A89347 Evaluation Board User Manual

DESCRIPTION

The A89347 integrated circuit (IC) can drive a wide variety of fan motor types. The IC has low driver-on resistance ($R_{DS(ON)}$) power outputs that are 3 A-capable. To drive 12 V fans in the 1 W to 30 W range, a high-power package option (suffix LP) is available.

A key feature of the A89347 is closed-loop speed control with flexible speed-curve configurations. This feature allows elimination of the microcontroller unit (MCU) for most applications that typically require them.

Programming of the A89347 EEPROM is required to change IC characteristics to match the application. A standard inter-integrated circuit (I^2C) 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 I^2C 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 functional operation.

Allegro provides a graphical user interface (GUI) software package to make it easy to program the A89347 and to control the fan motor operation. This user manual generally follows the structure of the GUI and provides additional details to assist with settings for each tab of the GUI program.

The Allegro A89347 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 A89347 or to an external connector. The external connector can be used to program an IC already installed into a motor module using a standard four-wire interface.

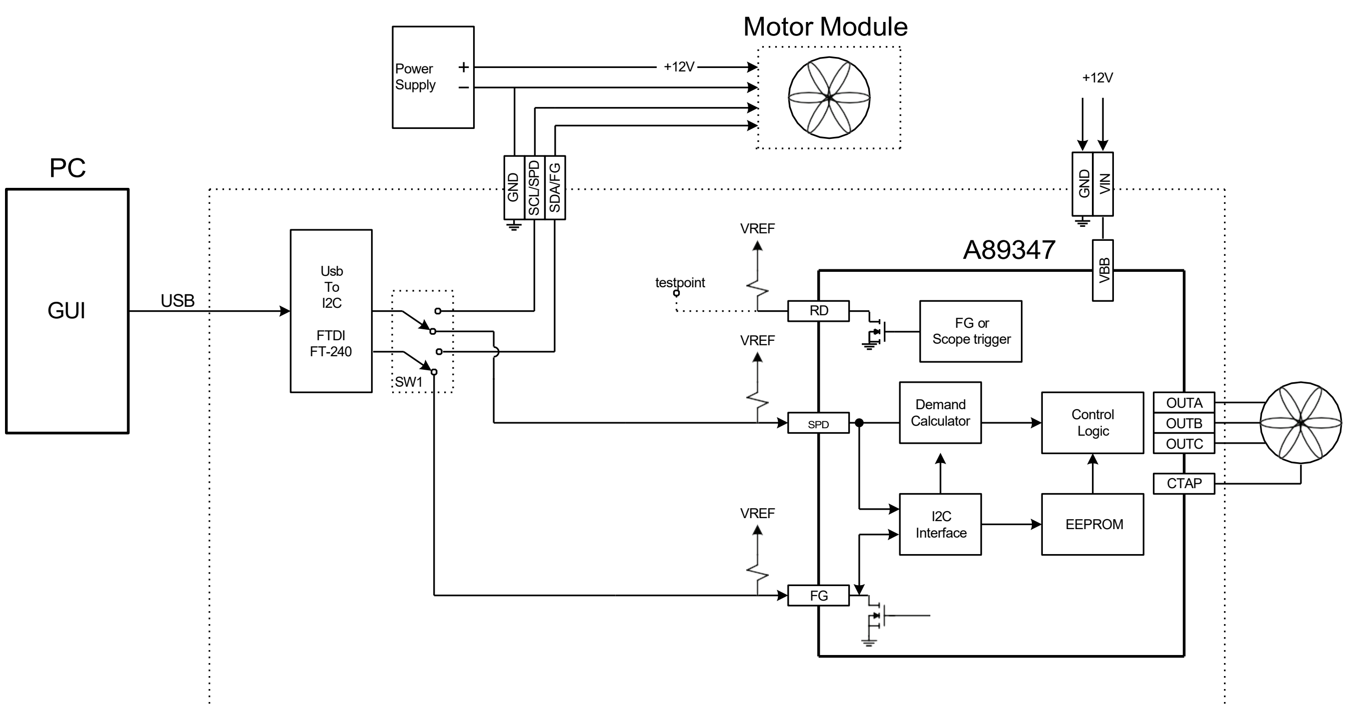

Figure 1: Application Diagram

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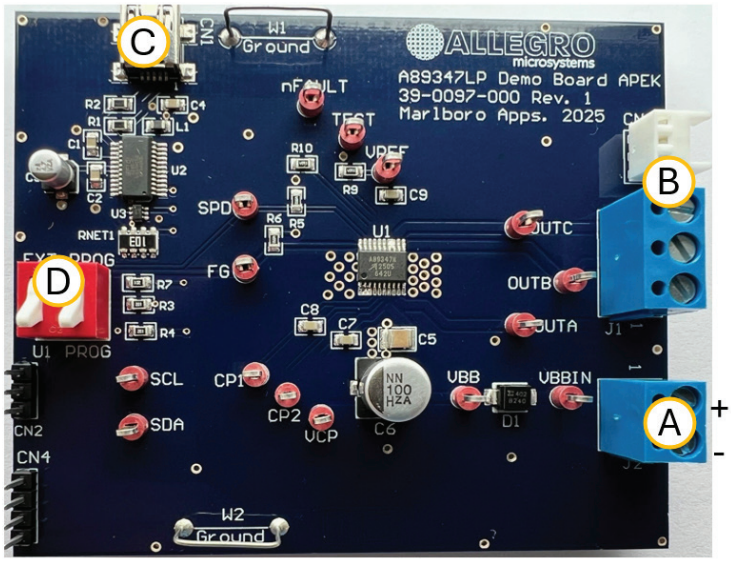
MAKING EVALUATION BOARD CONNECTIONS AND LAUNCHING A89347 GUI

Make the connections shown in Figure 2, then launch the A89347 GUI shown in Figure 3.



A. Power-supply input (J2): Connect the power supply to J2.
B. Motor-terminal connector (J1 or CN3): Connect to the motor terminal.
C. Min-USB connector (CN1): Connect the USB cable from the computer.
D. I²C selection (SW1): To enable the I²C interface to the device, toggle the switch to the U1 PROG position.

Figure 2: Evaluation Board Connections

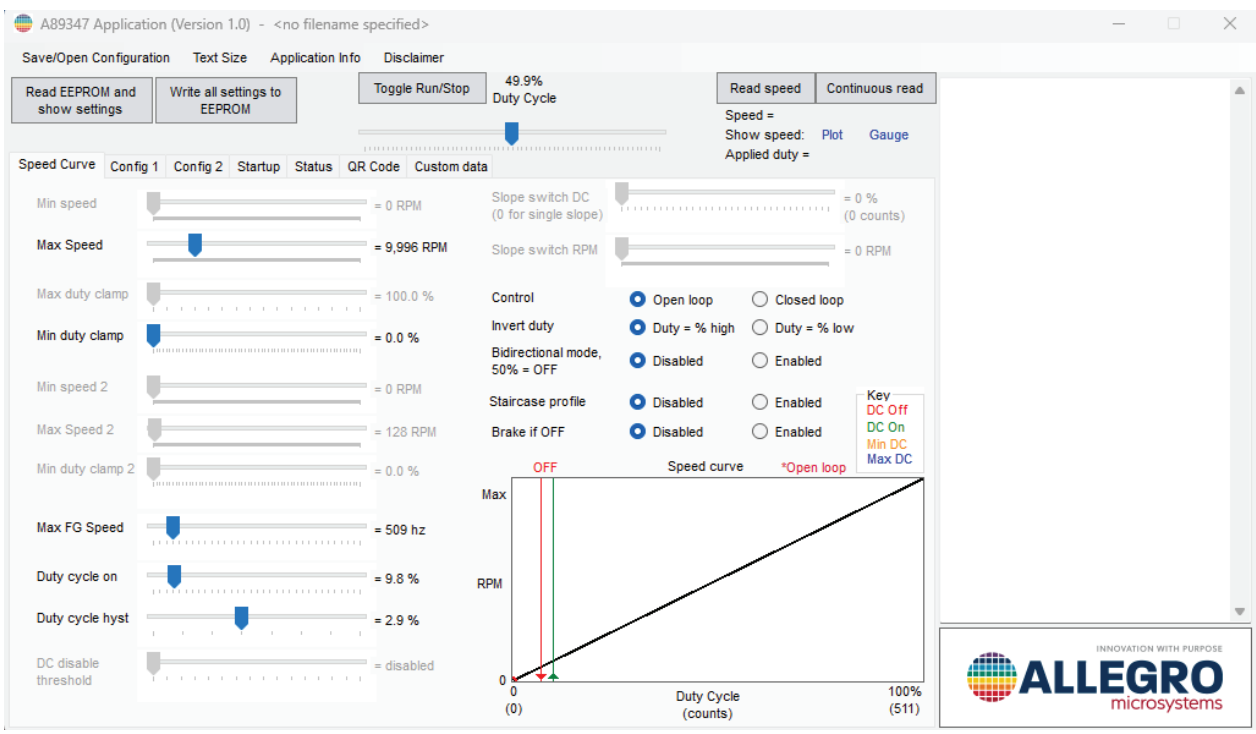


Figure 3: A89347 GUI

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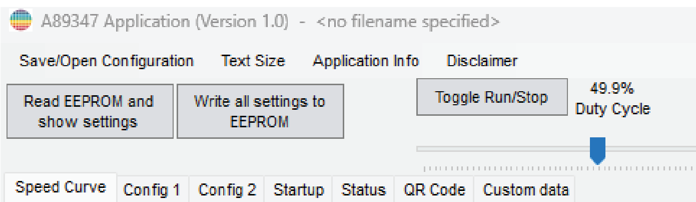
PROGRAMMING THE IC AND STARTING THE MOTOR USING THE RUN/STOP TOGGLE BUTTON

When the A89347 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. If it is desired 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 predefined configuration into the IC using the Save/Open Configuration menu. To start the motor, click the Toggle Run/Stop button.



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 $V_{EFF} = V_{BB} \times$ Duty, as represented in Figure 4.

In closed-loop mode, the duty applied to the motor windings is adjusted to meet the speed for which the IC is configured. If VBB 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 Figure1). 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. A89347 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 8% 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.

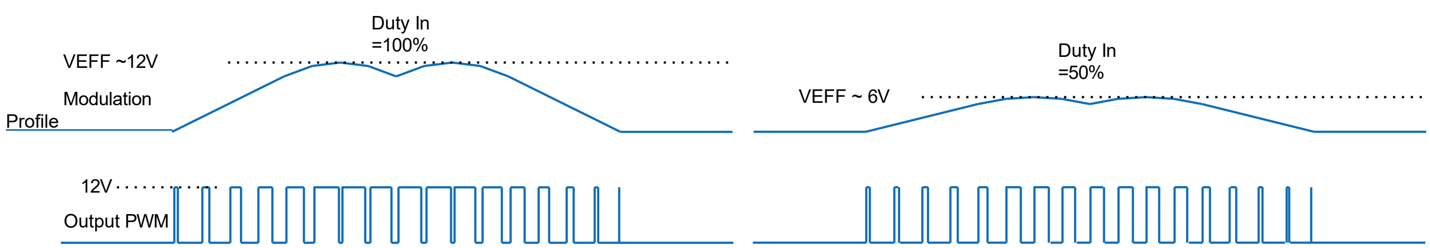


Figure 4: Open-Loop Operation

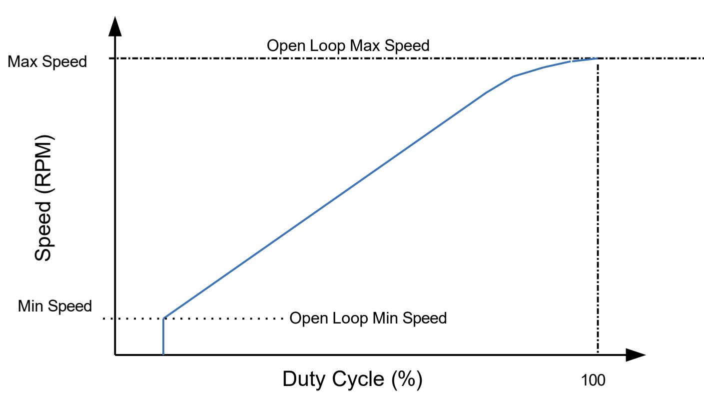


Figure 5: Example Open-Loop Curve

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Closed Loop

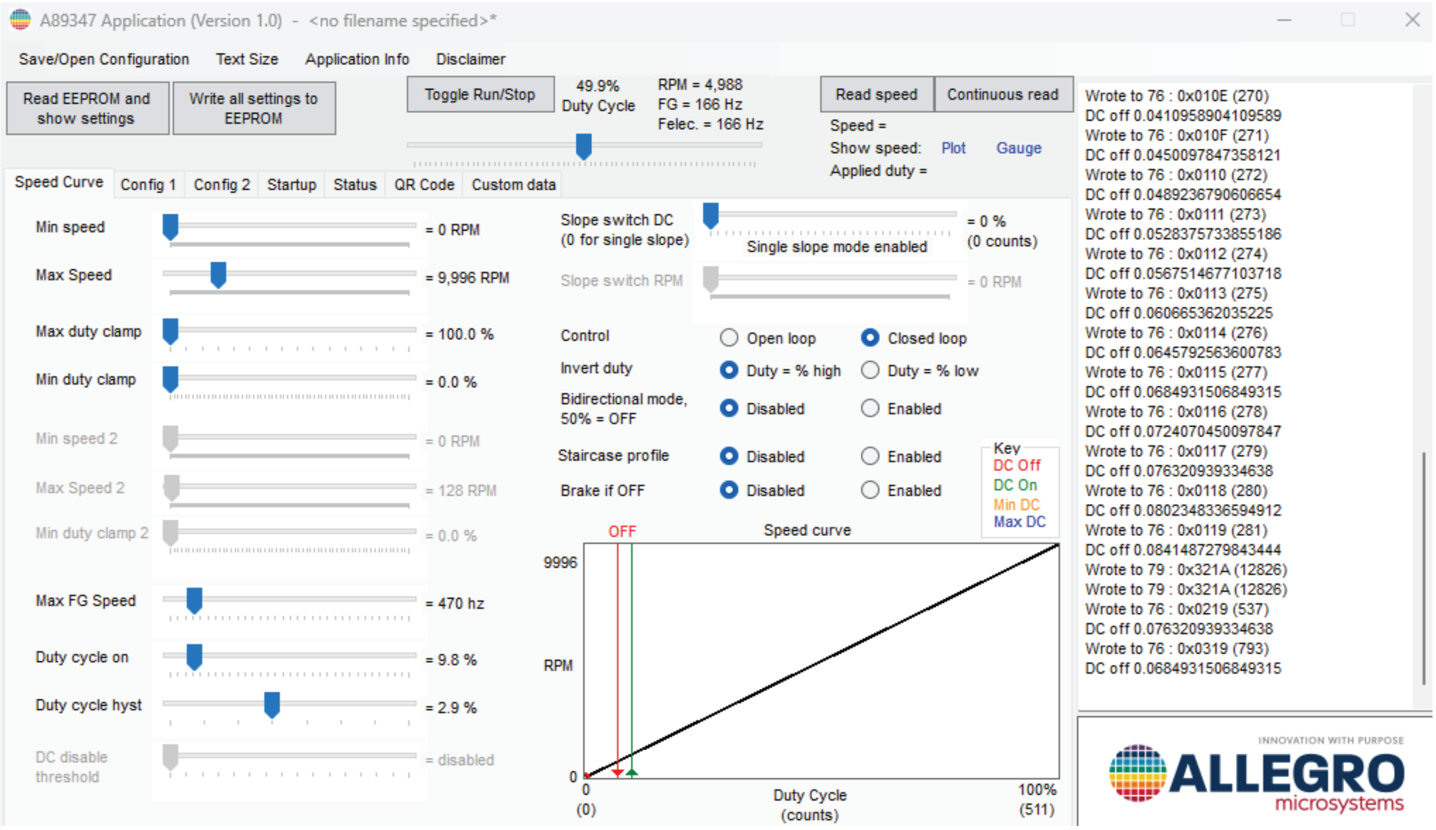
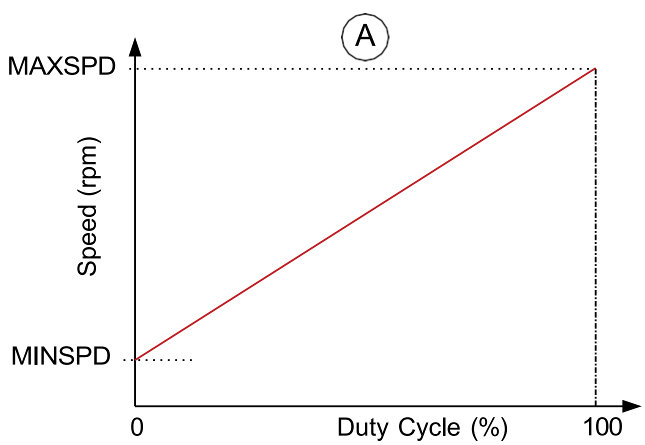


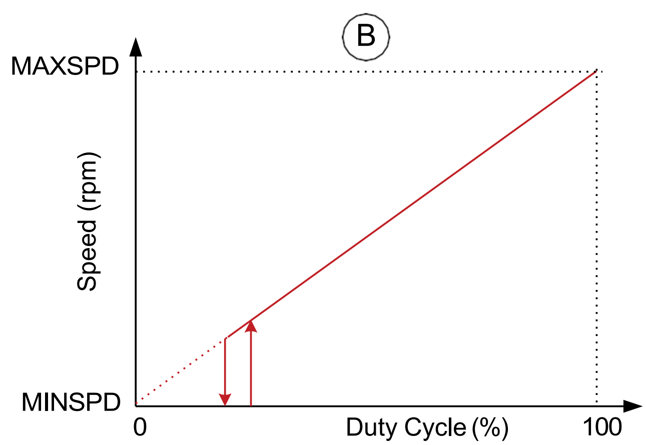
Figure 6: Screen Capture Closed-Loop Mode

SUPPORTED CURVES



1) Select slope by MAXSPD and MINSPD

Speed = Duty × (MAXSPD – MINSPD) + MINSPD



1) Select slope by MAXSPD and MINSPD = 0
2) Select DCON and DCOFF

NOTE: DCOFF must be greater than the minimum open-loop speed under any application condition

Speed = (Duty) × (MAXSPD)

NOTE: Inverted duty can be used on any curve to produce the mirror image

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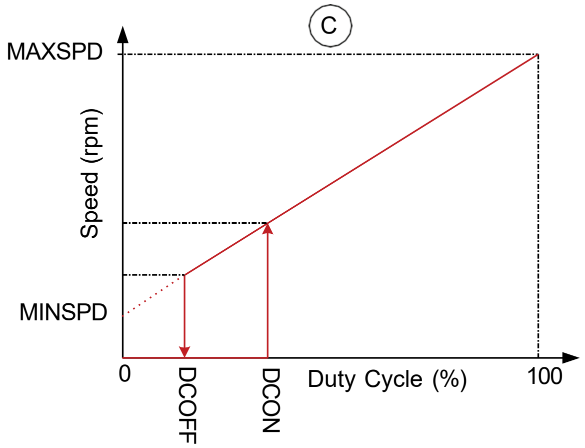
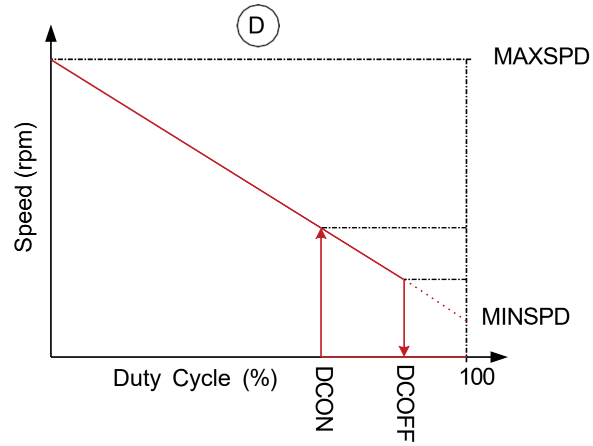
SUPPORTED CURVES (CONTINUED)



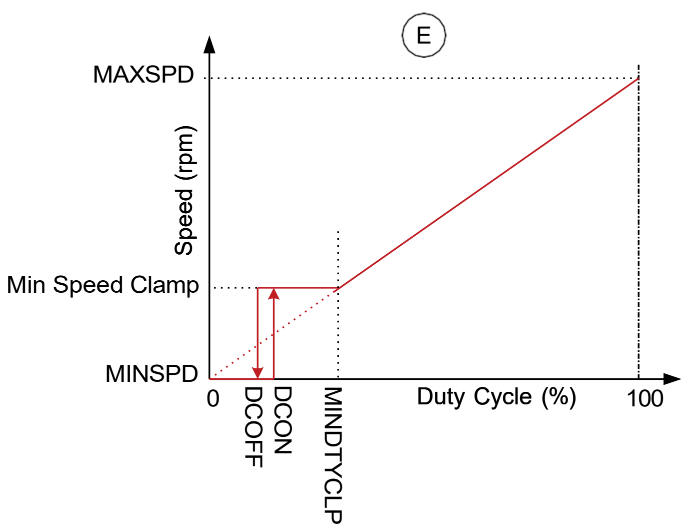
1) Select slope by MAXSPD and MINSPD
2) Select DCON and DCOFF

Speed = Duty × (MAXSPD – MINSP4) + MINSPD



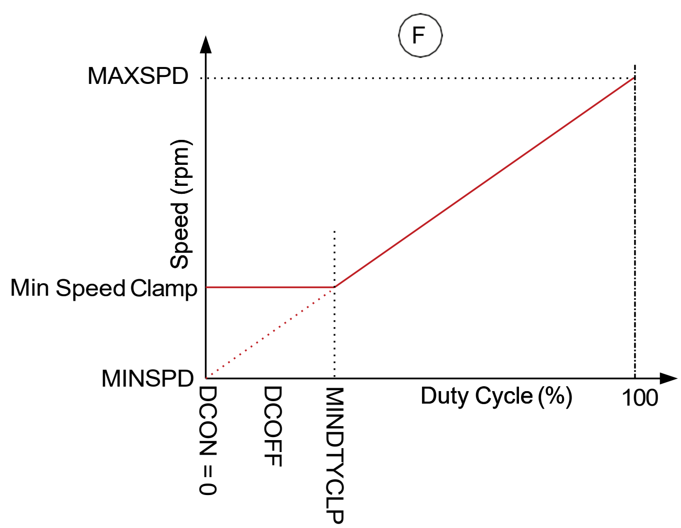
1) Select slope by MINSPD and MAXSPD
2) Select DCON and DCOFF
3) Set the inverted duty bit

Speed = (1 – Duty) × (MAXSPD – MINSP4) + MINSPD



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

Min Speed at Clamp = MINDTYCLP × (MAXSP4)



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

NOTE: Inverted duty can be used on any curve to produce the mirror image

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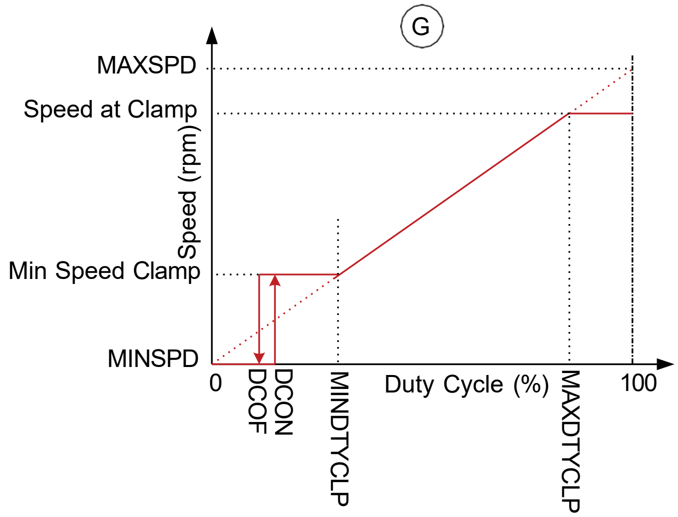
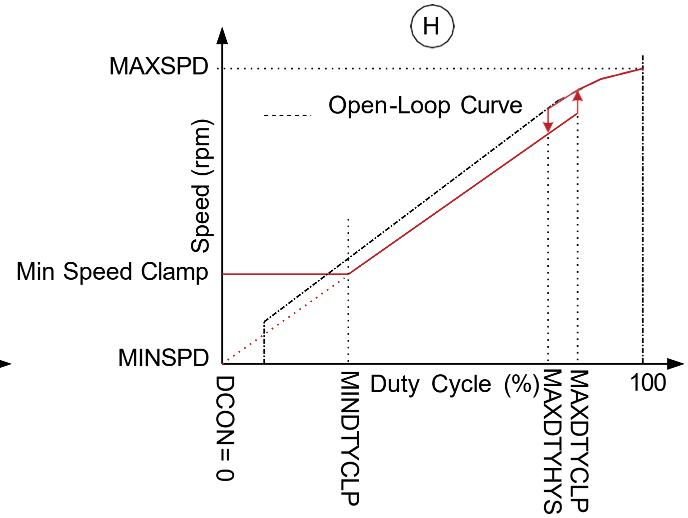
SUPPORTED CURVES (CONTINUED)



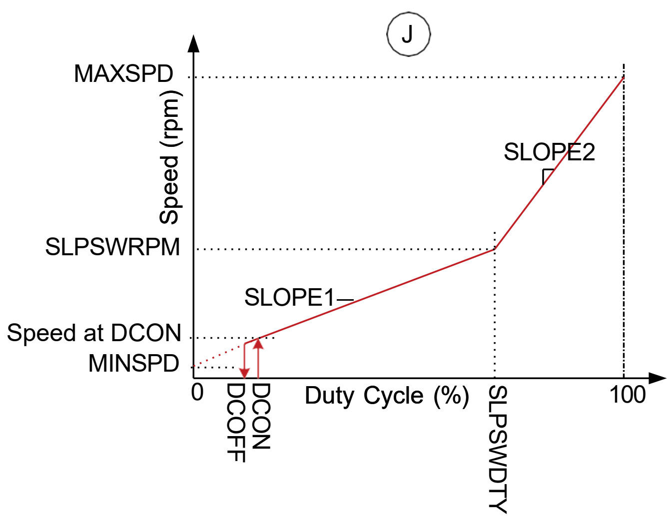
1) Select slope by MAXSPD and MINSPD = 0
2) Select DCON and DCOFF
3) Select Min Duty Clamp → MINDTYCLP
4) Set MAXDTYCLP
5) Select "Run At Max Duty Clamp"

Speed at Max Clamp = MAXDTYCLP × (MAXSP4)

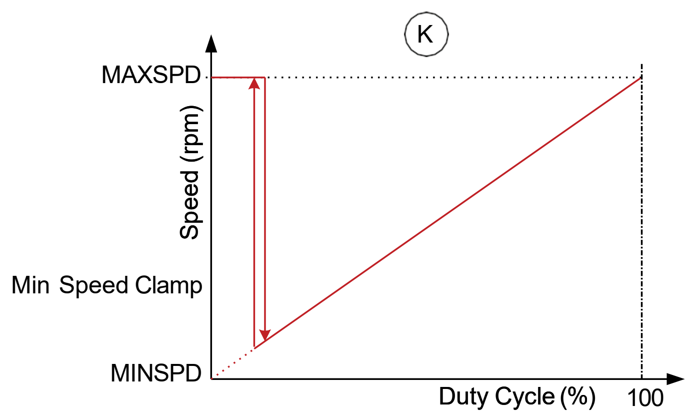


1) Select slope by MAXSPD and MINSPD = 0
2) Select DCON = 0%
3) Select Min Duty Clamp → MINDTYCLP
4) Set MAXDTYCLP and MAXDTYHYS
5) For MAXOFF, select "Run at Open Loop Level"

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, SLPSWDTY, and SLPSWRPM
3) Set Slope1 by adjusting MINSPD so that speed at DCON achieves target:
Speed at DCON = {DCON × (SLPSWRPM – MINSP4)/SLPSWDTY + MINSPD}



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

NOTE: Inverted duty can be used on any curve to produce the mirror image

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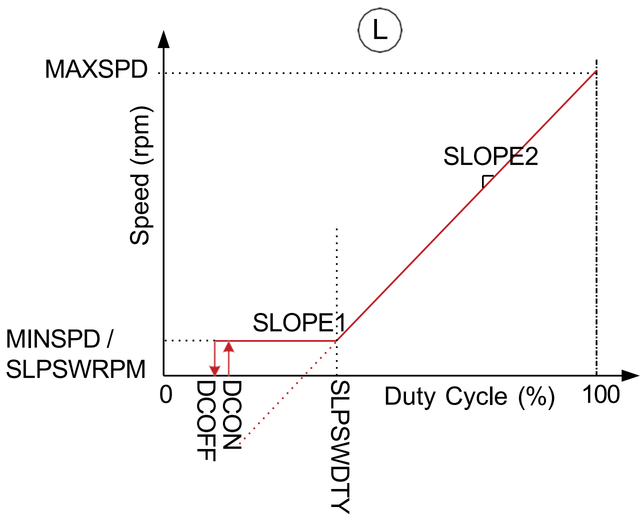
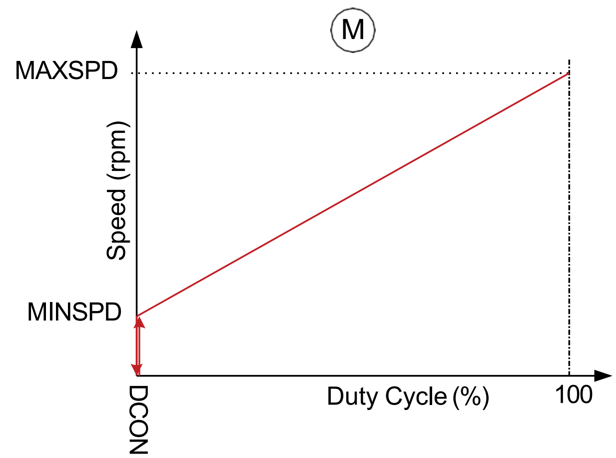
SUPPORTED CURVES (CONTINUED)



1) Set DCON and DC OFF
2) Set Slope2 by MAXSPD, SLPSWDTY, and SLPSWRPM
3) Slope1 by adjusting MINSPD equal to SLPSWRPM

NOTE: This curve has an appearance that is similar to curve E. The difference is that SLOPE2 allows a y-intercept that is less than zero. The SLOPE1 min y-intercept can not be less than zero.



1) Select slope by MAXSPD and MINSPD
2) Select DCON to min value near zero (0.2%)
3) Set DCOFF to zero

NOTE: Inverted duty can be used on any curve to produce the mirror image

There are other combinations possible. The curves A through M are meant to show the variables that can be changed.

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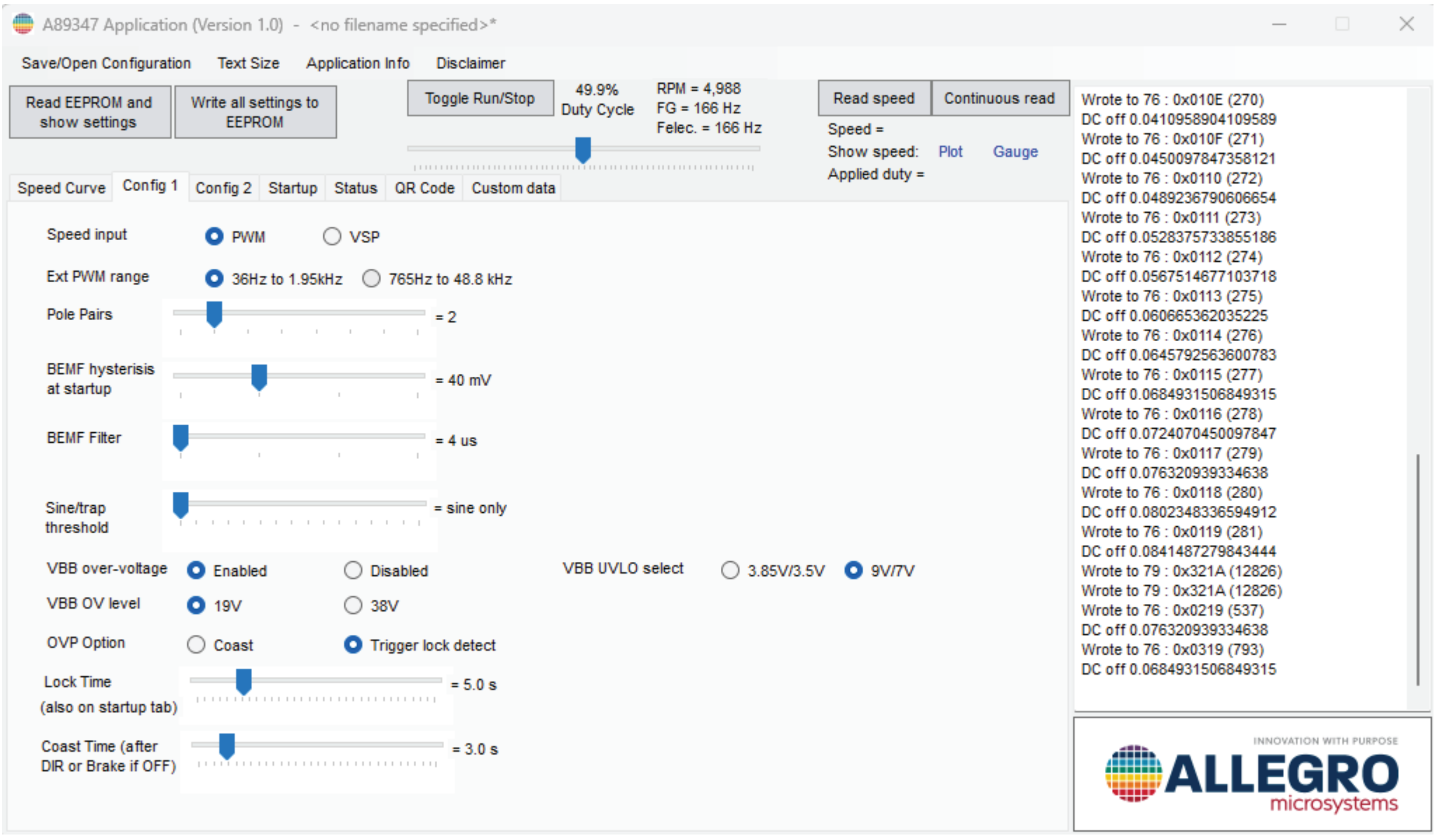
CONFIG 1

The Configuration 1 tab is used to select various settings, as described in this section.



Speed Input

Select the speed control choice of duty cycle or analog voltage:

- Duty cycle control is applied with the pulse-width modulation (PWM) frequency in the range of 34 Hz to 100 kHz.
- Analog voltage mode uses the speed demand, based on a 0 to 2.5 V range, where 2.5 V = 100%. The resolution is 9 bits. For systems that use power-supply voltage (VSP) to control the motor speed, pull the SPD pin up to VREF with a 20 kΩ resistor for 100% ON.

External PWM Range

Select based on the frequency of the PWM input signal.

Pole Pairs

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

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

$F_{ELEC} = FG_{OUT} \times (\#pole\text{-}pairs)/2$ $FG_{OUT} = F_{ELEC} \times 2/(\#pole\text{-}pairs)$ $RPM = F_{ELEC} \times 60/(\#pole\text{-}pairs)$ $RPM = 30 \times FG_{OUT}$

Bemf Hysteresis/Bemf Filter

The sensorless algorithm measures position by checking the voltage on the phase A winding compared to the center-tap winding when the current is zero. Bemf hysteresis and bemf time filter are represented in Figure 7

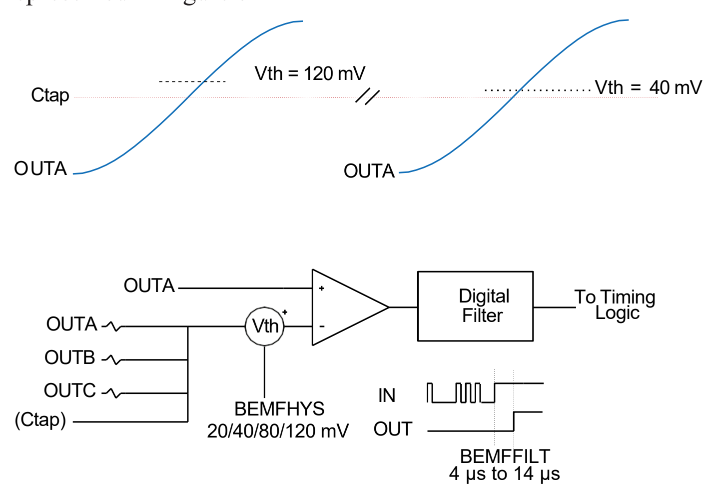
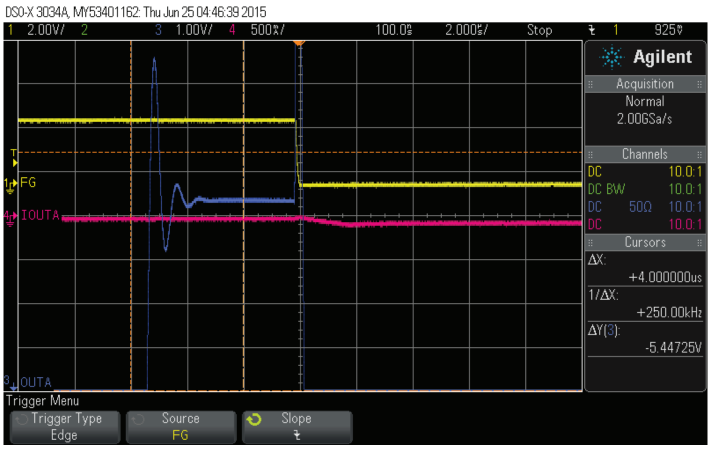


Figure 7: BEMF Hysteresis and BEMF Time Filter

BEMFHYS is enabled during startup or when the motor drive is disabled. During typical operation, the BEMFHYS level is automatically set to 0 mV. For some motors, the handling of a rotor-lock condition might improve (i.e., shut down quicker) at high BEMFHYS levels. Except when lock-detection issue exist, the recommended BEMFHYS 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 the PWM signal, and they must be filtered out for proper position measurement. Use of the minimum practicable filter-time value is recommended. The filter time must be less than half the PWM frequency. If FPWM = 48 kHz, the GUI does not allowvalues of 12 µs or 16 µs. Two different motors showing different duration transients and recommended settings are shown in the scope plots in Figure 8.

BEMFFILT = 4 µs



BEMFILT = 8 µs

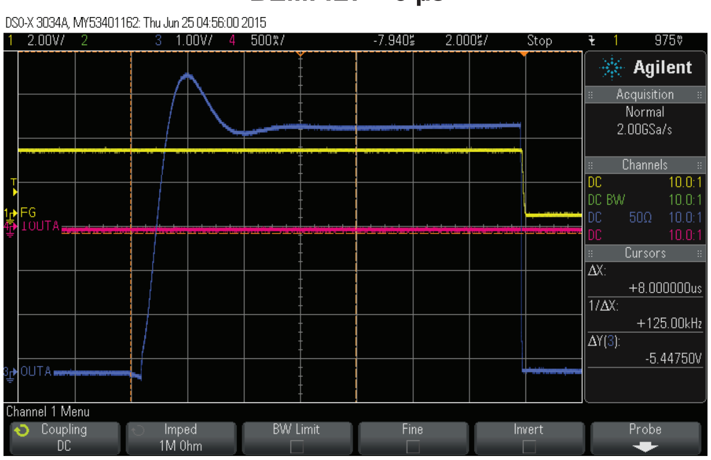


Figure 8: Scope Plots of Different Motors with Different Transient Durations and Recommended Settings

Sine/Trap Threshold

A89347 has an optional trapezoidal mode. Trapezoidal mode might be desired in high-speed applications ($F_{ELEC} > 1.2$ kHz). Using the threshold setting is it possible to run in sine mode at lower speed and to switch over to trapezoidal operation at extreme high speed.

VBB Overvoltage

If the power-supply voltage exceeds the programmed threshold, the A89347 outputs can become disabled. With OVPOPT = 1, the outputs remain disabled for t_{LOCK} to allow the motor to coast to a slower speed. After t_{LOCK}, if V_{BB} has reduced to less than the hysteresis level, a typical startup operation resumes.

VBBOV	VBBOV-DIS	OVPOPT	OVPTH	OVP Function
x	1	x	n/a	Disabled
0	X	0	19 V	Disable outputs when $V_{BB} > V_{BBOV}$
0	0	1	19 V	Latch off for t_{LOCK}
1	X	0	38 V	Disable outputs when $V_{BB} > V_{BBOV}$
1	0	1	38 V	Latch off for t_{LOCK}

VBB Undervoltage

If V_{BB} is less than the selected value, the A89347 outputs remain disabled.

Lock Detect

When the rotor is in a locked condition, the A89347 turns off for the programmed duration (t_{LOCK}). A typical startup occurs after the lock timeout. The EEPROM variable RETRY provides an option to count the number of lock events and prevent restart attempts after the count is exceeded. To resume operation after the retry count is exceeded, PWM must be cycled OFF → ON. A lock-event count can also be triggered by a thermal-shutdown, overvoltage-protection (OVP), or overcurrent-protection (OCP) event.

Coast Time

If the "BRAKE if OFF" bit is set (Speed Curve Tab), the A89347 turns off for the programmed duration (t_{COAST}) before braking. This coast time is also used if the direction is changed (Startup tab).

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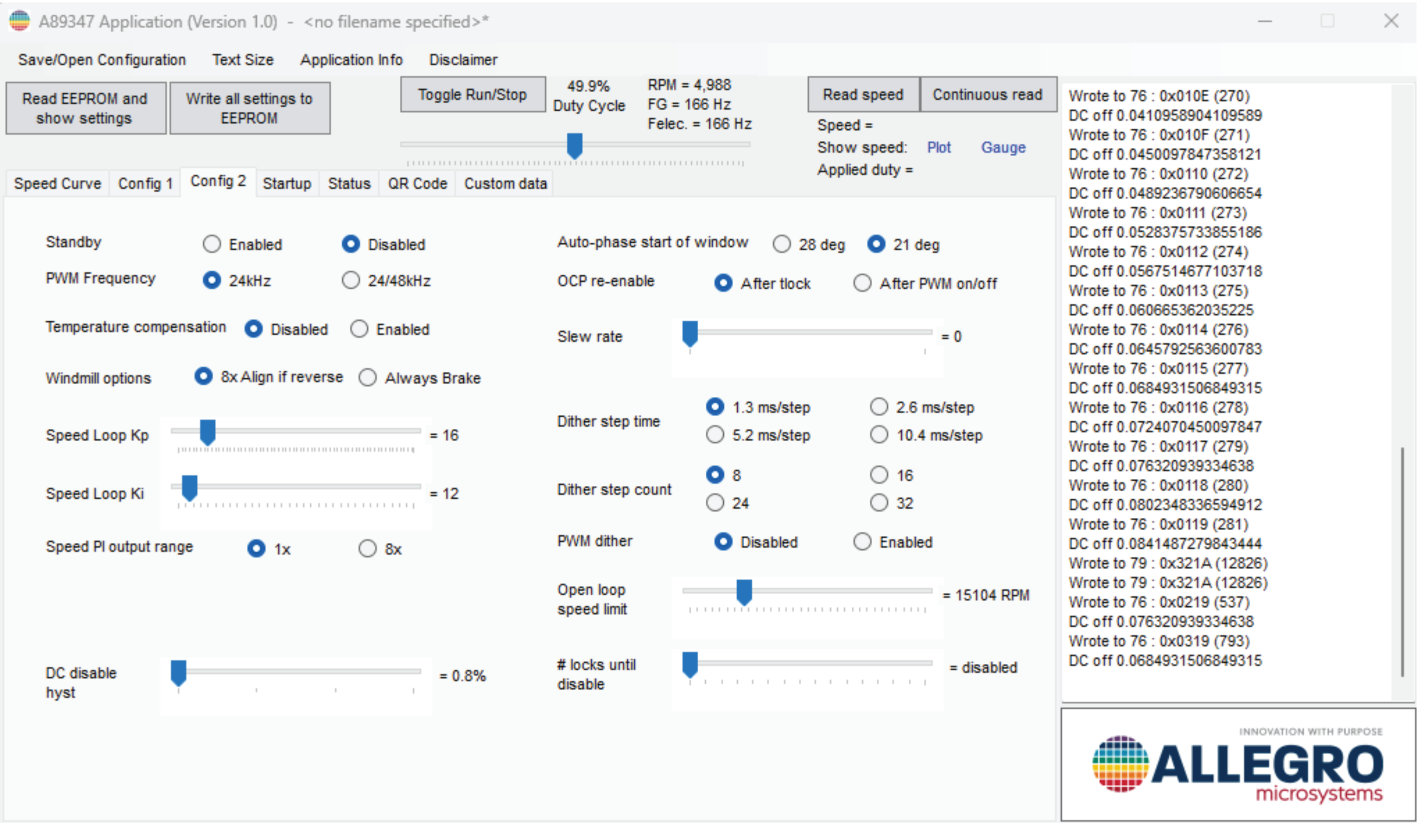
CONFIG 2



PWM Frequency

Selects the output frequency applied to the motor windings (24 kHz or 24/48 kHz). For high-speed applications, there is some benefit to running at a higher PWM frequency because there are more PWM cycles per electrical period. 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, near 10%. In this situation, there is a limitation as the calculated duty slices approach the dead time of the output stage. This introduces distortion in the sine wave. Using 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 24/48 kHz option allows optimization based on the applied duty. With this setting, the logic switches from 24 kHz to 48 kHz depending on the applied duty, as shown in Figure 9.

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

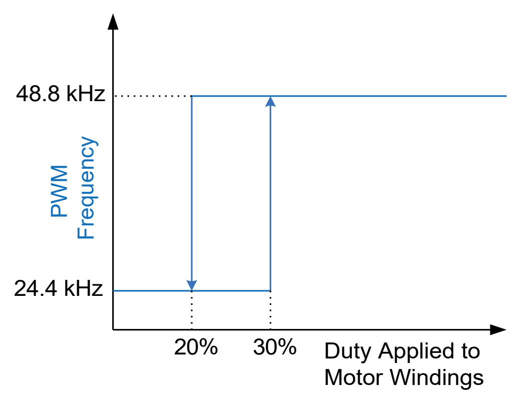


Figure 9: 24/48 Option—Logic Switches from 24 kHz to 48 kHz, Depending on Applied Duty

Standby

Standby mode operates the IC in an ultralow-power mode that allows its use in battery systems. Standby mode turns off the VREF pin, which disables all logic. The device wakes up when PWM signals are applied to the SPD pin. To initiate standby mode, holding the SPD pin low for longer than the programmed lock duration (t_{LOCK}).

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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 (OUTB and OUTC held low, OUTA off) 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.
   B. If the motor is moving forward, the startup sequence is skipped:
      i. A startup demand is estimated based on the crude estimate of how fast the motor is moving.
      ii. The crude estimate is calculated by the MAXSPD variable. (Ensure MAXSPD is set properly.)
      iii. An appropriate demand is applied, and the typical sinusoidal drive is enabled.
2. Always Brake
   A. If the motor is not moving in the forward or reverse direction, the brake mode is applied to slow down the motor.
   B. After 500 ms, the outputs are disabled briefly to determine if the motor remains in rotation.
   C. If the motor is moving, the IC brakes for an additional 500 ms and the check is performed again to determine if the motor remains in rotation.
   D. If motor movement is not detected, the IC brakes for an additional 500 ms, then restarts.

NOTES:

- To maximize startup reliability, use of the “8X Align” setting is generally recommended.
- To improve the resynchronization waveform, setthe MAXSPD variable to 20% to 30% greater than the maximum speed expected in the application

Speed-Loop Kp/Ki

The closed-loop speed-control system contains a 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 (16/12) work well for typical seat cooling fans. For larger types of fans, such as appliance fans, increase the gain settings as needed. For small 1U server fans, settings the recommended Kp/Ki setting is 16/2.

Speed Pi Output Range

Most motors should use the default 1× setting. For very slow (< 30 Hz) electrical frequency, choose the 8× setting.

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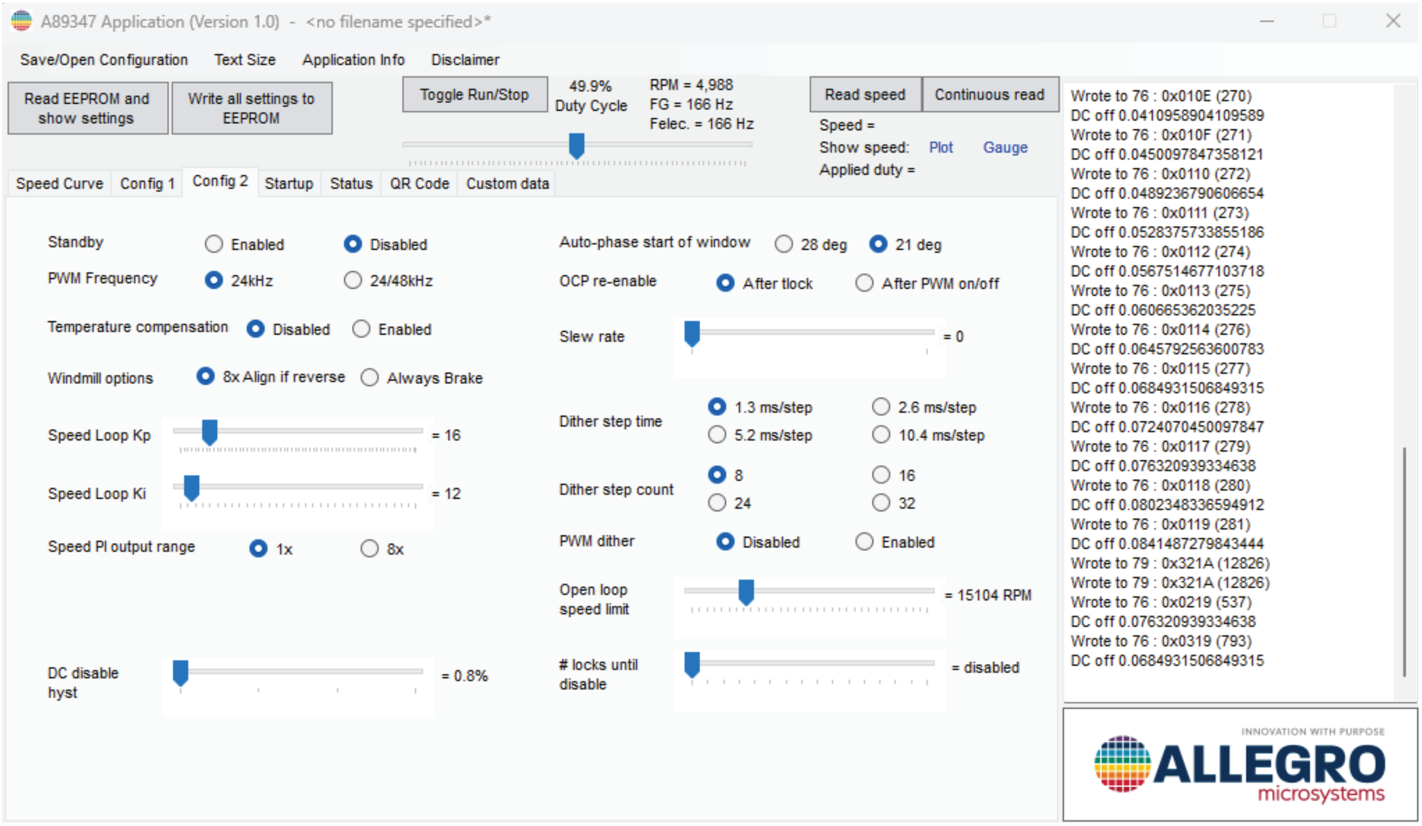
CONFIG 2 (CONTINUED)



DC Disable HYST

To ensure the motor does not accidentally turn on for a noisy input signal on the SPD pin, hysteresis for the DC disable feature can be increased. The DC disable feature is set on the speed curve tab.

Auto-Phase Start of Window

The sensorless driving algorithm measures position by opening up 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. Except for applications where a poor current waveform is noted during acceleration, use of the 21-degree setting is recommended.

OCP Re-Enable

Overcurrent protection prevents damage to the IC in the case of a motor pin short to ground, shorted load, or motor lead short to battery. The overcurrent protection is a latched fault. The OCP bit determines the method of reset of this latched fault.

When the fault is cleared, a typical startup is attempted. If OCP is set low, the fault is cleared by toggling SPD from OFF to ON. If the OCP bit is high, a retry is attempted at the end of the programmed lock OFF time, t_{OFF}. A power cycle also always clears the fault and attempts another restart.

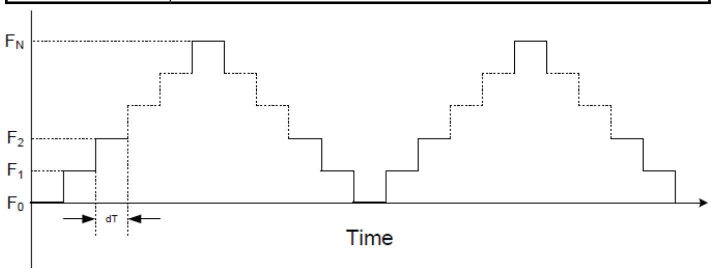
Slew Rate

The A89347 offers two choices for the dV/dt output setting. Setting this bit to the value 1 slows the rate of dV/dt by approximately 50%.

Dither

The optional dither feature is used to modulate the frequency of the PWM applied to the motor windings. The purpose of this feature is to improve electromagnetic-interference (EMI) performance.

EEPROM variable	Function
DITHENB	0 = Disable dithering; 1 = Enable dithering function
DITHDT	1.28/2.56/5.12/10.48 ms per step → time to apply PWM before jumping to the next step
DITHSTP	Number of steps F_N = 8/16/24/32



DITHSTP	F_0 = Initial PWM	F_N = Final PWM
16	24.5 kHz	26042
32	24.5 kHz	27902
16	49 kHz	52083
32	49 kHz	55803

Open-Loop Speed Limit

This feature measures the speed of the motor and reduces the duty applied to the motor windings if the speed is exceeded. If V_{BB} increases or airflow changes in a manner that would result in higher speed, the motor effectively runs at this speed limit. 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.

Number of Locks Before Disable

This feature counts the number of lock events and, if the count is exceeded, startup attempts cease and retries only resume after a power cycle or PWM off/on sequence.

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STARTUP

Introduction

Startup variables are selected via the startup tab of the GUI.

The A89347 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 10.

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.

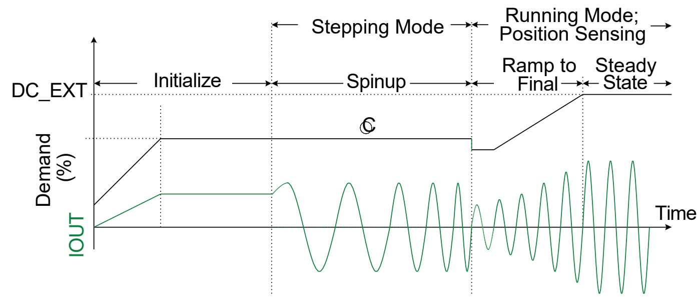
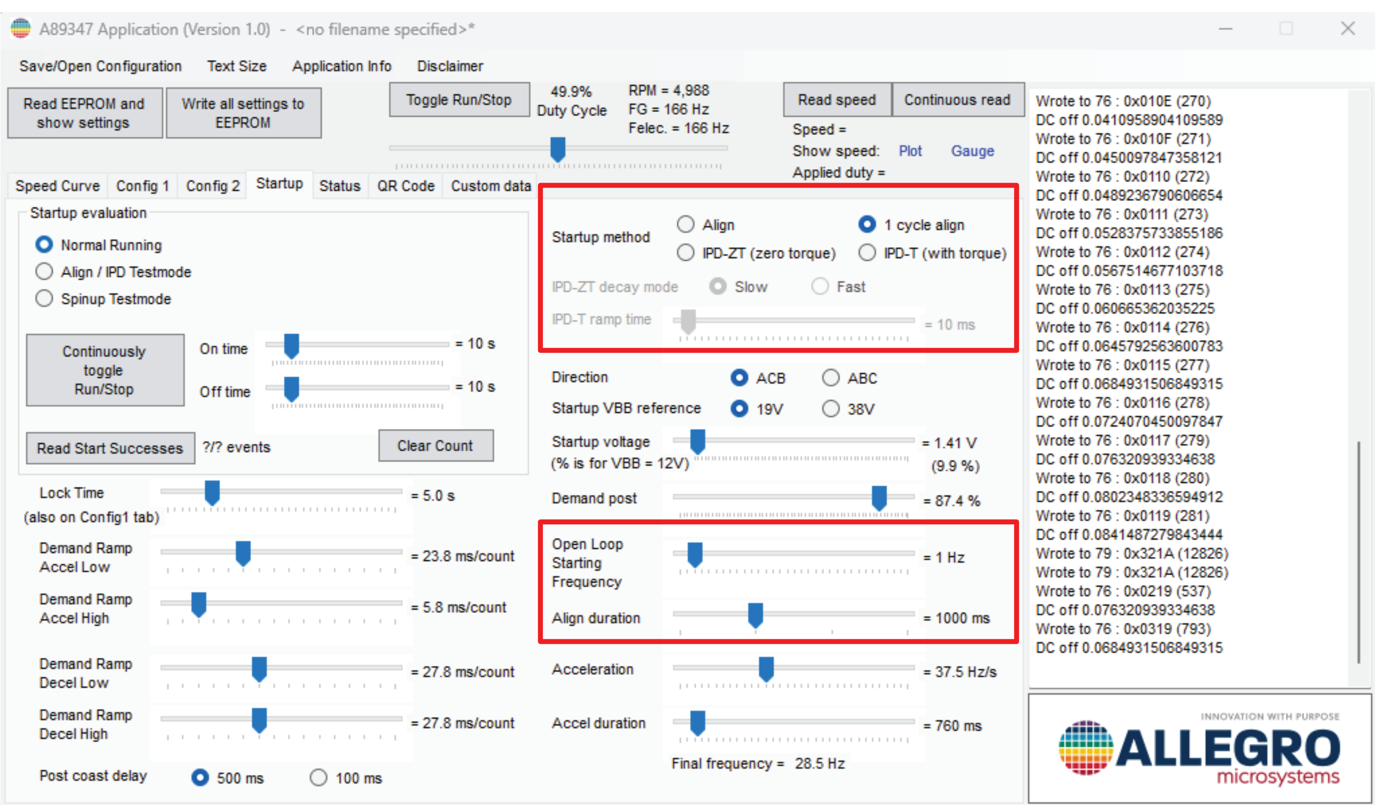


Figure 10: Startup Operation

Step 1: Initialize/Startup Method

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. Four initialization methods are possible, as described next.



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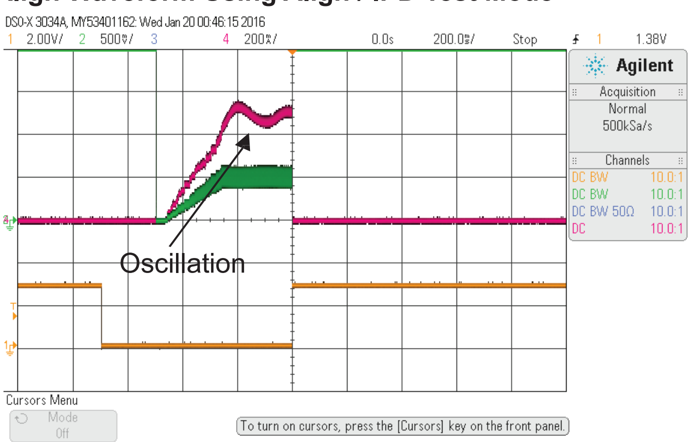
INITIALIZATION METHOD 1: ALIGN

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 revolution, 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.

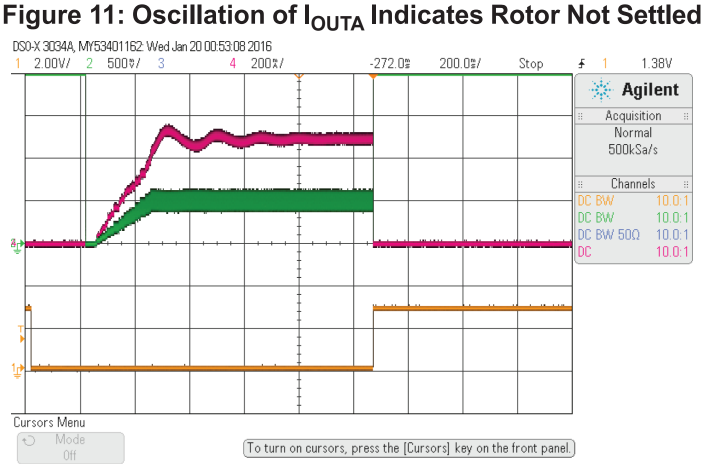
The align duration (ALIGNT) is used to program the duration for which a position is held. This duration should be set to a value long enough to allow the motor position to settle. The worst-case duration should consider various stopping locations of the rotor. Typically, the worst-case settling time 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.

Align Waveform Using Align / IPD Test Mode



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

Figure 11: Oscillation of I_{OUTA} Indicates Rotor Not Settled

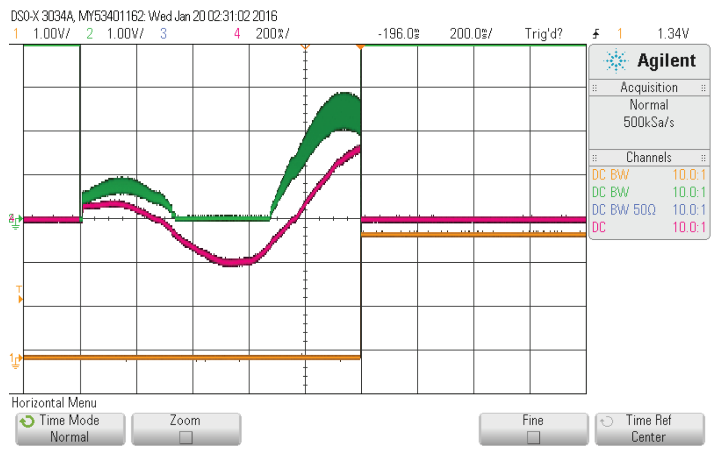


CH1 = TEST signal, CH2 = Startup demand (outA filtered), CH4 = I(outA)

Figure 12: Increasing Align Time Allows Enough Time For Rotor Position to Settle

INITIALIZATION 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 13: Single-Cycle Align Waveform

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INITIALIZATION METHOD 3: IPD-ZT

The IPD-ZT method determines the rotor position, as opposed to rotor movements to a known location. If the position can be determined, IPD- ZT results in the fastest startup and can avoid rotor reversal. For some motor characteristics, the IPD-ZT method fails to find the correct location. In this 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-ZT is a two-step method. The first step applies a 50%-duty zero-torque voltage waveform to the windings and determines the location to be one of two positions separated from each other by 180 degrees. The second step applies short current pulses to determine which of the two positions is correct.

CH1 = TEST signal, CH2 = outA, CH4 = I(outA)

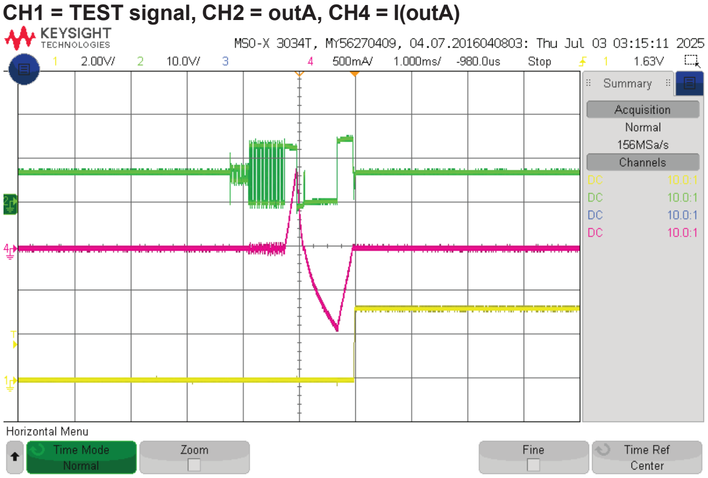

Figure 14: IPD-ZT Waveform

INITIALIZATION METHOD 4: IPD – T

If the second stage of the IPD-ZT method does not correctly identify the position, the IPD-T method might be a better option, depending on motor characteristics. The IPD-T method uses the same first stage as described in the IPD-ZT method, then applies an increasing torque that initiates motor movement in the proper direction. Minor direction reversal might occur. To modify the rate of change of the increasing torque, select the IPD ramp time appropriately: If the time is too fast, minor audible noise or overshoot during reversal of direction might result; if the ramp time is too long, the startup duration might be too long.

RECOMMENDATIONS:

1. The IPD-ZT method is often the best option because it does not require parameters to be set and it achieves the fastest startup.
2. The IPD-T method is the second-fastest startup option, and it might provide an improvement in audible noise compared to the IPD-ZT method.
3. If the rotor does not have significant cogging torque or if the rotor has high friction such that the motor can stop in any mechanical location, the one-cycle method is appropriate. For this type of motor, it is rare but possible for the motor to stop at exactly 180° between the two starting positions. If this is the in the fixed-position mode, the proper direction to move the rotor is not known because the force is equal in both directions, and the startup operation might fail.

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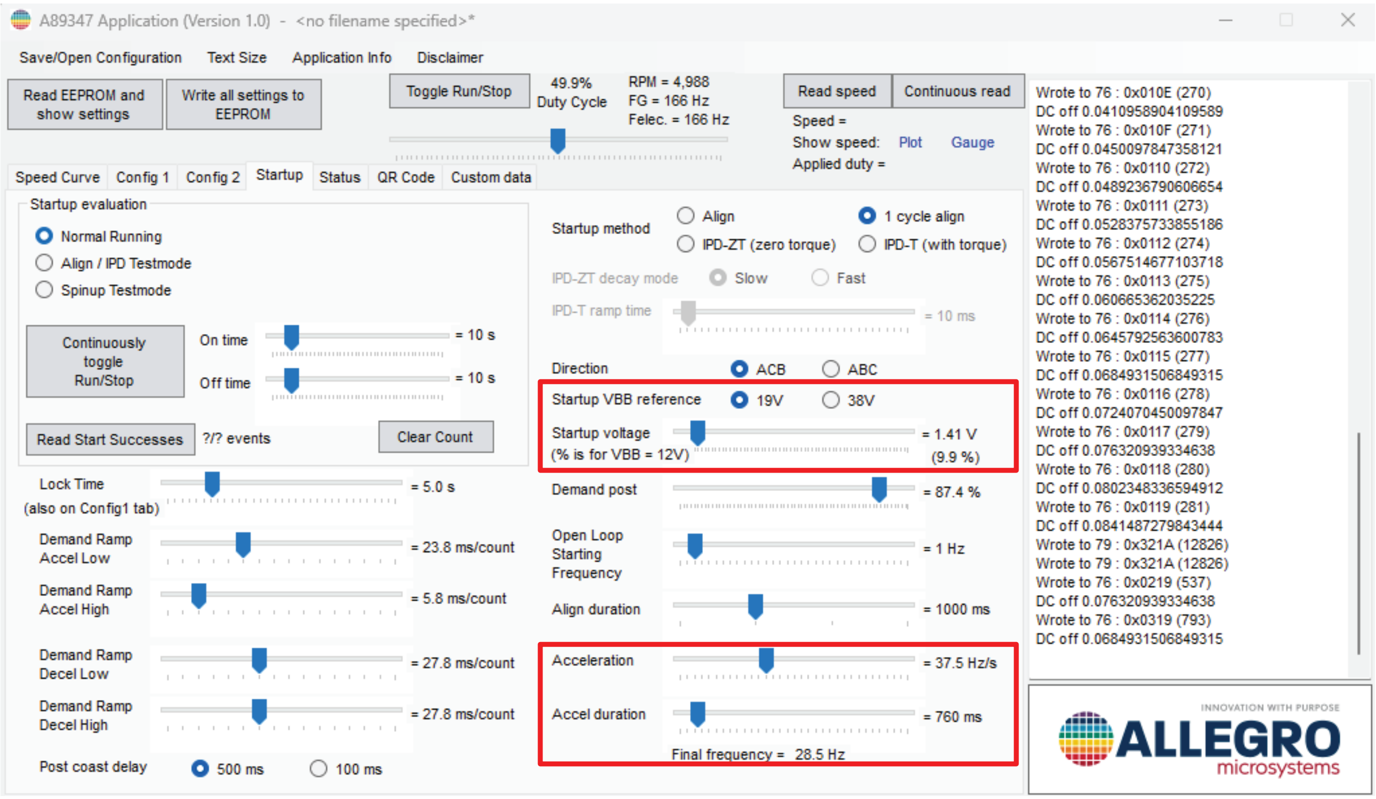
Step 2: Accelerate



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

1. **Startup Voltage**. This is the effective voltage, V_{EFF}, applied to the motor. The starting torque is proportional to the current and V_{EFF}, as:

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

   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:

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

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

2. **ACCEL.** Acceleration constant, in Hz/s.

3. **ACCELT.** Sets the duration of motor acceleration in stepping mode. The electrical frequency at end of acceleration is estimated as:

   $$F_{FINAL}\ (Hz) = F_{INIT}\ (STRTF) + ACCEL \times ACCELT$$

NOTE: When using align mode, set the starting frequency to 0.3 Hz.

Startup VBB Reference

- For 12 V applications, choose 19 V
- For 24 V applications, choose 38 V

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 pont 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.

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 = TEST	C3 = OUTA-CTAP differential probe
C2 = OUTA	C4 = I(OUTA)

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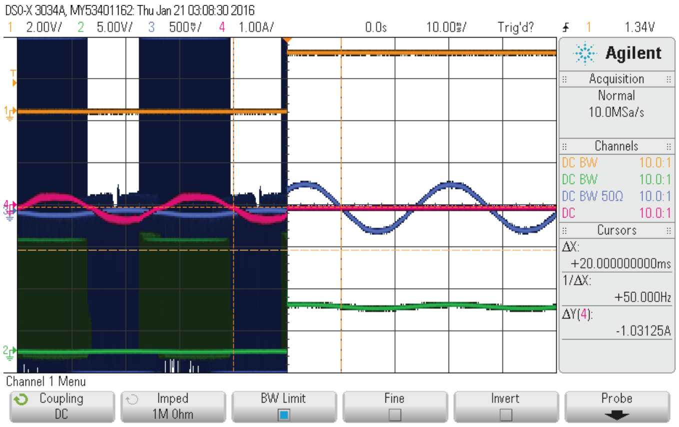


Figure 15: Phase Lag Approximately 70°

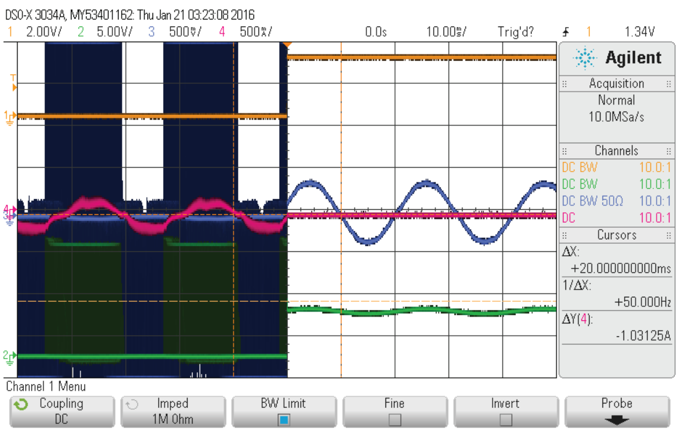
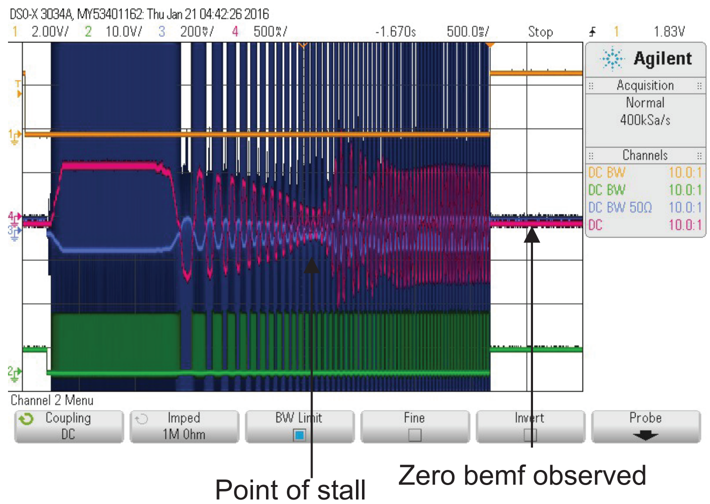


Figure 16: Phase Lag Near 0°

RECOMMENDATIONS:

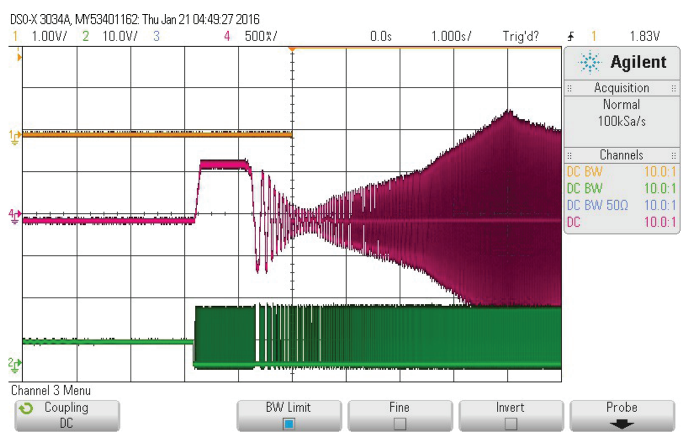
1. Choose STRTDMD to be approximately 25% of peak current at maximum speed.
   - This is a guideline, not a strict rule. For some motor/load types, the optimal performance requires a different starting torque.
   - As a rule, a lower value of STRTDMD reduces acoustical noise at the point of transfer between the stepping and running modes of operation.
2. Adjust ACCELT and ACCELD 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.
3. Check startup at multiple rotor initial positions.
   - If the phase angle is not repeatable, recheck the settings for Align.
4. 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.
5. The minimum frequency (F_{FINAL}) is 5 Hz.
6. Set F_{FINAL} such that peak-to-peak bemf voltage is at least four times the BEMFHYS level (Config 1 tab).
7. Set ACCELT to a long-duration value to show where the motor stalls (see Figure 17).



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

During a stall, zero bemf is observed on VOUT.

Figure 17: Determine Point of Stall



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

Figure 18: Good Startup
Shows Smooth Rise of Current Waveform

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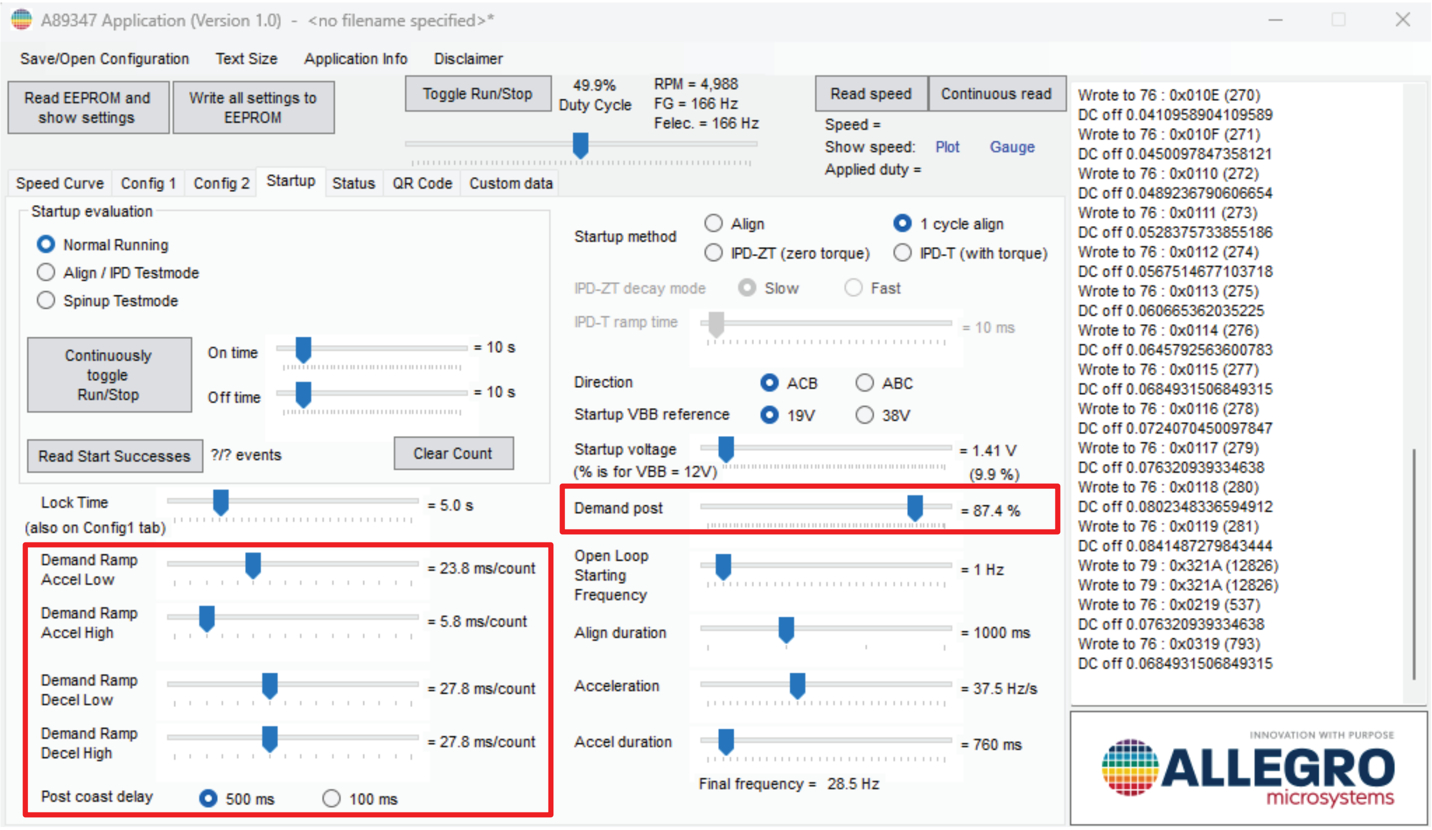
Step 3: Ramp to Target Speed



DEMAND POST

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, before the final ramp to target speed begins.

POST-COAST DELAY

After the open-loop stepper startup, there is a period of transition into position-sensing mode. This transition period can be programmed to be 100 ms or 500 ms. The longer setting of 500 ms is recommended.

ACCEL/DECEL RAMP RATES

- **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:

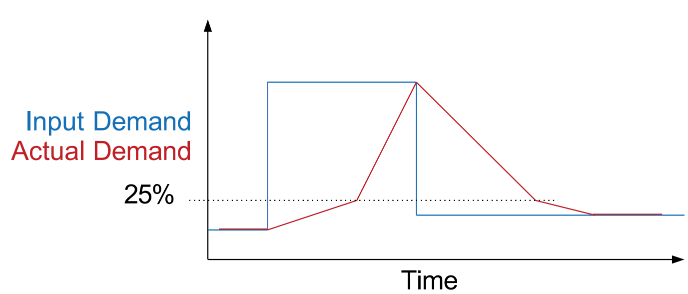
- For a 15% to 100% change:

$$T_{ACCEL} = (25\% - 15\%) \times 511 \times 23.8\ ms/count + (90\%-25\%) \times 7.8\ ms/count \rightarrow 3.8\ s$$

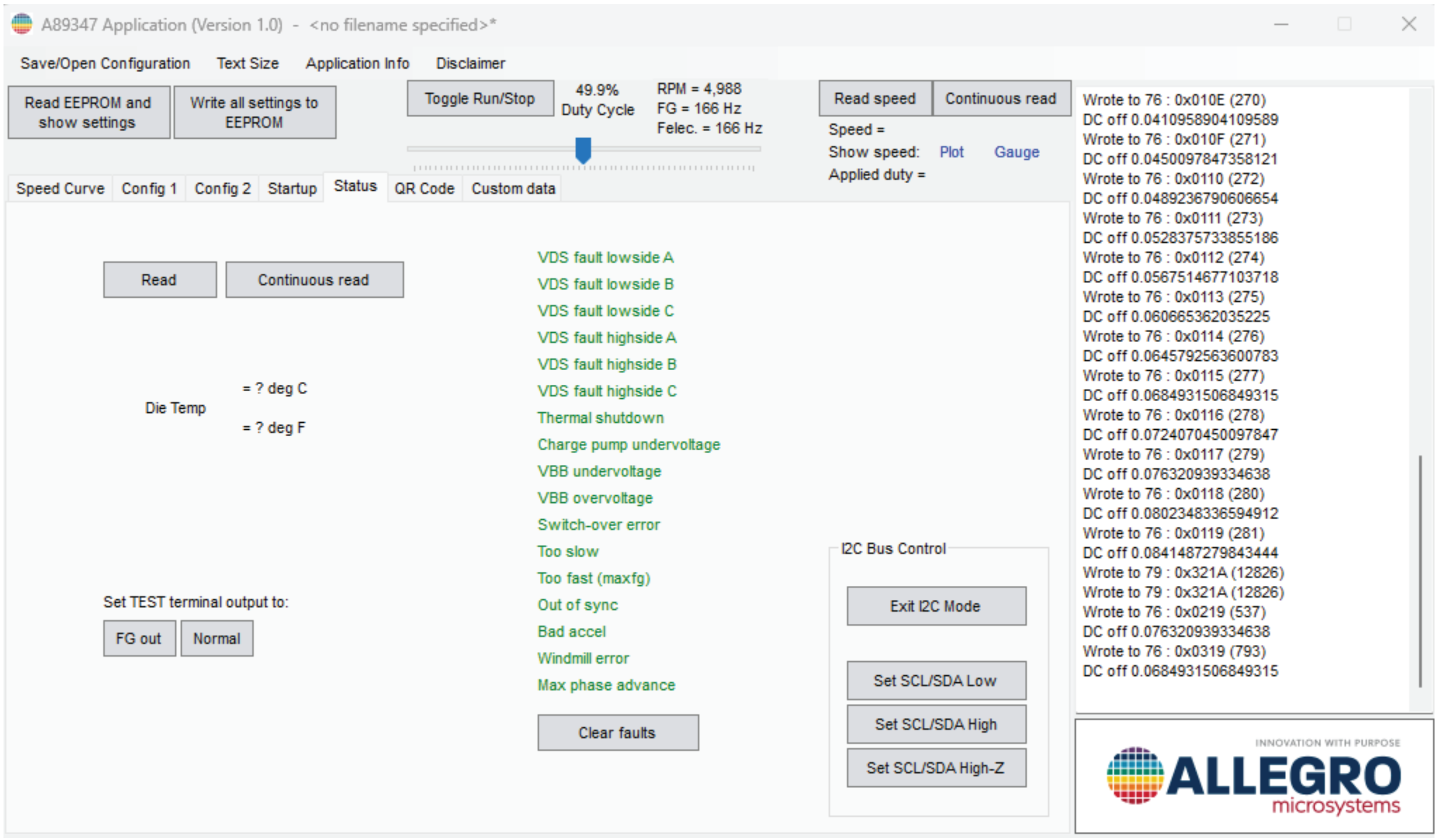
- For a 85% to 20% change:

$$T_{DECEL} = (85\% - 25\%) \times 511 \times 15.8\ ms/count + (25-20\%) \times 15.8\ ms/count \rightarrow 5.04\ s$$

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 final speed.



STATUS



Die Temp

In test mode, the internal circuit used to monitor the chip temperature is made available using an onboard analog-to-digital converter (ADC). The A89347 has a high-current capability to drive fans up to 2.5 A with small printed circuit boards (PCBs). If pull-up resistors are connected to the FG and SPD inputs, the I^{2}C port can be used to monitor the die temperature during various loading conditions of the fan.

This tool can be used to study real-life thermal conditions of the motor PCB. Accuracy should be better than ±10%. Alternatively, this measurement can be obtained with a thermocouple attached 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 the package measurement based on the phi juntion-top package parameter (Ψ_{JT}), which is approximately 0.5°C/W for the LP package

Fault Readout

Various fault modes can be read by the serial port to assist with debug operations. The faults are latched and can be cleared by the Clear Faults button.

Test Output

When using the GUI mode, an internal motor-speed signal might be useful. This is available on the TEST pin with the Test Output Button.

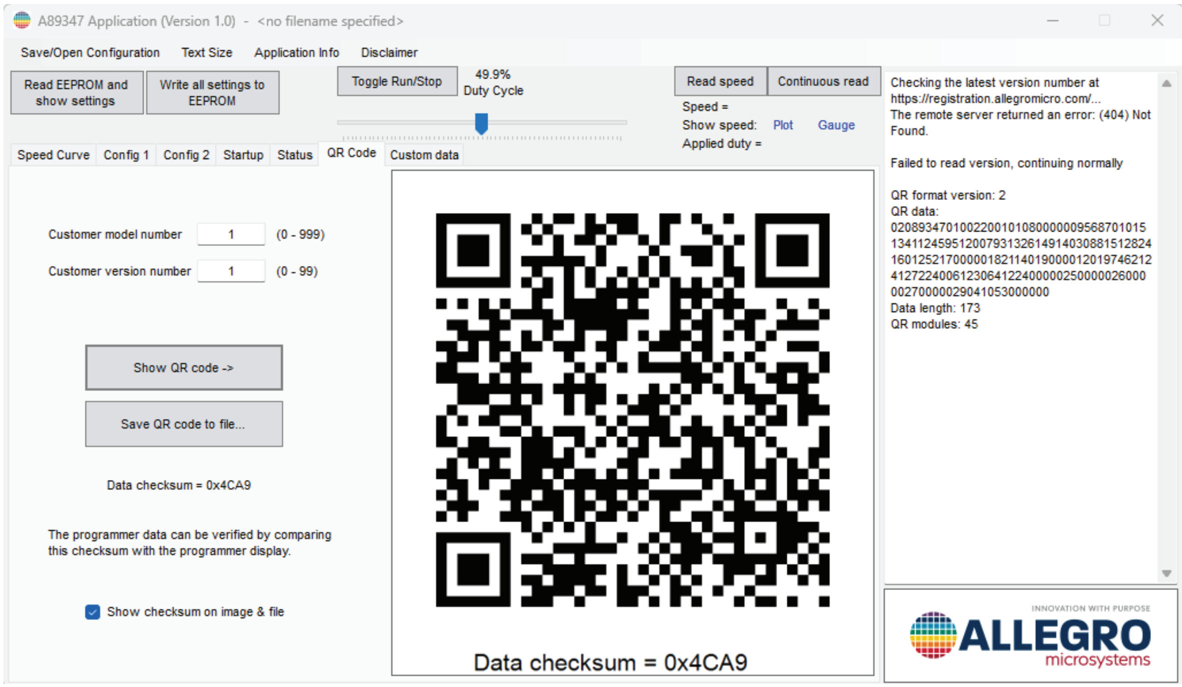
I^{2}C Bus Control

Provides I^{2}C bus control, primarily for debug purposes.

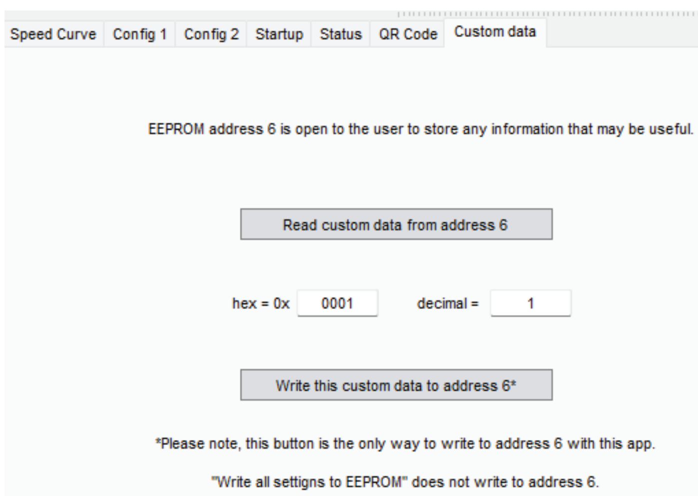
QR CODE AND CUSTOM DATA

Neither the QR code feature nor the custom data feature are motor-function related. The QR code feature helps customers generate a desired QR code, and the custom data feature is used by customers to store an ID code in EEPROM.

QR Code



Custom Data



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SERIAL PORT MODE

Typically, the IC is controlled by duty cycle input and uses the EEPROM data that is stored to create the speed-curve profile. However, it is possible to use direct serial port control to avoid programming EEPROM.

When using direct control, the input duty cycle command is replaced by writing a 9-bit number to register 165.

For example:

REGADDR[data]: (in decimal) 165[511] → Duty = 100%

165[102] → Duty = 102/511 = 20%

Upon power-up, the IC defaults to duty-cycle input mode. To use serial-port mode, the internal registers should be programmed before turn-on of the part. The sequence to use serial-port mode is:

1. Drive the FG and SPD pins low.
   NOTE: If SPD is not driven low before power up, motor tries to start immediately because the default high value demand is 100% on signal.
2. Power up the IC.
3. Program registers for parameter settings that correspond to each of the EEPROM memory locations.
   A. REGADDR = 64 + EEPROM ADDR.
   B. Program register addresses 72 to 94, corresponding to EEPROM addresses 8 to 30.
   C. If desired, use the GUI text file to define the hex data for each of the EEPROM addresses.
4. Write to register 165 to start the motor.

After entering serial port mode, the standby mode function becomes disabled. If standby mode is required, it is possible to exit serial port mode, and return control of the motor speed input to the SPD pin. After control is returned to the SPD pin, standby mode is again possible with LOW applied to SPD for longer than the programmed lock duration. To exit serial port mode, write the value 1 to bit 14 of register 166. The exit bit is self-clearing.

Other I²C Registers

Register	Bits		Function	Description
165	[8:0]	R/W	Speed demand input	Duty (%) = code/511
166	14	W	I²C exit	Set to 1 to change operation from I²C mode back to SPD pin control
128	[8:0]	R	Duty applied	Actual demand to the motor windings
138	[7:0]	R	Die temperature	Temp °C = 3 + (code – 133)/2
144	[15:0]	R/W	Number of startup failures	Cleared by writing zero or by powerup
145	[15:0]	R/W	Number of startup attempts	Cleared by writing zero or by powerup

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EEPROM MAP

Address	Register	Bits	Name	Description	Default Setting	Default Value
0	64	15:0	Reserved	Allegro reserved	–	
1	65	15:0	Reserved	Allegro reserved	–	
2	66	15:0	Reserved	Allegro reserved	–	
3	67	15:0	Reserved	Allegro reserved	–	
4	68	15:0	CAS	Customer code	–	
5	69	15:0	Reserved	Allegro reserved	–	
6	70	15:0	Extra	For customer use	–	
7	71	15:0	PASSWORD	Password	–	
8	72	3:0	MAXDTYCLP	Range = 100% to 76.5%, LSB = 1.56%	100%	0
		9:4	MINDTYCLP	Range = 0 to 50%, LSB = 0.8%	0%	0
		13:10	DCDISTH	Range = 100% to 76.7%, LSB = 1.56% DCDISTH(%) = 100% – (code – 1) × 1.56%	Disabled	0
		15:14	DCDISHYS	0 = 0.8%; 1 = 1.6%; 2 = 2.4%; 3 = 3.2%	0.8%	0
9	73	8:0	STRTDMD	Range = 0 to VBBRNG, LSB = VBBRNG/511	1.41 V	38
		15:9	DMDPOST	Range = 0 to 100%, LSB = .8%	87.4%	111
10	74	7:0	TCOAST	Coast time for brake or direction change	3 s	30
		15:8	OPNLPMAX	Maximum speed limit for open-loop mode	15104 rpm	59
11	75	7:0	ACCELT	Range = 0 to 20.4 s, LSB = 80 ms	760 ms	19
		15:8	ACCEL	Range = 0 to 99.6 Hz/s, LSB = 0.78	37.5 Hz/s	96
12	76	7:0	DCON	Range = 0 to 100%, LSB = 0.4%	9.8%	25
		10:8	DCHYS	Range = 0.8 to 6.25%, LSB = 0.8%	2.9%	3
13	77	3:0	DMDRMPAL	Range = 3.8 to 63.8 ms/count, LSB = 3.8	23.8 ms/count	5
		7:4	DMDRMPAH	Range = 1.9 to 32/count, LSB = 1.9	5.8 ms/count	2
		11:8	DMDRMPDL	Range = 3.8 to 63.8 ms/count, LSB = 3.8	27.8 ms/count	6
		15:12	DMDRMPDH	Range = 3.8 to 63.8 ms/count, LSB = 3.8	27.8 ms/count	6
14	78	6:0	KP	Closed-loop Kp	16	16
		7	PIGAIN	0 = Low speed; 1 = High speed	0	0
		15:8	KI	Closed-loop	12	12
15	79	7:0	MAXSPD	Maximum electrical frequency	509 Hz	24
		15:8	TLOCK	0 to 25.5 s	5 s	50
16	80	13:0	SPDSLP1	Calculated slope of speed curve	10000 rpm max speed	1252
17	81	11:0	MINSPEED	Range = 0 to 4096, res = 1 rpm	0 rpm	0
		15:12	TRAPDTY	Duty to switch to trap drive LSB = 6.25%	Sine only	0
18	82	0	CL	Speed control mode: 0 = Open loop; 1 = Closed loop	Open	0
		1	DIR	0 = A→C→B 1 = A→B→C	A→C→B	0
		2	UVLO	0 = Low (3.85 V) 1 = High (8.75)	High	1
		3	SPDSEL	Speed control select: 0 = PWM duty; 1 = Analog	PWM	0
		6:4	PP	Pole pair = PP + 1	2 pole-pair	1
		8:7	ALIGN	0 = 3 → 500 ms/1 s/1.5 s/2 s	1 s	1
		9	OVPOPT	0 = Disable; 1 = Lock detect	Lock detect	1
		10	SLEW	Output dV/dt select	80 ns	0
		11	Unused	Must set to 0	–	0
		13:12	BEMFHYS	Bemf hysteresis level for startup	40 mV	1
		14	SOWAUTO	Initial value of window	21 deg	1
		15	OCPOPT	0 = Reset after t_{LOCK} 1 = Reset after PWM on/off	t_{LOCK}	0

EEPROM MAP (continued)

Address	Register	Bits	Name	Description	Default Setting	Default Value
19	83	0	STBYDIS	Standby mode: 0 = Enable; 1 = Disable	Disabled	1
		1	PWMF	Motor PWM selection	24 kHz	0
		2	DTYIN	0: Low frequency (34 Hz); 1: High frequency	Low	0
		4:3	BEMFILT	Time filter	4 µs	0
		5	TCENB	Temperature compensation: 0 = Off; 1 = On	Disabled	0
		6	WINDMILL	0 = Resynchronize; 1 = Brake until stop	Resynchronize	0
		7	POSTCOAST	0 = 500 ms; 1 = 100 ms	500 ms	0
		9:8	DITHDT	Dither time (ms per step)	1.3	0
		11:10	DITHSTP	Dither number of steps	8	0
		12	DITHENB	0 = Disabled; 1 = Enable dither function	Disabled	0
		13	VBBOVDIS	0 = Enable; 1 = Disable	Enabled	0
		14	VBBOV	0 = 19 V; 1 = 38 V	19 V	0
		15	VBBRNG	0 = 19 V; 1 = 38 V	19 V	0
20	84	0	DTYINV	0 = Typical; 1 = Inverted	Typical	0
		1	Reserved	Allegro reserved: Set to one	1	1
		2	STAIR	1 = Enable staircase	Disabled	0
		3	DIR50	1 = Enable direction change based on 50% duty	Disabled	0
		4	BRKOFF	0 = Coast; 1 = Brake	Disabled	0
		6:5	STRT	0 = Align; 1 = One cycle; 2 = IPD – ZT; 3 = IPD-T	One cycle	1
		7	IPDTOPT	0 = Slow Decay 1 = Fast decay	Slow	0
		8	Reserved		Set to 1	1
		14:9	DUTYC	Range = 0 to 100% LSB = 1.56%	60.86%	38
21	85	7:0	SPEEDA	Range = 0 to 8160, RES 32 rpm	2016 rpm	63
		15:8	SPEEDB	Range = 0 to 8160, RES 32 rpm	3008 rpm	94
22	86	7:0	SPEEDC	Range = 0 to 8160, RES 32 rpm	4000 rpm	125
		15:8	SPEEDD	Range = 0 to 8160, RES 32 rpm	4992 rpm	156
23	87	5:0	DUTYA	Range = 0 to 100%, LSB = 1.56%	20.16%	12
		13:8	DUTYB	Range = 0 to 100%, LSB = 1.56%	40.51%	25
24	88	11:0	MINSPD2	Range = 0 to 4096, res = 1 rpm (DIR50 mode)	0	0
		15:12	RETRY	Number of retry attempts when rotor locked (0 = Function disabled)	Disabled	0
25	89	13:0	SPDSLP2	Calculated slope of speed curve (DIR50 and dual-slope mode)	10000 rpm max speed	1252
26	90	5:0	MINDTYCLP2	Range = 0 to 50%, LSB = 0.8% (DIR50)	0	0
		13:6	SLPSWDTY	Slope switch duty for dual-slope mode	Disabled	0
		15:14	Unused		–	–
27	91	15:0	SLPSWRPM	Slope switch rpm for dual-slope mode	0	0
28	92	15:0	Reserved	Allegro reserved: Locked	–	–
29	93	7:0	IPDRMP	Duty ramp for I_{PD} – T	10 ms	9
		15:8	STRTF	Frequency for single-cycle startup mode	1 Hz	16
30	94	15:0	Reserved	Allegro reserved: Must be set to zero	0	0
31	95	15:0	Reserved	Allegro reserved: Locked	–	–

ALLEGRO microsystems
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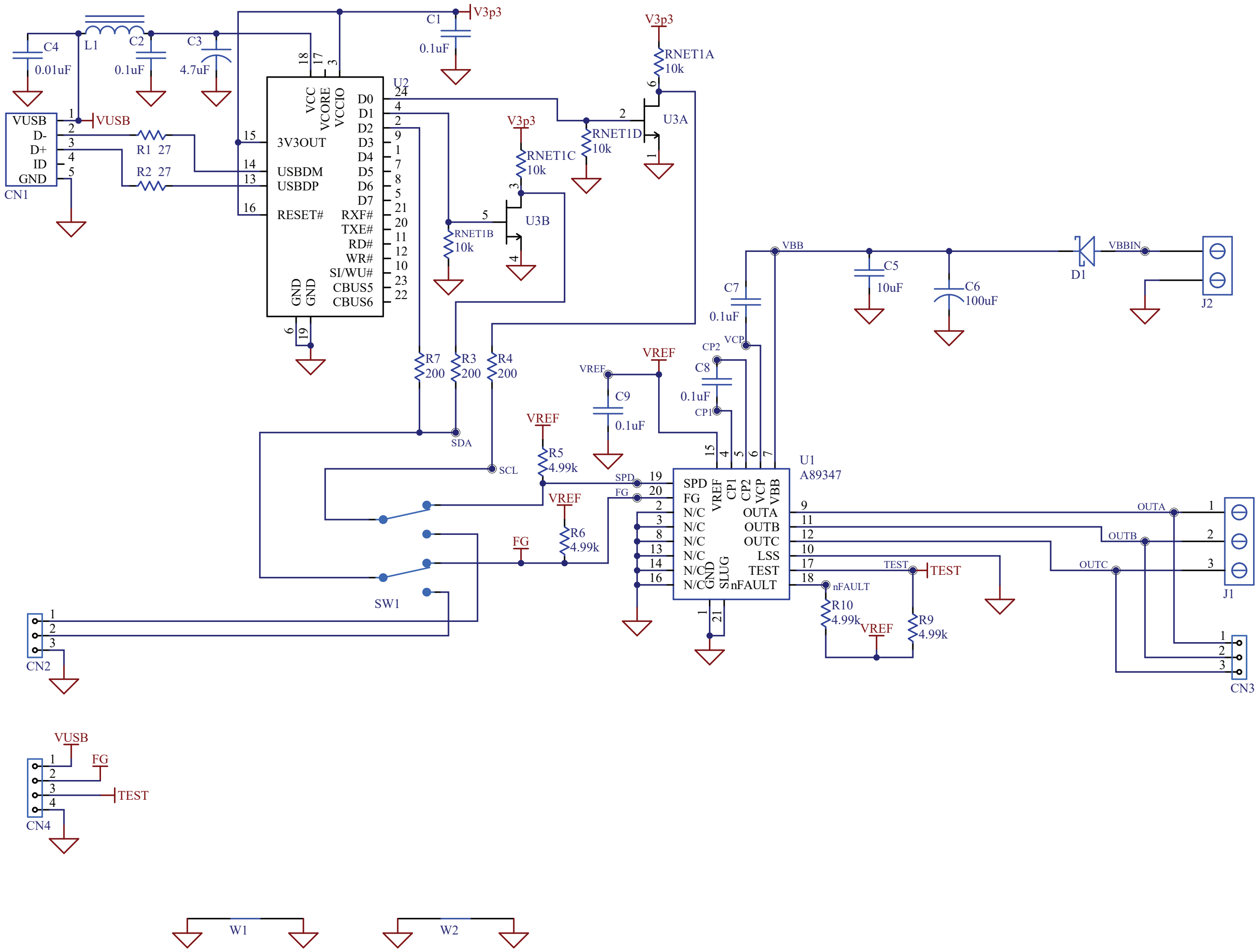
SCHEMATIC



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BILL OF MATERIALS

Item	Quantity	Designator	Value	Description	Part Type	Footprint
1	5	C1, C2, C7, C8, C9	0.1 µF	25 V Capacitor	Kemet C0805C104K3RACTU Digikey 399-1168-1-ND	0805
2	1	C3	4.7 µF	35 V Capacitor	Chemi-Con EMZA350ARA4R7MD61G Digikey 565-EMZA350ARA4R7MD61GCT-ND	UCC D61 Cap
3	1	C4	0.01 µF	50 V Capacitor	Yageo CC0805KRX7R9BB103 Digikey 311-1136-1-ND	0805
4	1	C5	10 µF	50 V Capacitor	Samsung CL32B106KBJNNWE Digikey 1276-3388-1-ND	1210
5	1	C6	100 µF	50 V Capacitor	Chemi-Con EMZA500ARA101MHA0G Digikey 565-EMZA500ARA101MHA0GCT-ND	UCC HA0
6	1	CN1		USB Mini-B Receptacle	EDAC 690-005-299-043; Digikey 151-1206-1-ND	EDAC 690-005-299-043
7	7 Pins	CN2, CN4		Cut from 50-Pin Strip	Samtec TSW-150-07-T-S; Digikey SAM1035-50-ND	3-Pin 0.1” Connector, 4-Pin 0.1” Connector
8	1	CN3		Molex 3-Pin Verticle Recep-tacle	Molex 0022022035; Digikey WM3201-ND	Molex 3-Pin 4455-N Vertical2
9	15	CP1, CP2, FG, nFAULT, OUTA, OUTB, OUTC, SCL, SDA, SPD, TEST, VBB, VBBIN, VCP, VREF		Large Test Point	Keystone Electronics 5010; Digikey 36-5010-ND	PAD 57 125 TP HB
10	1	D1		Schottky Diode	Diodes Inc. B240-13-F; Digikey B240-FDICT-ND	DO-214AA
11	4			Bumpon Foot	3M SJ-5303 (CLEAR); Digikey SJ5303-7-ND	Bumpon Foot
12	1	J1		3-Pin Screw-Down Connector	On Shore ED120/3DS; Digikey ED1610-ND	3-Pin screw-down connector2
13	1	J2		2-Pin Screw-Down Connector	On Shore Technology ED120/2DS; Digikey ED1609-ND	2-pin screw-down connector
14	1	L1		Ferrite Bead	Laird MI0805K400R-10; Digikey 240-2389-1-ND	0805
15	1			PCB	39-0097-000 Rev. 1	
16	2	R1, R2	27 Ω	1/8W Resistor	Vishay/Dale CRCW080527R0FKEA Digikey 541-27.0CCT-ND	0805
17	3	R3, R4, R7	200 Ω	1/8W Resistor	Panasonic ERJ-6GEYJ201V; Digikey P200ACT-ND	0805
18	4	R5, R6, R9, R10	4.99 kΩ	1/8W Resistor	Panasonic ERJ-6ENF4991V; Digikey P4.99KCCT-ND	0805
19	1	RNET1	10 kΩ	4 Isolated Resistors	YC324-JK-0710KL; Digikey YC324J-10KTR-ND	YC324 Series - 2012
20	1	SW1		Dual SPDT Switch	Grayhill 76STC02T; Digikey GH7720-ND	76STC02T
21	1	U1		Three Phase Sensorless Motor Driver	A89347LP	20-Pin LP w/slug
22	1	U2		USB 8-Bit FIFO IC	FTDI FT240XS-R; Digikey 768-1127-1-ND	SSOP-24 (150 mil)
23	1	U3		Dual N-Channel FETs	Toshiba Semi SSM6N15AFU,LF Digikey SSM6N15AFULFCT-ND	SOT-363
24	2	W1, W2		22 Gauge Bus Wire (300 mm Above PCB)	Alpha Wire 298 SV005; Digikey 298SV005-ND	Scope Ground

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Revision History

Number	Date	Description
–	July 10, 2025	Initial release

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