

## A89301 Evaluation Board User Guide

### DESCRIPTION

The A89301 evaluation board is designed to aid system designers in evaluating the operation and performance of the A89301 motor controller IC. This user guide provides step-by-step instructions on how to use the A89301 evaluation board to program the Allegro A89301 motor controller IC. In addition, this document contains feature descriptions that are not shown in the A89301 datasheet.

### FEATURES

- USB communications to allow a GUI to control the device via I<sup>2</sup>C
- Programs devices to control a motor

### EVALUATION BOARD CONTENTS

- APEK89301GES-01-T evaluation board



Figure 1: A89301 Evaluation Board

Table 1: A5947GET Evaluation Board Configurations

Configuration Name	Part Number
APEK89301GES-01-T	A89301GESSR

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## USING THE EVALUATION BOARD

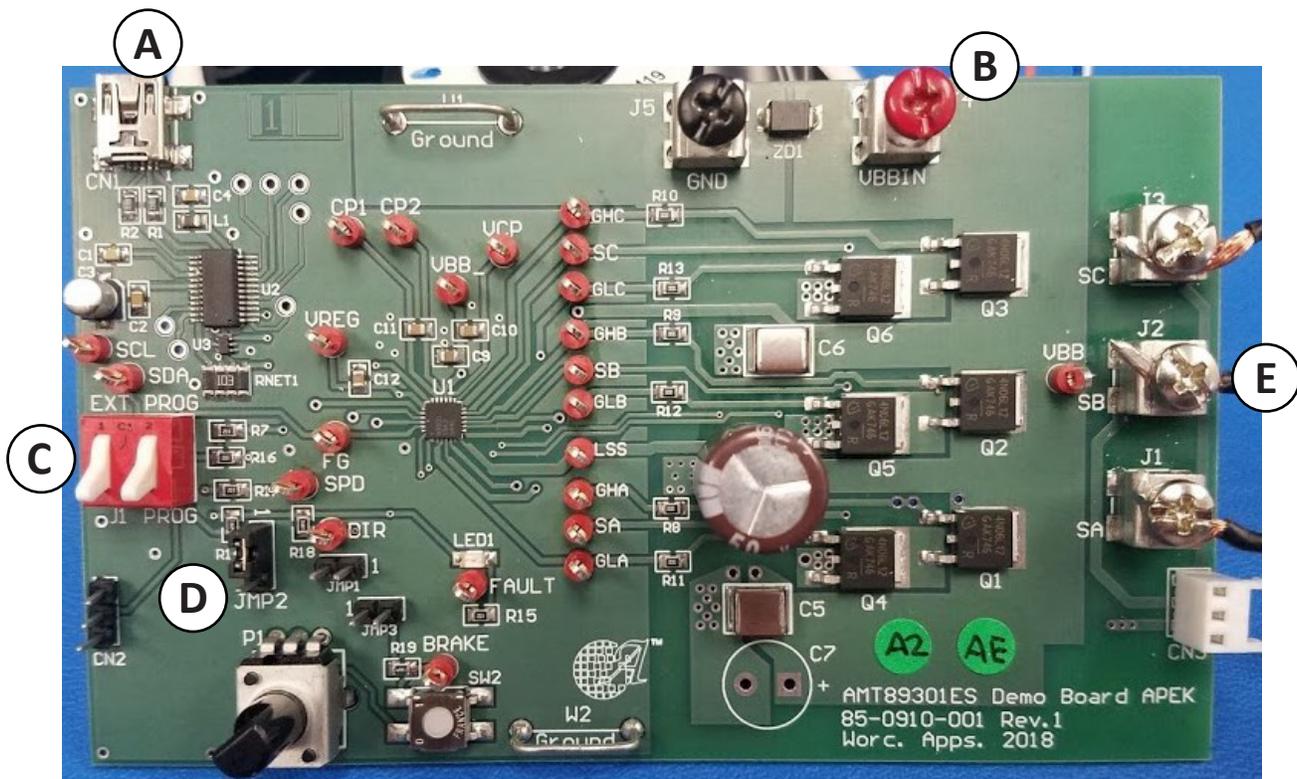
### Equipment Required

- Motor
- Voltage supply to power motor
- Standard A Male to Mini B Male USB cable (not included)
- Personal computer for USB control
- Software; see Related Links

### Step 1: Make Evaluation Board Connections.

- Connect USB cable to computer.
- Connect power cables to VBBIN and GND.
- Set the switch to U1 PROG.
- Set JMP2 to upper position.
- Do **not** connect motor phases SA, SB, SC yet.\*
- Turn on power to rated voltage.

\* The default settings in the A89301 may not be appropriate, which could cause damage to the IC or motor. Settings should be verified before connecting a motor.



## Step 2: Launch the GUI.

A89301 Application (Version 1.8) - <no filename specified>

Save/Open Configuration   Text Size   Application Info   Disclaimer

Read EEPROM and show settings   Write all settings to EEPROM   Toggle Run/Stop    Set speed demand via I2C   Read   Continuous read

100.0% speed demand

Speed =  
Current =  
Show plot   Show gauge

Setting PWM reg to 0  
Wrote to 81 : 0x2200 (8704)  
Read from 81 : 0x2200 (8704)

General   **Advanced**   Standby / Protection   CISS   Status   IPD   Lock Detect   Startup test

Pole pairs  (used only for calculations here; saved in the settings file but not saved in EEPROM)

Rated voltage  = 11.6 V

Rated speed  = 69.4 Hz  
= 1041.5 RPM

Motor resistance  = 1.02 ohms

Rated current  = 1.864 A

Startup current (relative to rated current)

- 1/4x (466 mA)
- 1/2x (932 mA)
- 3/4x (1.40 A)
- 1x (1.86 A)
- 3/8x (699 mA)
- 5/8x (1.17 A)
- 7/8x (1.63 A)

Max start current  Disabled    Enabled

Acceleration  = 5.75 Hz/s

Acceleration range (Hz/s)  0 to 12.75    0 to 816

Speed control  Open loop    Closed loop

Direction  ACB    ABC

SPD input mode  Digital    Analog

Digital speed input  PWM    Clock mode - freq to speed (for closed loop only)

PWM input freq  > 2.8 kHz    <= 2.8 kHz

Speed response time constant  = 2.00 sec

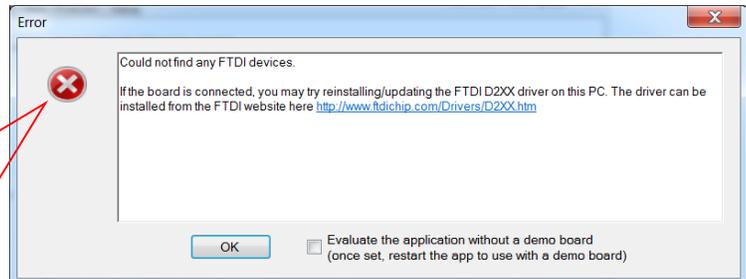
Speed input OFF threshold  10%    15%    6%    20%

FG function  Normal FG    Disabled, I2C mode

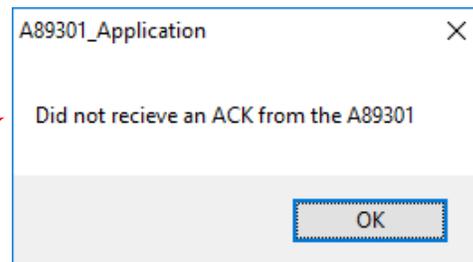
Allegro<sup>®</sup> MicroSystems, LLC

## Step 2: Launch the GUI. (continued)

**B.** If you see this error message, install the USB to I2C chip driver (FTDI D2XX). Check USB cable connection.



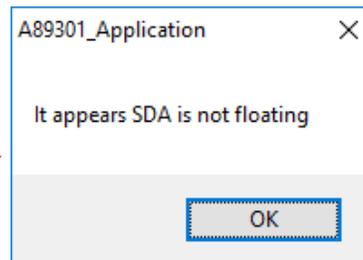
**C.** Make sure the power supply is ON, and the switch is set to 'U1 PROG'.



**D.** Try talking to the IC again. (As I2C\_SDA is shared with functional mode FG pin, it is possible the first attempt failed because the FG is pulled low).

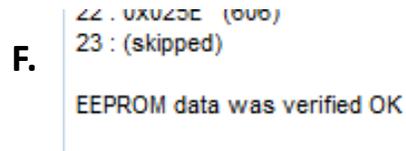
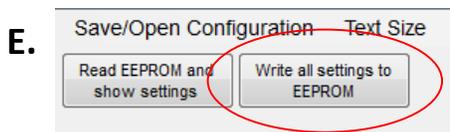
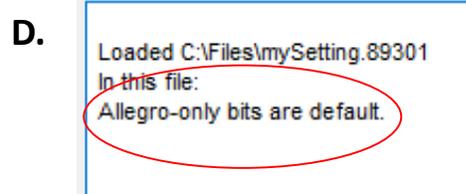
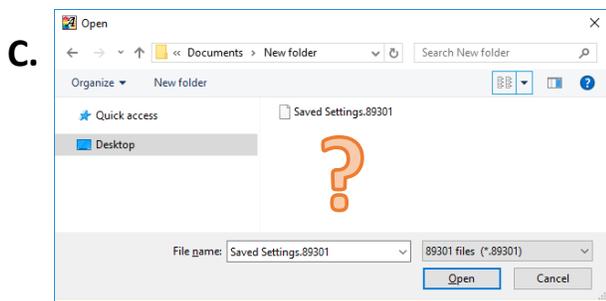
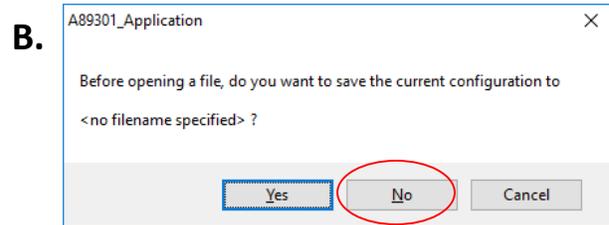
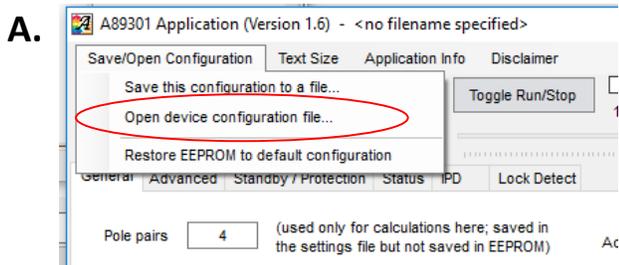
To guarantee this won't happen again in the future, disable the FG function:

FG function     Normal FG     Disabled, I2C mode



### Step 3: Load saved parameters, if previously saved.

Device parameters can be saved to a file. If a file for this (or similar) application has been created, open that file. Verify the Allegro-only bits in the file are their default values.



## Step 4: Configure the basic parameters.

Note: These numbers do not need to be very accurate; use the best estimation. There is fine tuning later in the process.

The number of pole pairs. For example, 12 pole motor: input 6 pole pairs. See [NOTE 1](#) to determine the number of poles.

Pole pairs  (used only for calculations here; saved in the settings file but not saved in EEPROM)

Rated voltage  = 11.6 V

Rated speed  = 71.2 Hz  
= 1067.9 RPM

Motor phase to center tap resistance, measure phase to phase R and divide by two.\*

Motor resistance  = 1.02 ohms

Rated current  = 1.864 A

\*Be sure to use an accurate multimeter. A better option may be to apply a current through the motor, measure voltage across it, and calculate resistance.

Sense resistor value  = 12.4 mohms

The supply voltage that motor will be working at. For example:

- Computer fan, 12 V power supply: input 12 V.
- Supply voltage speed control, range 8 V to 24 V: input 24 V.
- Lithium battery system, voltage 11.1 V to 12.6 V: input 12 V.

Expected motor speed at 'Rated Voltage', normal load condition, and 100% control demand.

For example, pedestal fan, 1300 rpm with blades and 1450 rpm without blades: input approximately 1300 rpm.

Motor operation current under 'Rated Voltage', with normal load condition. Rated Voltage, Rated Speed, and Rated Current must be consistent.

In the "Advanced" page, there is a parameter defining the current sensing resistor value. Program this value appropriately.

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**Step 5: Start the motor.**

- A.** Connect motor phase A, B, and C.
- B.** Keep 'Set speed demand via I2C' checked.
- C.** Select the speed demand to 50%, and click Toggle Run/Stop.



The motor should start spinning.  
If it does, go to **step 9**.  
If not:

Doesn't move at all,  
go to **step 6**.

Shook a little bit  
then stopped, go  
to **step 7**.

Spun more than 5  
cycles and stopped,  
go to **step 8**.

**Step 6: If motor does not move at all:**

**A.** Look at the LED indicator connected to the Fault pin, and follow the fault table to determine the root cause.

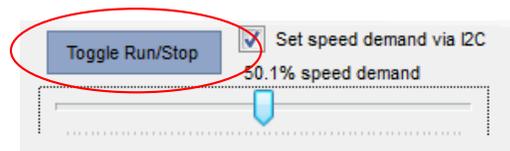


**B.** If the LED is off, connect a current probe and voltage probe to the motor outputs and check if there is any current / voltage output to the motor phase. If there is voltage but no current, check motor phase connections.

Lock detected	low	constant on
OCP	0.67s high 0.67s low	slow flashing
OTP	0.67s low 0.17s high 0.08s low 0.17s high 0.08s low 0.17s high	long-short-short flashing
system error	0.08s low 0.08s high 0.08s low 1.09s high	double short flashing
OVP	0.17s high 0.17s low	fast flashing
zero speed demand	0.25s high 0.08s low 0.34s high 0.67s low	long-short flashing

**C.** If the fault indicator LED is showing the “zero speed demand”, double check the I2C speed demand setting is correct.

**D.** Toggle Run/Stop to retry startup.



**Step 7: If motor shakes a little and stops:**

**A.** Look at the LED indicator connected to the Fault pin, and follow the fault table to determine the root cause.



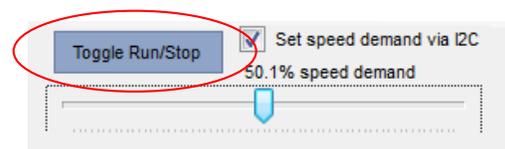
**B.** If it is OCP, check the phase output wire connections.

Lock detected	low	constant on
OCP	0.67s high 0.67s low	slow flashing
OTP	0.67s low 0.17s high 0.08s low 0.17s high 0.08s low 0.17s high	long-short-short flashing
system error	0.08s low 0.08s high 0.08s low 1.09s high	double short flashing
OVP	0.17s high 0.17s low	fast flashing
zero speed demand	0.25s high 0.08s low 0.34s high 0.67s low	long-short flashing

**C.** Otherwise, it is likely lock detection. If so, lower/slow down the acceleration setting. Note there are two acceleration ranges.



**D.** Toggle Run/Stop to retry the startup.



**Step 8: If motor spins more than 5 cycles and stops:**

**A.** Look at the LED indicator connected to the Fault pin, and follow the fault table to determine the root cause.



**B.** The problem is likely lock detection. If so, go to the Standby / Protection page and disable all the lock detect features.

**Standby / Protection**

Startup lock detect angle error threshold:  Disabled,  5 deg,  9 deg,  13 deg

BEMF lock detect filter:  Lock disabled,  Robust,  Medium,  Sensitive

Extend lock detect mask:  Disabled,  Enabled

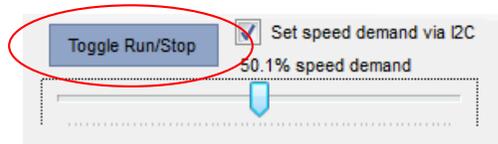
Open phase protection:  Disabled,  Enabled

Vibration lock detect:  Disabled,  Enabled

Over-speed fault > 138.9 Hz (2x the rated speed):  Disabled,  Enabled

Lock detected	low	constant on
OCP	0.67s high 0.67s low	slow flashing
OTP	0.67s low 0.17s high 0.08s low 0.17s high 0.08s low 0.17s high	long-short-short flashing
system error	0.08s low 0.08s high 0.08s low 1.09s high	double short flashing
OVP	0.17s high 0.17s low	fast flashing
zero speed demand	0.25s high 0.08s low 0.34s high 0.67s low	long-short flashing

**C.** Toggle Run/Stop to retry the startup.



**D.** One by one, enable each lock detect feature to determine which is the cause of the fault and which can be re-enabled.

**Step 9: While the motor is spinning, go to the Status page; click ‘Read Status’.**

**A.** While the motor is spinning, go to the Status page. Click ‘Read Status’.

**B.** The system diagnostics function will show you IC temperature, motor speed, supply current, phase current, and supply voltage. Compare the supply current and voltage data with the result showing on the power supply.

The screenshot shows a web interface for a motor controller. At the top, there are tabs for 'Advanced', 'Standby / Protection', 'Status', 'IPD', and 'Lock Detect'. The 'Status' tab is selected. Below the tabs, there are two buttons: 'Read Status' and 'Continuous Read'. The main area displays various diagnostic parameters:

Motor speed	0x0000, 0	= 0 Hz, 0 RPM
Bus current	0x0000, 0	= 0 mA
Q axis current	0x0000, 0	= 0 mA
Vbb ADC	0x0000, 0	= 0.0 V
Control demand	0x0000, 0	= 0.0 %
Amplitude command	0x0000, 0	= 0.0 %
Phase advance angle	0x0000, 0	= 0 deg

Below the parameters, there is a section for 'State, address 127:' with a list of status options: 'Initial', 'Spinning', 'Brake', and 'Lock detected'. The 'Spinning' option is currently selected.

**C.** The **Control demand** is the amplitude that is commanded (it should match the I2C speed demand value). The **Amplitude command** is the actual amplitude provided to the motor phase. If the command is less than the demand, it is because of the current limit. This problem is solved in **Step 11**.

The screenshot shows a control interface for speed demand. It features a 'Toggle Run/Stop' button and a checked checkbox labeled 'Set speed demand via I2C'. Below the checkbox, the text '50.1% speed demand' is displayed. A horizontal slider bar is shown with a blue arrow pointing to the 50.1% mark.

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## Step 10: Adjust the motor inductance.

- A. Motor inductance is difficult to measure—it varies with operation frequency, phase current (saturation), and also with the rotor position. Thus, A89301 provides an easy method to adjust the inductance value and achieve the best efficiency.



- B. While the motor is spinning, connect a current probe to phase A, and connect a voltage probe to phase A.

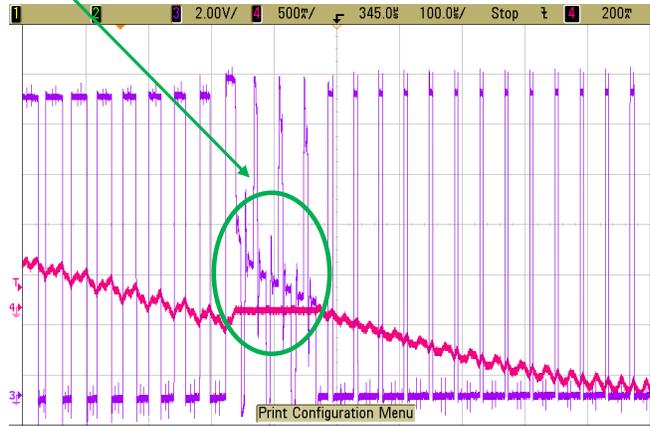
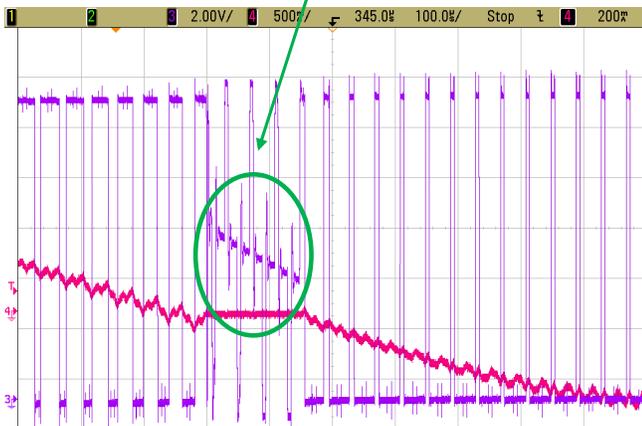
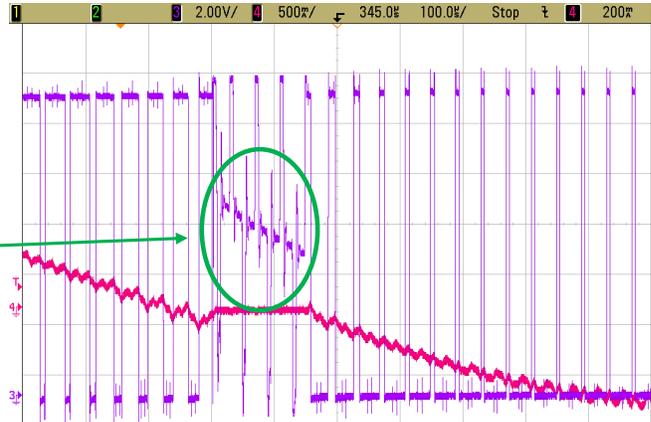
- C. Enable the open window which is a debug function. Remember to disable the window before finalizing the parameters.



## Step 10: Adjust the motor inductance. (continued)

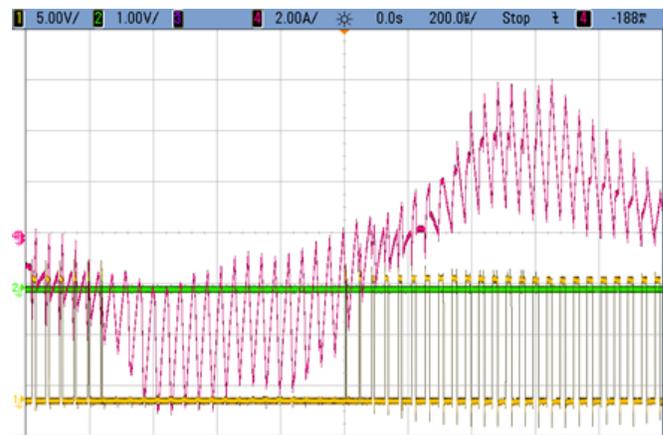
D. There will be a small window opened on phase A (winding current is flat at 0A). Observe phase A voltage inside the window:

- If voltage  $> V_{BB}/2$ , increase L.
- If voltage  $< V_{BB}/2$ , decrease L.
- If voltage  $= V_{BB}/2$ , best efficiency.



## Step 10: Adjust the motor inductance. (continued)

- E. It may not be possible to find an inductance value that makes the phase A voltage exactly  $V_{BB}/2$ . If not, choose the closest setting.
- F. Theoretically, adjusting the inductance value at one speed will work for all other speeds. However, it is recommended to verify at another speed. If it doesn't work at other speed, it is recommended to make the adjustment at rated speed.
- G. For motors running at high speed ( $> 500$  Hz), opening the window may cause a big distortion in the phase current, which can trigger the lock detection. In this case, capture the first window waveform, stop the oscilloscope, and then make the adjustment.
- H. For motors with very low inductance, if the phase current looks like this, set the inductance value to level 0 or 1, and then start the adjustment.
- I. The Direct drive angle feature bypasses automatic phase angle adjustment. If enabled, the inductor setting slider is used to set the fixed advance angle, in units of degrees.



Direct drive angle     Disabled     Enabled

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## Step 10: Adjust the motor inductance. (continued)

- J. There is another way to double-confirm the inductance is optimized.
- Control the motor to a fixed high speed (around 80% of rated speed).
  - Read phase current RMS from scope.
  - Change the inductance setting around the value from the previous step.
  - List the RMS current for each inductance setting and choose the one with smallest RMS current.
  - For example, look at the table, inductance setting 2 will cause the minimum current at fixed speed (3000 rpm). Therefore, choose setting 2.

inductance setting	phase RMS current	motor speed
0	2.35 A	3000 rpm
1	2.25 A	3000 rpm
2	2.21 A	3000 rpm
3	2.28 A	3000 rpm
4	2.39 A	3000 rpm

---

## Step 11: Fine tune the general parameters.

- A. Increase the speed demand to 100%, and read the status.
- B. The bus current value should match the actual bus current shown on the power supply or a multi-meter. If not, adjust the sense resistor value slightly (on the advanced page).
- C. The 'Control demand' and 'Amplitude command' should be both 100% (511).
- D. If the 'Amplitude command' is less than 511, go to the general parameter page and increase the 'Rated current' value. The motor speed should increase while the 'Rated current' value is increased.
- E. When the 'Control demand' and 'Amplitude command' are both 511, record the 'Motor speed' from the status page. Enter this value as the 'Rated speed' parameter.
- F. Record the 'Bus current' from the status page. Enter this value as the 'Rated current' parameter.

The screenshot displays a control interface with the following elements:

- Bus current:** A text box containing the hexadecimal value `0x0000, 0`, followed by the text `= 0 mA`.
- Sense resistor value:** A horizontal slider with a triangular handle. The text `= 12.4 mohms` is positioned to the right of the slider.
- Control Panel:** A light blue box containing:
  - A blue button labeled `Toggle Run/Stop`.
  - A checked checkbox labeled `Set speed demand via I2C`.
  - A slider set to `100% speed demand`.
- Control demand:** A text box containing `0x0000, 0`, followed by `= 0.0 %`.
- Amplitude command:** A text box containing `0x0000, 0`, followed by `= 0.0 %`.

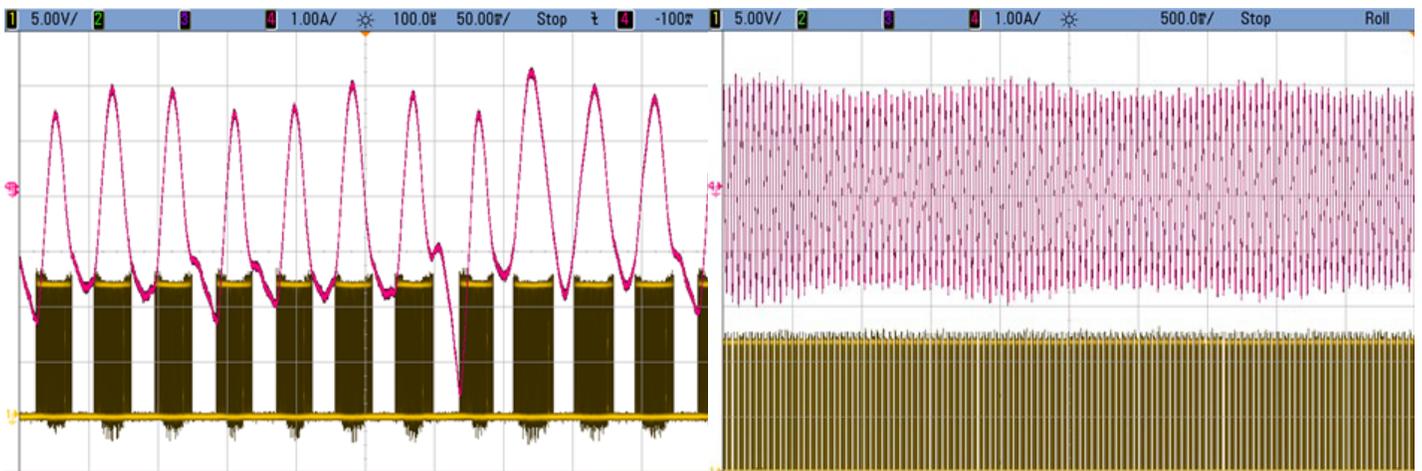
## Step 12: PID Parameters.

- A. Restart the motor.
- B. If the PID parameter is too high or too low, operation will fail. Connect a current probe and voltage probe for the debugging.

- If current shows distortion within in one electrical cycle, the PID parameter is too high.



- If current shows low frequency oscillation, the PID parameter is too low.



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### Step 13: Startup Mode and Startup Settings.

- A. If this is an air purifier type of application which doesn't require zero reverse rotation startup, and startup time is not critical, select 'Align & go'.
- B. If this is a ceiling fan or pole fan application which strictly requires no reverse rotation at startup, select '2 pulse IPD'.
- The 'IPD current threshold' must be set high enough so that startup is reliable, and as low as possible to minimize the acoustic noise during IPD.
- C. For some motors, due to manufacturing tolerance (inductance error between phase to phase), the 2 pulse IPD won't be able to detect the initial position reliably. In that case, select '6 pulse IPD'.
- D. If this is a seat cooling fan or pump where faster startup is desirable and slight reverse oscillation at startup is acceptable, select 'Slight move'.
- Adjust the 'Slight move amplitude demand', and choose the best startup performance. Too high a value will cause severe startup oscillation, and too low a value will cause startup failure.
- E. [NOTE 2](#) explains how to use the GUI's IPD page to test the performance.
- F. Compare these three options in the application and choose the best fit.

Startup mode     2-pulse IPD     Slight move  
 6-pulse IPD     Align & go

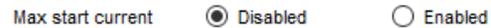
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## Step 13: Startup Mode and Startup Settings. (continued)

- G. A89301 provides 7 options for the startup current. The motor phase current will gradually increase from the programmed value.



If 'Max start current' is enabled, the control demand is ignored, and 100% control demand is always used. The current will be limited by the startup current setting.



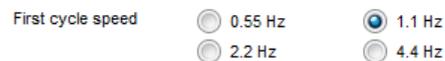
- H. Reducing the startup current may cause startup to fail in open-loop mode, even if startup was verified successful before the change. In this case, reduce the acceleration accordingly.

- I. If faster startup is required, increase the acceleration value. Startup current may need to be increased accordingly.



- J. Note the startup current and acceleration only affects the reliability and startup time. If the motor fails after at least 5 cycles, then changing the startup parameters won't help.

- K. Increasing the first cycle speed will make the startup faster.



- L. Perform a comprehensive test to ensure startup reliability. The GUI provides the startup test tool of reliability test. Refer to [Note 4](#).
- 1) Different initial position.
  - 2) Different initial speed.
  - 3) Different supply voltage.
  - 4) Different operation temperature.

## Step 14: Lock detect parameters.

Note: If there is any issue with lock detect, refer to [NOTE 3](#) for further debugging.

Detect the lock during startup. If it is disabled, a locked motor condition can still be detection after startup stage, it just takes longer.

In the normal operation, the motor generates BEMF. The algorithm observes the BEMF by calculating the current and voltage, and reports abnormal BEMF. Select Robust will get rid of the mis-trigger but it takes longer to detect.

Disabled, lock detect begins once the motor reaches 6% of rated speed. Enabled, it becomes 12%.

For ceiling fan, with flexible shaft connection, there is a lock condition when the shaft and motor keep vibrating and cause 'papapa' noise.

Enabled, the IC will report a failure if the motor "speed" is abnormally fast.

A89301 attempts to start the motor again after 5s or 10s waiting. But it will only attempt so many times, then stop attempting until power cycle, or restart the motor demand (speed demand).

Lock detect waiting time.

Startup lock detect angle error threshold:  Disabled,  5 deg,  9 deg,  13 deg

BEMF lock detect filter:  Lock disabled,  Robust,  Medium,  Sensitive

Extend lock detect mask:  Disabled,  Enabled

Vibration lock detect:  Disabled,  Enabled

Over-speed fault > 138.9 Hz (2x the rated speed):  Disabled,  Enabled

Lock detect restart attempts:  Always,  3 times,  5 times,  10 times

Lock detect reset attempt duration:  5 s,  10 s

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## Step 15: Speed control mode.

- A. The term “Speed Control” is used here, however the motor speed is controlled directly only when “closed-loop speed” is enabled. If it is not enabled, the control setting provided through I2C or the SPD pin is proportional to the output amplitude, which only indirectly changes the motor speed.
- B. So far, I2C has been used for speed (amplitude) control, as it is an easy method for debug. It is not limited to debug use however—the customer can use the I2C mode in final production if there is an MCU (or other type of controller) in the system.
- C. The speed control options are described in the datasheet “Speed Control” section.

Speed input             10%             6%  
OFF threshold         15%             20%  
(ON = setting+2%)

- D. If the demand is less than a threshold, A89301 will not try to spin the motor.
  - For example: ‘SPD input mode’ is digital, and PWM is selected. The ‘Speed input OFF threshold’ is set to 10%. Here, 5% PWM will not start the motor, but it won’t enter standby mode either. Only a 0% PWM will trigger the standby mode.

Frequency to             7.00 RPM/Hz  
speed ratio

- E. When “clock mode (freq to speed)” is enabled, the frequency to speed ratio is adjustable. The unit of clock input frequency is “Hz”, the unit of the speed is “RPM”, so the number of pole pairs needs to be programmed correctly before adjust this parameter.

Speed response             2.00 sec  
time constant

- F. When “closed loop speed control” is enabled, the speed response time constant is adjustable.

---

## Step 16: Other settings.

Standby mode  Enabled  Disabled  
Delay standby until stationary  Disabled  Enabled

- A. When speed demand is 0 and SPD pin voltage is low, the IC will enter the standby mode. If Delay standby until stationary is set, the IC will not enter standby until the motor stops rotating. VREF and Charge Pump will be disabled in standby mode. If the application requires VREF when speed demand is zero, disable the standby mode.

Brake mode  Brake when safe  100% uncontrolled  
Safe braking threshold current (relative to rated)  1x (1.86 A)  2x (3.73 A)  
 4x (7.46 A)  8x (14.9 A)

- B. When the external Brake button is pressed, A89301 will stop the motor as fast as possible. But because of the potential overstress damage to the MOSFETs, selecting the “Brake when safe” option is recommended. Then system will not apply the brake until the braking current is less than the threshold (calculated by the motor speed). If the hardware design has a big safety margin, choose “100% uncontrolled”.
- C. Keep the default OCP parameters unless unexpected overcurrent conditions are experienced.

---

## Step 16: Other settings. (continued)

Open drive       Disabled       Enabled  
Power control enable       Disabled       Enabled

- D. 'Open drive' is a debug option which will keep the system in the open-loop (stepper motor) state. In case after all this practice, the motor can't be made to spin, enable the open drive, set the PID parameters to 0, and set the rated speed low. If the motor is able spin slowly in the open loop, the problem is related to PID parameter.
- E. 'Power control enable' is a debug option that will disable the current limit, and accelerate and decelerate buffer. In this mode, speed command will always be the same as speed demand. This will eliminate any current limit related issues.
- F. Remember to set these debug options back to default before finalizing the parameters.

Soft OFF       Enabled       Disabled  
Soft ON       Disabled       Enabled  
Soft off time       1 s       4 s

- G. These are the soft-on and soft-off features described in the datasheet.

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## Step 16: Other settings. (continued)

Accel buffer  None  Medium  Fast  Slow

Decel buffer  None  Medium  Fast  Slow

- H. The Accel buffer and Decel buffer only affect “open-loop speed control” mode. Keep the default setting if satisfied with the dynamic response of the system. If faster dynamic response is expected, choose fast or no buffer. If the application has a high-inertia motor (ceiling fan), choose slow buffer. Using a faster buffer with a slow system (ceiling fan) may cause lock detect mis-trigger.

Direction  ACB  ABC

- I. If the motor is not spinning in the desired direction, simply change the direction setting, *or (not and)* swap any two of the three motor terminals.

Dead time  = 400ns      Deadtime compensation  0  1

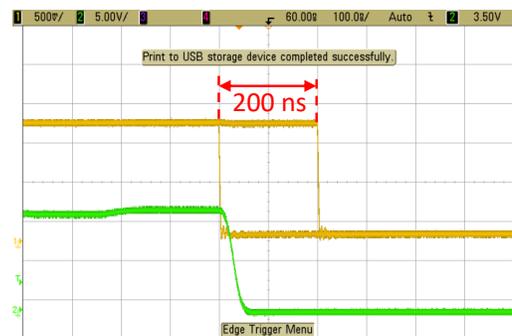
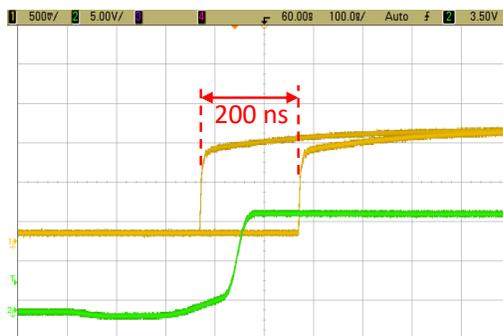
- J. The dead-time is the period of time between corresponding high- and low-side drivers are disabled and enabled, necessary to prevent shoot-through current if both high- and low-sides are enabled simultaneously. Typically, the default value is appropriate, but increase this time if shoot-through is occurring.
- K. Deadtime compensation can be enabled to reduce the current distortion due to deadtime. Keep it disabled if enabling the compensation makes current waveform worse. (The deadtime compensation may not be suitable for all motors).

## Step 17: MOSFET CISS settings (CISS tab).

A. These parameters are provided to compensate for the MOSFET parasitic input capacitance ( $C_{ISS}$ ). Higher capacitance and/or lower gate slew rate requires higher compensation. The settings can be selected via the table in the datasheet, or for better accuracy, via the test functionality provided in the application (this method is recommended). To use the app's test functionality:

- Do not connect anything to the motor terminals A, B, C—keep them floating
- Push the 'Run / stop test' button
- Connect the scope channel 1 to the Fault pin, and scope channel 2 to motor terminal A
- Trigger on the rising edges of channel 2
- Observe the time period between the alternating rising edges on channel 1 (yellow traces below)
- Adjust the 'MOSFET CISS compensation rising' slider until the time period is  $\text{deadtime} / 2$
- Now change the trigger to the falling edges of channel 2
- Observe the time period between the alternating falling edges on channel 1
- Adjust the 'MOSFET CISS compensation falling' slider until the time period is  $\text{deadtime} / 2$

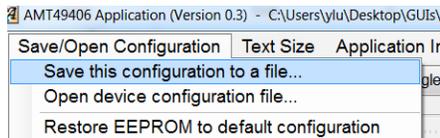
Example:  
Deadtime = 400 ns



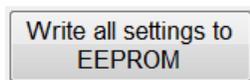
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## Step 18: Save the settings and write into the EEPROM.

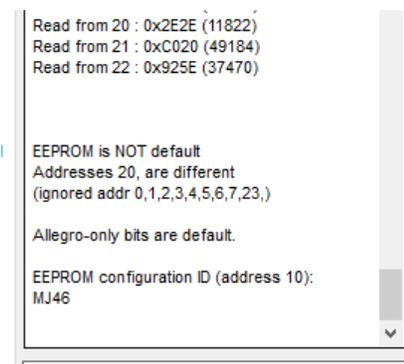
- A. Save the configuration to a file.



- B. Press “Write all settings to EEPROM” before shutting down the power.



- C. The Allegro-only bits in EEPROM can be verified by pushing the “Read EEPROM and show settings” button. After reading, the app will show if EEPROM is default and if the Allegro-only bits are default—the Allegro-only bits should always be default. (The default values of Allegro-only bits are shown on the following slide)



**Default values of Allegro-only bits.**

The red bits should always be set to the following values.  
 Bits with an 'X' is a user setting and can be set to 0 or 1.

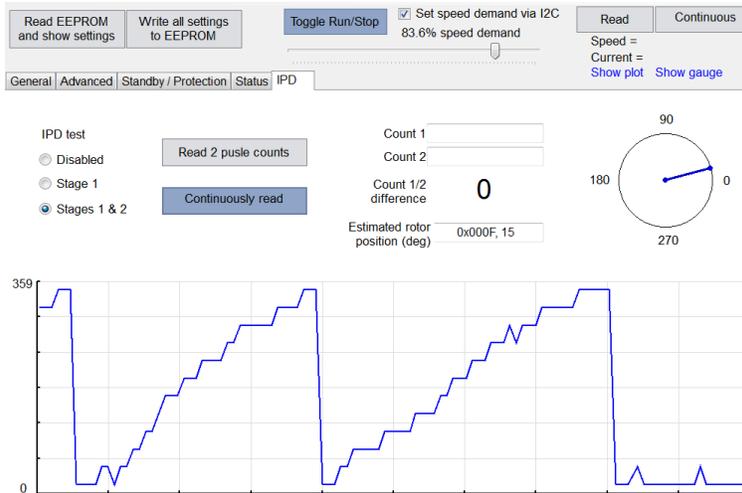
Address	Bit															
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EE8_REG72	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
EE9_REG73	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
EE10_REG74	X	X	X	0	X	X	X	X	X	X	X	X	X	X	X	X
EE11_REG75	1	X	0	X	X	X	0	0	X	X	X	0	X	0	0	0
EE12_REG76	X	0	X	X	X	X	X	X	X	X	X	X	X	X	X	X
EE13_REG77	0	X	0	0	0	0	0	1	X	X	X	X	X	X	X	X
EE14_REG78	0	0	0	0	1	1	1	0	0	0	0	X	0	1	0	1
EE15_REG79	X	X	1	1	X	X	X	X	X	X	1	1	X	X	0	1
EE16_REG80	0	0	X	X	X	X	X	X	X	X	X	X	X	X	X	X
EE17_REG81	0	0	1	0	0	0	X	X	X	X	X	X	X	X	X	X
EE18_REG82	X	X	X	X	X	X	X	X	0	0	0	0	1	1	0	1
EE19_REG83	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0
EE20_REG84	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
EE21_REG85	X	1	0	0	0	0	X	X	X	X	X	0	0	0	0	0
EE22_REG86	X	0	0	1	X	X	X	X	X	X	X	X	X	X	X	X

---

## NOTE 1. HOW TO DETERMINE THE NUMBER OF POLES

- A. Connect one motor terminal to the supply, one terminal to ground, and leave the last terminal floating. Increase the supply gradually, making sure the current doesn't become too high (should be about half of the rated current).
  
- B. This drives the motor to a particular phase. While manually rotating the shaft, count the number of detents (how many places the rotor settles in, or is pulled to) there are in one revolution. The number of detents is the number of pole pairs.

## NOTE 2. TESTING THE IPD PERFORMANCE



- A. The IPD performance test is valid for '2-pulse IPD', '6-pulse IPD', and 'Slight-move' modes.
- B. Go to the IPD page, select IPD test stage, enable 'Continuously Read Angle', and push 'Toggle Run/Stop' to start driving.
- C. The motor will not spin but will make some noise. Slowly manually rotate the rotor, and the detected motor position will be shown in the "clock" plot and the "X-Y" plot.
- D. If 'Stage1' is selected (available for '2-pulse IPD' and 'Slight-move' options), the output will successively step up from 45° to 195°, then back to 45°, if spun in target direction. If spun in the opposite direction, the output will successively step down from 195° to 45°, then back to 195°.
- E. If 'Stage1&2' is selected (available for '2-pulse IPD' and '6-pulse IPD' options), the output will successively step up from 15° to 345°, then back to 15°, if spun in target direction. If spun in the opposite direction the output will successively step down from 345° to 15°, then back to 345°.
- F. The 'counter 1' and 'counter 2' are only for '2-pulse IPD' and 'States 1&2' options. In this case, press 'Read 2 pulse counts' button, count 1 and 2 will display the width of the 2 pulses, and the difference will be calculated. The difference is expected to be above 3 or below -3.

## NOTE 2. TESTING THE IPD PERFORMANCE (continued)

### Make judgments

- A. If the detected motor angle steps are not successive in 'Stage 1' while slowly rotating the rotor (for example, if it jumps from 45° to 135° and then back to 75°), then the '2-pulse IPD' and 'Slight-move' modes are not proper startup modes for this motor. Choose '6-pulse IPD'.
- B. If 'Stage 1' is good, or if '6-pulse IPD' is selected, and the detected motor angle steps are not successive in 'Stage 1&2' while slowly rotating the rotor (for example, if it jumps from 45° to 225° and then back to 45°, and especially when it jumps back and forth 180°), increase the 'IPD current threshold'.
- C. It is normal to have the result move one step (30 degrees) back and forth—this won't affect the startup reliability. See picture on right; this is acceptable.
- D. If 'Stage 1&2' is good, but the difference calculated between pulse 1 and 2 widths is only +/- 0, 1 or 2, we should increase the 'IPD current threshold'.



### IPD and VBB Slew Rate

- A. When using either IPD option, the voltage on VBB should be stable within 25 ms after a start signal is applied to the SPD terminal.
- B. This is important when the SPD terminal is biased such that the motor will begin to run immediately when VBB is applied, and the VBB supply slew rate is slow.
- C. If VBB is not stable within 25 ms of application of the start signal, the 'Delay start' option can be set, which extends the delay between the signal on the SPD terminal and motor startup to 100 ms. Note, if this option is enabled, the 100 ms delay is always preset—it is not limited to when applying power to VBB.

Delay start

Disabled

Enabled

### NOTE 3. DEBUGGING THE LOCK DETECT FEATURE

General Advanced Standby / Protection Status IPD Lock Detect

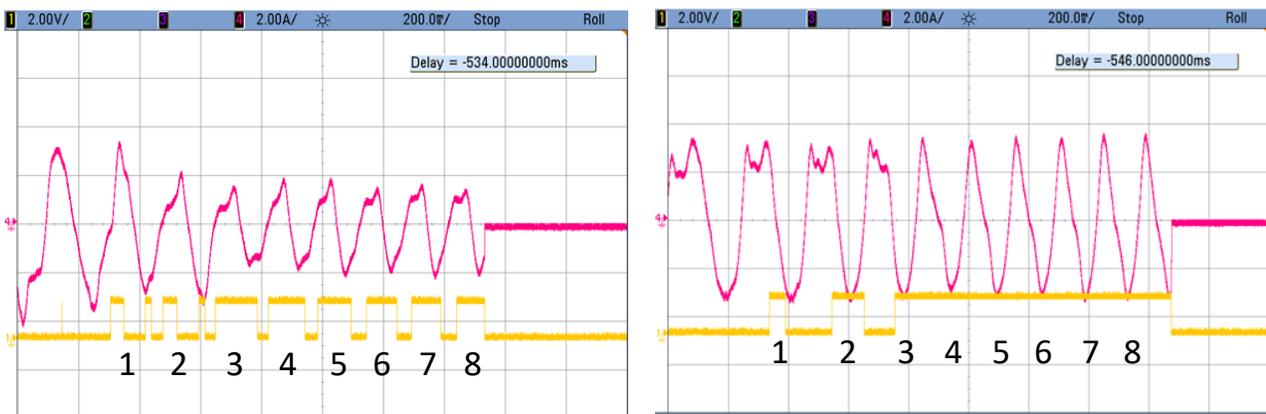
- A. Go to “Lock Detect” page to debug lock detection issues. Lock detection issue includes (1) Motor is locked, but IC can’t detect the lock, and (2) Motor is running okay, but IC detects a lock by mistake.
- B. Press the ‘continuous read’ button, and run the motor.
- C. The curve below shows the BEMF lock detect feature. If all the parameters are set correctly, the measured BEMF curve (blue) should be at 100%.
- D. Run the motor at maximum speed (rated voltage, 100% demand, and open loop). Fine tune the rated speed setting, rated current setting (step 11), and sense resistor setting. The blue curve will be near 100%.
- E. At other operating speeds, the blue curve might be slightly off the 100% reference, but as long as it doesn’t cross the 50% and 200% thresholds, the motor will operate normally.
- F. If the motor is locked by external force, the blue curve will cross one of the thresholds, and lock detect will be triggered. Step 14 sets the sensitivity of the BEMF lock detect .
- G. During startup, the blue curve will not be between the 50% and 200% thresholds, and this is normal.



### NOTE 3. DEBUGGING THE LOCK DETECT FEATURE (continued)

General Advanced Standby / Protection Status IPD Lock Detect

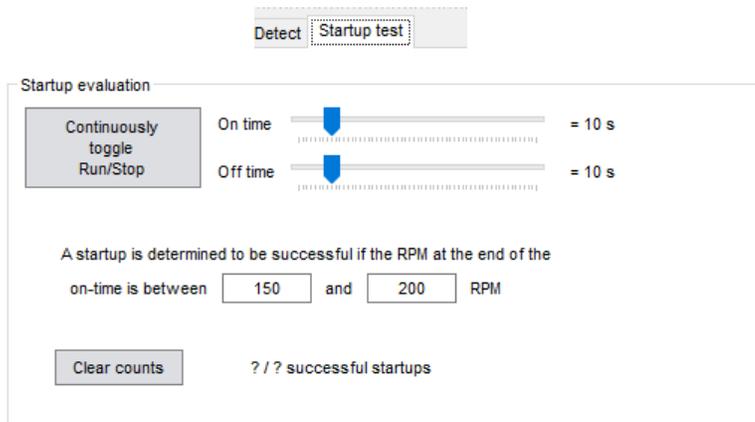
- A. This is primarily for ceiling fan applications with a loose connection (the stator can rotate some).
- B. To debug the vibration lock detect, press the “Threshold high” or “Threshold low” buttons, which will send the vibration detection signal to the “FAULT” pin.
- C. Use an oscilloscope to monitor the vibration signal. If the proper parameters are programmed, the signal should look like the picture below when the motor is vibrating.
  - While the motor is vibrating, “Threshold high” and “Threshold low” signals show pulses corresponding to the vibration pattern.
  - After 8 electrical cycles, the vibration lock detect will be triggered.
- D. If either “Threshold high” or “Threshold low” doesn’t show at least one pulse during each period, the IC is not able to detect the vibration condition, and the parameters need to be adjusted further.



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## NOTE 4. TESTING MOTOR STARTUP

- A. An automated testing feature is provided on the “Startup test” tab.
- B. Set the desired on-time, off-time (provide enough time for the motor to stop), and push the Run/Stop button.
- C. A startup is considered successful if the RMP at the end of the on-time is between the specified RPM limits.



## OTHER OPERATING FEATURES OF A89301

### Motor Operation Status Readback

The register `state_top_level[3:0]` holds the motor operation status, which can be read through I2C. The address is `127[15:12]`.

The grey highlighted items are FAULT related. It can be used to extract the fault condition instead of decoding the flash patterns on the Fault pin.

**Table 2: state\_top\_level Register**

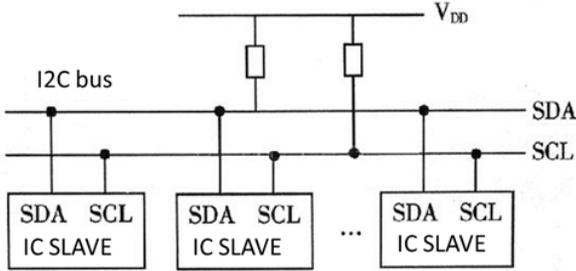
State Top Level	State
0	initial (idle)
1	first cycle (open loop)
2	IPD (initial position detection)
3	Normal spinning
4	n/a
5	Lock detected
6	Brake
7	Sleep (can't read it because IC is in sleep)
8	state
9	Windmill startup
10	Change direction
11	OCP (overcurrent protection)
12	OTP (overtemperature)
13	Bad system (VREG abnormal, VCP abnormal)
14	Brake external pin
15	Pre-Sleep (soft off state)

**Table 3: I<sup>2</sup>C Specifications and Timing**

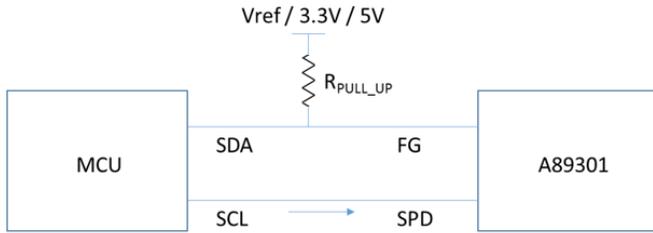
Characteristics	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
<b>I<sup>2</sup>C TIMING</b>						
SCL Clock Frequency	$f_{CLK}$		7	–	200	kHz
Bus Free Time (Between Stop/Start)	$t_{BUF}$		2.3	–	–	$\mu$ s
Hold Time Start Condition	$t_{HD:STA}$		0.6	–	–	$\mu$ s
Setup Time for Start	$t_{SU:STA}$		0.6	–	–	$\mu$ s
SCL Low Time	$t_{LOW}$		2.3	–	–	$\mu$ s
SCL High Time	$t_{HIGH}$		0.6	–	–	$\mu$ s
Data Setup Time	$t_{SU:DAT}$		350	–	–	ns
Data Hold Time	$t_{HD:DAT}$		50	–	900	ns
Setup Time for Stop	$t_{SU:STO}$		0.6	–	–	$\mu$ s
Signal Rising Time	$t_{R\_I2C}$	Both SCL and SDA	20	–	300	ns
Signal Falling Time	$t_{F\_I2C}$	Both SCL and SDA	20	–	300	ns

## I<sup>2</sup>C Hardware Connection

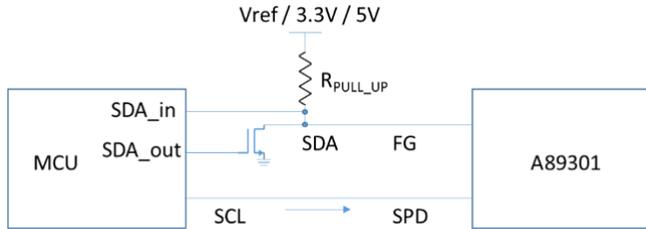
Standard I<sup>2</sup>C interface requires both SDA and SCL to be an open-drain structure, which achieves bidirectional communication.



The A89301 application is a single master, single slave system, so SCL is only an input for the A89301, which does not need a pull-up resistor. SDA is a bidirectional signal, which requires a pull-up resistor. The value of the pull-up resistor depends on the slew rate requirements on the SDA line; a range from 3.3 kΩ to 10 kΩ is recommended. If a slower communication rate is used, R<sub>PULL\_UP</sub> can be bigger in value. The pull-up voltage range is from V<sub>REF</sub> (2.8 V) to 5.5 V.



If the MCU does not support the I<sup>2</sup>C peripheral, or the user decides to program I<sup>2</sup>C with GPIO (general purpose input output), the following circuit is recommended. SDA<sub>in</sub> is an input signal, which receive the ACK (acknowledge) signal, or readback signal from A89301. SDA<sub>out</sub> is an output signal.



## OCL and OCP

The A89301 implements two stages of current protection: one is OCL (overcurrent limit) and the other is OCP (overcurrent protection).

The OCP condition is a catastrophic condition; for example, the short circuit between phase to phase, phase to GND, or phase to V<sub>BB</sub>. The function is implemented using a V<sub>DS</sub> comparator, comparing each V<sub>DS</sub> voltage and a reference voltage that is configurable (1 V or 2 V).

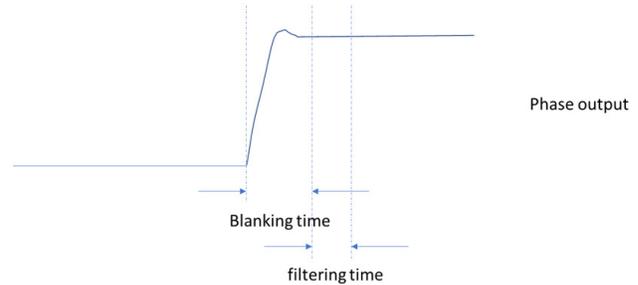
The OCL is not a catastrophic condition. It will be triggered during accelerate and motor stall conditions. When the OCL is triggered, the system will reduce the output voltage amplitude and regulate the current at the 1.125 × “rated current” level (bus current). Phase current peak is 1.3 × rated current level.

$$1.125 / (\sqrt{3}) / 2 = 1.3$$

## OCP Masking Time and Filtering Time

OCP condition has the highest priority; when it is triggered, the state machine will stop the motor immediately. However, blanking time and filtering time is implemented to prevent mis-triggering. Masking time is when one phase is turning on, and turning off, the V<sub>DS</sub> comparator will show a period of unstable output, which will be blanked out. Filtering time is a digital filter for each of the six potential OCP signals after the blanking logic.

The blanking time has been set at 640 ns by default, and filtering time has been set at 480 ns by default. Those numbers are configurable.



- |             |   |                                      |
|-------------|---|--------------------------------------|
| OCP filter  | <input checked="" type="radio"/> 480 ns | <input type="radio"/> Disable OCP    |
|             | <input type="radio"/> No filter         | <input type="radio"/> 120 ns         |
|             | <input type="radio"/> 240 ns            | <input type="radio"/> 360 ns         |
|             | <input type="radio"/> disable LS OCP    | <input type="radio"/> disable HS OCP |
| OCP masking | <input type="radio"/> No masking        | <input type="radio"/> 320 ns         |
|             | <input checked="" type="radio"/> 640 ns | <input type="radio"/> 1280 ns        |

## Bus Current vs. Q-Axis Current

The bus current is the average voltage drop measured from the current sense resistor, with an amplifier gain of 14.5. The Q-axis represent the phase current peak value (with 0.866 ratio).

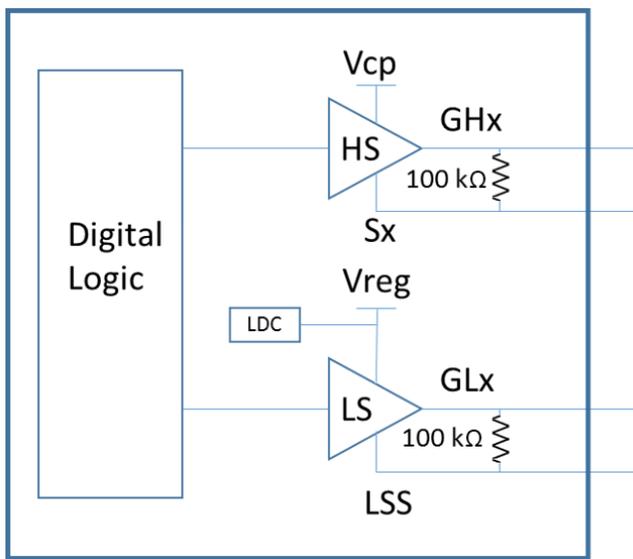
If the output duty is 100%, Q-axis current = bus current.

If the output duty is 50%, Q-axis current = 2 × bus current.

If the output duty is 33.3%, Q-axis current = 3 × bus current.

The bus current measurement is executed every 3 PWMs, (120 μs), but the I<sup>2</sup>C readback cannot be as fast as 120 μs.

## Gate Driver

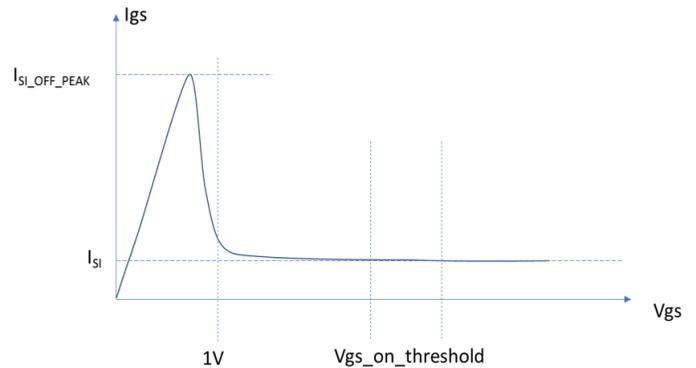


The A89301 gate driver outputs are current source/sink drivers.

Internally, 100 kΩ resistor is connected between GLx and LSS, and between GHx and Sx. When the device is in sleep mode, digital logic, charge pump, and regulators will be off. These 100 kΩ resistors pull down gate voltage to ensure the external MOSFETs are turned off in sleep mode.

The gate drive sink current  $I_{SI}$  and source current  $I_{SO}$  can be configured in EEPROM to adjust the MOSFET slew rate.

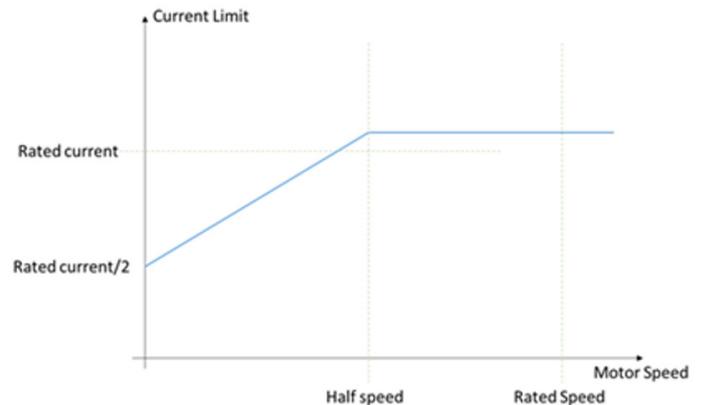
The  $I_{SI}$  in the Electrical Characteristics table is active when the external MOSFET is turning off. When the MOSFET is fully off (gate to source voltage  $V_{GS} < 1$  V), the gate drive will switch to a voltage source (short to LSS) to hold the MOSFETs in the off state. In voltage source mode, the sink drive is stronger. The typical  $I_{SI\_OFF\_PEAK}$  is 200 mA.



## Current Limit Level Ramping Up With Speed

Considering fan type applications, the load is increasing while the motor speed increases. For example, the “motor-rated current” is set at 3 A, and motor-rated speed is 6000 rpm, it can be assumed the system does not require 3 A current at one third of the rated operation speed (2000 rpm).

The startup current is implemented as a function of the motor speed, which is, in the following example, at zero speed, the current limit is  $\frac{1}{2} \times (932 \text{ mA})$ ; at full speed, the current limit is  $1 \times 1.125$ ; and between the zero speed and full speed, current limit follows the curve in below picture.



So, if the motor speed is less than half of the rated speed, the current limit will be less than the rated current, and even with load increasing, the operation current will not reach the rated current.

- Startup current (relative to rated current)
- 1/4x (466 mA)
  - 1/2x (932 mA)
  - 3/4x (1.40 A)
  - 1x (1.86 A)
  - 3/8x (699 mA)
  - 5/8x (1.17 A)
  - 7/8x (1.63 A)

---

## Charge Pump Capacitor Selection

The A89301 has a charge pump circuit which provides high-side N-channel MOSFETs gate-driving voltage and current. One pumping capacitor ( $C_p$ ) needs to be connected between CP1 and CP2, and one reservoir capacitor ( $C_R$ ) needs to be connected between VCP and VBB.

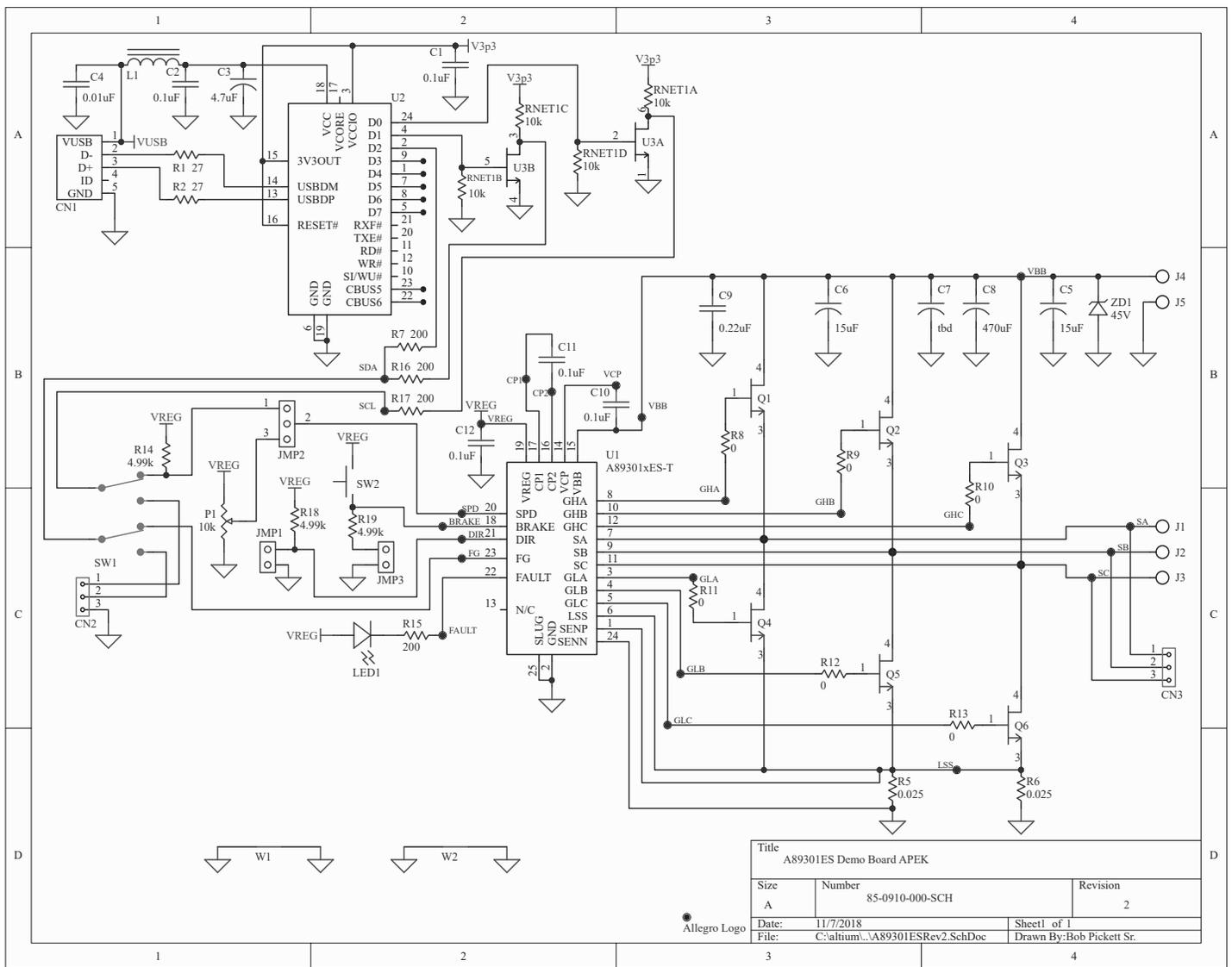
When the A89301 is in the normal operation mode (running a motor), the current drawn from VCP has the static component and the dynamic component. The static component is about 1.5 mA. The dynamic component is about 1.5 mA with 2000 nF CISS MOSFETs. The dynamic current is proportional to the switching frequency and the CISS of the MOSFET.

The values 0.1  $\mu$ F for the pumping capacitor and 0.1  $\mu$ F for the reservoir capacitor were used for product design, simulation, and verification; these meet the voltage ripple and stability requirements, and are recommended for user applications.

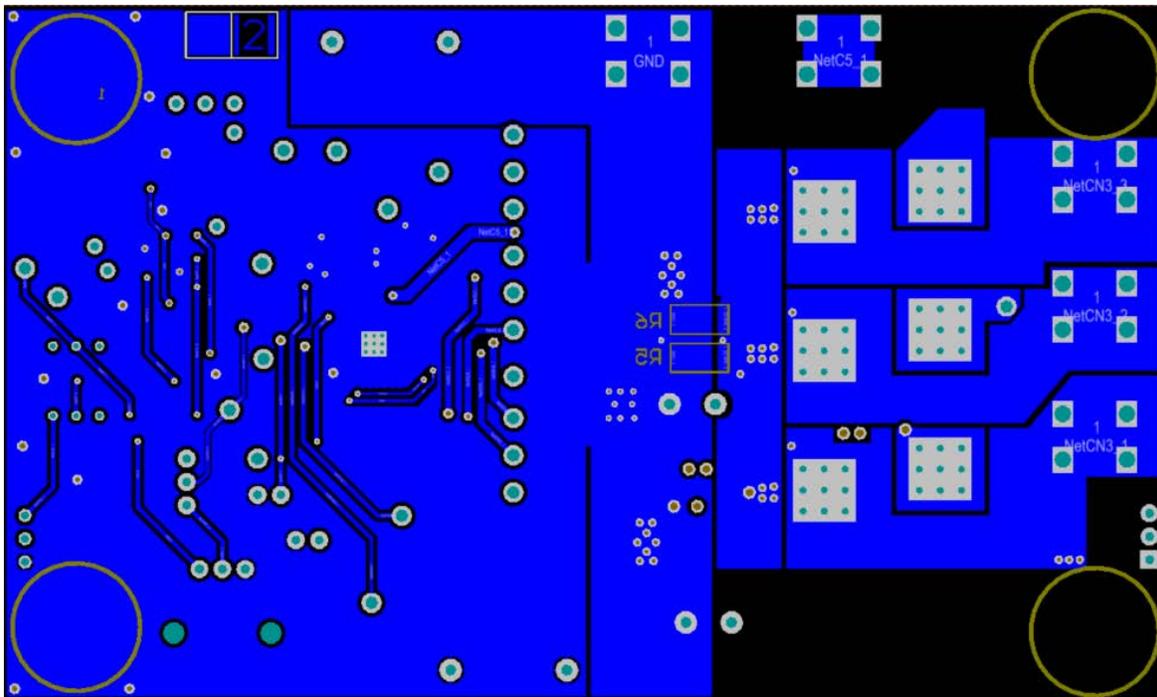
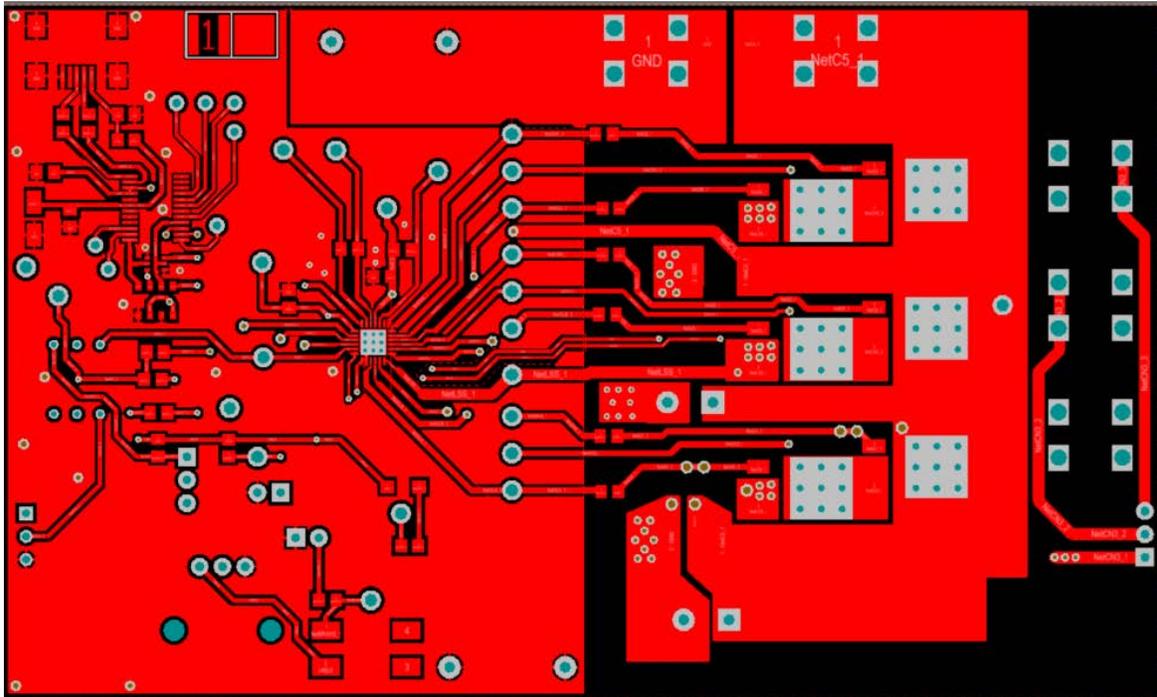
A lower valued reservoir capacitor will cause higher  $V_{CP}$  ripple—the worst case happens when the MOSFET has larger CISS and when the high-side three phases are turned on at the same time.

The pumping capacitor should be the same value as the reservoir capacitor: if it is too large, it will cause more  $V_{CP}$  ripple; if it is too small, the charge pump driving capability will be limited.

# SCHEMATIC



# LAYOUT



**Table 4: A89301 Evaluation Board Bill of Materials**

ELECTRICAL COMPONENTS				
Designator	Quantity	Description	Part Type	Footprint
BRAKE, CP1, CP2, DIR, FAULT, FG, GHA, GHB, GHC, GLA, GLB, GLC, LSS, SA, SB, SC, SCL, SDA, SPD, VBB, VBB_, VCP, VREG	23	Large Test Point	Keystone Electronics 5010; Digikey 36-5010-ND	PAD 57 125 TP HB
C1, C2	2	16 V Capacitor	Murata GRM219R71C104KA01D; Digikey 490-1683-1-ND	0805
C3	1	35 V Capacitor	Chemi-Con EMZA350ADA4R7MD61G; Digikey 565-2553-1-ND	UCC D61 Cap
C4	1	50 V Capacitor	Murata GRM216R71H103KA01D; Digikey 490-1664-1-ND	0805
C5, C6	2	100 V Capacitor	TDK CGA9P3X7S2A156M250KB; Digikey 445-7948-1-ND	2220
C7	1	50 V Capacitor	Not Installed	CAP10mmDIA_5mmPS
C8	1	50 V Capacitor	Chemi-Con EKY-500ELL471MK20S; Digikey 565-1610-ND	CAP10mmDIA_5mmPS
C9	1	50 V Capacitor	Murata GCM21BR71H224KA37L; Digikey 490-4970-1-ND	0805
C10, C11, C12	3	50 V Capacitor	TDK C2012X7R1H104K085AA; Digikey 445-7534-1-ND	0805
CN1	1	USB 2.0 Connector	EDAC 690-005-299-043; Digikey 151-1206-1-ND	EDAC 690-005-299-043
CN2, JMP1, JPM2, JMP3	10 Pins	Cut from 50-Pin Strip	Samtec TSW-150-07-T-S; Digikey SAM1035-50-ND	3-Pin 0.1" Connector, 2-pos. shunt
CN3	1	Molex 3-Pin Verticle Recepticle	Molex 0022022035; Digikey WM3201-ND	Molex 3-Pin 4455-N Vertical2
-	4	Bumpon Foot	3M SJ-5303 (CLEAR); Digikey SJ5303-7-ND	Bumpon Foot
J1, J2, J3	3	Screw Connector Terminal	Keystone 7701; Digikey 36-7701-ND	Keystone 7701 BottomOnly
J4	1	Red Screw Connector Terminal	Keystone 7701-2; Digikey 36-7701-2-ND	Keystone 7701
J5	1	Black Screw Connector Terminal	Keystone 7701-3; Digikey 36-7701-3-ND	Keystone 7701
L1	1	Ferrite Bead	Laird MI0805K400R-10; Digikey 240-2389-1-ND	0805
LED1	1	Red Surface-mount LED	Lite-On LTST-C150CKT; Digikey 160-1167-1-ND	1206 LED
-	1	PCB	85-0910-001 Rev. 2	
P1	1	1/20 W Potentiometer	Bourns PTV09A-4020F-A103; Digikey PTV09A-4020F-A103-ND	PTV09A-4 Pot.
Q1, Q2, Q3, Q4, Q5, Q6	6	60 V 50 A N-FET	Infineon IPD50N06S4L12ATMA2; Digikey IPD50N06S4L12ATMA2CT-ND	D-PAK, TO-252
R1, R2	2	1/8 W Resistor	Vishay/Dale CRCW080527R0FKEA; Digikey 541-27.0CCT-ND	0805
R5, R6	2	3 W Resistor	Bourns CRA2512-FZ-R025ELF; Digkey CRA2512-FZ-R025ELFCT-ND	2512 (6432 Metric)
R7, R15, R16, R17	4	1/8 W Resistor	Panasonic ERJ-6GEYJ201V; Digikey P200ACT-ND	0805
R8, R9, R10, R11, R12, R13	6	1/8 W Resistor	Panasonic ERJ-6GEY0R00V; Digikey P0.0ACT-ND	0805
R14, R18, R19	3	1/8 W Resistor	Panasonic ERJ-6ENF4991V; Digikey P4.99KCCT-ND	0805
RNET1	1	4 Isolated Resistors	CTS 744C083103JP; Digikey 744C083103JPCT-ND	CTS 744 Series
SW1	1	Dual SPDT Switch	Grayhill 76STC02T; Digikey 76STC02T-ND	76STC02T
SW2	1	Surface-mount momentary switch	C&K Components KSC201GLFS; Digikey 401-1755-1-ND	KSC201GLFS
U1	1	BLDC Motor Controller	A89301xES	ES_24-Pin_4x4QFN
U2	1	USB 8-Bit FIFO IC	FTDI FT240XS-R; Digikey 768-1127-1-ND	SSOP-24 (150mil)
U3	1	Dual N-CH Fet's	Toshiba Semi SSM6N15AFU,LF; Digikey SSM6N15AFULFCT-ND	SOT-363
W1, W2	2	22 Gauge Bus Wire (300 mils above PCB)		Scope Ground
ZD1	1	TVS Diode	Bourns SMBJ45A; Digikey SMBJ45ABCT-ND	DO-214AA

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## RELATED LINKS

A89301 Product Page: <https://www.allegromicro.com/en/products/motor-drivers/bldc-drivers/a89301>

Software Registration Site: <http://registration.allegromicro.com/login>

## APPLICATION SUPPORT

For applications support contact, go to <https://www.allegromicro.com/en/about-allegro/contact-us/technical-assistance> and navigate to the appropriate region.

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## Revision History

Number	Date	Description
–	February 27, 2019	Initial Release
1	March 6, 2020	Minor editorial updates
2	April 3, 2023	Added schematic, layout, bill of materials, related links, and minor editorial updates

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