

Fan speed (RPM) Legend

Block	Address	Name	Plot line type
HWM	57	TACH Target	―
HWM	56	Valid TACH Count	―
HWM	58	TACH Reading	―

Fan Drive Setting (51h)

Valid Speed = 6000 rpm

Valid Speed = 5800 rpm

Valid Speed = 5580 rpm

Figure 5.26 Spin-up Case 1 Fix 2

5.7.1.2 Case 2 - Valid RPM << Target RPM < Spin-up Level RPM

In this case, the target speed is smaller than the spin-up level speed (rpm60 or rpm75) and is much bigger than the valid speed. The theoretical plot of this situation is shown in Figure 5.27, "Theoretical Plot of Case 2".

Since the fan speed at the end of spin-up routine is always higher than the minimum valid speed, the EMC2102 will go to the normal operation after the spin-up routine.

Using the EVB-EMC2102 to test this situation with rpm75 (~5650 rpm), simply set the Valid TACH register (56h) with 4500 rpm and start the fan with TACH Target (57h) = 5500 rpm (Figure 5.28, "Spin-up Case 2").

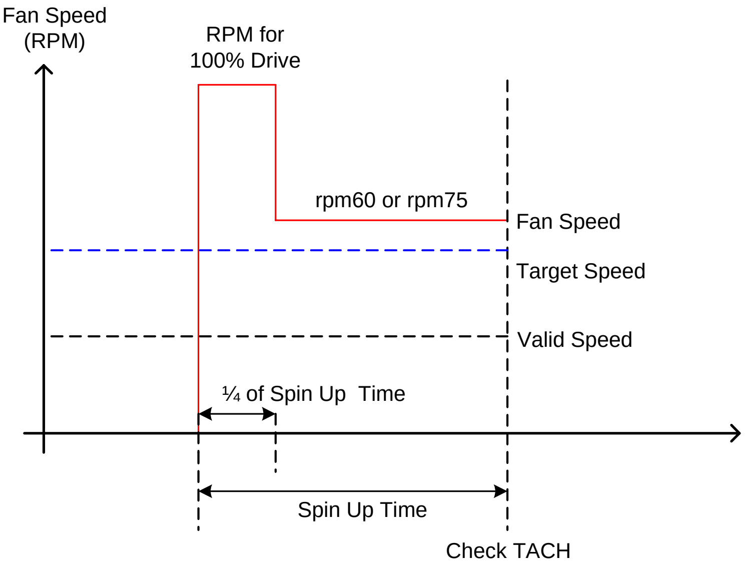
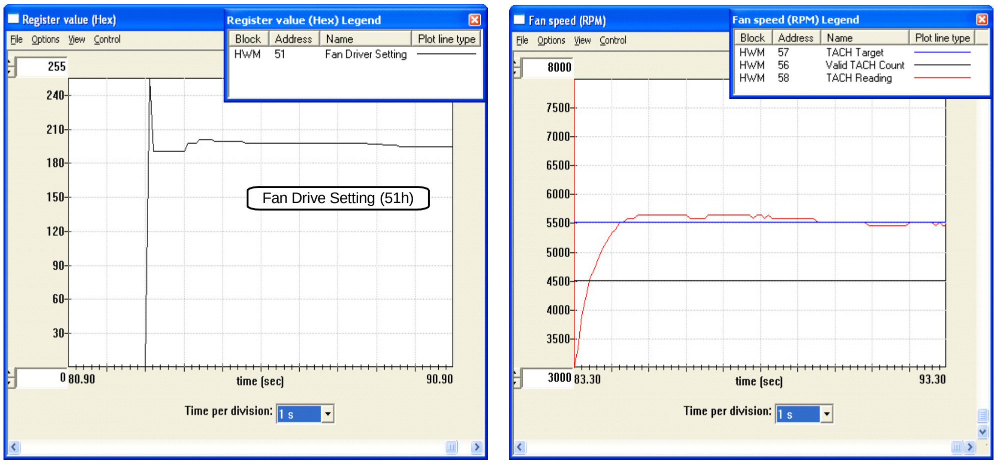


Figure 5.27 Theoretical Plot of Case 2



Register value (Hex) Legend

Block	Address	Name	Plot line type
HWM	51	Fan Driver Setting	▬

Fan speed (RPM) Legend

Block	Address	Name	Plot line type
HWM	57	TACH Target	🟦
HWM	56	Valid TACH Count	▬
HWM	58	TACH Reading	🟥

Figure 5.28 Spin-up Case 2

5.7.1.3 Case 3 - Valid RPM =< Target RPM << Spin-up Level RPM

In this case, the target speed is only a little greater than the valid speed, and both of them are much smaller than the spin-up level speed (rpm60 or rpm75). The theoretical plot of this situation is shown in Figure 5.29, "Theoretical Plot of Case 3".

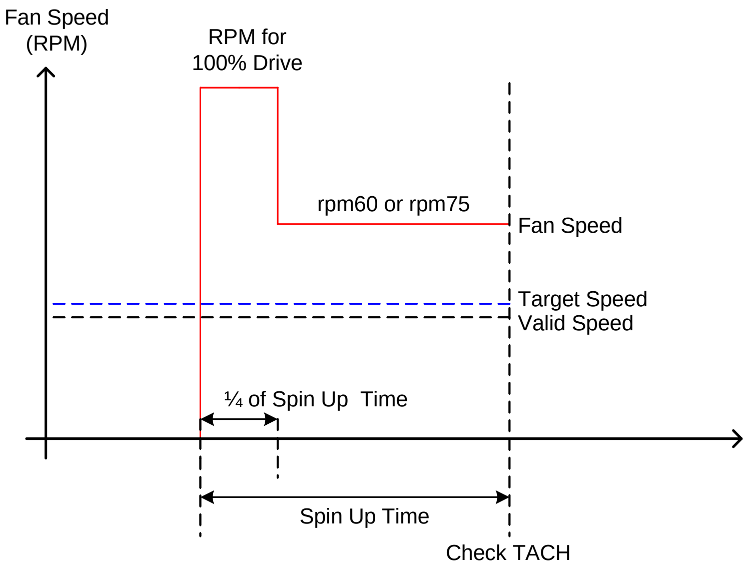


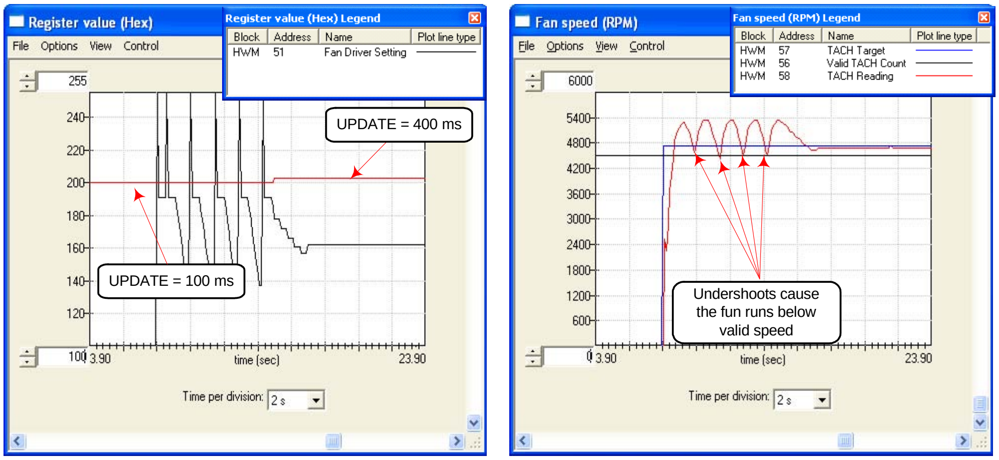
Figure 5.29 Theoretical Plot of Case 3

Since the fan speed at the end of spin-up routine is higher than the minimum valid speed, the EMC2102 should go to the normal operation after the spin-up routine. However, because the large speed difference between the spin-up level speed (rpm60 or rpm75) and the target speed, the closed-loop controller will try to make a big adjustment of its output to reach the target speed. With incorrect settings (such as big output step or short update time), this adjustment could easily cause an undershoot and make the fan speed below the valid rpm, and than make the spin-up routine restart.

Using the EVB-EMC2102 to test this situation with rpm75 (~5650 rpm), simply set the Valid TACH register (56h) with 4500 rpm, set the UPDATE (52h[2:0]) = 100ms and start the fan with 4700 rpm, the spin-up routine starts over ‘and over (Figure 5.30, "Spin-up Case 3").

To fix this problem, change the UPDATE (52h[2:0]) back to 400 ms. It will give the fan more time to reach the speed of the previous step and reduce the overshoot/undershoot. Another solution is to decrease the Fan Step settings which will force the controller to take smaller steps to achieve the target speed.

When the target speed is too close to the valid speed, the problem will not only occur when the fan starts. It may also cause problems in the normal operation after the spin-up, since the fan speed reading errors (caused by fan load changes, tachometer truncation errors, circuit noises, etc.) could drop it below the valid speed and cause a spin-up routine restart. (Figure 5.31, "Spin-up Routine Restarted During Normal Operation").



Register value (Hex) Legend

Block	Address	Name	Plot line type
HWM	51	Fan Driver Setting	——

Fan speed (RPM) Legend

Block	Address	Name	Plot line type
HWM	57	TACH Target	——
HWM	56	Valid TACH Count	——
HWM	58	TACH Reading	——

UPDATE = 400 ms

UPDATE = 100 ms

Undershoots cause the fun runs below valid speed

Figure 5.30 Spin-up Case 3

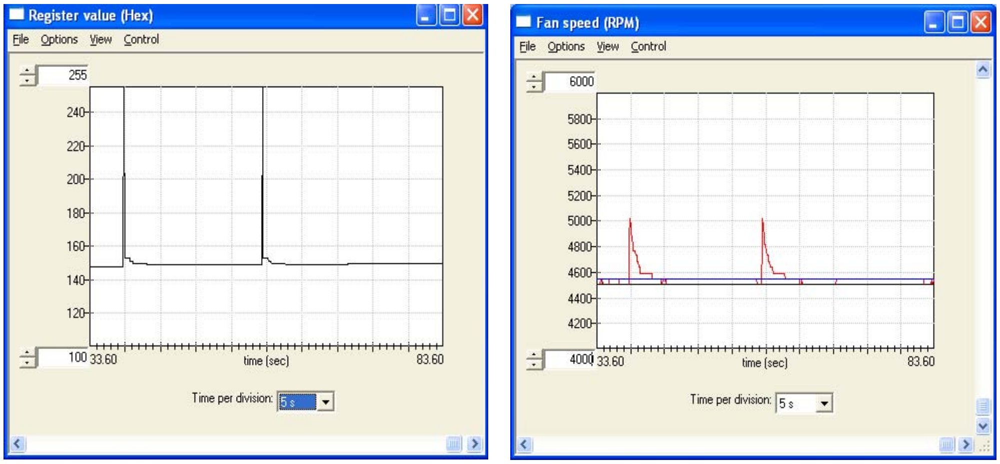


Figure 5.31 Spin-up Routine Restarted During Normal Operation

5.7.1.4 Case 4 - 4.Valid RPM < Spin-up Level RPM (rpm60 or rpm75) < Target RPM

In this case, the spin-up level speed (rpm60 or rpm75) is greater than the valid speed and smaller than the target speed, as shown in Figure 5.32, "Theoretical Plot of Case 4".

At the end of spin-up routine, the closed-loop control will drive the fan up to reach the target, therefore the fan speed will never be lower than the valid speed. The EMC2102 will go to the normal operation after the spin-up routine.

Using the EVB-EMC2102 to test this situation with rpm60 (~4500 rpm), simply set the Valid TACH register (56h) with 3500 rpm and start the fan with TACH Target (57h) = 5000 rpm (Figure 5.33, "Spin-up Case 4").

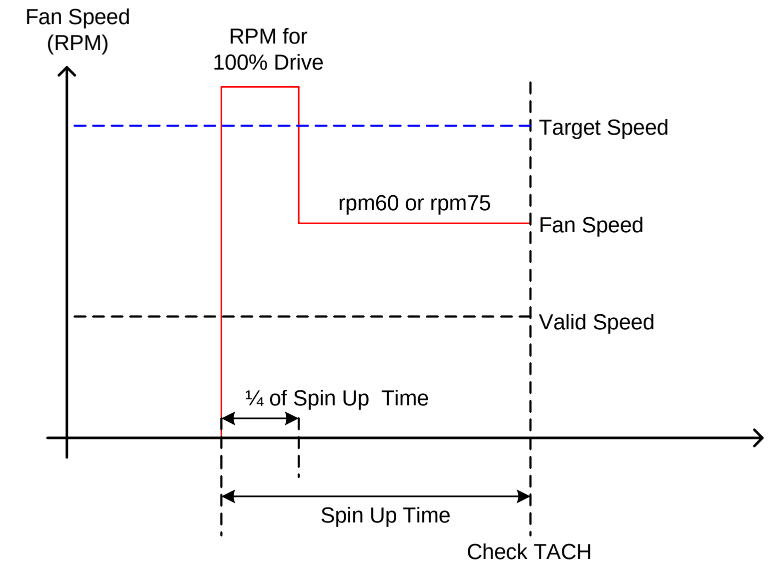
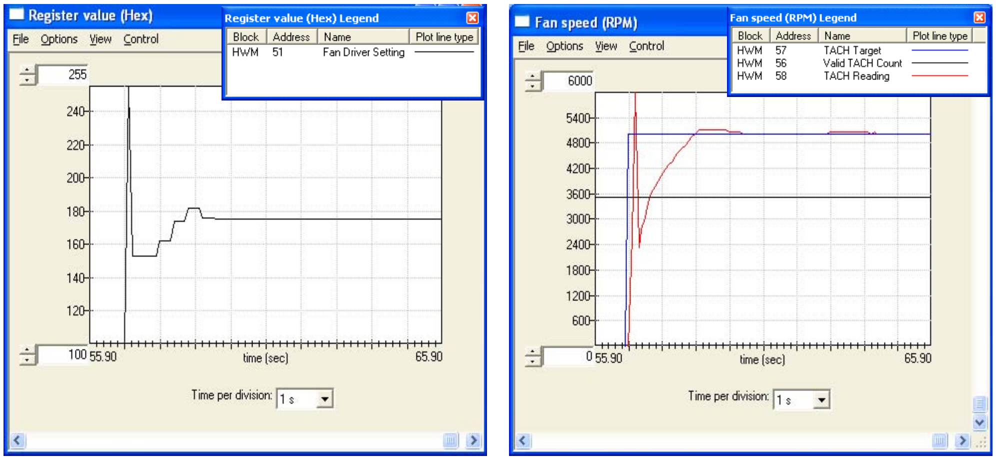


Figure 5.32 Theoretical Plot of Case 4



Register value (Hex) Legend

Block	Address	Name	Plot line type
HWM	51	Fan Driver Setting	――

Fan speed (RPM) Legend

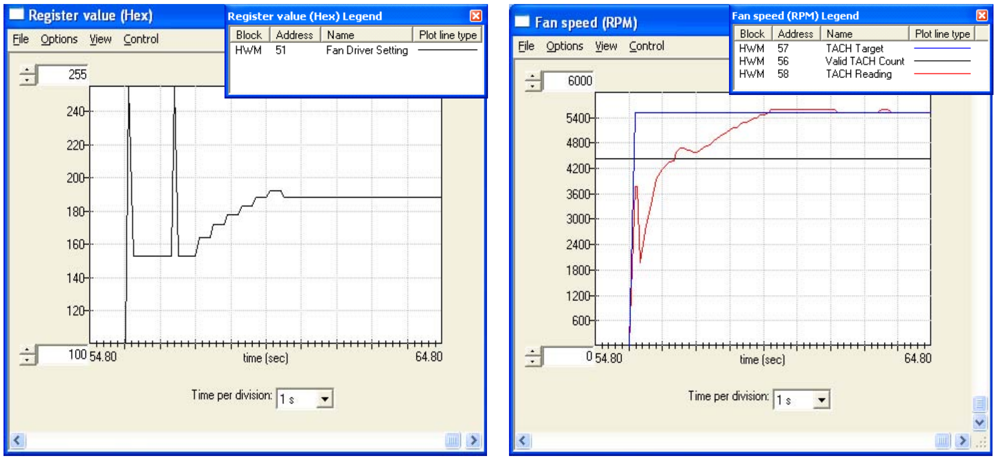
Block	Address	Name	Plot line type
HWM	57	TACH Target	――
HWM	56	Valid TACH Count	――
HWM	58	TACH Reading	――

Figure 5.33 Spin-up Case 4

5.7.1.5 Case 5 - Correct RPM Relationships with a Slow Response DC Fan

In this case, the spin-up routine is too short to make the fan reach a speed higher than the valid speed. Since the EMC2102 cannot detect a valid TACH at the end of spin-up routine, it will try to restart the fan. Depending on the fan, it is possible that after several spin-up cycles, the fan can reach the valid speed and operate normally.

Using the EVB-EMC2102 to test this situation with rpm60 (~4500 rpm), simply set the SPINUP_TIME (53h[1:0]) = 250 ms, Valid TACH (56h) = 4400 rpm, and start the fan with TACH Target (57h) = 5500 rpm. Multiple spin-up routines will be observed (Figure 5.34, "Spin-up Case 5").



Register value (Hex) Legend

Block	Address	Name	Plot line type
HWM	51	Fan Driver Setting	———

Fan speed (RPM) Legend

Block	Address	Name	Plot line type
HWM	57	TACH Target	———
HWM	56	Valid TACH Count	———
HWM	58	TACH Reading	———

Time per division: 1 s

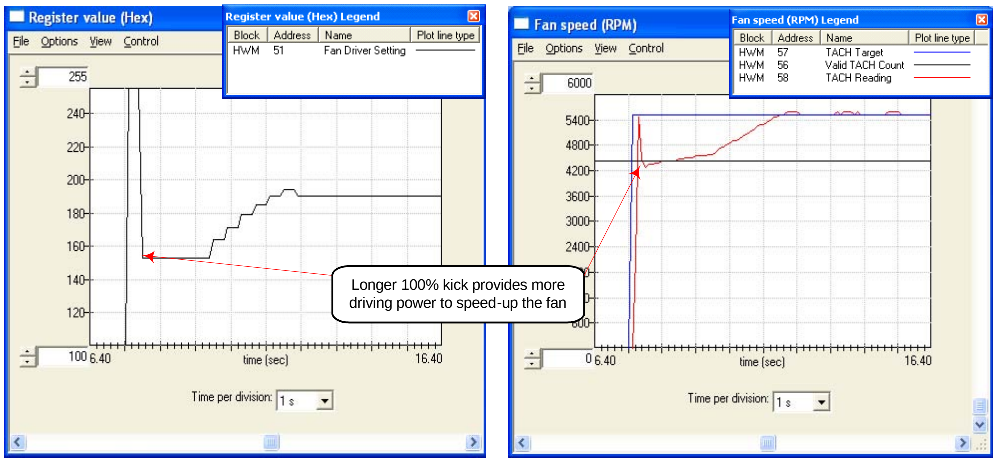
Time per division: 1 s

Figure 5.34 Spin-up Case 5

To fix this problem, stop the fan and set the SPINUP_TIME = 2s, and restart the fan with 5500 rpm.

Increasing Spin-up time will make a longer 100% "kick" time and provide the fan with more power to speed-up (Figure 5.35, "Spin-up Case 5 Fix").

The problem also can be fixed by changing the spin up level from 60% to 75% if not done already, as previously discussed.



Register value (Hex) Legend

Block	Address	Name	Plot line type
HWM	51	Fan Driver Setting	———

Fan speed (RPM) Legend

Block	Address	Name	Plot line type
HWM	57	TACH Target	———
HWM	56	Valid TACH Count	———
HWM	58	TACH Reading	———

Time per division: 1 s

Time per division: 1 s

Longer 100% kick provides more driving power to speed-up the fan

Figure 5.35 Spin-up Case 5 Fix

6 Appendix

6.1 DC Fan Basics - Poles, Tach Meter Pulses and Edges

An n-pole fan has n pairs of North-South magnetic poles which are generated by electromagnet coils. At anytime, only one pair of coils are driven and which coil pair gets driven is determined by a component called Hall Sensor. The architecture of a typical 2-pole DC fan is shown in Figure 6.1, "A Typical 2-pole DC Fan".

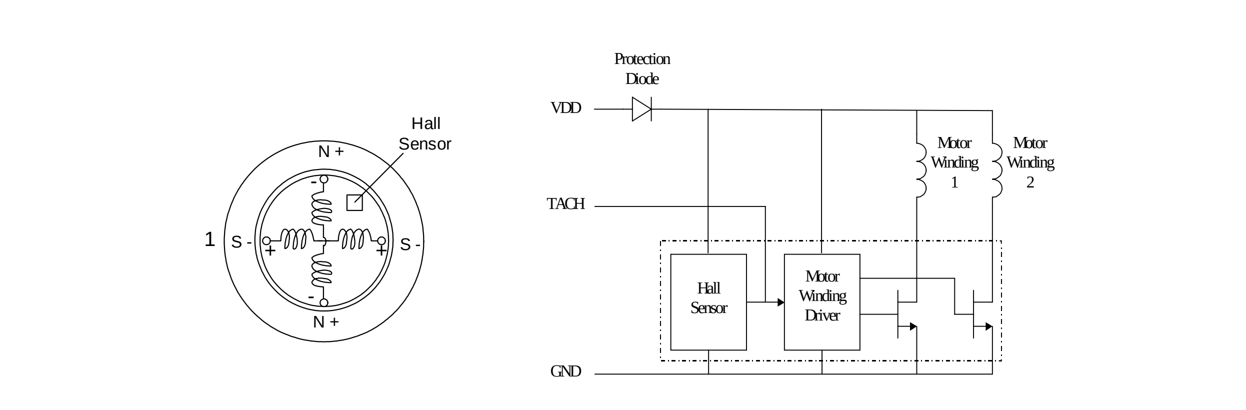


Figure 6.1 A Typical 2-pole DC Fan

The output of the hall sensor is also the TACH (or Tachometer) signal. When the magnetic field around the Hall Sensor changes its direction, the sensor's output level will follow the change to create a square wave signal as shown in Figure 6.2, "Output Signal of a 2-pole Fan".

Assuming 2-pole fan is running at a speed of 6000 RPM, it will rotate 100 revolutions per second. With 2 pulses per revolution, the TACH pulse signal frequency will be 200Hz (Figure 6.2). Since a higher RPM will yield a higher TACH frequency, or a shorter period between pulses, the TACH signal can be used by the EMC devices to determine the speed of the fan. Generally speaking, we have:

TACH Pulse Frequency (in HZ) = (RPM / 60) x (# of Pole)

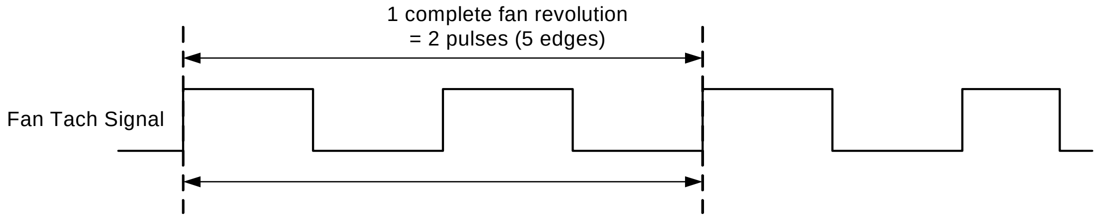


Figure 6.2 Output Signal of a 2-pole Fan

EMC2102 uses a clock (32.768KHz for example) to fill in a window between a programmable number of Tachometer edges. A counter starts on a specific rising edge and keeps counting until it sees the 'set' number of edges, and then saves the counted pulse numbers into register 58h, the TACH Reading register.

Note: Although users can set the number of edges (in register 52h) to either 3, 5, 7 or 9, it is strongly recommended using the default value 5 while driving a 2-pole DC fan. This equal to one complete fan revolution for a 2-pole fan.

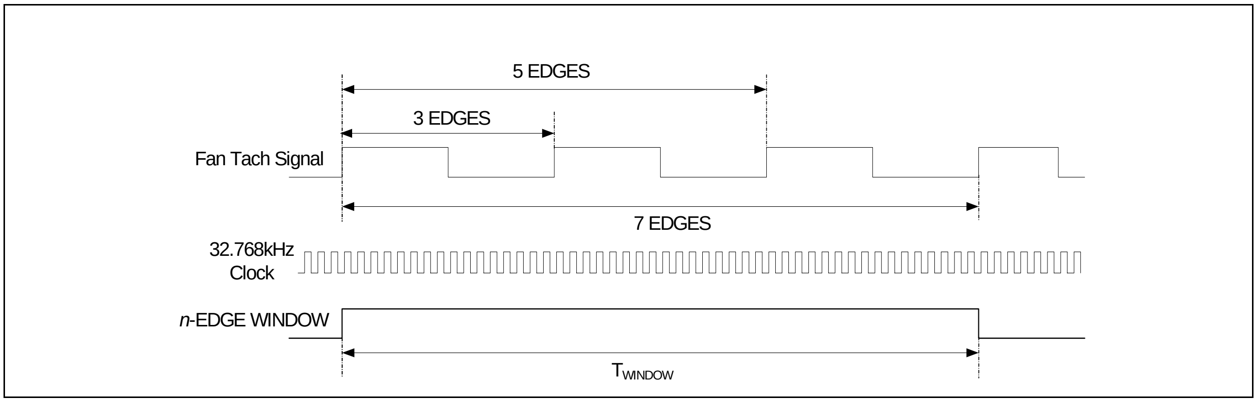


Figure 6.3 Fan TACH Measurement With EMC2102

ChipMan translates TACH counts to the RPM value and displays the fan speed. For applications not using ChipMan software, the following equation can be used to convert the TACH Reading values to the real RPM speeds.

$$RPM = \frac{EDGES - 1}{Poles} * \frac{983040}{COUNT} * m$$

where:

EDGES = number of edges set by register 52h[4:3]

COUNT = TACH Reading (58h) value **[1]**

Poles = number of pole pairs in the DC fan

m = factor defined by LIMIT2K (52h[6])
(m = 1 for 500 rpm and m = 4 for 2000 rpm)

6.2 Characterizing a DC Fan with EVB-EMC2102 and ChipMan

As a very important component in the closed-loop, the DC fan’s characteristics have a great impact on the control system’s performance. Using the EVB-EMC2102 and ChipMan software tool, a 5V DC fan’s characteristics can be easily tested.

In general, the following parameters need to be characterized:

- Minimum Startup Speed
- Stall Speed
- Minimum Valid TACH Speed
- Maximum Fan Speed
- Spin-up Level (i.e., rpm60 and rpm75. Refer to Section 5.3.1, "Fan Control Parameters" for more details)

6.2.1 General Setup

- Setup the system and make sure the hardware and software are working as discussed in Section 5.1, "Experiment 1 - Manual Fan Control".
- Unplug the on-board DC fan from connector P1
- Connect the DC fan to be tested to P1 (refer to EVB-EMC2102 User Manual for the DC fan connector pinouts)

- Verify the device is in Manual Mode (52h[7] = 0)

6.2.2 Set the Correct LIMIT2K Value

- Register 52h (FAN Configuration) bit 6 (LIMIT2K) is a fan dependent parameter as discussed in Section 5.5.2, "Fan Configuration Register (52h)". When reading the TACH Reading register (58h), ChipMan uses the default LIMIT2K value (2000 rpm) to convert it to an rpm speed
- If the RANGE is set to 500 rpm, the TACH Reading value on the ChipMan display should be multiplied by 0.5

6.2.3 Determine the Number of Poles and the Maximum Fan Speed

- Set the device in Manual Mode (52h[7] = 0)
- Start the fan with 100% output drive (register 51h = 255h)
- EMC2102 assumes that it is driving a 2-pole fan by default. If the fan speed in register 58h does not match the fan's maximum speed specified in its datasheet, then it is not a 2-pole fan. The EDGES value in register 52h has to be modified, or all speed readings displayed by ChipMan have to be re-calculated using Equation 1
- The value in 58h also can be compared to the fan's tachometer output frequency obtained by an oscilloscope to verify its correctness
- Record the rpm values in the TACH Reading register (58h) as the maximum fan speed
- The maximum fan speed for the EVB-EMC2102 on-board DC fan is about 7000 rpm

6.2.4 Determine the Minimum Startup Speed

- Set the device in Manual Mode (52h[7] = 0)
- Write a value (for example 80h) to Fan Driver Setting register (51h)
- If the fan cannot start, then increase the drive value until the fan start
- If the fan starts at the first drive value, then stop the fan (51h = 0) and write a smaller value to register 51h
- Repeat the above steps until the minimum startup speed is determined. Record the drive value in 51h and the fan speed in register 58h
- The minimal start speed for the EVB-EMC2102 on-board DC fan is about 4500 rpm with output drive of 9Eh

6.2.5 Determine the Stall Speed

- While the fan is running, reduce the fan drive value in register 51h, step by step, until the fan stops
- Write down the drive value in 51h and the fan speed in register 58h before the fan stops
- The stall speed for the EVB-EMC2102 on-board DC fan is about 3000 rpm (~70h)

6.2.6 Determine the Minimum Valid TACH Speed

- While the fan is running in non-RPM mode, reduce the fan drive value in register 51h, step by step
- Monitor the rpm values in the TACH Reading register (58h)
- Using an oscilloscope to observe the fan's Tachometer signal
- When invalid, the TACH signal will become erratic with incorrect values (usually much less TACH counts or very high rpm) in register 58h
- The TACH signal may be valid until the fan stalls. If it happens, the fan's stall speed could be used as the minimum valid TACH speed

6.2.7 Determine the Spin-up Levels (rpm60 and rpm75)

- Drive the fan with 60% of the maximum output (register 51h = 99h) and the rpm value in the TACH Reading register (58h) will be the fan’s rpm60
- Drive the fan with 75% of the maximum output (register 51h = BFh) and the rpm value in the TACH Reading register (58h) will be the fan’s rpm75

6.2.8 Using the Tested Parameters

All parameters discussed above will vary from fan to fan and with fan aging, therefore some margins have to be added when selecting the fan control settings. A minimum of 10% of full fan speed is recommended for margins.

6.2.8.1 Spin-up LEVEL (Register 53h[2])

This parameter has to be set so that the corresponding fan speed is greater than Minimum Startup Speed + Margin.

6.2.8.2 Minimum Fan Speed

To avoid stalling, the fan speed (a function of Fan Driver Setting [51h] or a function of TACH Target [57h]) needs to be greater than Stall Speed + Margin at all times.

6.2.8.3 Valid TACH Count Speed (Function of Register 56h)

The EMC2102 will not respond to any TACH Target (57h) value that has a corresponding speed slower than Minimum Valid TACH Speed + Margin, unless the value is FFh which will stop the fan. This ensures that the RPM control algorithm will not drive too low.

6.2.8.4 Maximum Fan Speed

Use the measured maximum fan speed minus margin as the Maximum Fan Speed.