A89303 EVALUATION BOARD USER GUIDE

By Allegro MicroSystems

INTRODUCTION

The A89303 integrated circuit (IC) is intended to drive small-form-factor automotive fuel pumps. The IC has 3 A-capable, low total driver on-resistance (low-$R_{DS(ON)}$) power outputs, and a high-power package option (suffix -LP) to drive 12 V fans in the range of 1 W to 15 W. A key feature of the A89303 is ultrafast startup that allows fast build-up of pressure. With a typical motorcycle fuel pump, the A89303 can reach 90% speed in less than 100 ms.

To change IC characteristics to match the application, the A89303 EEPROM must be programmed. A standard inter-integrated circuit (I2C) serial port can be used to program the IC. Because most fans have a four-wire interface (VBB, GND, FG, and PWM), the FG and PWM pins can each be used as I2C control lines, which allows the part to be programmed in the production line, after the motor is built.

A software package is available from Allegro to make it easy to program the A89303. This application note follows the structure of the graphical user interface (GUI) and provides additional details to assist with selection of settings for each tab of the program.

The Allegro A89303 evaluation board is connected to a PC with a standard USB mini cable. The SW1 switch on the evaluation board (EVB) allows the connection to be toggled between the A89303 and an external connector. The external connector can be used to program an IC already installed in a motor module with a four-wire connection.

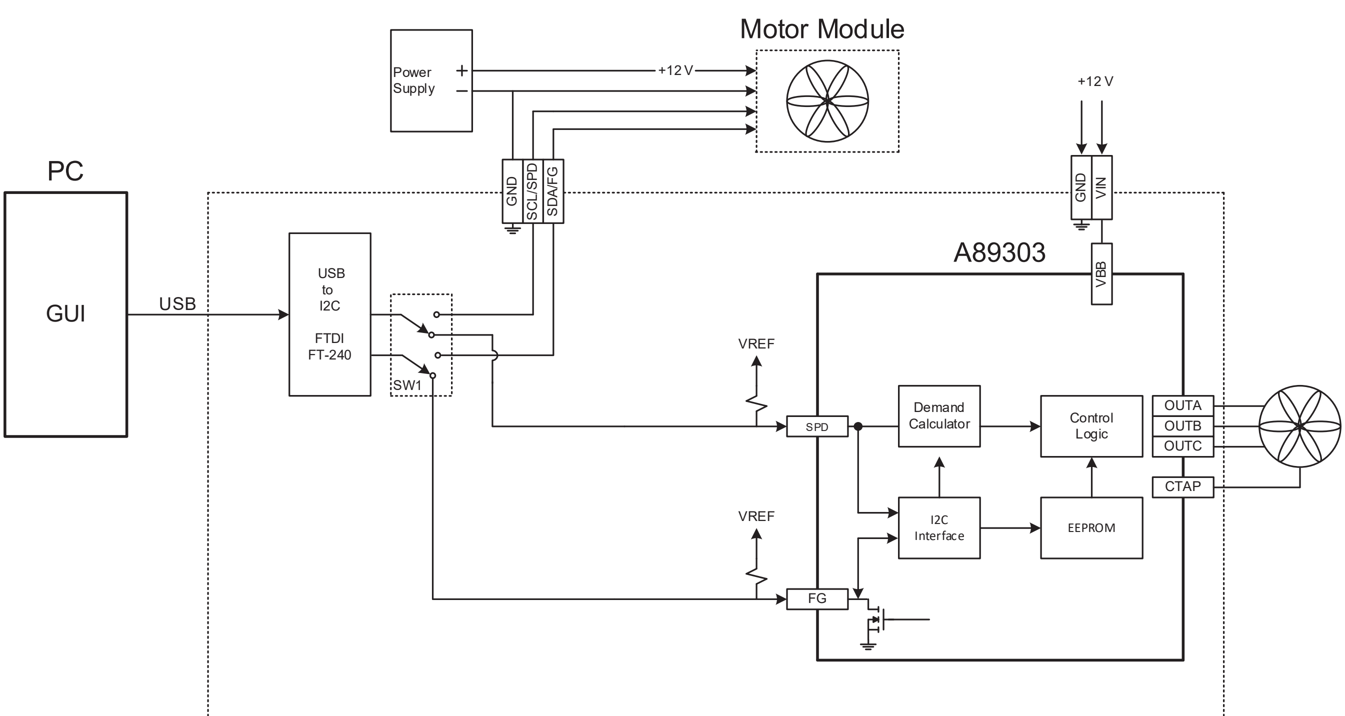

Figure 1: Block Diagram

PROGRAMMING THE IC

When the A89303 powers up, the contents of the EEPROM are loaded into the registers of the IC. These registers are temporary storage locations. When the IC powers down, the registers clear. When a change is made via the GUI, the change remains in effect until the device power reduces to less than the undervoltage low (UVLO) level. To save a particular setting, select "Write all settings to EEPROM". When the IC powers up, to understand the current status, select "Read EEPROM and show settings". Alternatively, a saved program that writes a predefined configuration into the IC can be loaded after powerup.

SETTINGS TAB

The settings tab of the GUI is shown in Figure 2. Details about variable selections follow.

Direction

Motor direction is managed by the sequence of pulse-width modulation (PWM) applied to the windings.

Brake If Moving

When enabled, this feature is used to make the IC check to see if the motor is moving before it attempts to start. If motion is detected, the motor brake (all three low sides on) is applied before the start is attempted. For the fastest startup, disable this function.

IPD

Initial position detection (IPD) determines the rotor position before the startup routine is applied. For a typical small-form-factor pump, use of the IPD feature does not offer a benefit because the feature does not improve startup time. For this reason, test of the startup time with IPD disabled as the default setup is recommended. Due to motor characteristics, it is also possible for the IPD routine to be unable to determine the proper location of the rotor. In that case, after approximately 5 ms, a typical "align mode" is attempted. It is recommended to set the align duration appropriately as a backup startup method. IPD is a two-step method. The first step applies a 50%-duty zero-torque voltage waveform to the windings and determines the location of the rotor to be in one of two positions located 180 degrees apart from each other. The second step applies short current pulses to determine which of the two positions is correct.

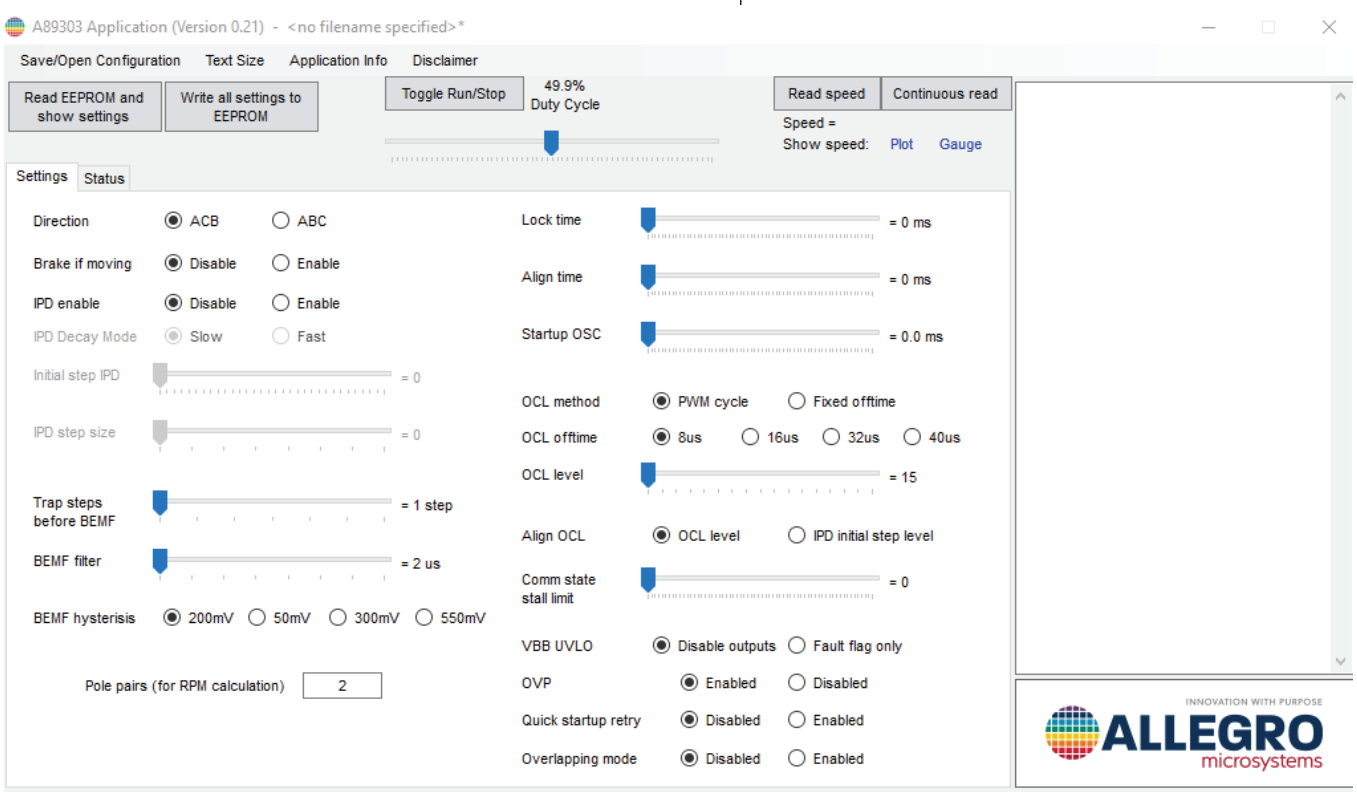

Figure 2: Settings Tab

IPD Enable

This option enables or disables initial position detection (IPD) features.

IPD Decay Mode

During the second stage of IPD, this choice controls how the current decays to zero after the injection pulse. Slow decay mode is recommended.

Initial Step IPD

This selection determines the first current level for the IPD current pulse. The current level is: I_{PULSE} = code × 10 mv/R_{sense}. (If a standard 100 mΩ sense resistor is used, each step is 100 mA.)

IPD Step Size

If the first current pulse does not detect the position of the rotor, additional attempts occur where the current steps up based on the step size selection. The maximum number of pulses is four. For example, if the initial step is 10 and the step size is 3, the current pulses applied are 1 A, 1.3 A, 1.6 A, and 1.9 A.

Trap Steps Before BEMF

The "Trap steps before BEMF" variable defines the number of steps taken before the back-electromagnetic-force (bemf) detection circuitry activates. The duration of the step is defined by the "Startup OSC" variable. The recommended value is 1.

BEMF Hysteresis/BEMF Filter

To determine the position measurement, the sensorless algorithm compares the voltage on the high-Z motor phase to the center-tap (C_{TAP}) voltage. This occurs when the current on the high-Z motor phase is zero.

The bemf hysteresis (BEMFHYS) and bemf time filter (BEMFFILT) are represented in Figure 3. During startup or when the motor drive is disabled, BEMFHYS is enabled. During typical run mode, the BEMFHYS level is set to 0 mV automatically. If a lock-detection issue does not exist, the recommended setting is 200 mV.

BEMFFILT is basically a time filter. When motor PWM is in progress, transients appear on the winding that is open-circuit during the position-measurement window. These transients appear coincident with the edges of the PWM. Proper position measurement requires these transients to be filtered out of the measurement. The 8 µs setting is recommended. Two motors with transients of different durations and recommended settings are shown in the scope plots of Figure 4 and Figure 5.

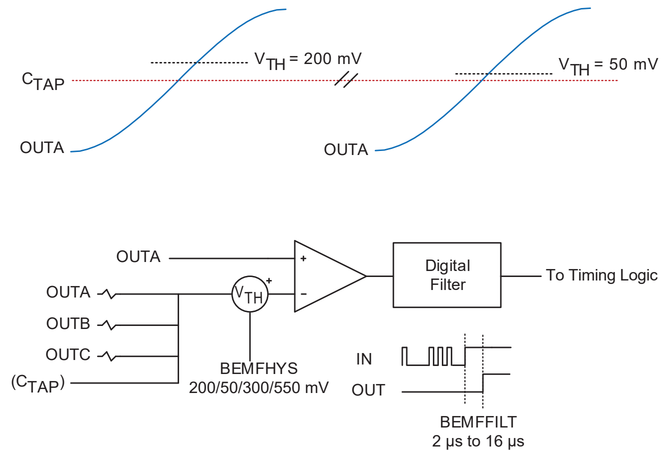

Figure 3: BEMF Hysteresis and BEMF Time Filter

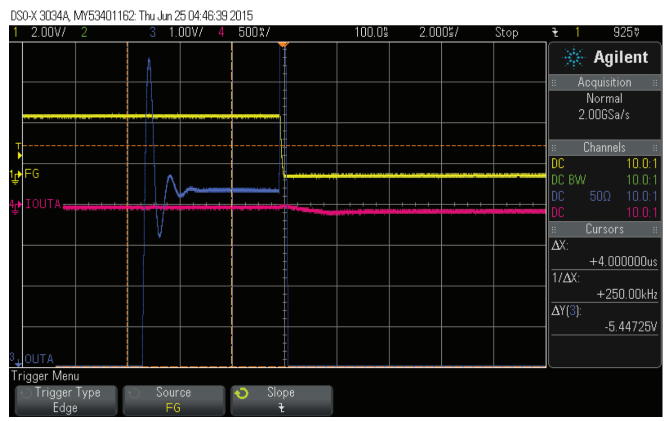

Figure 4: BEMFFILT = 4 µs

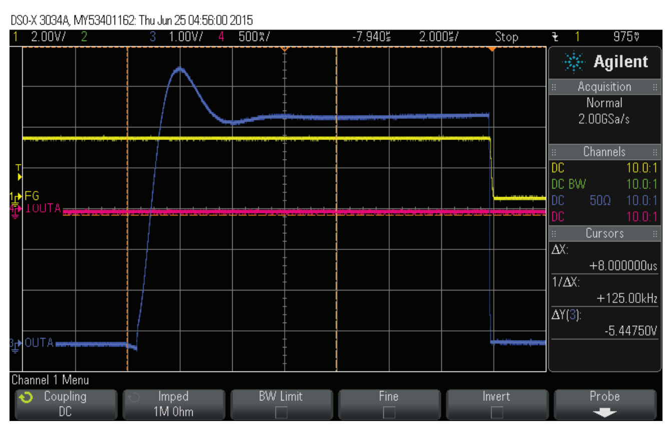

Figure 5: BEMFILT = 8 µs

Lock Time

This variable defines the time the motor is off after a lock-rotor event is detected. After the lock time, a typical restart is attempted.

Align Time

The first step of the startup sequence is to apply torque using state 5 (OUTA high, OUTB low, OUTC high-Z). If the align time is of sufficient duration, application of torque using state 5 moves the rotor to a known position. For a low-inertial motor-like pump, it is not necessary to wait for the rotor to settle into this known position. For the fastest startup, set this to a low value. The default setting is 2 ms.

Startup OSC

This variable defines the commutation time for the initial steps after the align stage. In addition, after bemf detection is enabled, the startup oscillator (OSC) time is used as the maximum limit of the commutation state. This means that, if bemf is not properly detected, the sequencer advances to the next state after the startup OSC time expires.

OCL Method

The overcurrent limit (OCL) function has two options:

- Fixed Off Time: After the current limit is reached, the appropriate driver turns off for the duration defined by the "OCL Off Time" variable.
- PWM Cycle: After the current limit is reached, the driver turns off for the remaining portion of the PWM cycle. The PWM period is fixed at 40 µs (25 kHz PWM).

OCL Off Time

If fixed off time is the chosen OCL method, four different off-time options are provided: 8, 16, 32, and 40 µs.

OCL Level

Sets the level of the overcurrent limit for startup control. To limit the current, the voltage on the sense resistor can be adjusted in 10 mV increments as:

$$I_{OCL} = (\text{code} \times 10\ \text{mV})/R_{SENSE}.$$

Ensure the sense resistor and the selected OCL level do not exceed the maximum rating of the IC (3.6 A).

Align OCL

The level of the align OCL feature is configurable via the "Initial Step IPD" variable. For applications that typically exhibit long-duration alignment times, this feature has the potential to quicken the time it takes for the rotor to settle into position. After alignment completes, the typical OCL level is used. For a typical low-inertia fuel-pump motor, use of the "OCL level" variable is recommended.

Comm State Stall Limit

This variable defines how many commutation (comm) states occur before the lock-detection logic is checked. The lock-detection logic checks for valid bemf crossings: For a valid bemf crossing, the counter increments; for an invalid bemf crossing, the counter decrements. In this way, the logic determines if the rotor is locked, and shutdown can occur to avoid overstress of the motor. The recommended value for this variable is 63.

VBB UVLO

This variable changes the behavior when a load-supply operating-range undervoltage-threshold (V_{BBUVLO}) event occurs:

- If "Disable outputs" is chosen, the fault flag is signaled, and the outputs are disabled.
- If "Fault Flag Only" is chosen, the outputs are not disabled, and the fault is flagged.
  - When both V_{BB} decreases and a charge-pump undervoltage is detected, motor outputs are disabled.

A charge-pump undervoltage occurs when V_{BB} is in the range of 3.9 V. Because the V_{BB} undervoltage falling threshold is nominally 4.25 V, approximately 350 mV of extra margin is available for low-V_{BB} conditions.

OVP (V_{BB} Overvoltage Level)

If this overvoltage protection (OVP) function is enabled when V_{BB} exceeds the V_{BBOV} threshold level, the motor coasts. After V_{BB} reduces to less than the hysteresis level, a typical restart occurs.

Quick Startup Retry

Typically, when a lock condition is detected, the motor shuts off for the programmed lock time. The quick-start option ignores the lock timer and attempts a restart immediately. If the following restart is also not successful, the typical lock time is used.

Overlapping Mode

During typical operation of the trapezoidal drive at the end of the commutation state, one output turns off and the output that was in the high-Z state turns on at the same time. For the overlapping mode, a delay occurs before turn-on of the high-Z output. For some motor applications, this can improve efficiency. For other motor applications, the effect is negligible. The amount of overlap is the width of the previous recirculation pulse.

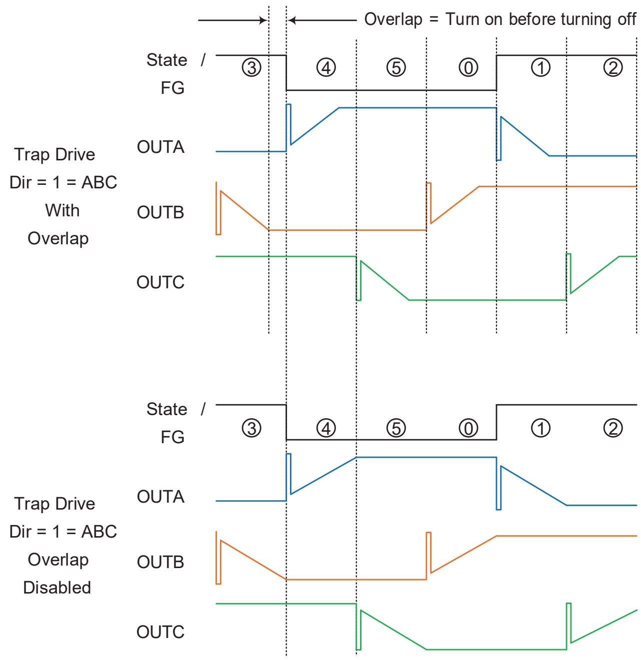

Figure 6: Overlapping Mode

Phase Advance

To optimize efficiency, the running algorithm uses an adaptive phase-advance method. For each commutation state, the timing for the recirculation pulse is measured. In this manner, as current and speed increase, the amount of phase advance increases. Using this measurement, the time delay (t_{PHA}) from the bemf zero-crossing to the next commutation is:

$$t_{PHA} = t_{COMM}/2 - t_{RECIRC}$$

where t_{RECIRC} is the measured time for recirculation.

Startup

Startup variables are selected via the settings tab of the GUI as described previously. The startup has three distinct areas of operation, as shown in Figure 7:

1. Initialize (Align)
2. Open Loop
3. Run

The programmed current, I_{OCL}, is used to start the motor. As motor speed increases, the running current of the motor decreases. The amount of time the motor runs at the maximum current level is dependent on V_{BB}, motor load, and motor characteristic.

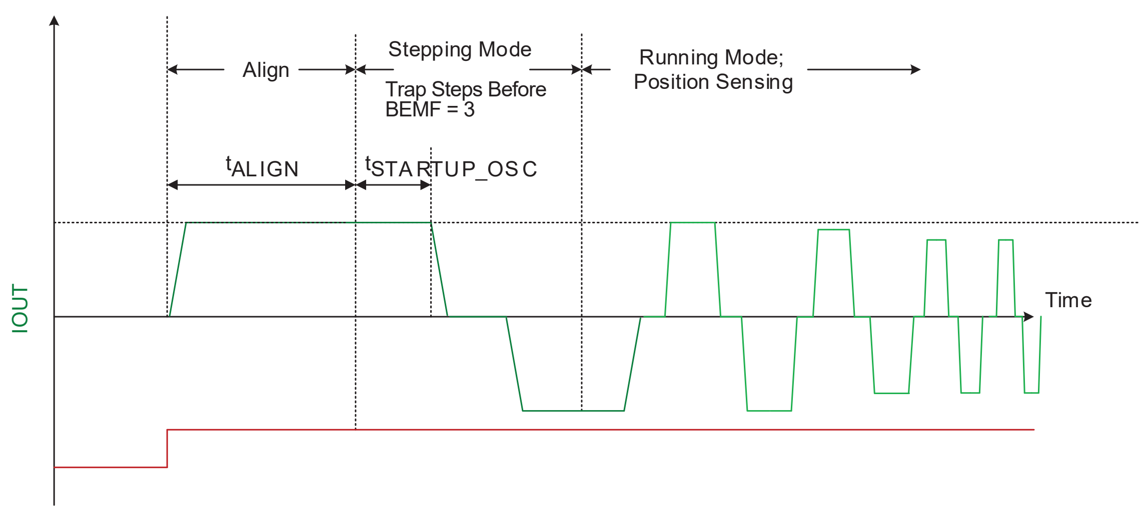

Figure 7: Startup

STATUS TAB

The status tab is shown in Figure 8. Details about variable selections follow.

Fault Readback

Faults are stored in register locations. For debug purposes, faults are accessible via the I2C serial port. If the fault is latched, the "Clear faults" button must be used to reset the fault register.

FF1/FF2 Output

When GUI mode is used, the FG signal can be routed to the FF1 pin for debug purposes.

Serial Port Mode

Typically, the IC is controlled by duty cycle. However, it is possible to use direct serial-port control instead of EEPROM programming.

When direct control is used, the input duty cycle command is replaced by writing a 9-bit number to register address (REGADDR) 165. For example:

REGADDR[data]: (in decimal)

165[511] → Duty = 100%

165[102] → Duty = 102/511 = 20%

Upon powerup, the IC defaults to duty-cycle input mode. To use serial port mode, the internal registers should be programmed before powerup of the part.

The sequence to use serial port mode is:

1. Drive the FG and PWM pins low.
   NOTE: If SPD is not driven low before powerup, the motor attempts to start immediately because the default high value to the PWM pin demands 100% of the on signal.
2. Perform an IC powerup.
3. (Optional) If the default settings are not acceptable, program the registers with the parameter settings that correspond to each of the EEPROM memory locations:
   A. REGADDR = 64 + EEPROM ADDR.
   B. Program register addresses 73 to 78 corresponding to EEPROM addresses 9 to 14.

   NOTE: It may be helpful to use the GUI text file to help define the hexadecimal data for each of the EEPROM addresses.
4. To start the motor at 100% demand, write the value 511 to register 165.

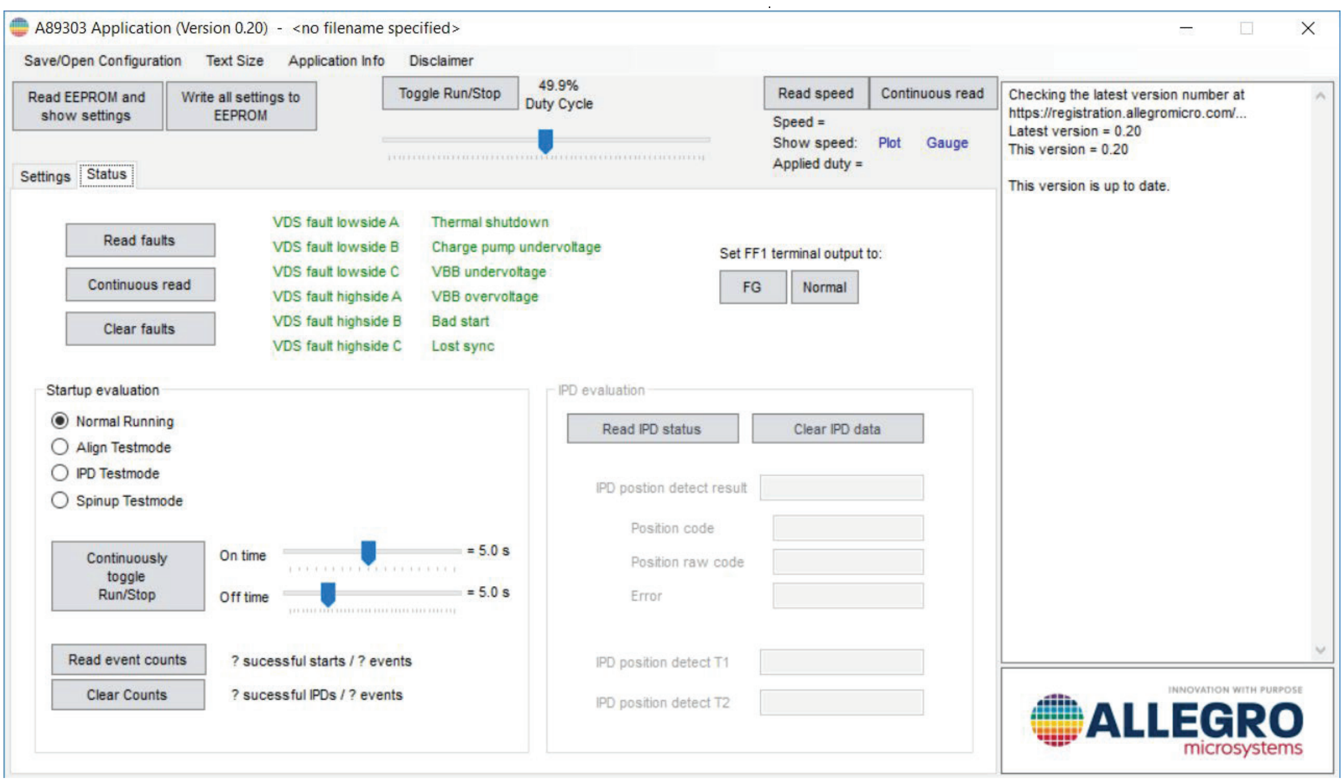

Figure 8: Status Tab

OTHER I2C REGISTERS

REG	Bits		Function	Description
165	[8:0]	r/w	Speed demand input	Duty (%) = code/511
80	[5:0]	w	I2C exit	To change operation from I2C mode back to PWM pin control, set bit 5 to the value 1
141	[15:0]	r	Electrical period time	Time in microseconds can be read back
144	[15:0]	r/w	Number of startup failures	Cleared by writing zero or powerup
145	[15:0]	r/w	Number of startup attempts	Cleared by writing zero or powerup
147	[9:0]	r	Fault status (1 indicates fault)	0 = VBBOV 1 = VBBUV 2 = VCPUV 3 = TSD 4 = OCPHSA 5 = OCPHSB 6 = OCPHSC 7 = OCPLSA 8 = OCPLSB 9 = OCPLSC

EEPROM MAP

For additional details, refer to the datasheet for EEPROM programming and the I2C interface.

I2C Register	EEPROM Address	Bits	Name	Description	Default Setting
64	0	15:0	DEV1	Allegro Reserved	–
65	1	15:0	DEV1	Allegro Reserved	–
66	2	15:0	DEV1	Allegro Reserved	–
67	3	15:0	DEV1	Allegro Reserved	–
68	4	15:0	DEV1	Allegro Reserved	–
69	5	15:0	DEV1	Allegro Reserved	–
70	6	15:0	DEV1	Allegro Reserved	–
71	7	15:0	TRIM1	Allegro Reserved	–
72	8	15:0	TRIM2	Allegro Reserved	–
73	9	0	UVMASK	0 = Typical, 1 = Mask	0x005C
		1	OVPDIS	1 = Typical, 1 = Disable	
		2	RETRY	0 = Disable, 1 = Enable	
		3	OVERLAP	0 = Disable, 1 = Enable	
		4	DEV2	Allegro Reserved—Set to 1	
		6:5	DEV2	Allegro Reserved—Set to 0	
74	10	0	DIR	0 = ACB, 1 = ABC	0x480C
		1	FGSTRT	0 = Disable, 1 = Enable	
		4:2	BEMFILT	Select BEMF Filter	
		6:5	BEMFHYS	Select BEMF Hysteresis	
		7	WIND	0 = Disable, 1 = Enable	
		8	IPDENB	0 = Disable, 1 = Enable	
		9	IPDDECAY	0 = Slow, 1 = Fast	
		10	DEV2	Allegro Reserved—Set to 0	
		13:11	STEPS	Select Trap Steps Before BEMF Detection	
75	11	5:0	ALIGN	Align Time	0x0001
76	12	5:0	LOCK	Lock Time	0x002A
77	13	1:0	TOFF	Fixed Off-Time Current Limit	0cFC4B
		7:2	OSC	Startup OSC	
		9:8	UNUSED	–	
		15:10	COMST	Commutation-State Stall Limit	
78	14	4:0	IPDINI	IPD Start Level	0x148D
		7:5	IPDSTEP	Select IPD Steps	
		12:8	OCL	Select Current Limit	
79	15	15:0	TRIM2	Allegro Reserved	–

Revision History

Number	Date	Description	Responsibility
–	January 10, 2025	Initial release	A. Berrera