

A89332, A89332-1 Evaluation Board User Manual**INTRODUCTION**

The A89332 and A89332-1 are gate drive integrated circuits (ICs) with functions very similar to the Allegro A89331 and A89331-1, which have integrated source and sink drivers. N-channel MOSFETs up to 30 A can be used. Closed-loop speed control with flexible speed curve configuration is also included, which eliminates the cost of using a microcontroller unit (MCU) for most applications.

The A89332 and A89332-1 have functions similar to previous-generation Allegro ICs A5931 and A5932. The following features were added:

- Power loss brake: Stops the fan when power is removed (89332 only).
- No power brake: Reduces the speed at which an unpowered or faulted fan can rotate when an external force is applied.
- Enhanced windmill: Allows improved resynchronization or restart from reverse motion.
- FCOL: Provides 32 bytes of user memory.
- AC loss: Provides a special function when power is briefly interrupted (89332-1 only)

TABLE OF CONTENTS

Introduction.....	1	Speed-Loop Minimum Duty.....	17
Programming the IC.....	2	Auto-Phase Start of Window.....	17
Speed Curve.....	2	Run Mode.....	17
Open Loop.....	3	Sine/Trap Threshold.....	17
Closed Loop.....	4	Gate Drive (Source/Sink).....	17
Supported Curves.....	4	Dead Time.....	17
Other Curves.....	8	Config 3.....	18
Brake if OFF.....	11	Maximum Electrical Frequency (Lock-Detect Level).....	18
Coast Time.....	11	OCP.....	18
Open-Loop Speed Limit.....	11	Coast Time.....	18
DC Disable Threshold.....	11	PWM Input Frequency.....	18
Direction.....	11	FG Mask.....	18
Maximum Electrical Frequency (Lock-Detect Level).....	11	Set I ² C Clock to PWM or Brake.....	19
Config 1.....	12	FCOL.....	19
FG/RD.....	12	Startup.....	20
FG at Start.....	12	Introduction.....	20
Pole Pairs.....	13	Step 1: Initialize.....	20
Quick Start.....	13	Recommendations:.....	22
BEMF Hysteresis/BEMF Filter.....	13	Step 2: Accelerate.....	23
BEMF Filter Range.....	13	Recommendations.....	24
RD Fault Option.....	14	Step 3: Ramp to Target Speed Control Variables.....	25
Clear RD.....	14	Coasting.....	25
VBB Overvoltage Level.....	14	Status Tab.....	26
Speed Pi Output Range.....	14	Fault Readback.....	26
Speed Feedback Clamp.....	14	nFAULT Terminal Output.....	26
Forced Open-Loop Applied Duty.....	14	Die Temperature.....	26
Config 2.....	15	Power Loss Brake (89332 Version Only).....	26
Post-Coast Delay.....	15	No Power Brake (89332 Version Only).....	26
PWM Frequency.....	15	Braking Characteristics.....	27
Temperature Compensation.....	16	EEPROM MAP.....	30
Windmill Options.....	16	Evaluation Board Schematic.....	33
Reverse Align Demand.....	16	Evaluation Board Bill of Materials.....	34
Speed Loop Kp/Ki.....	16	Evaluation Board Layout.....	36
Closed Loop at 25%.....	17	Layout Guide with Reference to Application Information in the Datasheet.....	37
OCL Level/OCL Enable.....	17		

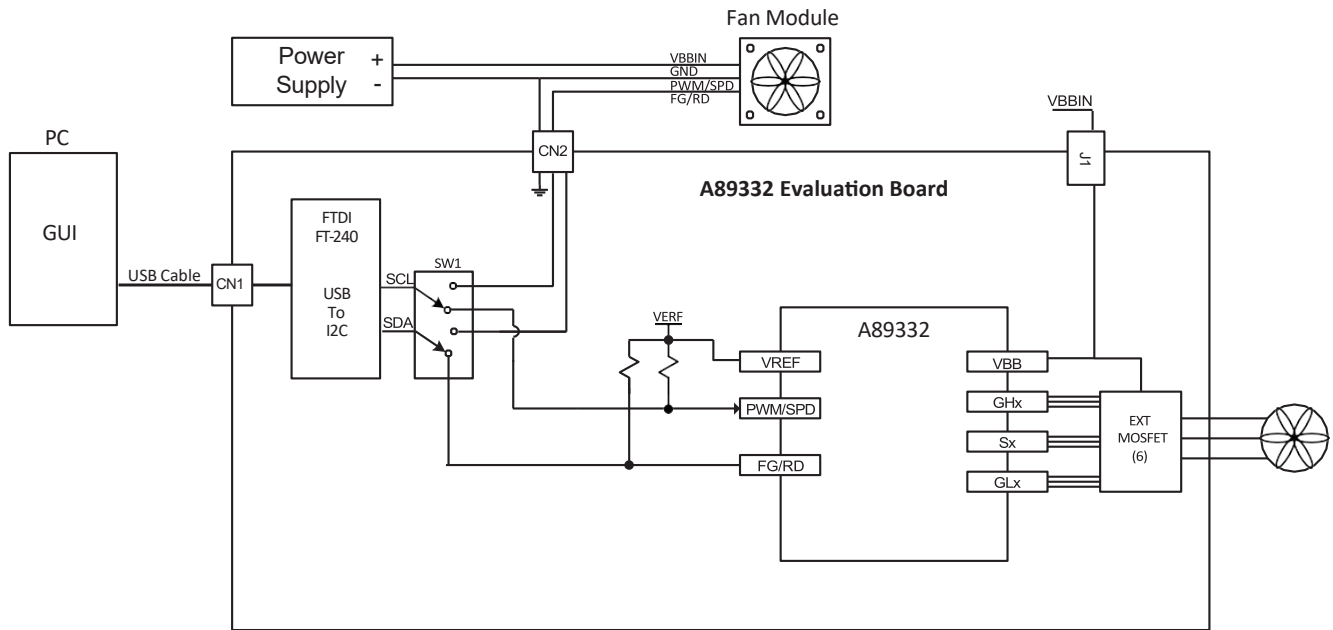


Figure 1: Application Diagram

Programming of the EEPROM is required to change IC characteristics to match the application. A standard inter-integrated circuit (I²C) serial port can be used to program the integrated circuit (IC). Because most fans have four-wire interfaces (VBB, GND, FG, and PWM), it is possible to program the part in the production line after the motor is built by using FG and PWM as the two I²C control lines.

The EEPROM included in the IC provides several functions:

- Ability to choose between open-loop and closed-loop operation and to set a specific desired speed-curve configuration.
- Ability to customize the startup profile to better match the motor and load pair.
- Ability to choose various device options that change the functional operation.

Allegro provides a software package to make it easy to program the A89332. This application note generally follows the structure of the graphical user interface (GUI) and provides additional details to assist with settings for each tab of the GUI program.

The Allegro A89332 evaluation board is connected to a PC with standard USB mini cable. A switch (SW1) on the evaluation

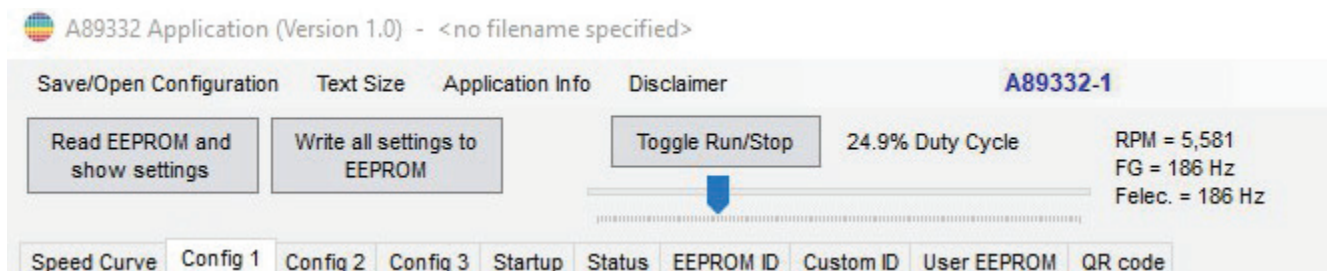
board (EVB) is used to toggle between connection to the A89332 or to an external connector. The external connector can be used to program an IC already installed into a motor module using a four-wire connection.

PROGRAMMING THE IC

When the A89332 powers up, the contents of the EEPROM are loaded into registers of the IC. The registers are temporary storage locations and are cleared when the IC powers down. When changes are made with the GUI, the changes remain in effect until the device powers down to less than the UVLO level. To save a particular setting, select “Write all Settings to EEPROM”. To determine the current status of the IC, when the IC is powered up, select “Read EEPROM and show settings”. Alternatively, after power up, a saved program can be loaded to write a pre-defined configuration into the IC.

Speed Curve

The speed curve tab is used to configure the relationship of the input duty cycle (or voltage in analog mode) to the voltage applied to the motor.



Open Loop

In open-loop mode, the speed input duty cycle is measured and the applied voltage to the windings is approximately $V_{EFF} = V_{BB} \times \text{Duty}$, as represented in Figure 3.

In closed-loop mode, the duty applied to the motor windings is adjusted to meet the speed for which the IC is configured. If V_{BB} reduces, the output PWM duty increases so that the programmed speed is maintained.

In open-loop mode, the options for speed-curve configuration are limited (shown in Figure 3). For open-loop mode, typically the speed-output signal, FG, is monitored by the system controller and the PWM duty can be used to “close” the loop and achieve the desired speed.

When selecting the closed-loop speed parameters, it is important to consider the limitations based on the open-loop curve. A89332 is a sensorless controller. Sensorless-type circuits depend on the back electromagnetic force (bemf) voltage of the motor to determine rotor position. Bemf is proportional to speed; therefore,

when the motor is stopped, bemf is zero. The minimum duty that can support the minimum speed depends on motor characteristics and is typically in the 3% to 15% range. The maximum open-loop speed should also be considered before setting the closed-loop curve. The power-supply voltage and load/airflow significantly impact the maximum open-loop speed. To study open-loop operation, set the closed-loop bit (CL) to zero.

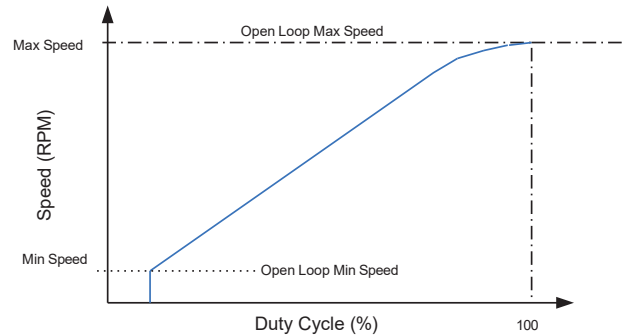


Figure 2: Example Open-Loop Curve



Figure 3: Open-Loop Operation

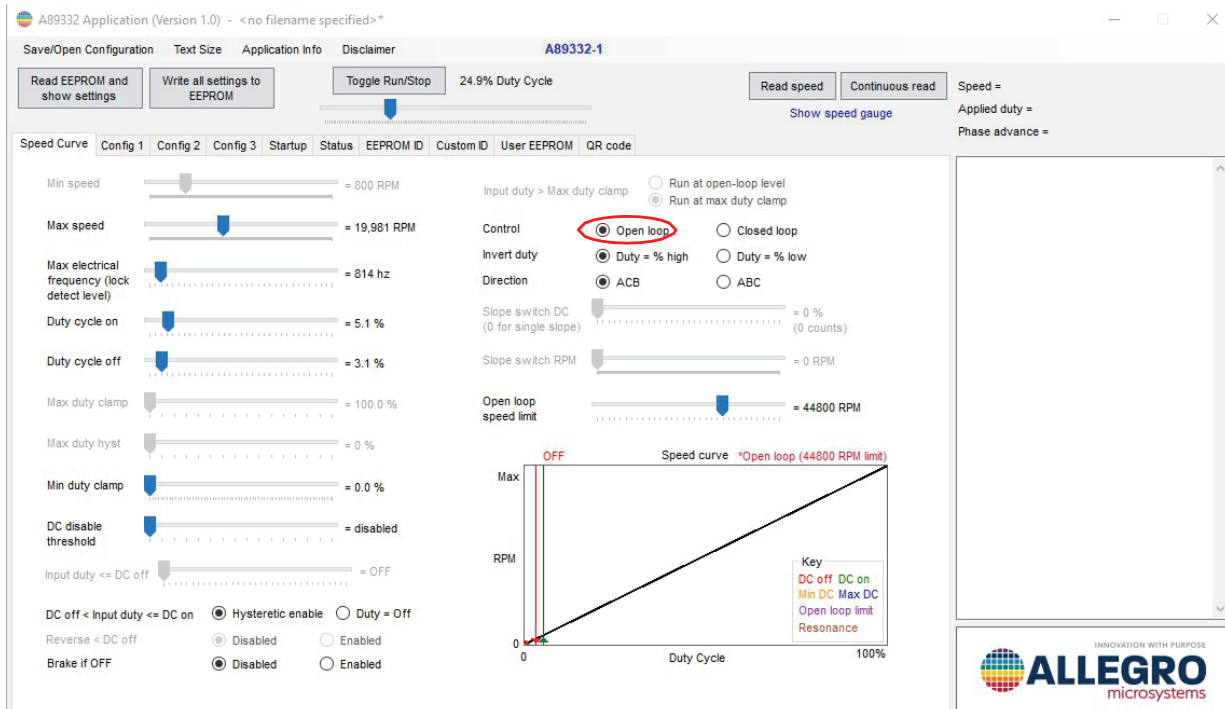


Figure 4: Screen Capture of Open-Loop Mode

Closed Loop

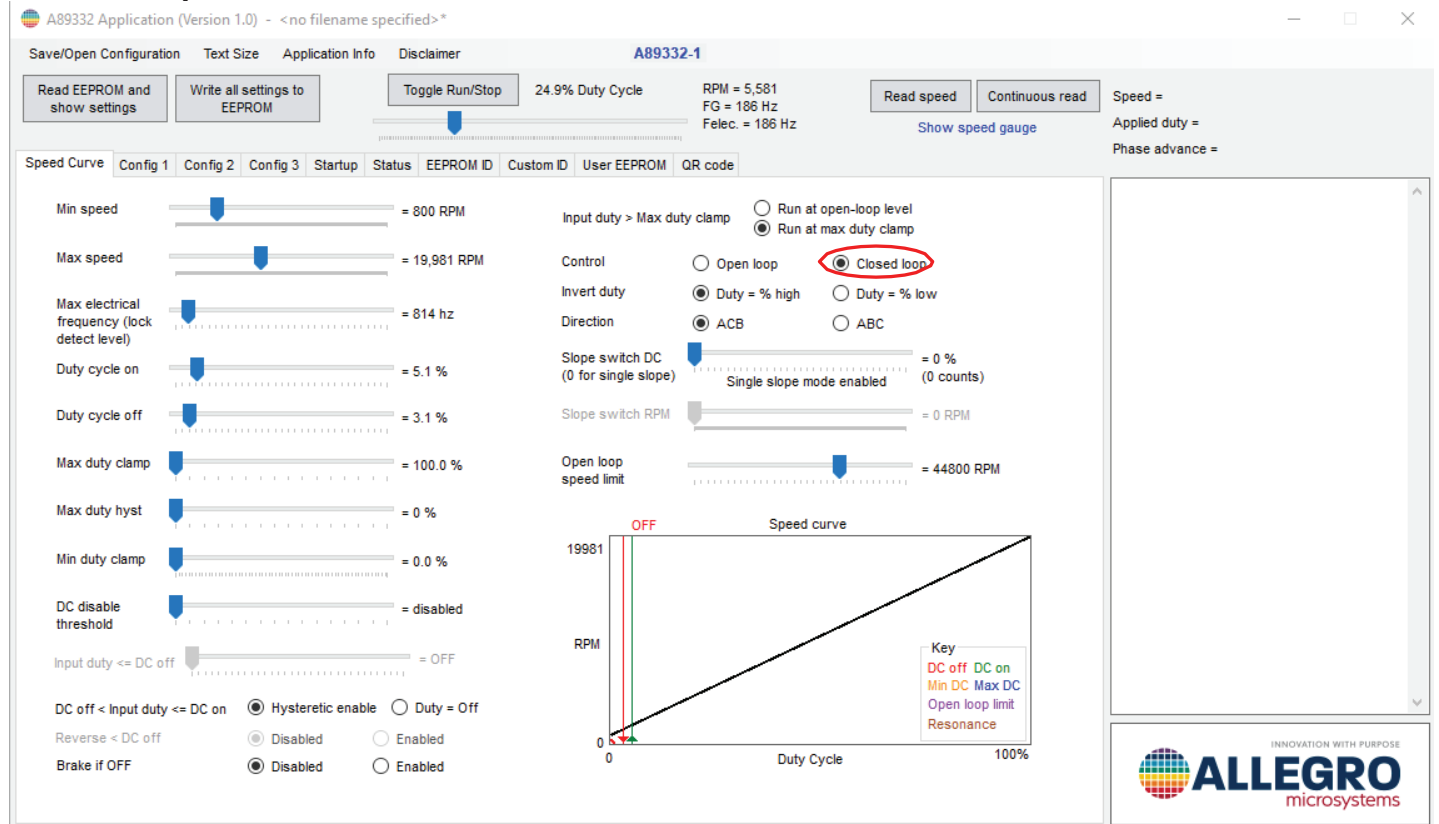
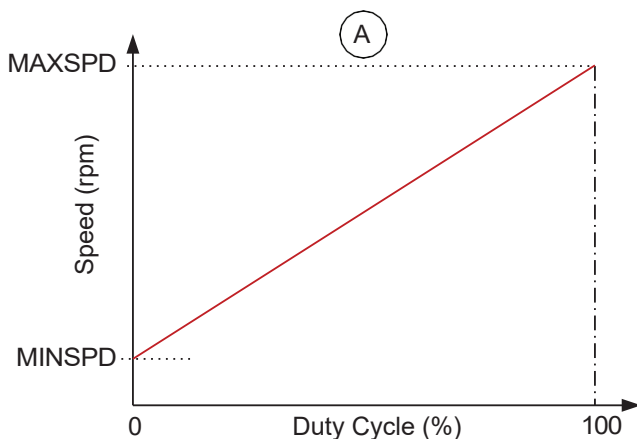


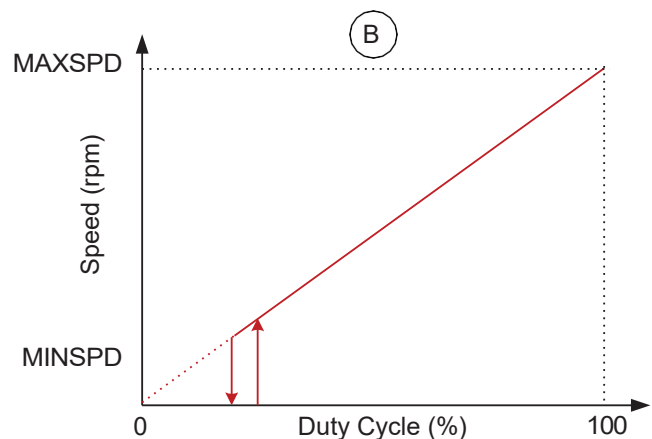
Figure 5: Screen Capture of Closed-Loop Mode

Supported Curves

NOTE: Inverted duty can be used on any curve to produce a mirror image. Other combinations are possible. Curves A through M in this section are intended to demonstrate the variables that can be changed.

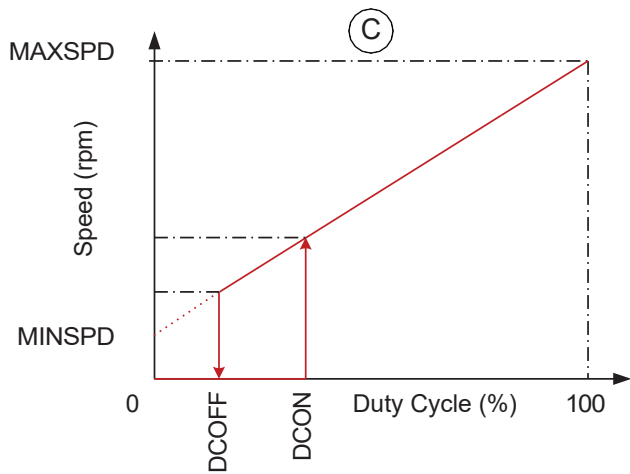


- 1) Select Slope by MAXSPD and MINSPD
- $$\text{Speed} = \text{Duty} \times (\text{MAXSPD} - \text{MINSPD}) + \text{MINSPD}$$



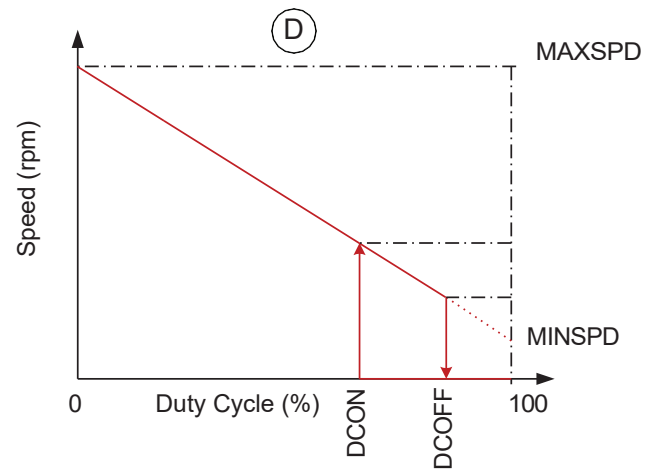
- 1) Select Slope by Max Speed and MINSPD = 0
 - 2) Select DCON and DCOFF
 - 3) Note: DCOFF must be greater than minimum open loop speed under any application condition
- $$\text{Speed} = \text{Duty} \times (\text{MAXSPD})$$

Supported Curves (continued)



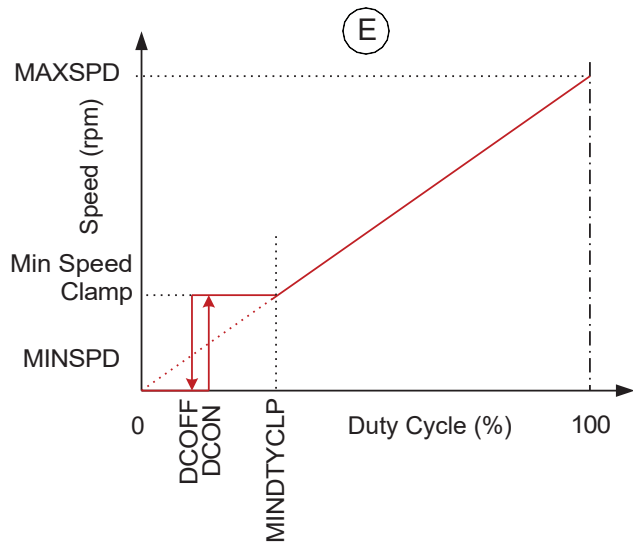
- 1) Select Slope by MAXSPD and MINSPD
- 2) Select DCON and DCOFF

$$\text{Speed} = (1 - \text{Duty}) \times (\text{MAXSPD} - \text{MINSPD}) + \text{MINSPD}$$



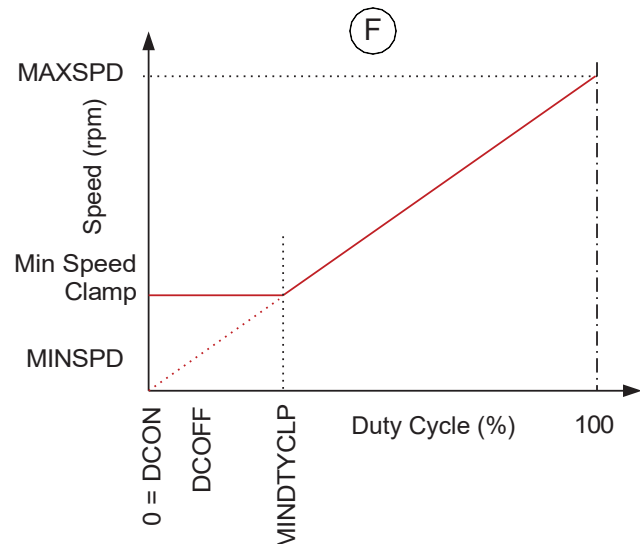
- 1) Select Slope by Min Speed and Max Speed
- 2) Select DCON and DCOFF
- 3) Set Invert Duty Bit

$$\text{Speed} = (1 - \text{Duty}) \times (\text{MAXSPD} - \text{MINSPD}) + \text{MINSPD}$$



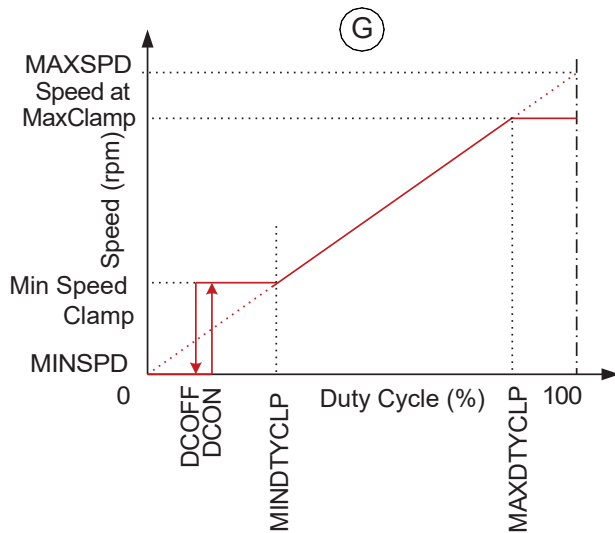
- 1) Select Slope by MAXSPD and MINSPD = 0
- 2) Select DCON and DCOFF
- 3) Select Min Duty Clamp → MINDTYCLP

$$\text{Min Speed @Clamp} = \text{MINDTYCLP} \times (\text{MAXSPD})$$



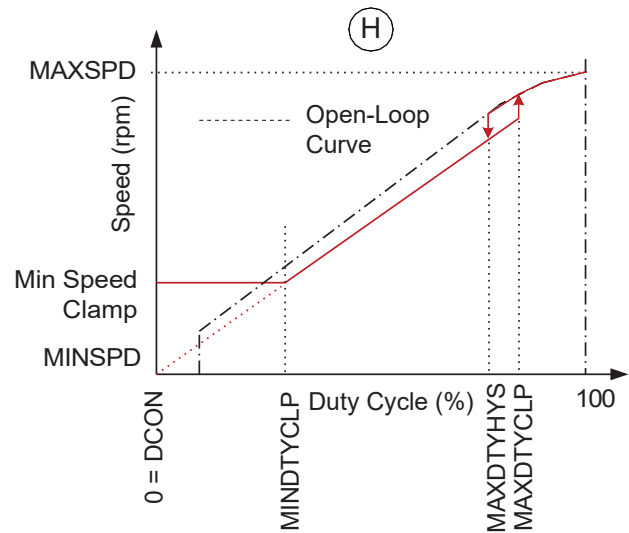
- 1) Select Slope by MAXSPD and MINSPD = 0
- 2) Select DCON = 0%
- 3) Select Min Duty Clamp → MINDTYCLP

Supported Curves (continued)



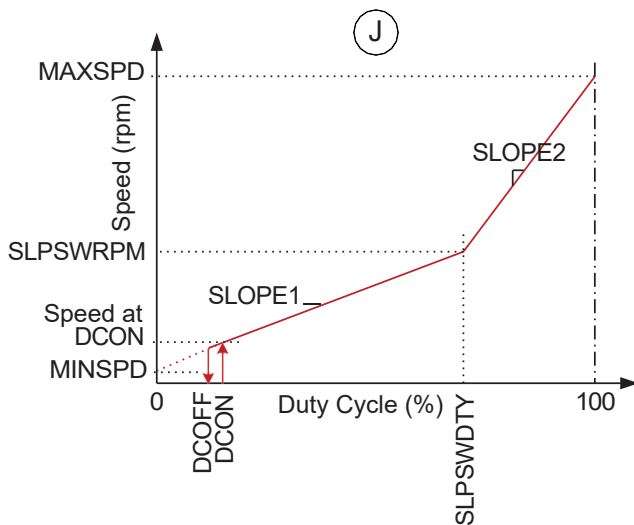
- 1) Select Slope by MAXSPD and MINSPD=0
- 2) Select DCON & DCOFF
- 3) Select Min Duty Clamp → MINDTYCLP
- 4) Set MAXDTYCLP
- 5) Select "Run At Max Duty Clamp"

Speed at Max Clamp – MAXDTYCLP × (MAXSP4)



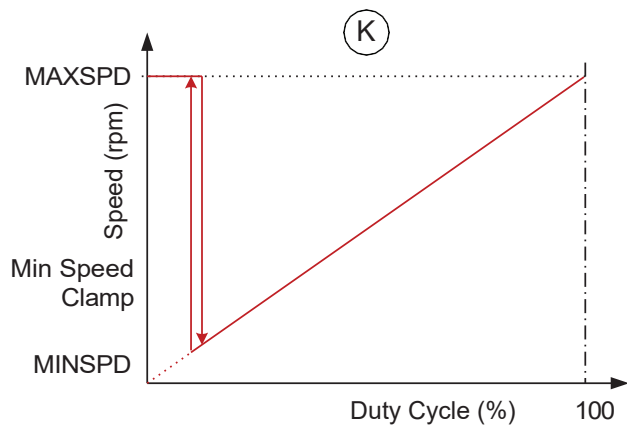
- 1) Select Slope by MAXSPD and MINSPD=0
- 2) Select DCON = 0%
- 3) Select Min Duty Clamp → MINDTYCLP
- 4) Set MAXDTYCLP & MAXDTYHYS
- 5) For MAXOFF, select "Run at Open Loop Level"

NOTE: Max Speed should be set close to open-loop maximum speed to minimize transients when switching from open to closed loop operation



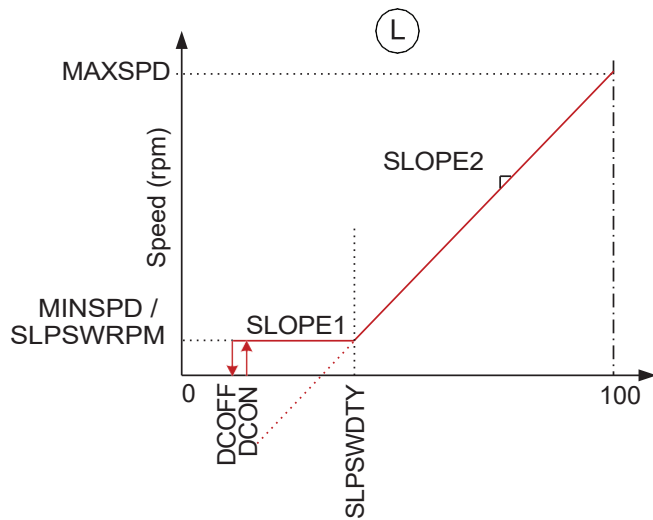
- 1) Set DCON and DCOFF
- 2) Set Slope2 by MAXSPD, SLPSWDY, and SLPSWRPM
- 3) Set Slope1 by adjusting MINSPD so that speed at DCON achieves target

Speed@DCON =
 $\{DCON \times (SLPSWRPM - MINSPD) / SLPSWDY + MINSPD\}$



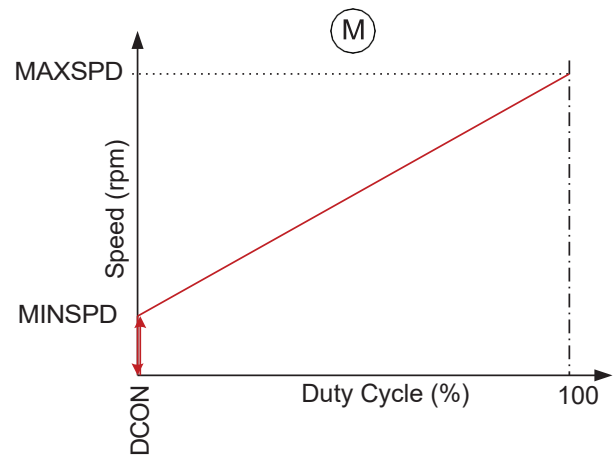
- 1) Select Slope by MAXSPD and MINSPD = 0
- 2) Select DCON and DCOFF
- 3) Set MAXOFF to "Duty = Max"

Supported Curves (continued)



- A) Set DCON and DCOFF
- B) Set Slope2 by MAXSPD, SLPSWDTY, and SLPSWRPM
- C) Set Slope1 by adjusting MINSPD equal to SLPSWRPM

NOTE: The curve appearance is similar to curve E. The difference is that SLOPE2 allows a Y-intercept to be less than zero. The SLOPE1 minimum Y-intercept cannot be less than zero.



- A) Select Slope by MAXSPD and MINSPD
- B) Select DCON to min value near zero (0.2%)
- C) Set DCOFF to zero

Other Curves

REVERSE WITH INPUT DUTY < DCOFF

This curve can be implemented as a fan-cleaning function by pulling air out rather than pulling air in. To set the speed when reverse operation occurs, adjust the variable MAXDTYOFF via the slider in the GUI.

A89332 Application (Version 1.0) - <no filename specified>*

Save/Open Configuration Text Size Application Info Disclaimer A89332-1

Read EEPROM and show settings Write all settings to EEPROM Toggle Run/Stop 2.4% Duty Cycle RPM = 5,592 FG = 186 Hz Felec. = 186 Hz Read speed Continuous read Speed = Applied duty = Phase advance =

Speed Curve Config 1 Config 2 Config 3 Startup Status EEPROM ID Custom ID User EEPROM QR code

Min speed = 800 RPM

Max speed = 19,981 RPM

Max electrical frequency (lock detect level) = 814 hz

Duty cycle on = 11.5 %

Duty cycle off = 4.5 %

Max duty clamp = 100.0 %

Max duty hyst = 0 %

Min duty clamp = 0.0 %

DC disable threshold = disabled

Input duty <= DC off = 28.0 % (285 counts)

DC off < Input duty <= DC on ☐ Hysteretic enable ☒ Duty = Off

Reverse < DC off ☐ Disabled ☒ Enabled

Brake if OFF ☒ Disabled ☐ Enabled

Input duty > Max duty clamp ☐ Run at open-loop level ☒ Run at max duty clamp

Control ☐ Open loop ☒ Closed loop

Invert duty ☒ Duty = % high ☐ Duty = % low

Direction ☒ ACB ☐ ABC

Slope switch DC (0 for single slope) = 0 % (0 counts) Single slope mode enabled

Slope switch RPM = 0 RPM

Open loop speed limit = 44800 RPM

DC = 28%, REVERSE Speed curve

RPM

Duty Cycle

Key

- DC off
- DC on
- Min DC
- Max DC
- Open loop limit
- Resonance

Setting PWM reg to 10.0% Wrote to 165 : 0x0066 (102)

Setting PWM reg to 9.1% Wrote to 165 : 0x005D (93)

Setting PWM reg to 8.7% Wrote to 165 : 0x0059 (89)

Setting PWM reg to 6.3% Wrote to 165 : 0x0040 (64)

Setting PWM reg to 5.0% Wrote to 165 : 0x0033 (51)

Setting PWM reg to 3.7% Wrote to 165 : 0x0026 (38)

Setting PWM reg to 3.3% Wrote to 165 : 0x0022 (34)

Setting PWM reg to 2.9% Wrote to 165 : 0x001E (30)

Setting PWM reg to 2.9% Wrote to 165 : 0x001E (30)

Setting PWM reg to 2.4% Wrote to 165 : 0x0019 (25)

INNOVATION WITH PURPOSE

ALLEGRO microsystems

FORWARD WITH INPUT DUTY < DCOFF

In case of a loss of PWM input signal, this curve can be implemented to set the motor speed via a pull-down on the PWM pin. To set the speed of the PWM input open/closed condition, adjust the variable MAXDXYOFF via the GUI slider.

A89332 Application (Version 1.0) - <no filename specified>*

Save/Open Configuration Text Size Application Info Disclaimer **A89332-1**

Read EEPROM and show settings Write all settings to EEPROM Toggle Run/Stop 2.1% Duty Cycle RPM = 5,592 FG = 186 Hz Felec. = 186 Hz Read speed Continuous read Speed = Applied duty = Phase advance =

Speed Curve Config 1 Config 2 Config 3 Startup Status EEPROM ID Custom ID User EEPROM QR code

Min speed = 800 RPM

Max speed = 19,981 RPM

Max electrical frequency (lock detect level) = 814 hz

Duty cycle on = 11.5 %

Duty cycle off = 4.5 %

Max duty clamp = 100.0 %

Max duty hyst = 0 %

Min duty clamp = 0.0 %

DC disable threshold = disabled

Input duty <= DC off = 28.0 % (285 counts)

DC off < Input duty <= DC on ☐ Hysteretic enable ☒ Duty = Off

Reverse < DC off ☒ Disabled ☐ Enabled

Brake if OFF ☒ Disabled ☐ Enabled

Input duty > Max duty clamp ☐ Run at open-loop level ☒ Run at max duty clamp

Control ☐ Open loop ☒ Closed loop

Invert duty ☒ Duty = % high ☐ Duty = % low

Direction ☒ ACB ☐ ABC

Slope switch DC (0 for single slope) = 0 % (0 counts) Single slope mode enabled

Slope switch RPM = 0 RPM

Open loop speed limit = 44800 RPM

Speed curve

DC = 28%

RPM

Duty Cycle

Key

- DC off
- DC on
- Min DC
- Max DC
- Open loop limit
- Resonance

Setting PWM reg to 7.0%
Wrote to 165 : 0x0048 (72)

Setting PWM reg to 6.3%
Wrote to 165 : 0x0040 (64)

Setting PWM reg to 5.4%
Wrote to 165 : 0x0037 (55)

Setting PWM reg to 4.6%
Wrote to 165 : 0x002F (47)

Setting PWM reg to 3.7%
Wrote to 165 : 0x0026 (38)

Setting PWM reg to 3.3%
Wrote to 165 : 0x0022 (34)

Setting PWM reg to 3.3%
Wrote to 165 : 0x0022 (34)

Setting PWM reg to 2.9%
Wrote to 165 : 0x001E (30)

Setting PWM reg to 2.4%
Wrote to 165 : 0x0019 (25)

Setting PWM reg to 2.1%
Wrote to 165 : 0x0015 (21)

INNOVATION WITH PURPOSE
ALLEGRO
microsystems

RESONANCE CURVE

To avoid a sensitive speed band, constant speed at a defined duty input range can be configured. Both duty at center resonance and width of resonance have limited range, and the GUI has a built-in

function to verify that settings are valid: If out of range, warnings are provided. Due to a lack of space in the GUI, resonance sliders are included on the Config 1 tab. This curve is also available in open-loop mode. Instead of speed, a duty range can be avoided.

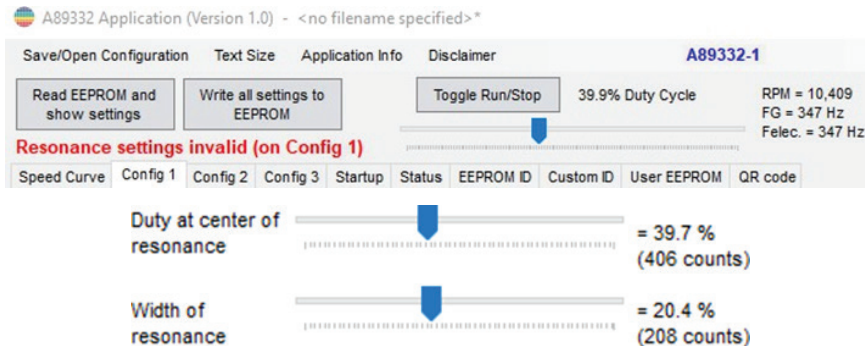


Figure 6: Resonance Sliders Are Located On Config 1 Tab

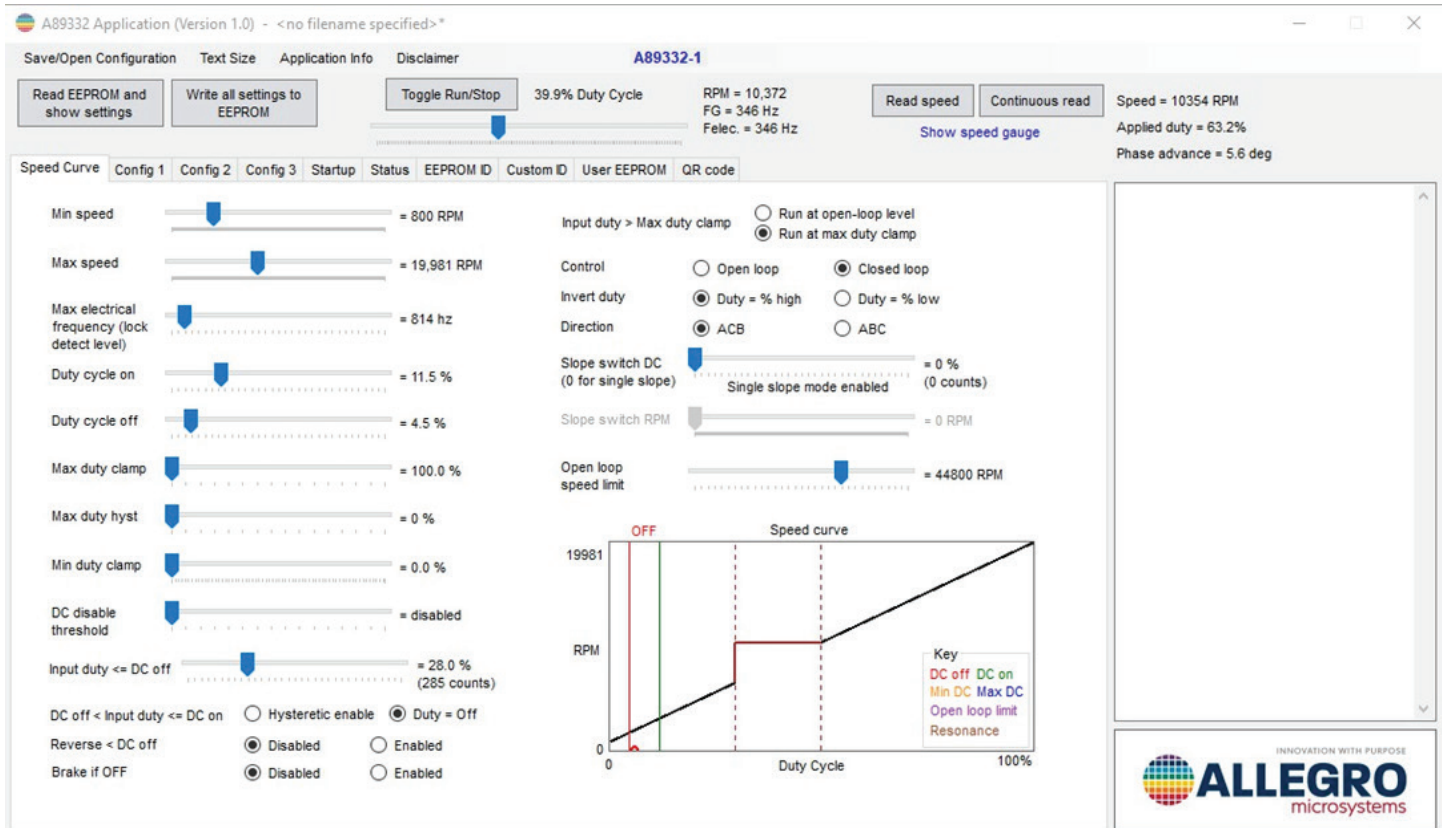


Figure 7: Resonance Curve

Brake if OFF

The A89332 has an option to brake the motor when the PWM input results in a disable state with the chosen speed curve. If the brake if off bit on the speed curve tab is set to 1, the IC waits for a coast time, then all sink drivers turn on to brake the motor. The coast time is set via a slider on the Config 3 tab. For brake assertion via the brake pin or power loss brake feature, the coast time is not used.

Coast Time

The variable t_{COAST} is set to program the duration that the motor coasts when $\text{BRKOFF} = 1$ or when a direction change occurs. The variable t_{COAST} is set on the Config 3 tab of GUI.

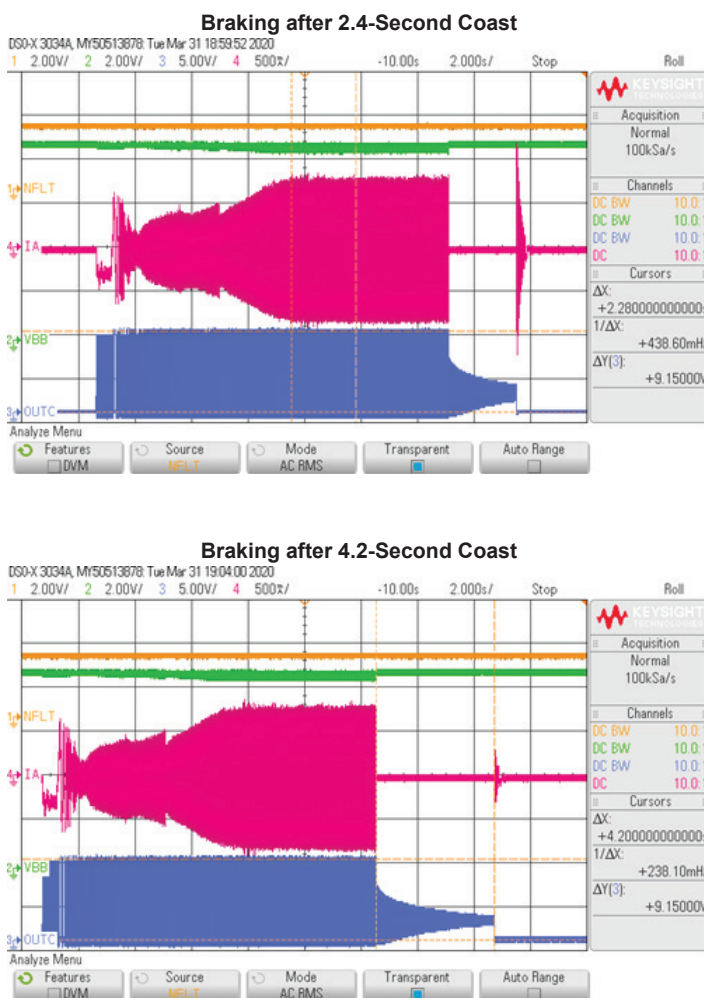


Figure 8: Coast Duration

Open-Loop Speed Limit

This feature measures the speed of the motor and reduces the duty applied to the motor windings if the speed limit is exceeded. Effectively, the motor runs at this speed limit if V_{BB} is increased or if airflow is changed in a manner that would result in a higher speed. Limiting the speed might reduce audible noise and power consumption for the atypical condition.

This feature does not function in closed-loop speed control mode.

DC Disable Threshold

This option allows a motor-off command if the duty cycle exceeds the defined threshold. This feature can be used to control motor operation with loss of the PWM signal or to control an issue caused by a PWM wire disconnection.

Direction

Motor direction is managed by the sequence of the PWM applied to the windings. The motor is disabled for the duration of t_{COAST} (set on the Config 3 tab), during which this bit is flipped.

Maximum Electrical Frequency (Lock-Detect Level)

The maximum electrical frequency (Max FELEC) setting is used to set the upper limit of the electrical frequency. This setting helps the motor shutdown quicker for rotor-lock conditions.

NOTE: The setting is for electrical frequency, which is only equal to the FG frequency if the number of pole pairs is set to two.

The recommended value for this setting is $1.25 \times$ the maximum electrical frequency expected. The maximum electrical frequency is also used to assist with resynchronization when the motor is turned on while spinning. Ensure the value is selected properly for open-loop mode as well as close-loop control.

NOTE: The GUI automatically changes the setting based on the MAXSPEED slider. To write directly, it can be overwritten.

CONFIG 1

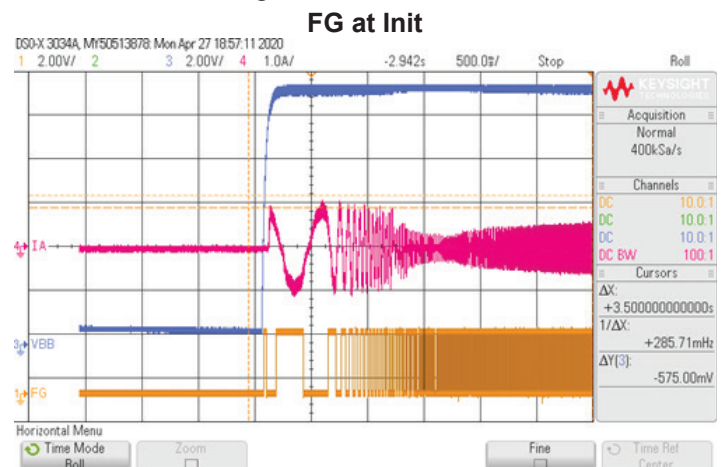
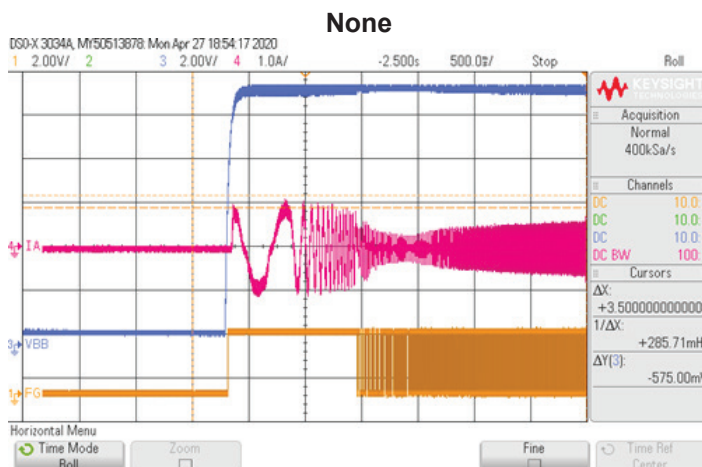
The configuration 1 (Config 1) tab selects various settings as described in this section.

FG/RD

Selects the output signal for the FG/RD pin. The frequency generator (FG) signal represents motor speed. The rotation detection (RD) signal indicates that the motor is not rotating at the expected speed. If the pin is programmed to RD mode, to write serial commands via I²C, ensure that the V_{BB} line is less than the UVLO threshold and the V_{IN} is greater than the V_{IN} threshold.

FG at Start

The A89332 uses a step-to-start routine, where the position is not measured. In that case, the actual speed signal is estimated based on the applied stepping frequency, which starts at a low value and gradually increases. When the frequency generator at initialization (“FG at Init”) feature is used, feedback is provided to the system during the stepping mode. When “None” is selected, the driver waits for the transition to typical running mode before allowing FG to change. In case of a rotor-lock condition, it might be preferable for the end system not to detect FG transitions when the motor is not moving.



Pole Pairs

Select the number of pole pairs of the motor. This is required so that the correct speed data can be displayed in the closed-loop speed-control mode. In open-loop mode, select the actual number of poles pairs, such that the FG speed feedback normalizes to the standard two periods per mechanical revolution.

If feedback of a standard two-period signal is not required, use the two pole-pair setting such that the FG signal represents one electrical revolution.

$$RPM = FG(Hz) \times 60/\#polepairs$$

Quick Start

If the rotor is locked, before attempting another re-start, the motor typically turns off for the duration of the lock time. If the quick-start option is selected, after the first locked-rotor failure, t_{OFF} is 500 ms. After the second locked-rotor failure, the typical lock time is used. The default setup is to have the quick-start feature disabled.

BEMF Hysteresis/BEMF Filter

The sensorless algorithm measures position by checking the voltage on the phase A winding, and comparing that voltage to the centertap winding when the current is zero.

The bemf hysteresis and bemf time filter are represented in Figure 9.

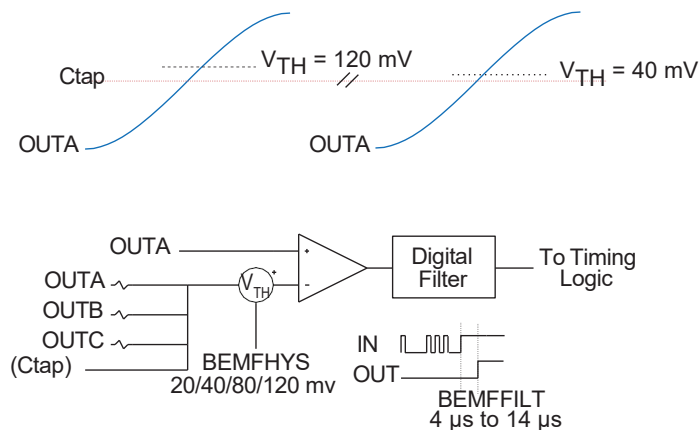


Figure 9: BEMF Hysteresis and BEMF Time Filter

During startup or when the motor drive is disabled, BEMFHYS is enabled. During typical operation, the BEMFHYS level is set to 0 mv automatically. When BEMFHYS is set to a high level, certain motors better handle a rotor-lock condition (i.e., shut down quicker). If an issue with lock detection does not exist, the recommended setting is 40 mV.

BEMFFILT is a time filter. During motor PWM, transients appear on the winding that is open circuit during the position-measurement window. These transients appear coincident with the edges of PWM and must be filtered out for proper position measurement. The 4 μ s setting is recommended. The filter time must be less than half the PWM frequency. If $FPWM = 48$ kHz, the GUI prevents the value from being set to 12 or 16 μ s. Scope plots for two different motors showing transients of different durations and the recommended settings are shown in Figure 10.

BEMF Filter Range

The A89332 and A89332-1 feature selections for a high and low bemf filter time range: when set to high, it offers 4, 8, 12, and 16 μ s selections; when set to low, it offers 1, 2, 3, and 4 μ s selections.

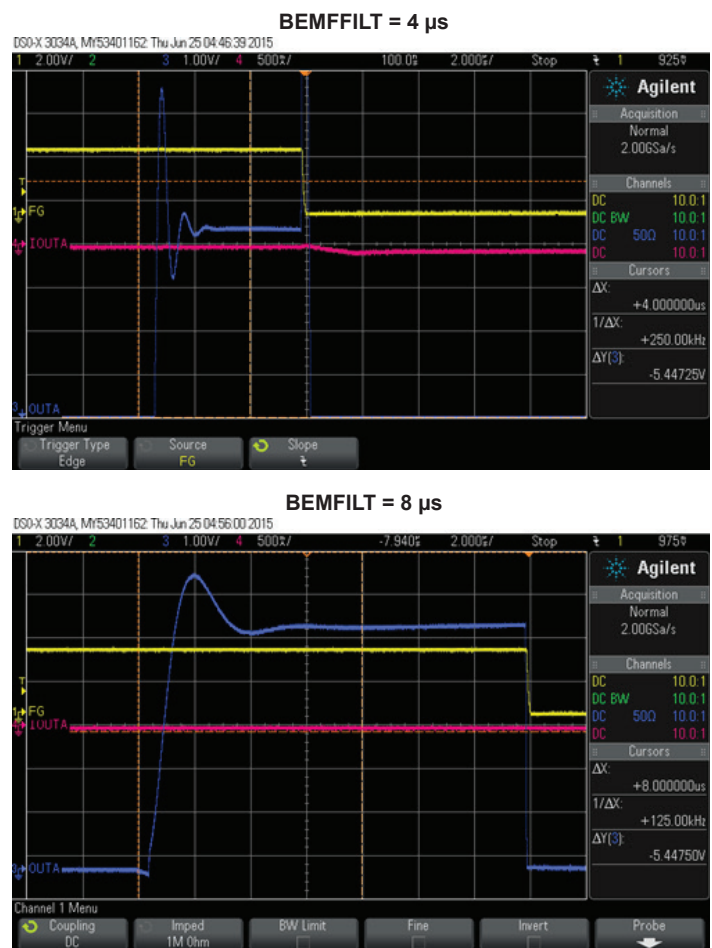


Figure 10: BEMF Filter Range

RD Fault Option

The FG/RD pin can be configured as a rotation-detection (RD) fault output. When the GUI is used to define the RD parameters, the status tab can be used to set the RD signal for output to the nFAULT pin for debug use.

For description and timing diagrams of the RD function, refer to the datasheet.

Clear RD

If a motor is commanded to the off state via the PWM duty input, this option changes the alarm output: If Clear RD is set to 0, the RD alarm is released when PWM is commanded to the off state; if Clear RD is set to 1, the RD alarm remains asserted when PWM is commanded to the off state.

VBB Overvoltage Level

If this function is enabled when V_{BB} exceeds the V_{BBOV} threshold, the motor coasts. Once V_{BB} reduces to less than the hysteresis level, a windmill restart occurs.

Speed Pi Output Range

For extremely slow motors (i.e., maximum electrical frequency < 60 Hz), select 8×; for other motors, use the default value of 1×.

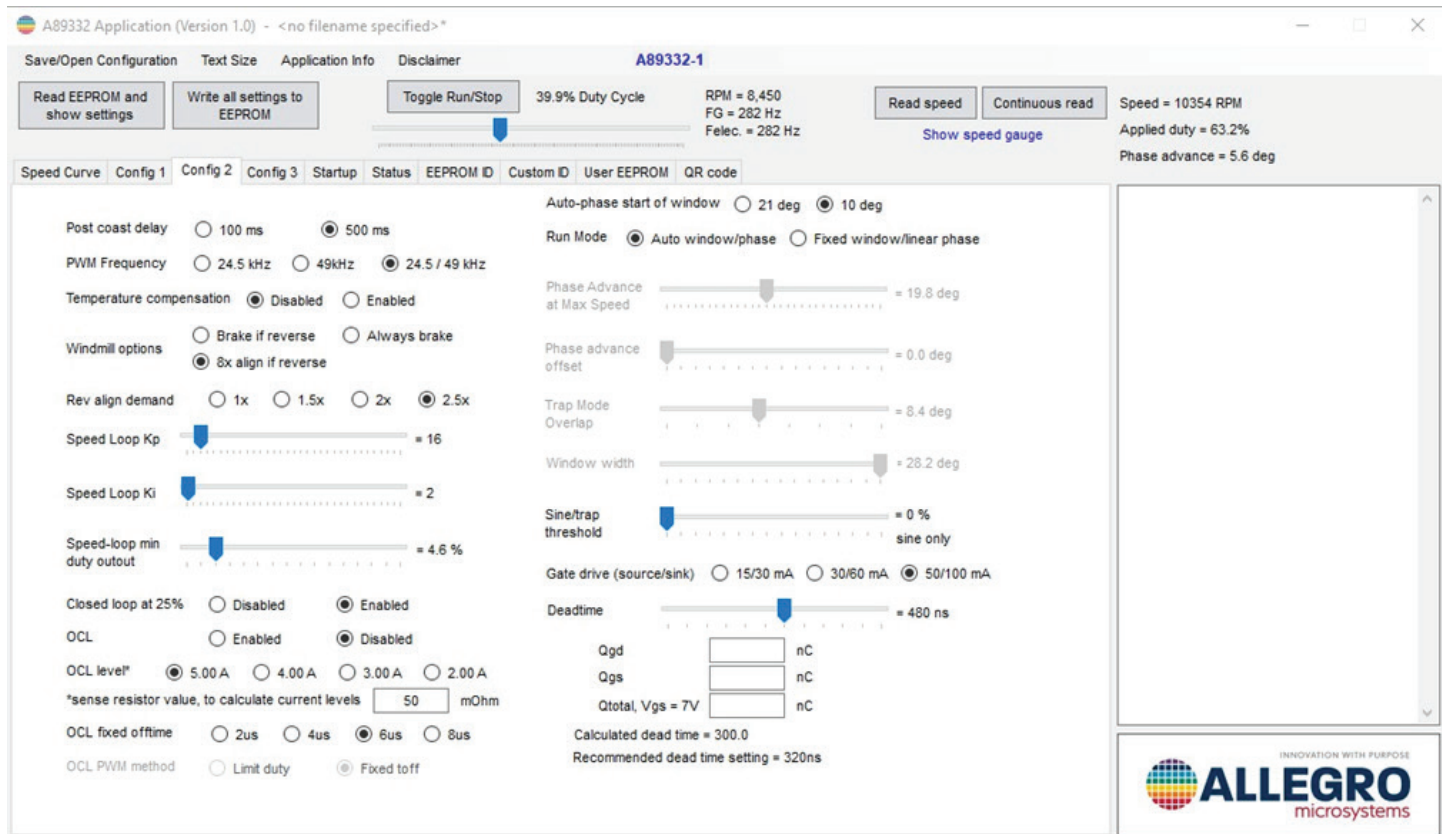
Speed Feedback Clamp

A89332/-1 adds (compared to the A5931/2) programmable speed feedback clamp to adjust the deceleration time when switching from forced open-loop to closed-loop speed control. The smaller the clamp value, the longer the deceleration time.

Forced Open-Loop Applied Duty

A89332/-1 adds (compared to the A5931/2) applied duty selection while motor speed is under forced open-loop control

CONFIG 2



Post-Coast Delay

The transition into position-sensing mode occurs after the open-loop stepper startup. This transition period can be programmed to be 100 ms or 500 ms. The longer duration, 500 ms, is recommended. The longer duration allows more time for the rotor position to synchronize to the applied PWM before ramping to the target speed.

PWM Frequency

Selects the output frequency applied to the motor windings (24.5 kHz, 49 kHz, or 24 kHz/49 kHz). because running at a higher PWM frequency results in more PWM cycles per electrical period, some high-speed applications can benefit from running at a higher PWM frequency. With more samples per period, the sine wave profile has more resolution, which can result in an improved current wave. For applications where the motor must operate at a low speed, the applied duty can be very small, approximately 10%. This scenario is limited by the calculated duty slices that approach the dead time of the output stage, which introduces distortion in the sine wave. Use of the lower PWM frequency improves the distortion at low duty. For a general guideline, use 24 kHz, unless the electrical period is less than 2 ms. If the application must operate over a wide speed range, the 24/49 kHz setting provides the choice to optimize based on

applied duty. With this setting, the logic switches from 24 kHz to 49 kHz depending on applied duty, as shown in Figure 11.

NOTE: In closed-loop mode, applied duty does not equal input duty.

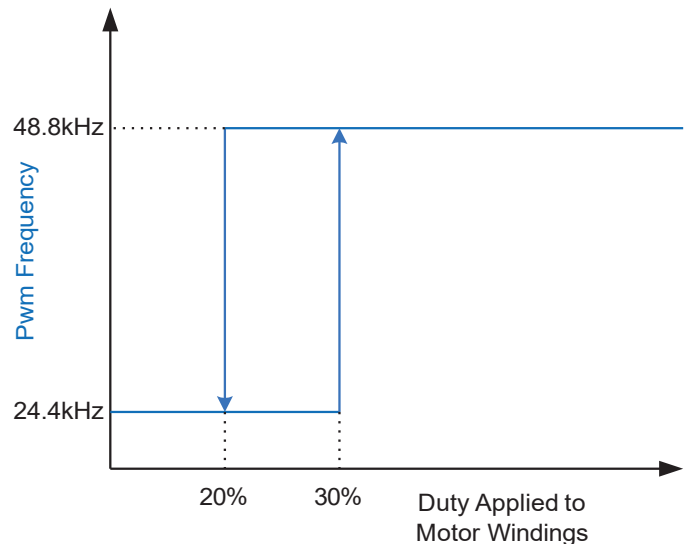


Figure 11: Logic Switches from 24 kHz to 49 kHz Depending on Applied Duty

Temperature Compensation

Startup torque depends on the applied voltage demand and the resistance of the motor. Motor resistance changes based on the ambient temperature. The temperature compensation uses the internal temperature measurement circuit to apply an adjustment to the startup torque based on the temperature measurement. If the motor is in a hot ambient environment, resistance increases, which increases in the applied demand as the system equalizes the startup torque.

NOTE: The temperature is based on the die temperature, which changes slightly based on self heating. If desired, temperature compensation can be disabled.

Windmill Options

Before the startup sequence begins, the sensorless system checks to see if the motor is moving and in what direction it is moving. In a typical startup sequence, the motor is assumed to be stationary. This is because startup of a nonstationary motor might not be reliable: If the motor is rotating in the correct direction, it is usually permissible to skip the startup and proceed to the typical operating mode; however, if the motor is rotating in the opposite direction, the motor should be stopped before a typical startup attempt. The motor can be stopped by braking (all outputs low) or by applying torque to the motor at a fixed point in the modulation profile (OUTA sourcing, OUTB and OUTC held low). Torque application at a fixed point stops the motor faster than the brake. The options for the windmill condition are:

1. 8x Align if Reverse

A. If the motor is moving in reverse:

- i. Stop the motor by applying the startup demand for 8 times the programmed “Align duration”.
- ii. The motor performs a typical restart at the end of the duration.
- iii. NOTE: Make sure “align duration” is programmed as desired. This is not visible in the GUI unless “Use Align Mode” is selected. See the startup tab.

B. If the motor is moving forward, the startup sequence is skipped:

- i. A startup demand is estimated based on the estimate of how fast the motor is moving.
- ii. The estimate is calculated by the MAXSPD variable. (Ensure MAXSPD is set properly.)
- iii. The demand is applied, and the typical sinusoidal drive is enabled.

2. Brake if Reverse

A. If the motor is moving in the reverse direction:

- i. Stop the motor by holding all three motor phases low. Every 500 ms, the outputs are disabled and the rotation is verified by checking for the bemf wave on motor phase A.
- ii. After the motor is stopped, startup occurs per the typical settings.
- iii. If the motor does not stop within 20 seconds, due to large external force, the logic attempts a startup.

B. If the motor is moving forward, enable the drive as described in step 1B.

3. Always Brake

A. If the motor is moving in the forward or reverse direction, brake the motor as described in step 2A.

NOTE:

- Use of the 8x Align if Reverse option is generally recommended. This mode allows a higher braking force than the low-side brake.
- To improve the resynchronization waveform, set the MAXSPD variable to be 20% to 30% greater than the maximum speed expected in the application. The GUI automatically sets an appropriate value when MAXSPEED is adjusted.

Reverse Align Demand

To allow a greater braking force when external forces cause the motor to spin in reverse, the “*8x Align Applied” feature has four demand selections. The programmed startup demand can be multiplied based on when the condition of reverse rotation occurs and the windmill setting of 8x Align if Reverse. For typical conditions, where the motor is stationary or moving in the forward direction, the standard startup demand is always used.

Speed Loop Kp/Ki

The closed-loop speed control system contains a proportional-integral (PI) controller. The sensorless driving algorithm limits the dynamic response of a speed change request via the demand ramp settings (see the startup tab). This limitation is required for smooth current response and quiet operation, and it limits the impact of the Kp/Ki gain settings. The default Kp/Ki settings (16/2) work well for small-form-factor 4056 high-speed server fans. For larger types of appliance fans, increase the gain settings as needed.

Closed Loop at 25%

If this function is disabled, the motor starts up in open-loop mode and ramps up speed until the target is reached. If the target speed is not reached, the system runs at 100% demand and switches over to closed-loop mode 10 seconds after the 100% applied duty is reached. With the function enabled, the controller switches to closed-loop mode when the actual speed is 25% of the target speed. The target speed is based on the input PWM duty. Enabling this feature can reduce I_{BB} overshoot for startup conditions. It is recommended for this feature to be enabled.

OCL Level/OCL Enable

An external sense resistor is used to measure the load current. For a given sense resistor value, four levels of current limit are selectable via EEPROM bits. The GUI calculates the four levels automatically based on the sense-resistor value entered. A current limit setting of at least 1.3 times the maximum expected run current is recommended. Additionally, the overcurrent limit disable (OCLD) bit can be set to disable the current limit function. Load current is measured based on the voltage developed across the sense resistor connected between LSS and GND.

There are two options for the current limit: “Fixed toff” turns off the source driver for the chosen time; “Limit Duty” adjusts the PWM amplitude to a lower value at a slow rate. Use of “Fixed toff/6 μ s” is recommended.

Speed-Loop Minimum Duty

In closed-loop operation, the motor requires more time to slow to the minimum speed. In this situation the internal speed loop must wait for the motor speed to be less than the new target. The minimum duty (min duty) selection sets a lower clamp so that some duty is always applied while waiting for the motor to decelerate. This feature prevents stalling.

To set the speed-loop min duty:

1. Set the motor to open-loop mode (speed curve tab).
2. Adjust the input duty to achieve the minimum speed required in the application.
3. Set “speed Loop min duty” to 1% less than this value.

Auto-Phase Start of Window

The sensorless driving algorithm measures position by opening a small window on the Phase A winding. During acceleration the window might open wider to allow smooth acceleration of the motor. The number defines the maximum number of electrical degrees that the window can open. During typical operation, the window width is approximately 10 electrical degrees. It is recommended to use the 10 degrees setting unless poor current waveform is noted during acceleration.

Run Mode

There are two options for sensorless drive. “Auto” adjusts the phase advance angle automatically based on proprietary drive algorithm. Essentially the drive adapts to the motor characteristic to find an efficient operating point across the speed range. “Linear” phase advance adjusts the phase angle based on a linear relationship of speed vs. angle. The linear mode uses a fixed window width, which typically is required to be reasonably wide to avoid motor stalling.

To use linear mode:

1. Before attempting to use the linear phase advance, optimize the startup parameters.
2. Determine the maximum speed in auto mode with input demand set to 100% with open-loop operation.
3. Set the speed-control mode to closed loop.
4. Set the maximum speed to 5% less than the maximum speed determined in step 1.
5. Set the run mode to linear, with phase advance initialized to 10 degree and the window set to 28.
6. Startup to 100% demand.
 - A. If stalling occurs while approaching maximum speed, increase the phase advance by a few degrees.
7. Adjust the phase advance while monitoring I_{BB} current to find the optimal (most efficient) operating point.
 - A. Test the input duty transients.
 - B. Test the startup-to-maximum speed.
8. If the window is set to a number greater than 235, repeat the exercise. A smaller window is more likely to encounter stalling during startup and demand changes. A window width smaller than 20 degrees is not recommended.

To adjust phase advance, auto mode is recommended instead of linear mode.

Sine/Trap Threshold

This setting controls the mode of operation: sine only, trap only, or switching from sine to trap mode. It also selects the threshold for when to switch from sine mode to trap mode.

Gate Drive (Source/Sink)

Set the gate drive source and sink current level.

Dead Time

Use of the value calculated by the GUI, which is based on the charge values of the selected MOSFETs, is recommended.

CONFIG 3

A89332 Application (Version 1.0) - <no filename specified>

Save/Open Configuration Text Size Application Info Disclaimer A89332-1

Read EEPROM and show settings Write all settings to EEPROM Toggle Run/Stop 39.9% Duty Cycle RPM = 8,450 FG = 282 Hz Felec. = 282 Hz Read speed Continuous read Speed = 10354 RPM Applied duty = 63.2% Phase advance = 5.6 deg Show speed gauge

Speed Curve Config 1 Config 2 Config 3 Startup Status EEPROM ID Custom ID User EEPROM QR code

Max electrical frequency (lock detect level) = 1017 Hz (duplicate on Speed Curve tab)

OCP ☒ Enabled ☐ Disabled

VDS threshold ☒ 0.5 V ☐ 0.75 V ☐ 1 V ☐ 2 V

OCP blank ☒ 0.6 us ☐ 1.3 us ☐ 1.9 us ☐ 2.5 us

Dell power loss ☒ Disabled ☐ Enabled

Coast Time after Dell power loss = 0.42 s

Power loss ☒ 10ms PWM low pulse ☐ >25% duty or 15S

OCL release ☐ >35% duty or 15S ☐ >45% duty or 15S

Dell powerloss OCL ☒ Disabled ☐ Enabled

Powerloss OCL level* ☐ 1500 mA ☐ 1200 mA ☒ 900 mA ☐ 600 mA

*sense resistor value, to calculate current levels 50 mOhm

89332-1 only

Set I2C clock to: PWM BRAKE

Coast time after brake if off or DIR change = 2.11 s

PWM input freq ☐ <3.2 kHz ☒ >2.5 kHz

FG mask in no-coast mode ☒ Disabled ☐ Enabled *Mask time set by postCoastDelay (0=1s, 1=5s)

FCOL duty range check ☐ Duty < 90% ☒ No check

FCOL enable ☒ Disabled ☐ Enabled

FCOL option ☒ HP (500ms wait, then preamble) ☐ Dell (2s wait, no preamble)

FCOL coast enable ☒ Normal driving ☐ Coasting during FCOL

FCOL duty release ☒ Invalid FCOL req ☐ 2S stuck high

INNOVATION WITH PURPOSE ALLEGRO microsystems

Maximum Electrical Frequency (Lock-Detect Level)

The maximum electrical frequency (max FELEC) setting is used to set the upper limit for electrical frequency. This setting helps the motor shut down quicker for rotor-lock conditions.

NOTE: The setting is for electrical frequency, which is equal to FG frequency only if the number of pole pairs is set to two. A value equal to 1.25 times the maximum electrical frequency expected is recommended. The maximum electrical frequency is also used to assist in resynchronization when the motor is turned on while spinning. Ensure this value is properly selected when using open-loop mode, as well as close-loop control.

OCP

The overcurrent protection (OCP) function is protection against short to ground, short to VBB, or motor load shorts. The integrated protection circuitry allows very short pulses of high current before disabling the motor outputs and triggering the fault pin low. OCP is a latched fault that can be reset by a recycle of VBB or by toggling the PWM line off to on. The options to change the blank time or to disable the function entirely are only for debug purposes. It is recommended for this function to be enabled and used with the default V_{DS} threshold of 0.5 V and programmed blank time of 0.6 μ s. If a false OCP is triggered, increase the OCP blank time first, then increase the V_{DS} threshold voltage.

Coast Time

Included is an option to allow the motor to coast when changing the direction of the motor via the GUI or I²C, or if using the “BRAKE if OFF” feature. If a motor is moving at full speed, there can be stress on the IC or loud audible events when motor is told to change direction or brake. This coast time allows the motor to slow before changing the mode of operation.

PWM Input Frequency

The A89332 measures the duty of the input PWM signal and converts it to a 10-bit number used to create the motor speed demand. Select this variable depending on the frequency of the input PWM signal.

FG Mask

If using the “No Coasting” option from the startup page, it is possible to receive some FG toggle signals before the lock detection logic shuts down the IC during a locked-rotor condition. This option can be used to mask off the FG toggling for the select mask time. FG mask time is 10 $\times$ the time selected with the “Post coast delay” option.

Set I²C Clock to PWM or Brake

This GUI option assists in creating parameters for FCOL or AC power loss. After selecting I²C to brake, open the SW1 SCL line, and add the jumper from the SCL test point to the BRAKE test point. This allows the PWM pattern to be sent to the PWM pin and the GUI to be used to test different options, read back speed, etc.

Dell AC Power Loss (89332-1 version only) options are provided to assist in achieving requirements presented by the Dell AC Loss specification. If this feature is enabled, when a “stuck Low” condition is detected and persists on the PWM line for longer than 500 microseconds, the motor coasts. Several related EEPROM selections provide some flexibility in managing the response of the IC for this event as follows:

- **Coast Time after Power Loss:** Determines the time to coast before a reattempt of a windmill start. The “always brake” windmill feature can be used to ensure that the motor stops after the coast time. Alternatively, the typical windmill resynchronization occurs.
- **Powerloss OCL:** Enables the current limit function when the condition is detected. This limits phase current rather than I_{BB} current.
- **Power Loss OCL Release:** Determines the event to release the Powerloss OCL, if enabled.
- **Powerloss OCL Level:** Provides four choices for the phase current limit. The duty applied during the AC loss event must be low enough that the OCL level selected does not limit the speed.

FCOL

This is a communication protocol used to output user data from an extra 64 bytes of EEPROM to the FG line. For the most recent details about the protocol, refer to the end user specification. The A89332 includes several options for FCOL because the specification was not completely defined at the time the logic was hard-coded into the IC.

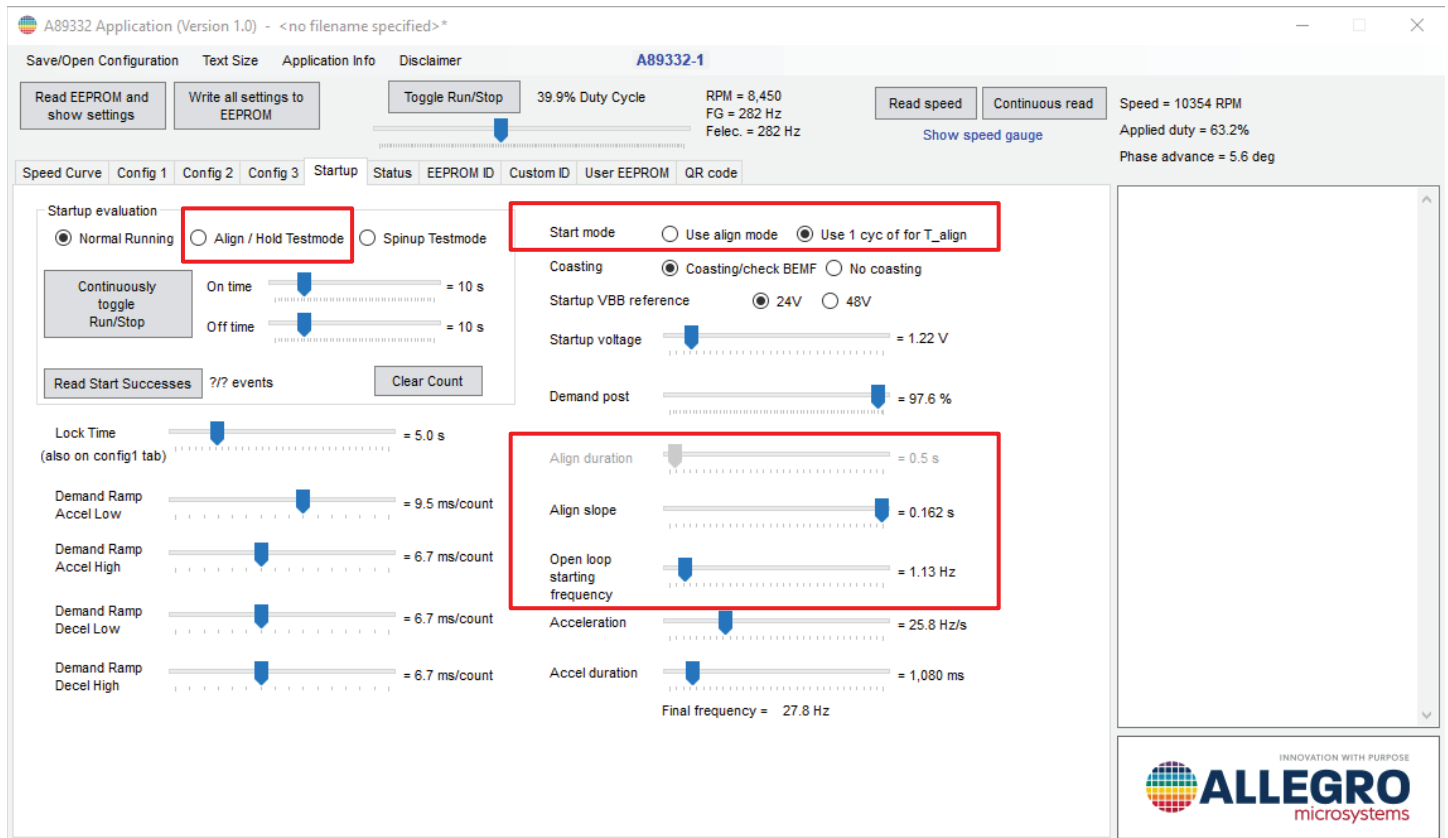
FCOL Duty Range Check: If an initiation signal is detected, this option determines if the duty is checked to determine whether or not to output the user memory.

FCOL Option: Two different wait times are possible after the initiation signal is detected before starting the data transfer.

FCOL Coast Enable: Determines if the motor should coast or not during the communication transfer. Because the transfer can take quite a bit of time, the motor could stop during this interval.

FCOL Duty Release: Two different timing options to define when the IC resumes following the duty input to determine motor speed.

STARTUP



Introduction

Startup variables are selected via the startup tab of the GUI. The A89332 uses a step-to-start sequence to accelerate the motor to a point where speed is adequate to allow reliable position measurements. The startup can be categorized into three distinct areas of operation, as shown in Figure 12.

1. Initialize (Align)
2. Accelerate
3. Ramp to target speed

The I_{OUT} waveform represents the current (torque) applied to the motor. The amount of torque in startup mode is linearly related to the startup demand (voltage) programmed. By applying a continuous sinusoidal current waveform, quiet operation is achieved.

The key parameter in addition to the magnitude of torque applied to the motor during startup is the acceleration rate. The acceleration value is chosen so that the motor can reliably ramp up the speed with the given applied torque. These two parameters are directly linked. Consider the trade-off between these two important parameters: A larger inertial load might require large current or slow acceleration; conversely, smooth start of a smaller load might be possible with a lower current or faster acceleration.

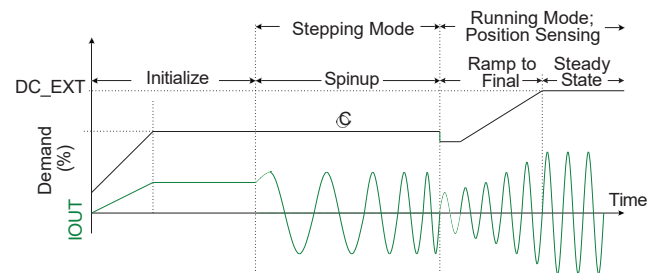


Figure 12: Startup Operation

Step 1: Initialize

START MODE

The purpose of the initialize state is to move the motor close to a defined location or to determine the current position before motor spin-up begins in the acceleration stage. Two methods are possible, as described next.

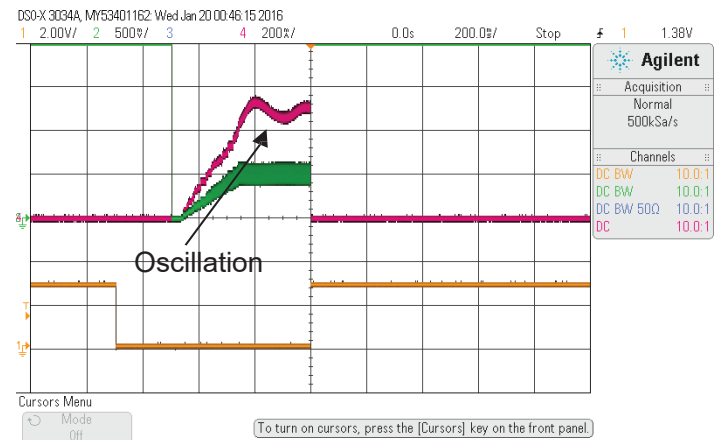
METHOD 1: ALIGN

The align method ramps up current by applying PWM to OUTA (sourcing current) with OUTB and OUTC held low (sinking current). This moves the rotor to a defined position in the electrical cycle. A defined number of positions exists per mechanical revo-

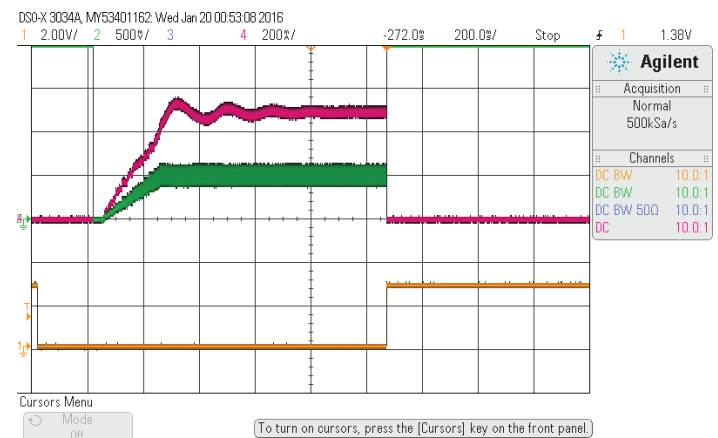
lution, depending on the number of pole-pairs of the motor. For example, a motor with four pole-pairs has four defined alignment positions, each separated by 90°; a motor with five pole-pairs has five defined alignment positions, each separated by 72°; etc.

- **ALIGNT:** The align duration (ALIGNT) is used to program the duration for which a position is held. This duration should be set to a value long enough to allow the motor position to settle. The worst-case duration should consider various stopping locations of the rotor. Typically, the worst-case settling time occurs halfway between two defined motor-stopping positions. The align test mode can be used to check the defined alignment positions. Some motors have cogging torque and move to cogging locations after the windings are de-energized. During the align test mode, the outputs are enabled to analyze the align waveform and motor response, then the outputs are turned off for the programmed lock time, and the cycle repeats. The idea is to move the rotor to various locations during the lock time to determine the worst-case initial position.
- **ASLOPE:** The align slope method (ASLOPE) initially ramps up the duty. Initially, the applied duty starts at 3%, then ramps up as defined by the slope. In some cases, position overshoot can be reduced by applying a slower ramp up of current. By reducing position overshoot, it might be possible to reduce the alignment time. The slope from the GUI is defined as the time to reach 100% duty cycle. The actual time to ramp up to the target current is less than the time displayed because, in most cases, the startup duty is in the range of 5% to 25%.

ALIGN WAVEFORM USING ALIGN/IPD TEST MODE



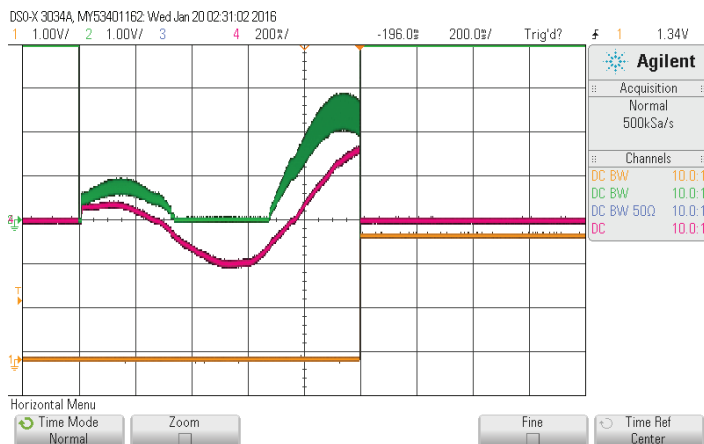
CH1 = TEST signal, CH2 = Startup demand (outA filtered), CH4 = I_{outA}
Figure 13: Oscillation of I_{outA} Indicates Rotor Not Settled



CH1 = TEST signal, CH2 = Startup demand (outA filtered), CH4 = I_{outA}
Figure 14: Increasing Align Time Allows Enough Time For Rotor Position to Settle

METHOD 2: SINGLE-CYCLE

The single-cycle method applies one continuous electrical cycle of sinusoidal modulation to initiate motor movement in the proper direction. The frequency of the electrical cycle is set by the open-loop starting-frequency variable, STRTF. Larger inertial loads might require smaller values of STRTF. The align slope setting works the same as in the align method. The general idea of the single-cycle method is to get the rotor close to the starting position and continuously moving in the proper direction. Unlike the align method, it is not required to reach and settle into the same position. Because a continuous waveform is applied, the motor tries to move (as opposed to trying to move to a position and stop). During the cycle, pausing might occur. This pausing varies depending on the initial position. Ensure that STRTF is set low enough that the rotor is visually observable as it nears the starting position for various initial rotor locations.



CH1 = TEST signal, CH2 = Startup demand (outA filtered), CH4 = I(outA)

Figure 15: Single-Cycle Align Waveform

Recommendations:

- Use the one-cycle mode, in general. The fixed-position method can be used on motors with cogging torque where the cogging-torque positions are not 180 degrees from the fixed align positions.
- Use a startup demand (torque) value that does not result in significant overshoot or reverse rotation during align mode.

Step 2: Accelerate

The screenshot shows the A89332 Application software interface. The 'Startup evaluation' section is highlighted with a red box, showing 'Spinup Testmode' selected. Other parameters like 'Acceleration' and 'Accel duration' are also highlighted with red boxes.

Key parameters visible in the highlighted sections:

- Startup evaluation:**
 - Normal Running (selected), Align / Hold Testmode, Spinup Testmode
 - On time = 10 s, Off time = 10 s
 - Lock Time = 5.0 s
 - Demand Ramp Accel Low = 9.5 ms/count
 - Demand Ramp Accel High = 6.7 ms/count
 - Demand Ramp Decel Low = 6.7 ms/count
 - Demand Ramp Decel High = 6.7 ms/count
- Start mode:**
 - Use align mode, Use 1 cyc of for T_align (selected)
- Coasting:**
 - Coasting/check BEMF (selected), No coasting
- Startup VBB reference:**
 - 24V (selected), 48V
- Startup voltage:**
 - 1.22 V
- Demand post:**
 - 97.6 %
- Align duration:**
 - 0.5 s
- Align slope:**
 - 0.162 s
- Open loop starting frequency:**
 - 1.13 Hz
- Acceleration:**
 - 25.8 Hz/s
- Accel duration:**
 - 1,080 ms
- Final frequency:**
 - 27.8 Hz

Open-loop acceleration increases motor speed to an acceptable level, after which the rotor position can be reliably measured.

1. Startup Voltage. Startup torque is proportional to the startup voltage applied to the motor:

$$Current = K \times V_{ST} / R_{MOTOR}$$

where $K = 1.15$, and R_{MOTOR} is the phase-to-phase resistance of the motor.

Most applications require startup across a power-supply range. In a reliable, consistent startup operation, the torque remains constant at different V_{BB} levels. This is achieved by measuring V_{BB} and adjusting the duty to compensate, as:

$$V_{ST} = V_{BB} \times Duty$$

For example, a V_{ST} of 2 V results in 20% duty at a V_{BB} of 10 V.

2. ACCEL. Acceleration constant, in Hz/s.
3. ACCEL.T. Sets the duration of motor acceleration in stepping mode. The electrical frequency at the end of acceleration is estimated as:

$$F_{FINAL} (Hz) = ACCEL \times ACCEL.T$$

SPIN-UP PARAMETERS

When the motor begins to rotate in stepper mode, the rotor position leads the *ideal* applied modulated voltage by approximately 90 electrical degrees. As the frequency of the applied voltage increases, the applied voltage nears the actual rotor position. If the applied voltage passes and leads the rotor position, the motor stalls. This is similar to excessively rapid operation of a stepper motor where, at some stepping-rate limit, the stepper motor lags and stalls. The rotor-position reference is defined by the zero-crossing point of the difference between OUTA and the motor common (CTAP). When this zero-crossing point aligns with the zero-crossing point of the current, the motor is at the synchronous point. Therefore, the phase difference between current and position can be analyzed in terms of the location of the ideal point.

The spin-up test mode provides an easy method to determine the proper match of STARTDMD and ACCEL by signaling a test signal at the programmed end of stepper mode.

NOTE: For the spin-up test mode, use the NOCOAST setting:

- C1 = RD (test signal)
- C2 = OUTA
- C3 = OUTA-CTAP differential probe
- C4 = I(OUTA)

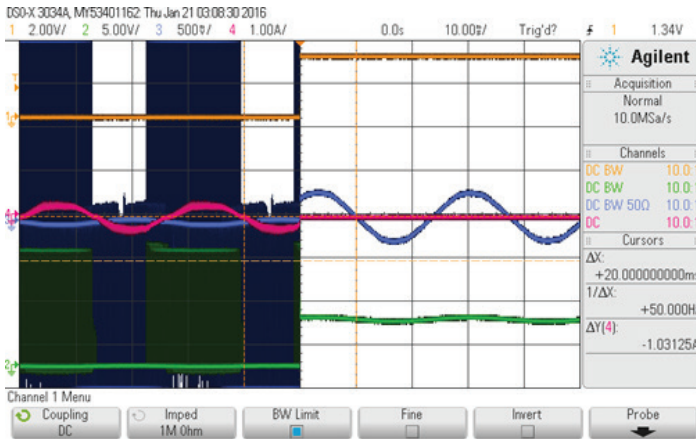


Figure 16: Phase Lag Approximately 70°

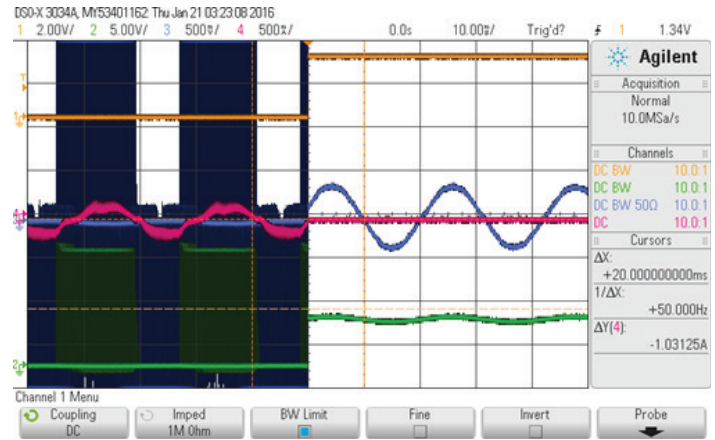
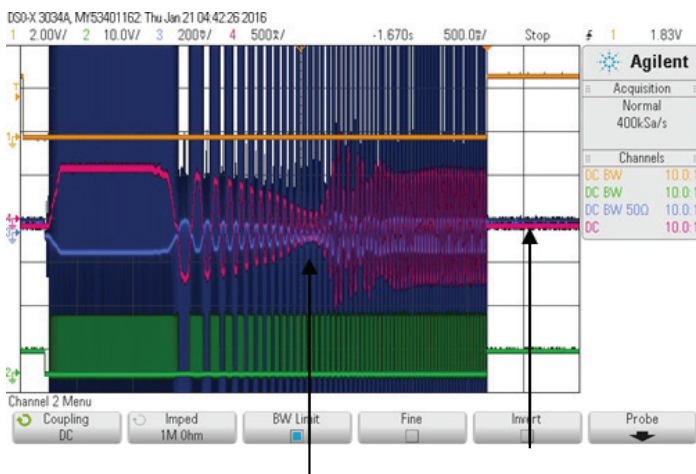


Figure 17: Phase Lag Near 0°

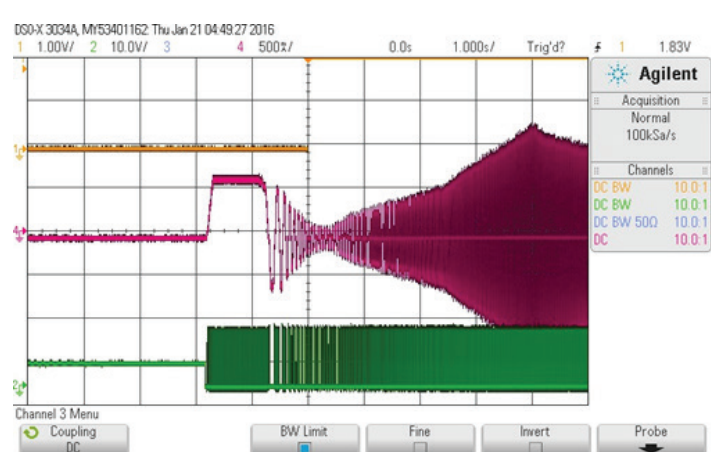
Recommendations

- Choose STRTDMD to be approximately 25% of peak current at maximum speed.
 - This is a guideline, not a strict rule. For some motor/load types, the optimal performance requires a different starting torque.
 - As a rule, a lower value of STRTDMD reduces acoustical noise at the point of transfer between the stepping and running modes of operation.
- Adjust ACCEL and ACCEL to determine the phase angle between 0° and 60°.
 - A phase angle that is closer to 0° might exhibit reduced acoustical noise at the transition to running mode.
 - A phase angle that is 60° to 90° typically does not exhibit issues.
- Check startup at multiple rotor initial positions.
 - If the phase angle is not repeatable, recheck the settings for Align.
- Check the overall starting waveform, including the ramp to final speed.
 - The goal is to obtain a smooth sinusoid that steadily increases to the final value.
- The minimum frequency (F_{FINAL}) is 5 Hz.
- Set F_{FINAL} such that peak-to-peak bmf voltage is at least four times the BEMFHYS level (Config 1 tab).
- Set ACCEL to a long-duration value to show where the motor stalls (see Figure 18).



Ch1: TEST Ch2: VoutA Ch3: Vout-Ctap Ch4: (Iout)
During a stall, zero bmf is observed on VOUT.

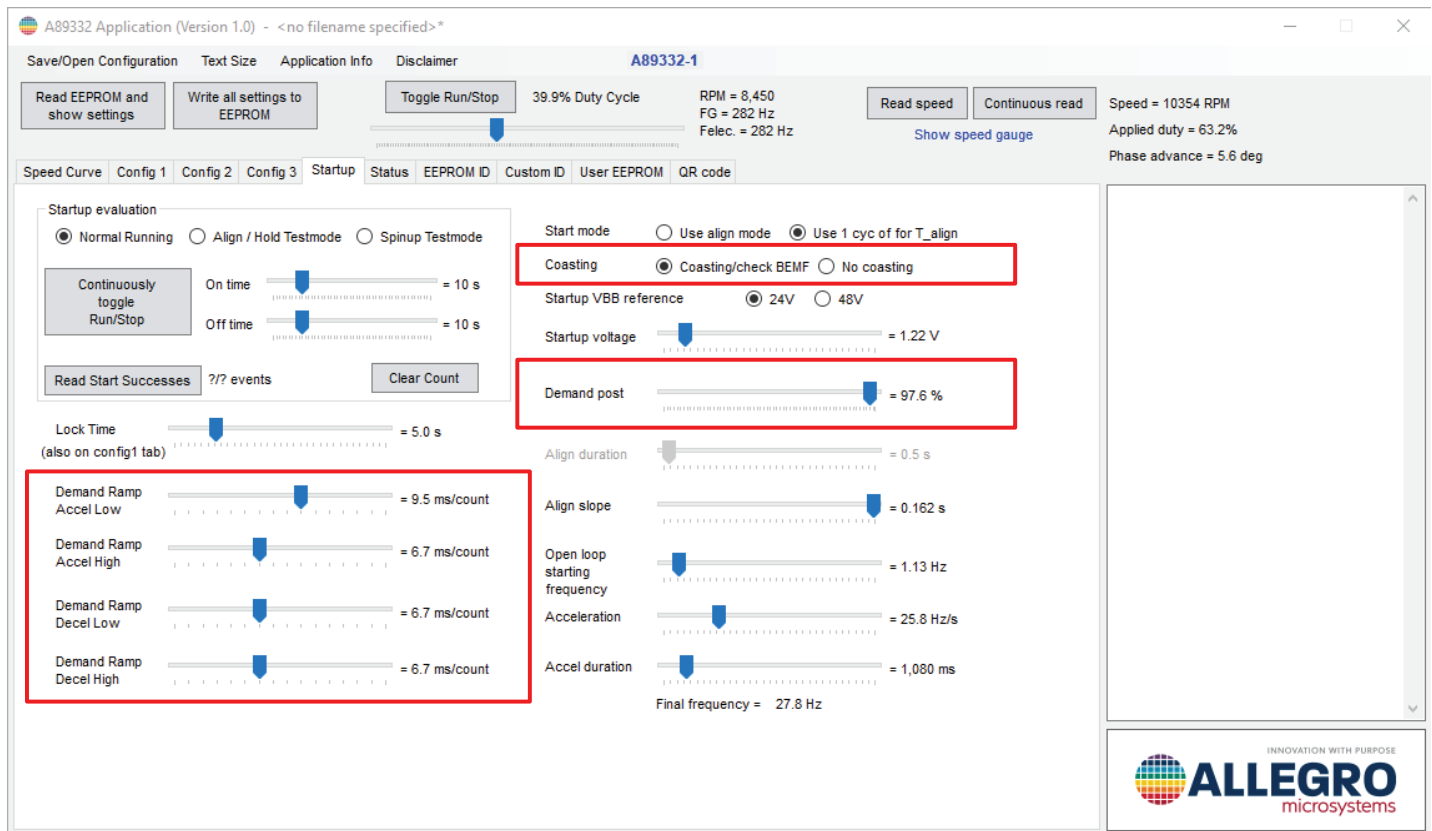
Figure 18: Determine Point of Stall



Ch1: TEST Ch2: VoutA Ch3: Vout-Ctap Ch4: (Iout)

Figure 19: Good Startup
Shows Smooth Rise of Current Waveform

Step 3: Ramp to Target Speed Control Variables



Coasting

After the starting sequence, there are two options. The coast option turns off all three motor phases and waits for a phase A zero-crossing to resume the sine drive. NoCoast continues the sine drive without interruption. Use of “Coasting/CheckBemf” is recommended.

DMDPOST: This represents the duty applied to the windings at the beginning of running mode. It is expressed as a percentage of the programmed startup demand. Typically, it is set to 100%. A change to this value can reduce current, which can result in lower audible noise in early stages of the running mode. The duty is held at this level for 500 ms or 100 ms, depending on the variable PCDLY (set on Config 2), before the final ramp to target speed begins.

- DMDRMPAL: Demand ramp during acceleration, low duty (less than 25%)
- DMDRMPAH: Demand ramp during acceleration, high duty (greater than 25%)
- DMDRMPDL: Demand ramp during deceleration, low duty (less than 25%)
- DMDRMPDH: Demand ramp during deceleration, high duty (greater than 25%)

Demand ramp variables control how fast the ramp rises at startup, as well as how fast duty changes when the duty input changes. For some motors, the running algorithm has better results (i.e., a

smoother current waveform) at low duty during acceleration with a slower ramp rate.

Using the settings shown in the GUI presented in this section, the minimum time for duty changes can be calculated as follows:

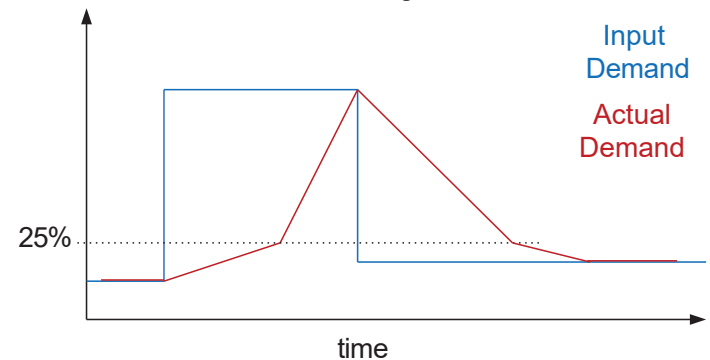
- For a 15% to 100% change:

$$T_{ACCEL} = (25\% - 15\%) \times 1023 \times 9.5 \text{ ms/count} + (90\% - 25\%) \times 1023 \times 6.7 \text{ ms/count} \rightarrow 5.42 \text{ s}$$

- For a 85% to 20% change:

$$T_{DECEL} = (85\% - 25\%) \times 1023 \times 6.7 \text{ ms/count} + (25\% - 20\%) \times 1023 \times 9.5 \text{ ms/count} \rightarrow 4.94 \text{ s}$$

NOTE: This is the minimum time for open-loop control. For closed-loop speed control, the speed control might require some additional time to settle to the final speed.



STATUS TAB

Fault Readback

Faults are stored in register locations and can be access via I²C. If the fault is latched, the clear fault button must be used to reset the register.

nFAULT Terminal Output

Various signals can be routed to the nFAULT pin to use as debug tools while controlling with the GUI. Upon power cycle, the nFAULT pin reverts to the typical function.

Die Temperature

In test mode, the internal circuit used to monitor chip temperature is made available using an onboard analog-to-digital converter (ADC). If pull-up resistors are connected to the FG and PWM inputs, the I²C port can be used to monitor the die temperature during various loading conditions of the fan.

This tool can be used to study the real-life thermal condition of the motor printed circuit board (PCB). Accuracy should be better than $\pm 10\%$. An alternative measurement method is to attach a thermocouple to the top of the package.

With the exposed pad connected to the ground plane, the junction temperature is reasonably close to the top of package measurement based on package parameter Ψ_{JT} (phi junction-top). Ψ_{JT} The J_T for the LP package is approximately 0.5°C/W.

Power Loss Brake (89332 Version Only)

The power loss brake (89332 version only) has a feature to stop the motor when power is disconnected from the motor module. With the VIN pin isolated from the VBB motor supply by a series diode, the pull-down on the VIN pin puts the part into a low-power standby mode and brakes the motor. The bias current from the A89332 slowly reduces the power supply. When the VBB voltage decays to 5 V, to regulate the VBB line to this lower level, brake pulsing might occur. As long as the motor is moving in the brake mode, energy is sufficient to maintain regulation of VBB and the braking force applied.

No Power Brake (89332 Version Only)

If A89332 is in a system with multiple fans, external forces can cause an unpowered system to rotate in reverse. In this case, it is desirable to slow the motor so the reverse rotation does not impact overall system efficiency in terms of airflow control. If the external force is large enough, the motor can develop enough voltage on the VBB line to enable the switching circuit that boosts VBB to a level high enough to apply the braking force.

For additional detail, refer to the scope plots in the Braking Characteristics section.

Braking Characteristics

Brake Behavior



- V_{IN} (blue) immediately drops to zero when the power connection is removed
- V_{BB} (green) decays to 5 V before pulsing of the motor outputs begins to regulate the V_{BB} line.
- OUTA (yellow) shows the short pulses that provide braking circuit power.
- I_A (red) shows the motor output current: As the motor slows down, current reduces.

NOTE Braking at the maximum speed results in the maximum current scenario. Consideration of the absolute maximum braking current is required. If motor braking at the maximum speed results in greater than this rating (6.5 A) use of neither the power loss brake feature nor the A89332 gate drive IC is recommended.

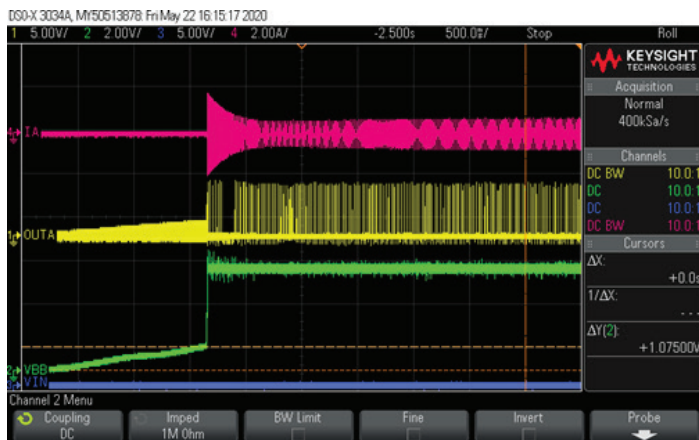
Zoom of Regulation Stage during Brake



- V_{IN} (blue)
- V_{BB} (green) regulating at 5 V
- OUTA (yellow)
- I_{OUT} (red)

NOTE: During a hot swap disconnect with the motor at high speed, the braking effect occurs immediately upon V_{IN} reducing to less than the threshold. If a hot-swap disconnect results in chatter on the V_{IN} line, the part can be re-enabled in the typical mode of operation. Because braking current can be high, the V_{BB} line can be pumped up as braking stops and current is discharged into the V_{BB} capacitor. For this scenario, TVS is recommended on the V_{BB} line.

No Power Brake

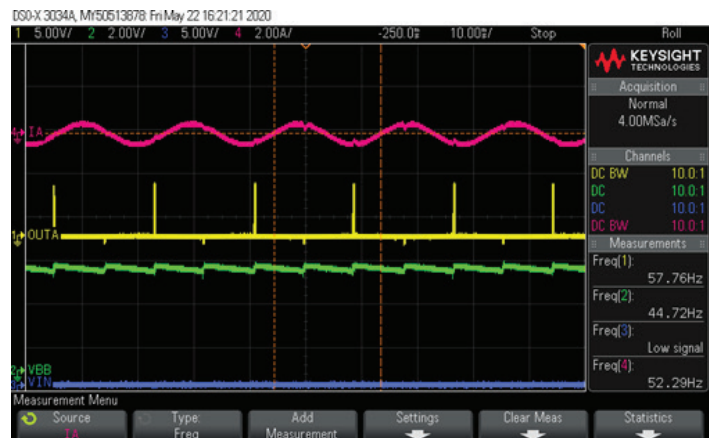


- V_{IN} (blue)
- V_{BB} (green)
- OUTA (yellow)
- I_A (red)

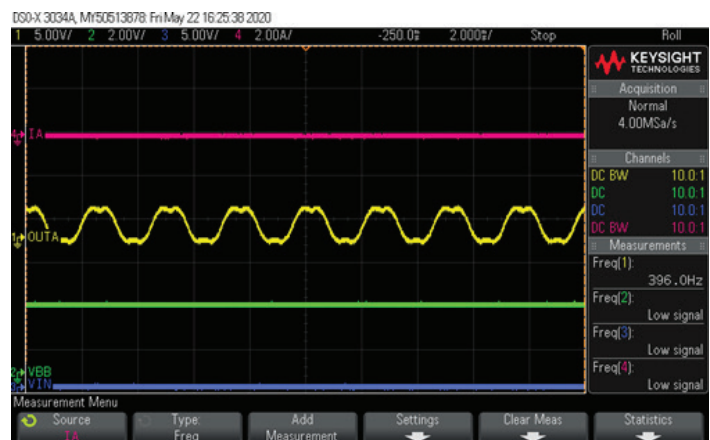
NOTE: It is important to note that external force needs to be large enough to develop the V_{BB} voltage to initially turn on the part (~1.1 V). After the braking force is applied, the external force can be reduced to some extent before the braking is disabled.

Zoom of No-Power Brake Waveform

PLB Enabled



PLB Disabled



- V_{IN} (blue)
 - V_{BB} (green)
 - Motor output (yellow)
 - Motor braking current (red)
 - External force applied
1. As the motor begins to spin due to external force, V_{BB} ramps up (green).
 2. As V_{BB} reaches approximately 1 V, pulsing begins to initiate braking.

NOTE: For this reference motor, rotation is at 50 Hz with the external braking feature applied. With the feature disabled, the external forces produced approximately 400 Hz (bottom).

FAULT MODES

A fault output is provided to indicate a potential issue with the PCB. Potential problems include:

- PCB short that prevents motor turn-on
- Motor output short
- Missing components
- Damaged components

If the device is powered and logic is operational, the output of nFAULT can be connected to the BRAKE pin to prevent the motor from freely rotating during the fault condition.

The following signals bring the output of nFAULT low:

- V_{BB} undervoltage
- Thermal shutdown
- Charge pump UVLO
- V_{BB} overvoltage
- Output V_{DS} fault (OCP)
- Loss of synchronization

Fault	Brake i/p	Fault Action	Latched	Readback Reg[Bit]
V_{BB} Undervoltage	X	Disable outputs	N	147[8]
TSD	X	Disable outputs	N	147[6]
V_{BB} Overvoltage	X	Disable outputs	N	147[9]
Charge Pump	H	Disable outputs	N	147[7]
	L	Brake	N	
VDS Fault	H	Disable outputs, fault reset by PWM off/on command or V_{BB} undervoltage	Y	147[5:0]
	L	Brake	Y	147[5:0]
Loss of Synchronization	H	Set lock-detect timeout—motor coasts	N	148[6:0]
	L	Set lock-detect timeout—motor brake	N	148[6:0]

EEPROM MAP

I2C REG	EE ADDR	Bits	Name	Description [1]	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	0	DTYIN	0 = low frequency < 3.2 kHz; 1 = high frequency > 2.5 KHz	0x0017
		2:1	REVDMD	0 = 1×; 1 = 1.5×; 2 = 2×; 3 = 2.5×	
		3	FGMSK	0 = disabled; 1 = enabled	
		4	FCOLCHK	0 = enabled; 1 = disabled	
		5	Reserved		
		6	bemfFiltTimeRgSel	Bemf comparator filter time range selection: 0 (default) = select bemf filter time range of 4, 8, 12, or 16 μs 1 = select bemf filter time range of 1, 2, 3, or 4 μs	
		9:7	forcedOpLpDutySel	Set applied duty during forced open loop: 0 (default) = external PWM duty; 1 = 90%; 2 = 91%; 3 = 93%; 4 = 95%; 5 = 97%; 6 = 99%; 7 = 100%	
		15:10	SpeedFeedBackClamp	Speed feedback clamp for deceleration time adjustment; default is 0	
70	6	15:0	Trim1	Allegro reserved	—
71	7	15:0	Trim2	Allegro reserved	—
72	8	3:0	MAXDTYCLP	Range = 100% to 76.5%; LSB = 1.6%	0x8000
		7:4	MAXDTYHYS	Range = 0 to 5.9%; LSB = 0.4%	
		14:8	MINDTYCLP	Range = 0 to 49.9%; LSB = 0.78%	
		15	CL25	0 = close loop when > target speed; 1 = close loop at 25% duty	
73	9	8:0	STRTDMD	LSB = $V_{BBRN}/511$	0XF81A
		15:9	DMDPOST	Range = 0 to 100%; LSB = 0.8%	
74	10	7:0	ALIGN	Range = 0 to 20.4 s; LSB = 100 ms	0xFD06
		15:8	ASLOPE	Range = 160 ms to 40 s	
75	11	7:0	STRTF	Range = 0 to 15.94 Hz; LSB = 0.0625 mHz	0x9812
		15:8	ACCEL	Range = 0 to 99.6 Hz/s; LSB = 0.78	
76	12	7:0	ACCELT	Range = 0 to 10.2 s; LSB = 40 ms	0x001B
		15:8	MAXOFFDTY	Range = 100% to 76.5%; LSB = 0.4%	
77	13	3:0	DMDRMPAL	Range = 0.9 to 15.3 ms/count; LSB = 0.9	0x6669
		7:4	DMDRMPAH	Range = 0.9 to 15.3 ms/count; LSB = 0.9	
		11:8	DMDRMPDL	Range = 0.9 to 15.3 ms/count; LSB = 0.9	
		15:12	DMDRMPDH	Range = 0.9 to 15.3 ms/count; LSB = 0.9	
78	14	8:0	RESPTY	Range = 0 to 100%; LSB = 0.2%	0x0000
			RESWID	Range = 0 to 50%; LSB = 0.4%	
79	15	7:0	MAXSPD	Maximum electrical frequency	0x320F
		15:8	TLOCK	0 to 25.5 s	
80	16	7:0	RDLOW	Range = 0 to 4095; LSB = 16 rpm	0x0000
		15:8	RDHIGH	Range = 0 to 4095; LSB = 16 rpm	

[1] For additional detail, refer to the user interface.

EEPROM MAP (continued)

I2C REG	EE ADDR	Bits	Name	Description ^[1]	Default Setting
81	17	7:0	RDBLK	Range = 0 to 25.5 s; LSB = 100 ms	0x0000
		11:8	RDDLTY	Range = 0 to 15 s; LSB = 1 s	
		15:12	RETRY	Count > 1 = number of lock-detect events before disable	
82	18	11:0	PHASLP	Calculated slope for linear phase advance	0xF0B7
		15:12	SOWLIN	Window width with linear phase advance	
83	19	0	OCLDIS	0 = typical; 1 = disabled	0xA509
		1	OCLOPT	0 = cycle by cycle; 1: reduce demand	
		3:2	PWMF	Motor PWM selection	
		5:4	BEMFFILT	Bemf comp filter	
		6	TCENB	Temperature compensation: 0 = off; 1 = on	
		8:7	WINDM	Windmill option	
		12:9	SPDCLP	Minimum clamp is speed-control mode	
		14:13	PHARNG	0 = > 32 krpm; 1 = 16 krpm to 32 krpm; 2 = 8 krpm to 16 krpm; 3 = < 8 krpm	
		15	PCDLTY	Post-coast delay: 0 = 100 ms; 1 = 500 ms	
84	20	0	CL	Speed-control mode: 0 = open-loop; 1 = closed	0x5B11
		1	PHA	Running mode: 0 = auto; 1 = linear phase advance	
		2	RDOPT	RD function mode select	
		3	FGRD	Pin function for FG/RD: 0 = FG; 1 = RD	
		6:4	PP	Pole pair = PP + 1	
		7	NOCOAST	1 = no coast; 0 = coast	
		8	ALIGNMODE	0 = align; 1 = one cycle	
		9	QCKSTRT	0 = disable; 1 = enable	
		10	RDPWM	0 = no alarm if PWM is off; 1 = alarm ignores PWM off	
		11	FGSTRT	0 = FG disabled during startup; 1 = FG enabled	
		13:12	BEMFHYS	Bemf hysteresis level for startup	
		14	SOWAUTO	Initial value of window	
		15	DIR	0 = ACB; 1 = ABC	
85	21	7:0	KP	Closed loop	0x0210
		15:8	KI	Closed loop	
86	22	7:0	SLPSWDTY	Duty at which slope changes	0x0000
		11:8	TRAPSWDTY	Duty to switch to trap	
		15:12	PHAOFF	Offset for linear phase advance	
87	23	14:0	SLPSWRPM	Range 0 to 16384; LSB = 1 rpm	0x0000
88	24	13:0	SPDSL2P	Calculated slope	0x8000
		15:14	gateDrSlewCtrl	Gate-drive source and sink-current level selection	

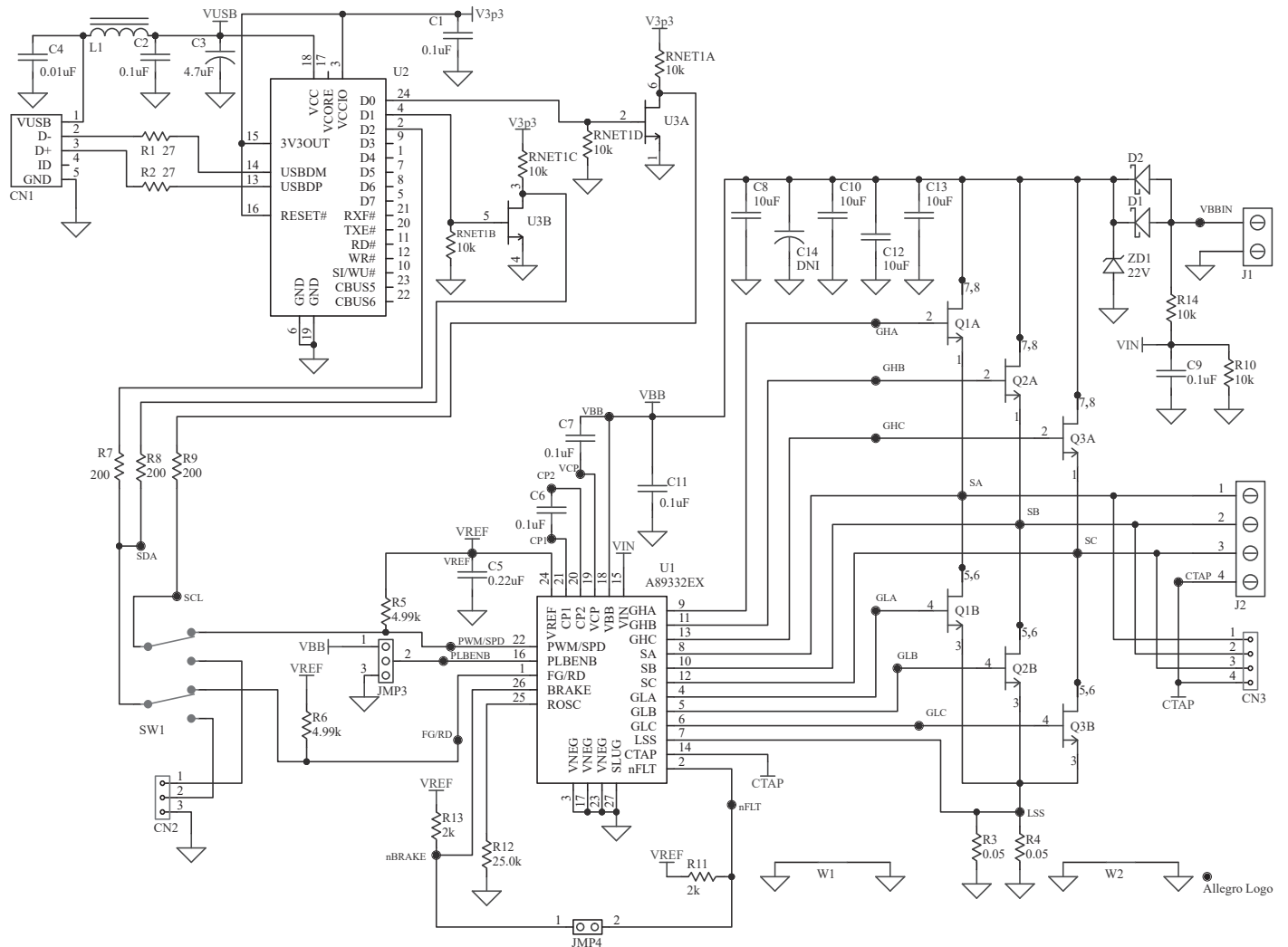
^[1] For additional detail, refer to the user interface.

EEPROM MAP (continued)

I2C REG	EE ADDR	Bits	Name	Description [1]	Default Setting
89	25	0	DUTYINV	0 = typical; 1 = invert	0x6102
		1	MAXDTYOPT	0 = run at open loop; 1 = run at MAXDTYCLP	
		2	ONOFFCNTL	0 = typical hysteretic on/off; 1 = off between DC_ON and DC_OFF	
		3	PIOPT	0 = 1×; 1 = 8×	
		4	REVOPT	1 = reverse when duty < DC_OFF and ONOFFCNTL = 1	
		6:5	OCLLEV	OCL level	
		8:7	ACOCL	AC loss OCL level	
		12:9	DCDISTH	Threshold for DC disable function	
		15:13	TRAPOL	Trapezoidal overlap control	
90	26	7:0	TCOAST	Coast time for brake or direction change	0xAF15
		15:8	OPNLPMAX	Maximum speed limit for open-loop mode	
91	27	11:0	MINSPD	Minimum speed (Y-intercept)	0x0320
		13:12	OVPSEL	Overvoltage-protection threshold selection	
		14	VBBREF	V _{BB} reference voltage selection	
		15	BRKOFF	0 = coast; 1 = brake when PWM off state after t _{COAST}	
92	28	13:0	SPDSLPI	Calculated slope of speed curve	0x84B0
		15:14	OCLTOFF	OCL off-time select	
93	29	7:0	DCON	Range = 0 to 49.9%; LSB = 0.2%	0x101A
		15:8	DCOFF	Range = 0 to 49.9%; LSB = 0.2%	
94	30	3:0	DEADT	Dead time selection	0x000 A
		5:4	OCPVDSSel	OCP V _{DS} threshold selection	
		7:6	BLANK	Blank time for OCL	
		8	OCPDIS	OCP disable: 0 = enabled; 1 = disabled	
		9	ACLOSS	0 = disable; 1 = enable	
		11:10	ACLOSSREL	Duty at which ACLOSS OCL function is released	
		12	ACLOSSOCL	0 = disable; 1 = enable	
		13	FCOLOPT	Wait before data output	
		14	FCOLCOAST	0 = typical drive; 1 = disable motor during data output	
		15	FCOLENB	0 = disable; 1 = enable	
95	31	15:0	Trim3	Allegro reserved	—
n/a	32-63		USER	User-defined memory	—
	32	15:8	BYTE 0		0x0000
		7:0	BYTE 1		
	33-61	15:8	BYTE 2,4,6...		
		7:0	BYTE 3,5,7...		
	63	15:8	BYTE 62		
		7:0	CHKSUM	For read back	

[1] For additional detail, refer to the user interface.

EVALUATION BOARD SCHEMATIC

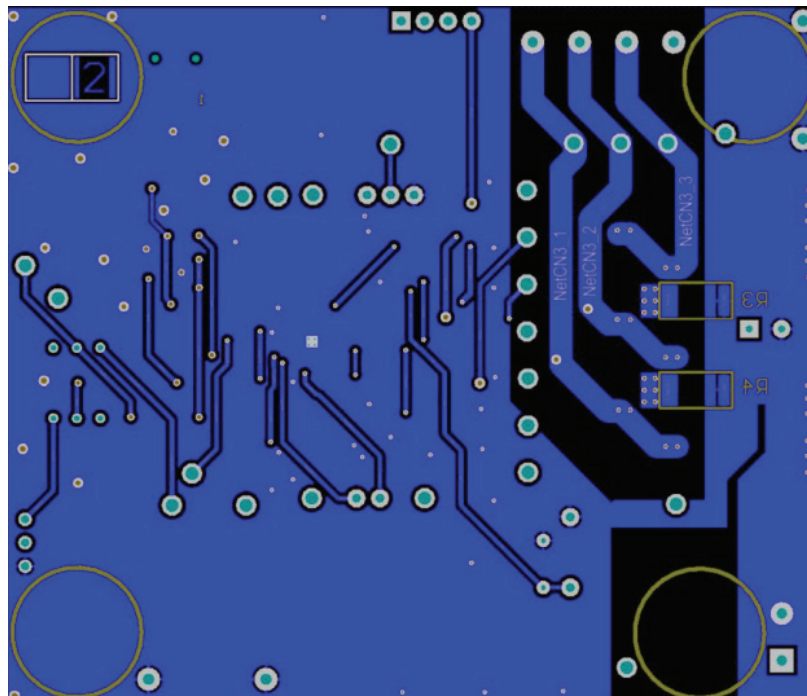
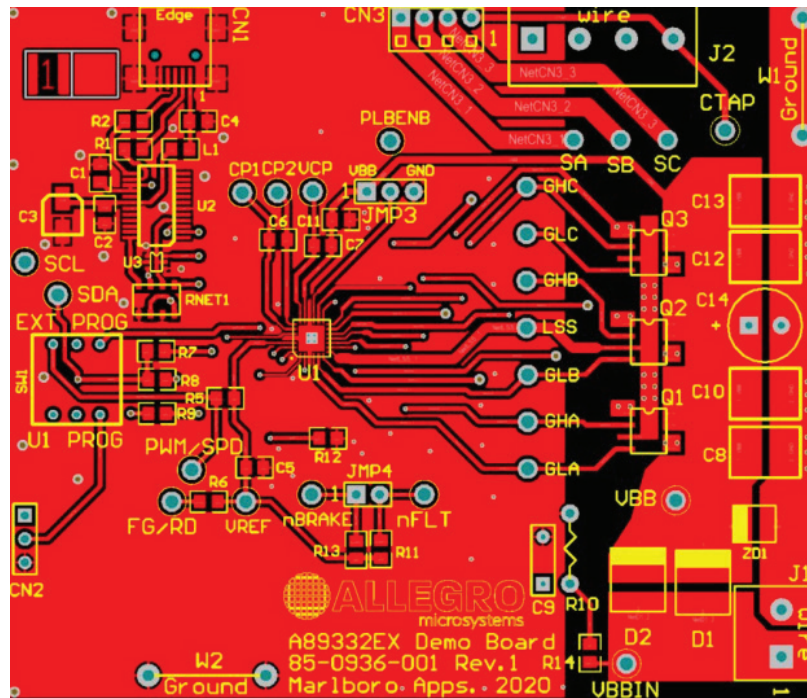


EVALUATION BOARD BILL OF MATERIALS

Item	Quantity	Designator	Value	Description	Part Type	Footprint
1	5	C1, C2, C6, C7, C11	0.1 μ F	50 V capacitor	TDK CEU4J2X7R1H104K125AE; Digikey 445-7856-1-ND	0805
2	1	C3	4.7 μ F	35 V capacitor	Chemi-Con EMZA350ADA4R7MD61G; Digikey 565-2553-1-ND	UCC D61 Cap
3	1	C4	0.01 μ F	50 V capacitor	Yageo CC0805KRX7R9BB103; Digikey 311-1136-1-ND	0805
4	1	C5	0.22 μ F	50 V capacitor	Murata GCM21BR71H224KA37L; Digikey 490-4970-1-ND	0805
5	4	C8, C10, C12, C13	10 μ F	50 V capacitor	Samsung CL32B106KBJNWE; Digikey 1276-3388-1-ND	2220
6	1	C9	0.1 μ F	50 V capacitor	Vishay K104K15X7RF5TL2; Digikey BC1084CT-ND	0.2" Cap
7	1	C14	Not Installed		DNI	Cap, 8 mm dia., 3 p, 5 mm spacing
8	1	CN1		USB 2.0 connector	EDAC 690-005-299-043; Digikey 151-1206-1-ND	EDAC 690-005-299-043
9	8 Pins	CN2, JMP3, JMP4		Cut pins from 50-pin strip	Samtec TSW-150-07-T-S; Digikey SAM1035-50-ND	3-pin 0.1" connector, 3-pos. shunt, 2-pos. shunt
10	1	CN3		Molex 4-pin vertical receptacle	Molex 22-02-2045; Digikey WM3202-ND	Molex 4-pin 4455-N vertical
11	24	CP1, CP2, CTAP, FG/RD, GHA, GHB, GHC, GLA, GLB, GLC, LSS, nBRAKE, nFLT, PLBENB, PWM/SPD, SA, SB, SC, SCL, SDA, VBB, VBBIN, VCP, VREF		Large test point	Keystone 5010; Digikey 36-5010-ND	PAD 57 125 TP HB
12	2	D1, D2		40 V/3 A Schottky diode, 40 V 3 A Schottky diode	On Semiconductor MBRS340T3G; Digikey MBRS340T3GOSCT-ND	DO-214AB
13	4			Bump on foot	3M SJ-5303 (CLEAR); Digikey SJ5303-7-ND	Bump on foot
14	1	J1		2-pin screw-down connector	On Shore Technology ED120/2DS; Digikey ED1609-ND	2-pin screw-down connector 2
15	1	J2		4-pin screw-down terminal block	On Shore ED120/4DS; Digikey ED2227-ND	4-pin screw-down connector
16	1	L1		Ferrite bead	Laird MI0805K400R-10; Digikey 240-2389-1-ND	0805
17	3	Q1, Q2, Q3		Dual N-channel MOSFET	Diodes Inc. DMG4800LSD-13; Digikey DMG4800LSD-13DICT-ND	8-pin SO
18	4 Pins	QC9, QR10		Sockets for C9 and R10.	Mill-Max 801-43-050-10-001000; Digikey ED6350-ND	
19	2	R1, R2	27 Ω	1/8 W resistor	Vishay/Dale CRCW080527R0FKEA; Digikey 541-27.0CCT-ND	0805
20	2	R3, R4	0.05 Ω	2 W resistor	Ohmite MCS3264R050FER; Digikey MCS3264R050FERCT-ND	2512
21	2	R5, R6	4.99 k Ω	1/8 W resistor	Panasonic ERJ-6ENF4991V; Digikey P4.99KCCT-ND	0805
22	3	R7, R8, R9	200	1/8 W resistor	Panasonic ERJ-6GEYJ201V Digikey P200ACT-ND	0805
23	1	R10	10 k Ω	1/4 W resistor	Stackpole RNF14FTD10K0 Digikey RNF14FTD10K0CT-ND	0.3" resistor
24	2	R11, R13	2 k Ω	1/8 W resistor	Panasonic ERJ-6GEYJ202V Digikey P2.0KACT-ND	0805
25	1	R12	25.0 k Ω	1/10 W resistor	TE Connectivity CPF-A-0805B25KE; Digikey A124124CT-ND	0805
26	1	R14	10 k Ω	1/8 W resistor	Stackpole RMCF0805FT10K0 Digikey RMCF0805FT10K0CT-ND	0805
27	1	RNET1	10 k Ω	4 isolated resistors	CTS 744C083103JP; Digikey 744C083103JPCT-ND	CTS 744 series

Item	Quantity	Designator	Value	Description	Part Type	Footprint
28	1	SW1		Dual SPDT switch	Grayhill 76STC02T; Digikey 76STC02T-ND	76STC02T
29	1	U1		Three-phase sensorless fan driver	A89332EX	26-Pin EX
30	1	U2		USB 8-bit FIFO IC	FTDI FT240XS-R; Digikey 768-1127-1-ND	SSOP-24 (150 mil)
31	1	U3		Dual N-channel FETs	Toshiba Semi SSM6N15AFU.LF; Digikey SSM6N15AFULFCT-ND	SOT-363
32	2	W1, W2		22-gauge buss wire (300 mils above PCB)		Scope ground
33	1	ZD1	22 V	TVS Zener	Littelfuse SMBJ22A; Digikey SMBJ22ALFCT-ND	DO-214AA

EVALUATION BOARD LAYOUT



LAYOUT GUIDE WITH REFERENCE TO APPLICATION INFORMATION IN THE DATASHEET

- Make a large GND plane for the IC on the top and bottom of the PCB, connect all GND pins to the plane, and use wide trace to connect the IC GND plane to the power GND in a star-connection fashion.
- Place the ROSC resistor close to the IC and connect it to the GND plane (avoid placement of the connection through the via) as the top priority. Place the capacitor of VBB, VREF, and Charge Pump as close to the IC as practical and connect to the GND plane.
- Add thermal vias to the exposed pad area.
- Avoid the parallel trace of GLx and GHx.
- Do not allow high-frequency switching traces—GLx, GHx, PWM, FG, and ROSC trace—to cross each other.
- For a very space-limited PCB, add a capacitor (560 pF is suggested based on simulations) in parallel with ROSC (25 k Ω).

Revision History

Number	Date	Description
–	November 17, 2025	Initial release

Copyright 2025, Allegro MicroSystems.

Allegro MicroSystems reserves the right to make, from time to time, such departures from the detail specifications as may be required to permit improvements in the performance, reliability, or manufacturability of its products. Before placing an order, the user is cautioned to verify that the information being relied upon is current.

Allegro's products are not to be used in any devices or systems, including but not limited to life support devices or systems, in which a failure of Allegro's product can reasonably be expected to cause bodily harm.

The information included herein is believed to be accurate and reliable. However, Allegro MicroSystems assumes no responsibility for its use; nor for any infringement of patents or other rights of third parties which may result from its use.

Copies of this document are considered uncontrolled documents.

For the latest version of this document, visit our website:

www.allegromicro.com