APEK49400

AMT49400 Evaluation Board User Guide

DESCRIPTION

The AMT49400 evaluation board is designed to aid system designers in evaluating the operation and performance of the AMT49400 integrated sensorless FOC BLDC driver IC. This user guide provides step-by-step instructions on how to use the AMT49400 evaluation board to run a motor using the Allegro AMT49400. In addition, this document contains feature descriptions that are not shown in the AMT49400 datasheet.

FEATURES

- USB communications to allow a GUI to control the device via I²C
- Configure device to control a motor

EVALUATION BOARD CONTENTS

- APEK49400GLK-01-T evaluation board

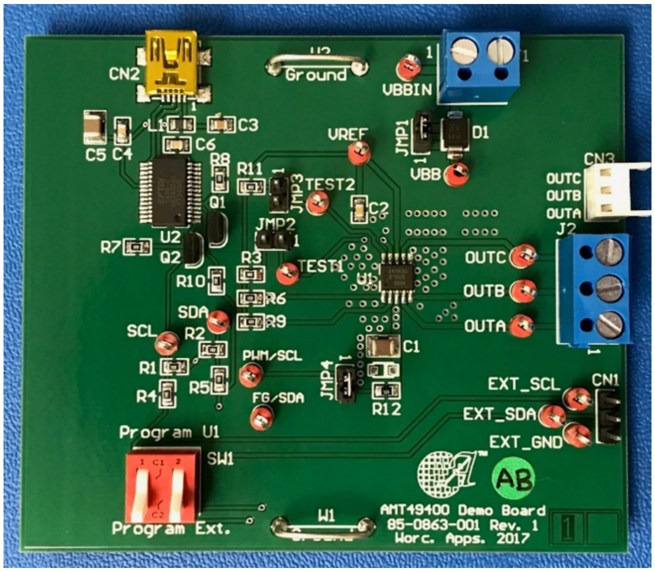

Figure 1: AMT49400 Evaluation Board

Table 1: A5947GET Evaluation Board Configurations

Configuration Name	Part Number
APEK49400GLK-01-T	AMT49400GLKATR

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USING THE EVALUATION BOARD

Equipment Required

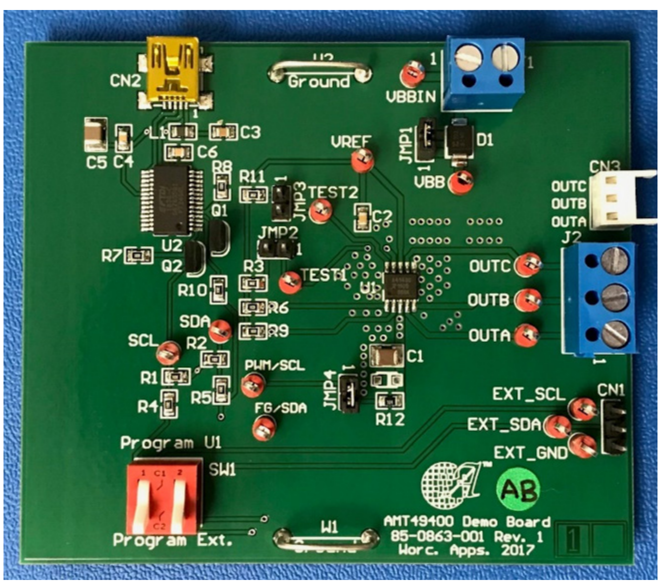
- Motor
- Voltage supply to power motor
- Standard A Male to Mini B Male USB cable (not included)
- Personal computer for USB control
- Software; see Related Links

Step 1. Run with default program.

If the application meets the following requirements, run the motor with the default program and fine tune the parameters later.

Requirements:

- Fan or pump application.
- Rated voltage range: 5 to 16 V.
- Rated current range: 200 mA to 1.5 A
- Rated motor speed: 100 to 600 Hz.
- Phase to CT resistance: 2 to 10 Ω.



To run the motor with the default program:

- Connect the power supply from J1 (<18 V).
- Connect the motor windings from J2 or CN3.
- Set the switch SW1 to program Ext.
- Put on JUMP1 and JUMP4.
- Power on.

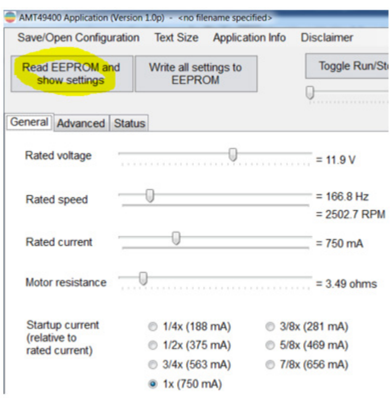
Step 2. Using GUI to tune parameters.

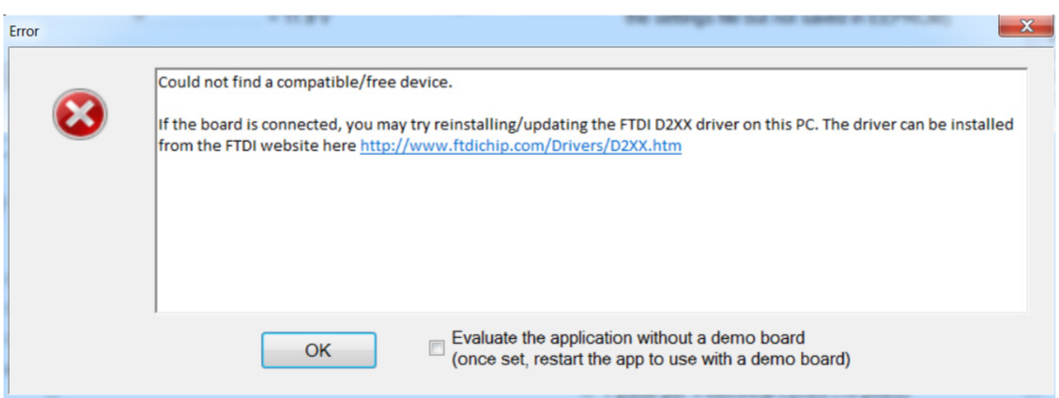
If the motor is not spinning properly, tune the parameters. If the motor is spinning, it is also recommended to go through Step 2 to ensure the parameters are optimized, and that the advanced options and protection options are selected as desired.

COMMUNICATING THROUGH THE USER INTERFACE (SOFTWARE).

To use the GUI:

- Connect USB cable to CN2.
- Launch the AMT49400 Application Software.
- Keep power supply on.
- Set the switch SW1 to program U1.
- Click Read EEPROM and show settings.





If the above error message appears, check the USB connection and make sure the FTDI chip driver is installed properly.

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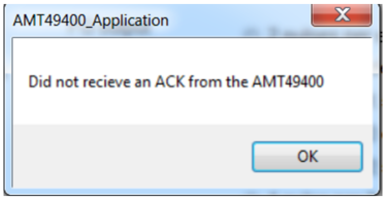
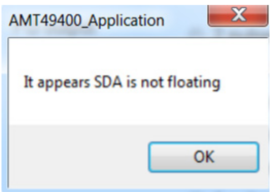


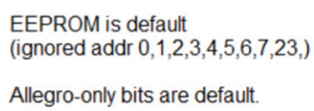
If the above error message appears, verify the switch SW1 is in the correct position (U1) and also make sure the power is turned on.



If above error message appears, it means the AMT49400 FG pin output is low. When the AMT49400 is controlling a motor, the FG pin is the speed indicator pin. It goes high and low with about 50% probability. If the I^2C command is sent when the FG pin is low, the communication will fail, and the error message “SDA is not floating” appears.

When this error message appears, click OK and then click Read EEPROM to try again until it passes.

Once the first I^2C communication has passed, the FG pin will be dedicated for the i2c_SDA function, and the “SDA not floating” error will no longer appear.



If GUI communication is successful, the above message will be shown.

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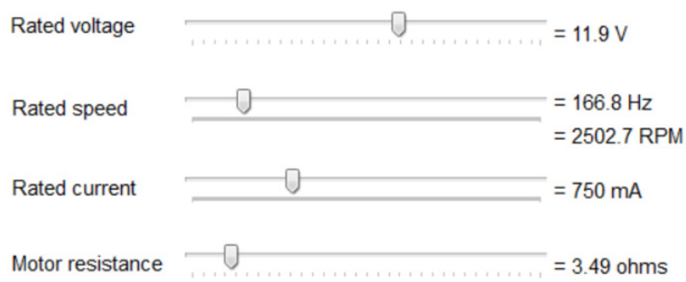
SETTING BASIC PARAMETERS.

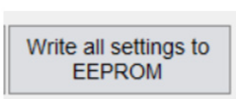
The Basic parameters are in the General Page.

- Set the motor pole pairs. If the motor pole pairs parameter is not known, refer to "Note 1. How to determine the number of pole pairs.".



- Rated voltage is the typical application voltage. If this is a fixed voltage application (for example, V_{BB} could vary from 11.5 to 12.5 V), use 12 V. If this is a variable voltage application (for example, V_{BB} could change from 6 to 16 V), use 16 V.
- Rated speed is the motor full speed (100% control demand) under rated voltage with typical load. For fan motors, use the rated speed with fan blades.
- Rated current is the bus current (the number shown on the power supply) at rated voltage and rated speed.
- Motor resistance is the motor phase to CT resistance. If phase-to-phase is measured, divide the result by two.

If you have changed any parameters rather than the default. Press 'Write all setting to EEPROM' and power off.



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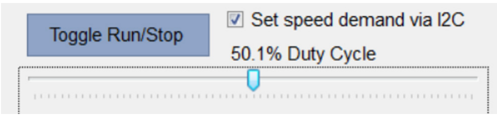
Step 3. Starting the motor.



To start the motor:

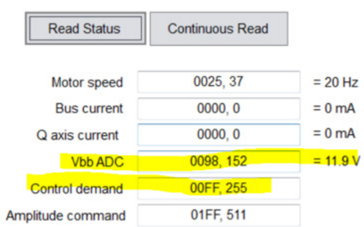
- Power on. Click Read EEPROM and show setting. The parameters changed in step 2 should display.
- Check the ‘Set speed demand via I2C’.
- Select the speed demand to 50%, and click Toggle Run/Stop.
- Motor should start to spin.

If motor is not spinning, it could be one of the following three conditions. Because the default program does not have lock detection enabled, if the motor is not running, AMT49400 cannot detect the lock condition and stop driving automatically. After fixing the connection or parameters, click Toggle Run/Stop to stop driving and retry.

MOTOR DOES NOT SPIN AT ALL.

If motor is not moving at all:

- Confirm the 3 motor wires are connected correctly.
- Confirm V_{BB} is above 4 V and below 18 V.
- Make sure there is no short circuit on the PCB board (phase to VBB, phase to phase, or phase to GND).
- Go to the GUI Status page and click Read Status. The Vbb ADC should equal power supply voltage, and the Control demand should be around 255 (50% demand). If not, reprogram the IC (refer to “Step 10. Restore the configuration.”), replace the IC, or replace the evaluation board.



MOTOR SHOOK AND STOPPED.

If the motor shook a little and stopped, it is likely caused by a startup failure during acceleration. Click Toggle Run/Stop to stop driving, and adjust the startup parameters as shown in “Step 4. Setting startup parameters.”.

MOTOR SPUN MORE THAN 5 CYCLES AND STOPPED.

If the motor spun several cycles (usually more than 5) and stopped, it is caused by an operation failure in the closed loop (FOC). Click Toggle Run/Stop to stop driving, and adjust the parameters as shown in “Step 5. Adjusting the motor inductance and PID parameters.”.

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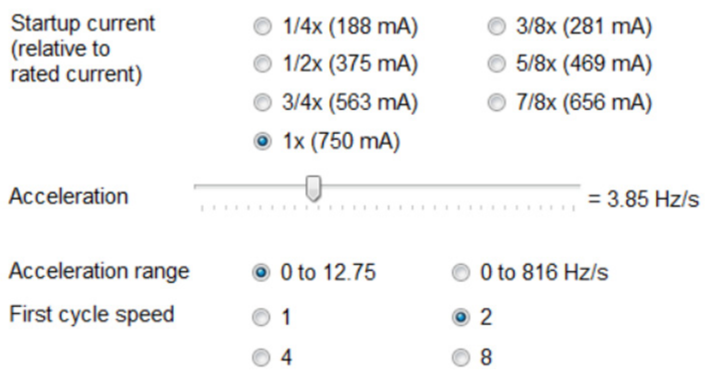
Step 4. Setting startup parameters.

The startup parameters will affect startup; it will not affect the closed loop operation. If the motor fails at closed loop operation, go to "Step 5. Adjusting the motor inductance and PID parameters.".



- These 4 parameters are related to startup. Before entering closed loop (FOC), the motor runs in an open loop startup state. Higher acceleration requires high startup current. Slower first cycle speed will make startup more reliable but makes startup time longer.
- The Startup current is a percentage of the rated current. Increasing startup current *will not* make startup faster but lower startup current may cause startup to fail.
- To make the startup faster, increase the Acceleration first, then increase the startup current accordingly.
- To reduce the startup current, decrease the startup current first, then decrease the Acceleration accordingly.
- Overall, startup current and acceleration time are traded off for startup time and reliability.
- Perform a comprehensive test to ensure startup reliability, including:
  - □ Different initial position
  - □ Different initial speed
  - □ Different supply voltage
  - □ Different operation temperature
- Click the 'Write all setting to EEPROM' to save the changes in the EEPROM.

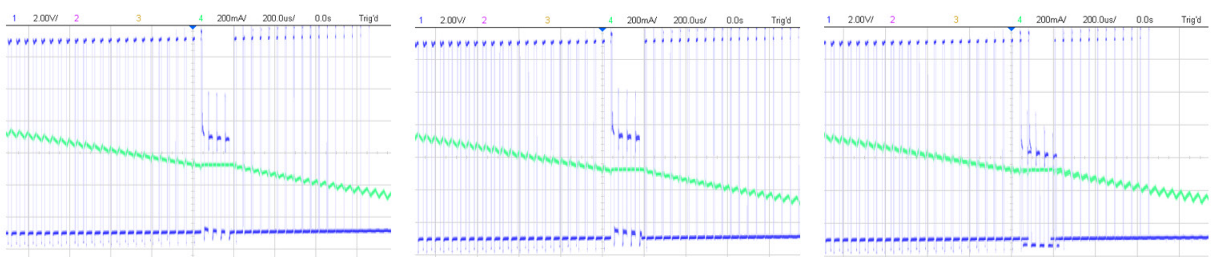
Step 5. Adjusting the motor inductance and PID parameters.

Motor inductance and PID parameters will affect closed loop (FOC) operation, it will not affect open loop startup. If the motor fails during startup (shaking but not spinning), go to “Step 4. Setting startup parameters.”.

MOTOR INDUCTANCE

Motor inductance is difficult to measure—it varies with operation frequency, phase current (saturation), and also with rotor position. The AMT49400 provides an easy method to adjust the inductance value and achieve the best efficiency.

- While the motor is spinning, connect a current probe and a voltage probe to phase A.
- Enable the open window which is a debug function. Remember to disable the window before finalizing the parameters.
- There will be a small window opened on phase A (winding current is flat at 0 A). 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.



Voltage = $V_{BB}/2$ Voltage > $V_{BB}/2$ Voltage < $V_{BB}/2$

- Disable the “open window” after the inductance adjustment.
- Click the ‘Write all setting to EEPROM’ to save the changes in the EEPROM.

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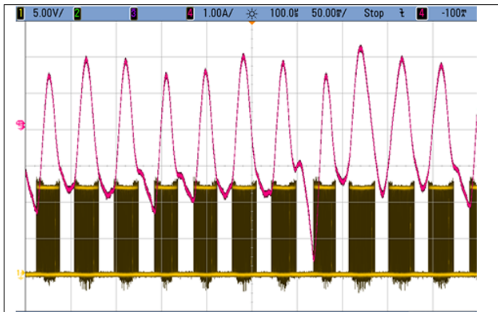
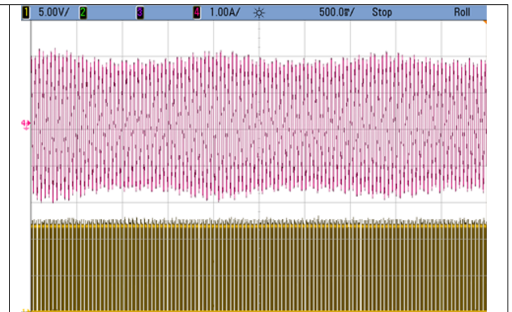
PID PARAMETERS

- Restart the motor and click ‘Read EEPROM and show settings’.
- 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 one electrical cycle, the PID parameter is too high.
  - □ If current shows low frequency oscillation, the PID parameter is too low.



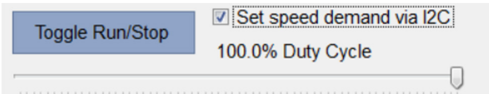
PID too high



PID too low

- Click the ‘Write all setting to EEPROM’ to save the changes in the EEPROM.

Step 6. Fine tuning the parameters.

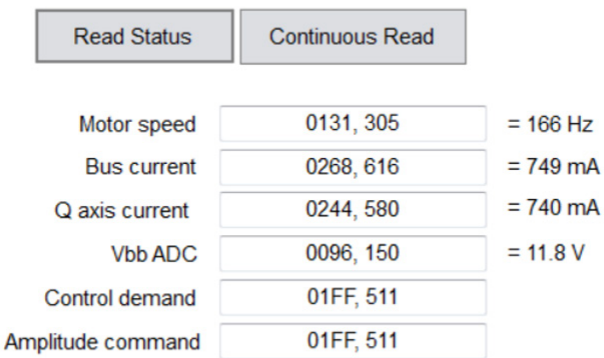


- Increase control demand to 100%.
- While the motor is spinning, go the Status page and click 'Read Status'.
- Motor speed indicates the motor operation speed in the unit of electrical frequency (Hz) and RPM.
- Bus current is the average supply current; it should be close to the value shown on the power supply.
- Q-axis current is proportional to the peak phase current with the ratio of 0.866. If the amplitude command is 100%, the Q-axis current is equal to the bus current. If the amplitude command is X %,

$$\textit{Q-axis current} = \textit{Bus current} / X\%.$$

$$\textit{peak phase current} = \textit{Q-axis current} / 0.866.$$

- **Control demand** is the amplitude commanded (it should match the I2C speed demand value).
- **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. At this point, both should be 100% (511).
- If Amplitude command is not 100%, go to the General page and increase the rated current until it reaches 100%.



- 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.
- Record the 'Bus current' from the status page. Enter this value as the 'Rated current' parameter.
- Click the 'Write all setting to EEPROM' to save the changes in the EEPROM.

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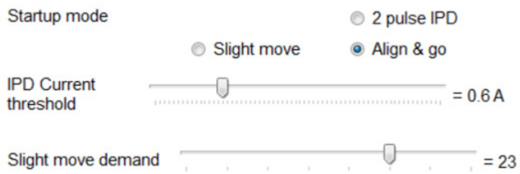
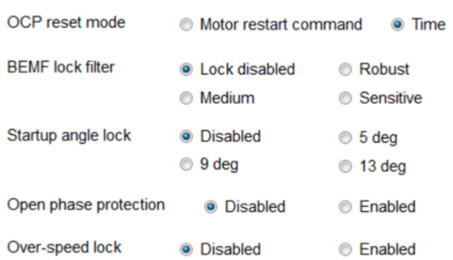
Step 7. Startup mode.



- In most applications, such as computer or appliance fans where zero reverse rotation startup is not required and startup time is not critical, select 'Align & go'.
- For some applications, such as hard disk drivers where no reverse rotation at startup is required, 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.
- 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.
- Compare these three options for the application and choose the best fit.
- Click the 'Write all setting to EEPROM' to save the changes in the EEPROM.

Step 8. Protection options.

The AMT49400 has overcurrent (short circuit), overtemperature, open phase, and mechanical lock protection features. The protection functions also have some options.



- **OCP reset mode.** OCP is overcurrent protection (or short-circuit protection). It is always enabled, protecting the motor and the device. After OCP is detected, there are two options for reset: one is after 5 seconds, the other is upon power cycle or wake up from standby mode.
- **BEMF lock filter.** When the motor is mechanically locked, inside the FOC algorithm, the calculated BEMF will be abnormal; sensing the abnormal BEMF will trigger the lock detection event. The Robust option will avoid mistriggering lock detection during accelerate, decelerate, load change, or V_{BB} change, but takes longer to detect. The Sensitive option will detect the lock event very quickly, but in some cases, it may trigger an unexpected lock event. The BEMF lock can be disabled.
- **Startup angle lock.** BEMF lock only works when the motor is running in closed-loop operation. During startup, because BEMF is small, BEMF lock is not relied upon. Start angle lock is provided to detect a lock condition during startup; it will stop driving and protect the motor before entering the closed loop operation. The start angle lock can be disabled.
- **Open phase protection.** Works when one of the three phases is not connected; the AMT49400 will stop driving and retry after 5 seconds.
- **Over-speed lock.** The FOC sensorless algorithm will sometimes try to drive the motor much faster than it should during the lock condition; in this case, enabling the Over-speed lock will effectively protect the system.
- Click the 'Write all setting to EEPROM' to save the changes in the EEPROM.

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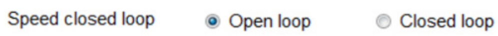
Step 9. Other settings.

SPEED CLOSED LOOP



First, the term “closed loop” must be clarified:

- Speed closed loop means the motor speed is maintained to be constant regardless of the supply voltage change and the load condition change.
- Closed loop operation in other sections of this document means the AMT49400 drives the motor after open loop startup, the FOC algorithm kicks in, and the position observer starts to work—that is, the position observer loop.
- In this document, when the FOC position observer loop is discussed, the terms “Closed loop (FOC)” or “Closed loop operation” are used. If the constant speed closed loop is discussed, the term “Speed closed loop” is used.

The AMT49400 provides the Speed closed loop option; if it is disabled, the control demand will control the average amplitude the phase outputs, which indirectly controls the motor speed. But if V_{BB} or the load changes, the motor speed will change.

If the speed closed loop is enabled, the motor speed is compared to the reference speed, and error is feedback and controlled to be zero in the steady state. In the speed closed loop system:

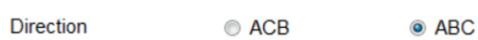
$$close\_loop\_speed = rated\_speed \times duty\_input$$

Enabling or disabling the speed closed loop on the fly may cause motor stop. Click Toggle on/off to restart.

Speed closed loop response time (time constant of the speed closed loop) can be configured through the EEPROM.

Higher value represents slower adjustment.

MOTOR DIRECTION



Motor direction can be changed by swapping any two of the three phase terminals. It can also be changed by the changing the Direction setting.

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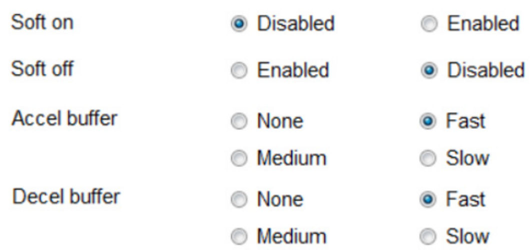
OPERATION SETTINGS



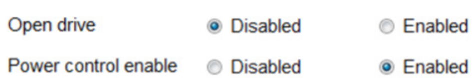
Soft on and soft off make motor on-off transitions smoother; see datasheet for more details.

Accelerate buffer and Decelerate buffer are not valid in speed closed loop. In speed open loop mode, if the accelerate buffer and decelerate buffer are enabled, when user control demand has a step increasing or step decreasing, the real amplitude command will not change drastically, which makes the transition smoother. Choosing 'None' will disable the buffer. If false lock detection is experienced during acceleration or deceleration, choose a slower buffer setting.

Delay start will delay the startup by 100 ms after power on or demand on. It is designed to avoid issues caused by unstable power supply. If the system on/off is controlled by PWM (power supply is always on), disable this setting.

Click the 'Write all setting to EEPROM' to save the changes in the EEPROM.

DEBUGGING SETTINGS



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

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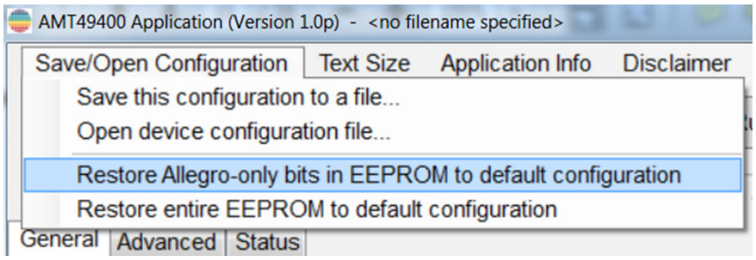
Step 10. Restore the configuration.

The Allegro-only bits are shaded in gray in the datasheet; these bits should not be changed by the user. If for any reason, some of the Allegro-only bits have been changed, the following message will appear when “Read EEPROM and show setting” is clicked.

Allegro-only bits ARE NOT DEFAULT!
Addresses 14(0), are different

To fix this, select “Restore Allegro-only bits in EEPROM to default configuration”.

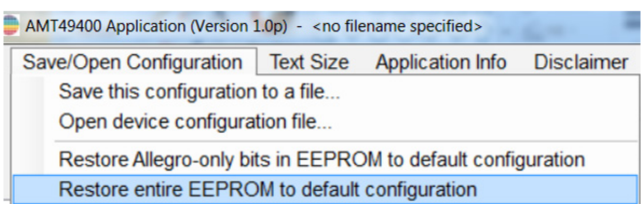


After fine tuning the parameters for the motor, and “Write all setting to EEPROM” has been clicked, if “Read EEPROM and show settings” is clicked again, the following message will appear. This is normal. Go to Step 11 and finalize the tuning process.

EEPROM is NOT default
Addr 10, are different
(ignored addr 0,1,2,3,4,5,6,7,23,)

Allegro-only bits are default.

However, if erroneous parameters were entered and the motor fails to spin, select “Restore entire EEPROM to default configuration”, which is similar to “restore to the factory setting”.



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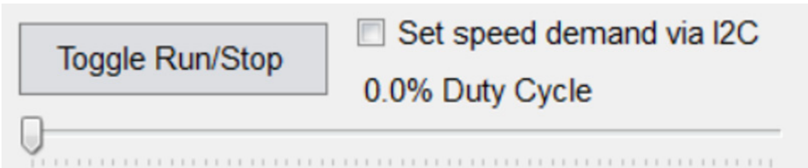
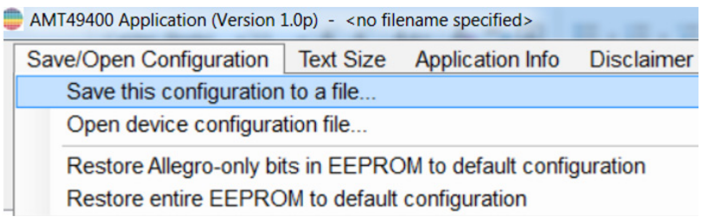
Step 11. Finalize the parameters and program the EEPROM.

If all parameters are confirmed, uncheck “Set speed demand via I2C” and set the speed demand to 0. Note that the motor will start to spin when “Set speed demand via I2C” is unchecked because the PWM pin is high.



Click “Write all settings to EEPROM”.

Select “Save this configuration to a file…”. Once saved, the configuration file can be loaded at a later time by selecting “Open device configuration file…”.



Power off, disconnect the USB cable, put SW1 to program Ext.

Power on:

- Use PWM signal to control the motor speed.
- Check the motor speed from FG pin.
- Run other necessary verifications.

Default Value EEPROM Map

The bits showing 1 or 0 are Allegro-only bits. Do not change them.

The rest bits (showing X) can be configured. The values shown in the 'default (Hex)' column are the default values in brand-new ICs.

bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	default(Hex)
EE8_REG72	X	X	X	0	X	X	X	X	X	X	X	X	X	X	X	X	4133
EE9_REG73	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1D4D
EE10_REG74	X	X	X	0	0	X	X	X	X	X	X	X	X	X	X	X	E24C
EE11_REG75	1	1	0	1	X	X	0	0	X	0	0	0	X	0	0	0	DC80
EE12_REG76	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	X	021E
EE13_REG77	X	X	1	0	0	0	0	1	X	X	X	X	X	X	X	X	211E
EE14_REG78	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0B00
EE15_REG79	1	0	0	1	0	1	1	0	X	X	1	1	X	X	0	1	9671
EE16_REG80	1	1	X	X	X	X	X	X	X	X	1	0	X	1	0	0	C56C
EE17_REG81	X	X	X	0	X	X	X	X	X	X	X	X	X	X	X	X	2000
EE18_REG82	0	0	X	X	X	X	X	X	0	0	0	0	1	1	1	1	0F0F
EE19_REG83	0	0	0	1	1	0	0	1	0	1	1	0	0	0	1	0	1962
EE20_REG84	0	1	1	0	0	0	1	0	X	X	X	X	X	X	X	X	6298
EE21_REG85	0	1	0	0	0	0	X	X	X	X	X	1	0	0	1	0	40B2
EE22_REG86	0	0	0	0	0	0	0	0	0	0	X	X	X	X	X	X	001E

Note 1. How to determine the number of pole pairs.

- 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 does not become too high (current should be about half of the rated current).
- 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.

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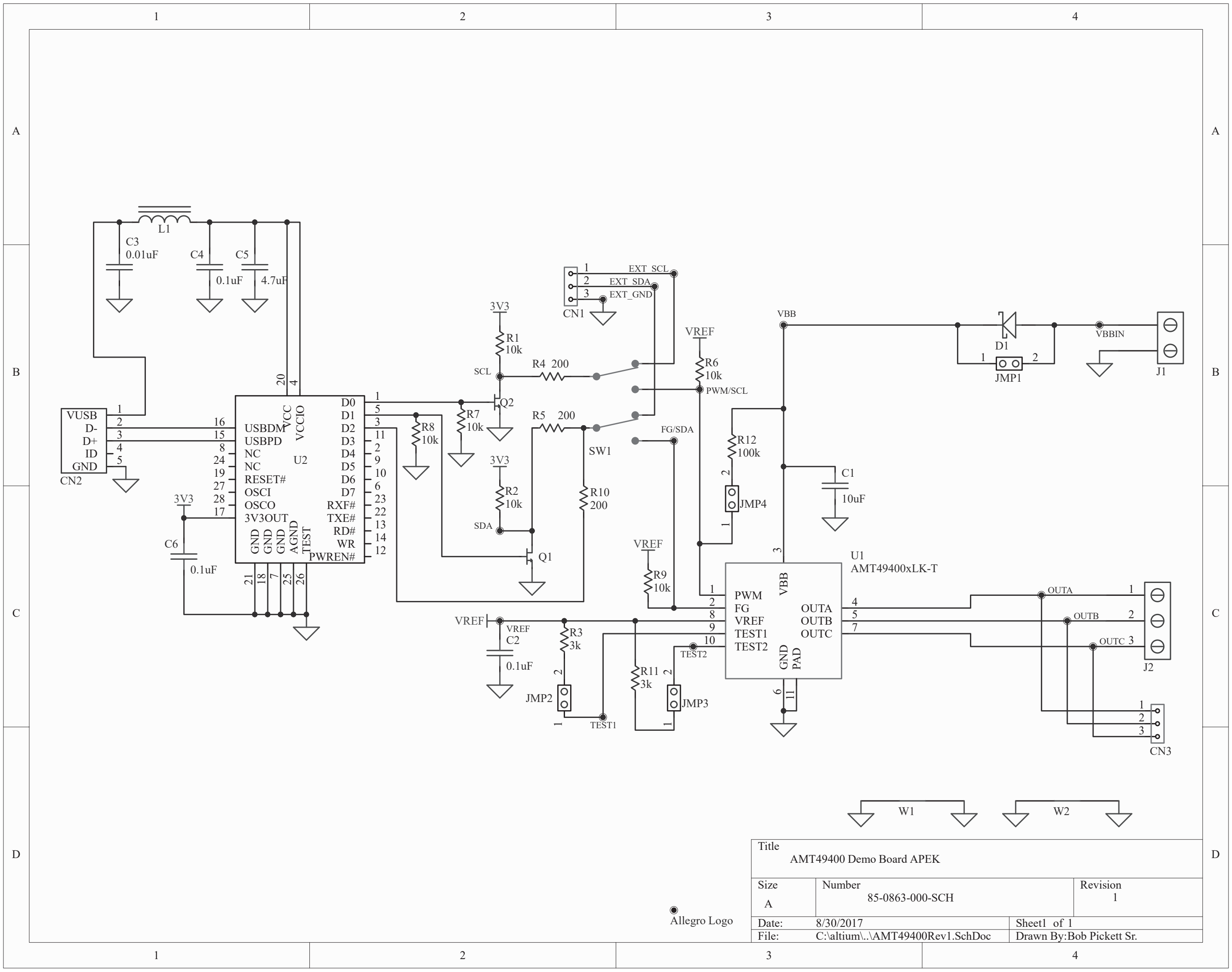
SCHEMATIC



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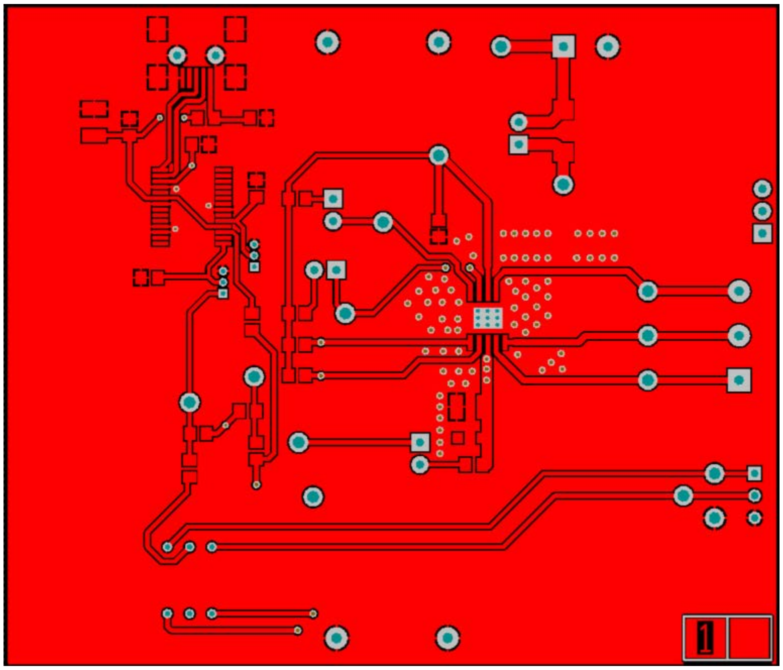
LAYOUT



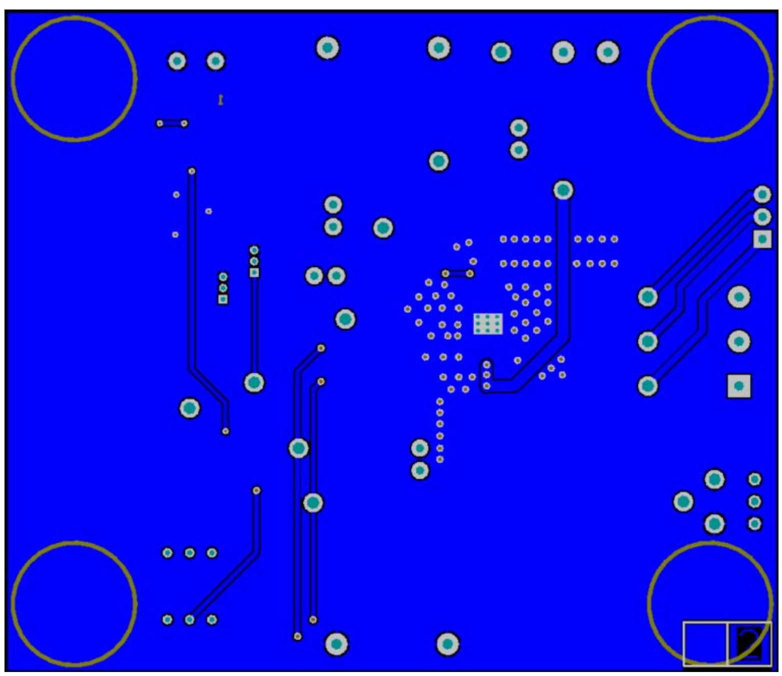


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Table 2: AMT49400 Evaluation Board Bill of Materials

ELECTRICAL COMPONENTS					
Designator	**Quantity**	**Value**	**Description**	**Part Type**	**Footprint**
C1	1	10 µF	25 V Capacitor	TDK C3225X7R1E106M250AC; Digikey 445-1434-1-ND	1210
C2, C4, C6	3	0.1 µF	25 V Capacitor	Kemet C0805C104K3RACTU; Digikey 399-1168-1-ND	0805
C3	1	0.01 µF	50 V Capacitor	Yageo CC0805KRX7R9BB103; Digikey 311-1136-1-ND	0805
C5	1	4.7 µF	16 V Capacitor	Taiyo Yuden EMK325B7475KN-T; Digikey 587-1392-1-ND	1210
CN1, JMP1, JMP2, JMP3, JMP4	11 Pins		Cut from 50-Pin Strip	Samtec TSW-150-07-T-S; Digikey SAM1035-50-ND	2-pos. shunt, 3-Pin 0.1" Connector
CN2	1		USB Mini B Recepticle	EDAC 690-005-299-043; Digikey 151-1206-1-ND	EDAC 690-005-299-043
CN3	1		Vertical through-hole 3-pin recepticle	Molex 0022022035; Digikey WM3201-ND	Molex 3-Pin 4455-N Vertical
EXT_GND, EXT_SDA, EXT_SCL, FG/SDA, OUTA, OUTB, OUTC, SCL, SDA, PWM/SCL, TEST1, TEST2, VBB, VBBIN, VREF	15		Large Test Point	Keystone 5010; Digikey 36-5010-ND	PAD 57 125 TP HB
D1	1		Schottky Diode	Diodes Inc. B240-13-F; Digikey B240-FDICT-ND	DO-214AA
	4		Bumpon Foot	3M SJ-5303 (CLEAR); Digikey SJ5303-7-ND	Bumpon Foot
J1	1		2-Pin Screw Down Connector	On Shore Technology ED120/2DS; Digikey ED1609-ND	2-pin screw down connector
J2	1		3-Pin Screw Down Terminal Block	On Shore ED120/3DS; Digikey ED1610-ND	3-pin screw down connector
L1	1		Ferrite Bead	Laird MI0805K400R-10; Digikey 240-2389-1-ND	0805
	1		PCB	85-0863-001 Rev. 2	
Q1, Q2	2		60 V 270 mA N-FET	Diodes ZVN3306A; Digikey ZVN3306A-ND	TO-92 Compatible
R1, R2, R6, R7, R8, R9	6	10 kΩ	1/8 W Resistor	Panasonic ERJ-6GEYJ103V; Digikey P10KACT-ND	0805
R3, R11	2	3 kΩ	1/8 W Resistor	Panasonic ERJ-6GEYJ302V; Digikey P3.0KACT-ND	0805
R4, R5, R10	3	200 Ω	1/8 W Resistor	Panasonic ERJ-6GEYJ201V; Digikey P200ACT-ND	0805
R12	1	100 kΩ	1/8 W Resistor	Vishay/Dale CRCW0805100KJNEA; Digikey 541-100KACT-ND	0805
SW1	1		Dual SPDT Switch	Grayhill 76STC02T; Digikey GH7720-ND	76STC02T
U1	1		3-Phase Fan Driver	AMT49400xLK-T	LK-10
U2	1		USB FIFO IC	FTDI FT245RL-REEL; Digikey 768-1011-1-ND	28LP no slug
W1, W2	2		22 Gauge Bus Wire (300 mils above PCB)		Scope Ground

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RELATED LINKS

AMT49400 Product Page: https://www.allegromicro.com/en/products/motor-drivers/bldc-drivers/amt49400

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
–	March 25, 2019	Initial release
1	March 27, 2020	Minor editorial updates
2	April 6, 2023	Added schematic, layout, bill of materials, related links, and minor editorial updates

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